



IODDP

INTEGRATED OCEAN
DRILLING PROGRAM

UK newsletter **32**
April 2007



IODP Highlights

Expedition 310: Tahiti Sea Level

- A total of 37 boreholes across 22 sites were cored in water depths ranging from 41.65 to 117.54 m.
- 630m of core recovered from the reef terraces seaward of the living barrier reef.

Expedition 311: Cascadia Margin Gas Hydrates

- Expedition 311 was ODP/IODP's fourth dedicated gas hydrate leg (after Legs 146, 164, and 204).
- 1217m of core recovered, 21 pressure cores, and 11 holes were logged.

Expedition 312: Superfast Spreading Crust III

- First ever in-situ dike/gabbro contact recovered from an intact section of oceanic crust (Core 312-1256D-213R).
- Along with efforts of Leg 206 and Expedition 309, the first complete section through the upper oceanic crust has been obtained.

Editor:

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Front Cover: Inside of the HYACINTH refrigerated logging van showing the long pressure transfer chamber in the centre with the Geotek Pressurized Multi-Sensor Core Logger (MSCL-P) being adjusted at the far end by Peter Schultheiss. The HYACINTH storage chambers can be seen at the rear on the right hand side. *Photo courtesy: IODP.*

Foreword

Sir Geoffrey Allen, Chair of the UK-IODP Steering Committee

Welcome to this newsletter reporting on the first 3 years of the NERC UK-IODP Directed Programme. NERC committed funds to membership of the IODP (2003-2008) through its participation in the European Consortium for Ocean Research Drilling (ECORD), recognising the potential that drill cores have to contribute essential scientific information to its strategic priorities. The Autumn will see publication of a new NERC strategy for the next 5 years – 'Next Generation Science for Planet Earth'. A draft strategy is out currently for consultation. It is already clear that IODP outputs will continue to be relevant to most of the areas identified, e.g. Earth System Science, Natural Hazards, Natural Resources and Biodiversity.

As the first phase of UK-IODP will end in 2008, the steering committee has now been invited to bid for an extension of UK membership and the directed programme from 2008-2013. In March, a draft of the bid was circulated by the Science Coordinator to the community, seeking comment and canvassing support. NERC Council will decide on future membership of IODP and the future of the directed programme in June 2007.

Our bid is based on the salient features of these first 3 years:-

- the directed programme aims to support NERC strategy,
- senior UK scientists participate in the IODP Science Advisory Structure, as a member of ECORD Council and the current ESSAC office is hosted in Cardiff during Chris McLeod's chairmanship,
- a large number of UK scientists are involved in formulating and implementing research drilling proposals,
- there is a vibrant uptake of grants and other forms of research support,
- the unique value of IODP expeditions for

- training the next generation of scientists,
- involvement of all the research-active UK geoscience departments and NERC institutes in the IODP.
- immediate prospect of joint academy/industrial drilling proposals coming from the Industrial Liaison Panel (ILP),
- newsletters, conferences, workshops for writing new drilling proposals, university visits by the Science Coordinator and the work of the ILP to keep the community informed.

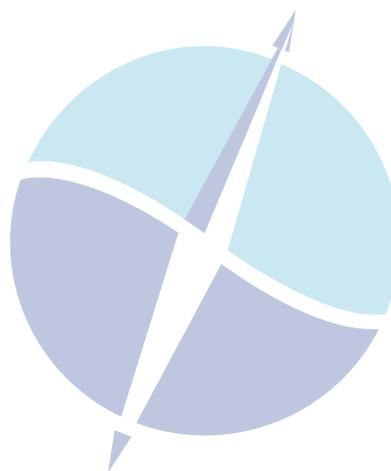
Preparation of the bid was helped considerably by the outcome of a searching examination of the programme by a NERC review panel in February 2007 and also by a study commissioned by ECORD which indicates that the contributions to IODP from Germany, France and the UK are comparable and of a high standard.

Whilst waiting for the outcome of the bid, we are mindful of the exciting prospects for 2007. As we go to press, the RSS *James Cook* is completing its maiden voyage. Aboard is a UK-IODP site-survey team working on a

new drilling proposition. It is receiving considerable media attention. The *JOIDES Resolution* is due to emerge in mid 2007, from its refit, as the 'Science Ocean Drilling Vessel'. Its first expedition in the Equatorial Pacific follows from a site-survey mounted by NSF and UK-IODP in 2006 (See Newsletter 31). ESO is planning its third Mission Specific Expedition for 2007. Eagerly awaited also is the first expedition of the *Chikyu* which will add a formidable capacity for riser-drilling to the IODP facilities.

2007 is set fair – what will 2008 bring?

The UK-IODP steering committee thanks the community warmly for its continuing efforts in support of IODP. Floreat UK-IODP!



Upcoming expeditions

New Jersey Shallow Shelf – IODP Expedition 313

Stephen Hesselbo (University of Oxford) and Greg Mountain (Rutgers University)

After one or two setbacks, which included earlier this year the foundering of the platform-of-choice below the waves in the Gulf of Mexico, it is now likely that drilling for the IODP New Jersey Shallow Shelf Expedition 313 will commence in June 2007. The expedition targets Early to mid Miocene (~24–14 Myr old) siliciclastic sediment sequences on this old passive continental margin of the Atlantic Ocean, with the primary aims of estimating the timing and magnitudes of eustatic sea-level changes, and determining the relationship between sea-level change and sedimentary architecture of the paralic and nearshore sediment prism [see www.eso.ecord.org/expeditions/313/313.htm for prospectus]. Major developments in the Earth system over approximately this period include intense Antarctic glaciation at the beginning of the Early Miocene and at the end of the Middle Miocene, events which bracket a mid-Miocene ‘Climatic Optimum’ when ice sheets were at a relative minimum. Thus the expedition will yield information about changing amplitudes and frequencies of short-term sea-level change through contrasting glacial states.

The New Jersey margin provides a good location to investigate the history of sea-level change and its relationship to sequence stratigraphy for several reasons: rapid depositional rates, tectonic stability, and well-preserved, cosmopolitan fossils suitable for age control characterize the sediments of this margin throughout the time interval of interest (summary in Miller and Mountain, 1994). In addition, there exists a large set of seismic, well log, and borehole data with which to frame the general geologic setting from the coastal plain across the shelf to the slope and rise (Miller and Mountain, 1994). The three holes to be drilled (sites MAT-1, MAT-2 and MAT-3; Figure 1) form a key element in the transect of boreholes. This transect has been developed over the last fifteen years in a multi-agency effort to document eustatic sea-level history for the whole of the mid to late Cenozoic. The ‘New Jersey/Mid-Atlantic Transect’ (NJ/MAT) has included drilling both onshore and offshore (ODP Legs 150X, 174AX, 150 and 174A;

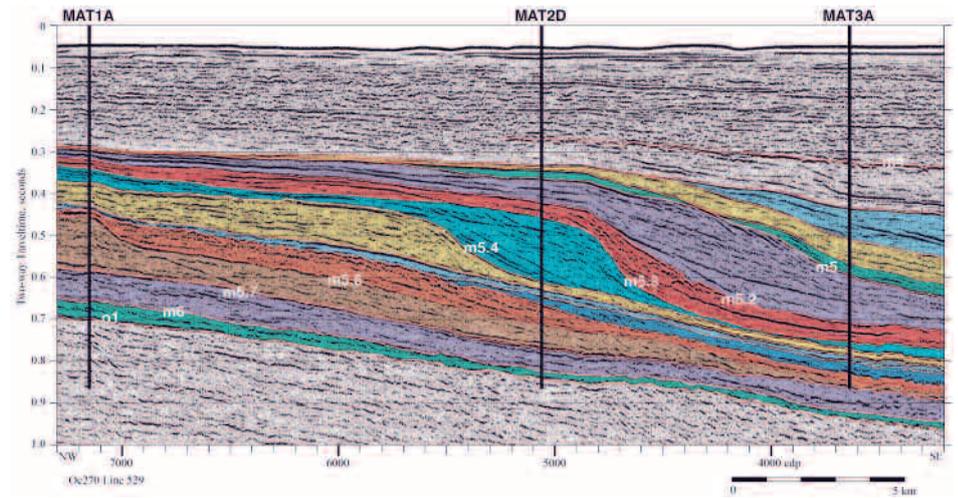


Figure 1. Seismic reflection profile showing Expedition 313 drill sites in relation to regionally mapped Early Miocene to mid Miocene depositional sequences (shaded). See Figure 2 for geographic locations.

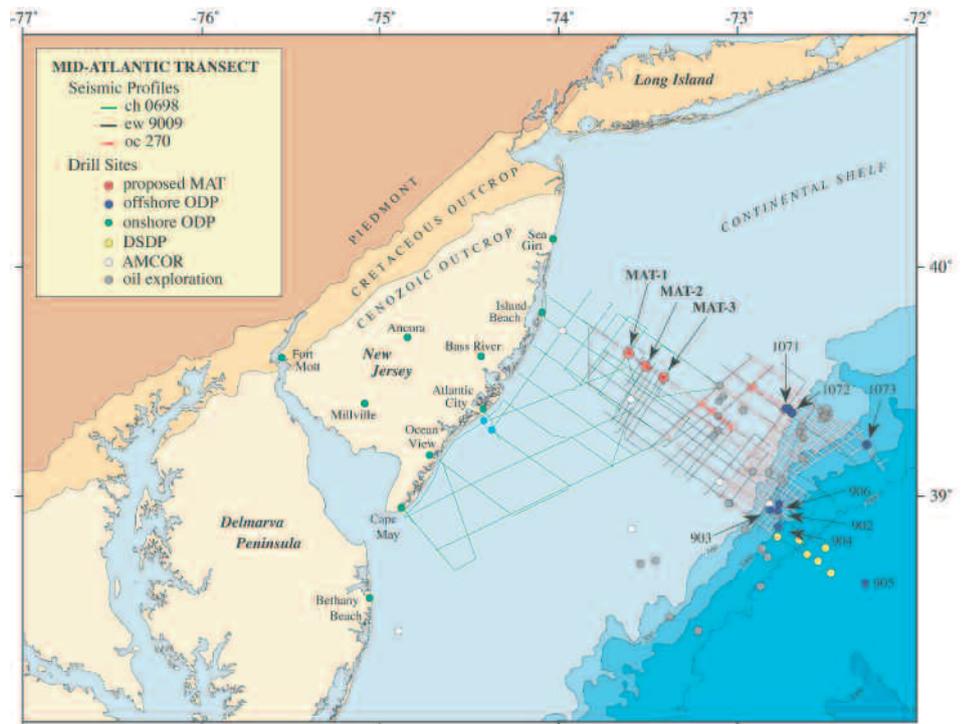


Figure 2. Drill sites for Expedition 313 (MAT-1, MAT-2 and MAT-3) and positions of boreholes drilled previously as part of the New Jersey/Mid Atlantic Transect.

Figure 2). Expedition 313 is different from these previous missions in that it promises to recover cores from the region most sensitive to sea-level change, the shallow shelf, and the technology aboard the mission specific platform will be well suited for recovering sand-prone shelf sediments (in contrast to the situation with the *JOIDES Resolution*).

Previous drilling in the Jew Jersey margin has provided dates for sequence stratigraphic surfaces spanning ages from the before the Eocene through to the Pleistocene, and facies and biofacies data from onshore sites have provided the basis for eustatic estimates which have included one- and two-dimensional backstripping procedures to identify the effects of water and sediment loading. However,

studies of the onshore deposits have given an incomplete record of change because lowstand components of the sequences are missing in these locations and the slope sites give no quantitative information about bathymetric change. Expedition 313 sites will sample for the first time both lowstand and highstand deposits of the Early to mid Miocene (Figure 2). In addition to providing quantitative eustatic estimates through complete sea-level cycles, data from Expedition 313 will provide information to test assumptions needed to make glacioeustatic estimates from $\delta^{18}O$ records, and to evaluate the Cenozoic sea-level/ $\delta^{18}O$ calibration that was on backstripping the incomplete onshore record. Although both backstripping and $\delta^{18}O$

methods have large inherent assumptions, the convergence of results from the two methods suggests that a testable eustatic model can be produced for the past 42 Myr, and perhaps for the older record as well. Other outstanding issues that we hope to resolve through acquisition of these cores include: 1) the bathymetry of siliciclastic clinoform surfaces, which form the basis for most sequence stratigraphic models but are presently largely unconstrained in such ancient shelf settings; 2) the relationships between environmental and climatic changes taking place on land and those taking place in the ocean during sea-level cycles, 3) relationships between oceanic parameters that reflect Milankovitch processes (such as seawater carbon-isotope

Pacific Equatorial Age Transect (PEAT): Summary

The PEAT Expedition Co-Chiefs (Heiko Pälike (National Oceanography Centre, Southampton), Mitch W Lyle, Naokazu Ahagon and Isabella Raffi), and PEAT Proponents (from the UK: Neil Mitchell, University of Manchester).

Following a successful NERC and NSF funded site survey cruise in March and April 2006, IODP Proposal 626 is now in the middle of its implementation phase by the operator, USIO. Proposal 626 ("Pacific Equatorial Age Transect") was conceived in 2003, and made its journey through the IODP Science Advisory Structure, culminating in the approval of drill sites by the Environmental Protection and Safety Panel (EPSP) in June 2006. A call for applications to join the Science Party was conducted in November/December 2006, and staffing decisions are still underway. The current ship schedule for the SODV contains two combined expeditions that are designed to meet the major science objectives of this palaeoceanographic programme (as of 7 March 2007, and subject to change, the two expeditions are set to take place between the second half of March and July). The location of approved drill sites is shown in Figure 1.

The science objectives of the expeditions are multifaceted: As the largest ocean, the Pacific is intricately linked to major changes in the global climate system that took place during the Cenozoic. Throughout the Cenozoic the Pacific plate has had a northward component. Thus, the Pacific is unique, in that the thick sediment bulge of biogenic rich deposits from the currently narrowly focused zone of equatorial upwelling is slowly moving away from the equator. Hence, older sections are not deeply buried and can be recovered by drilling. Previous ODP Legs 138 and 199 were designed as transects across the

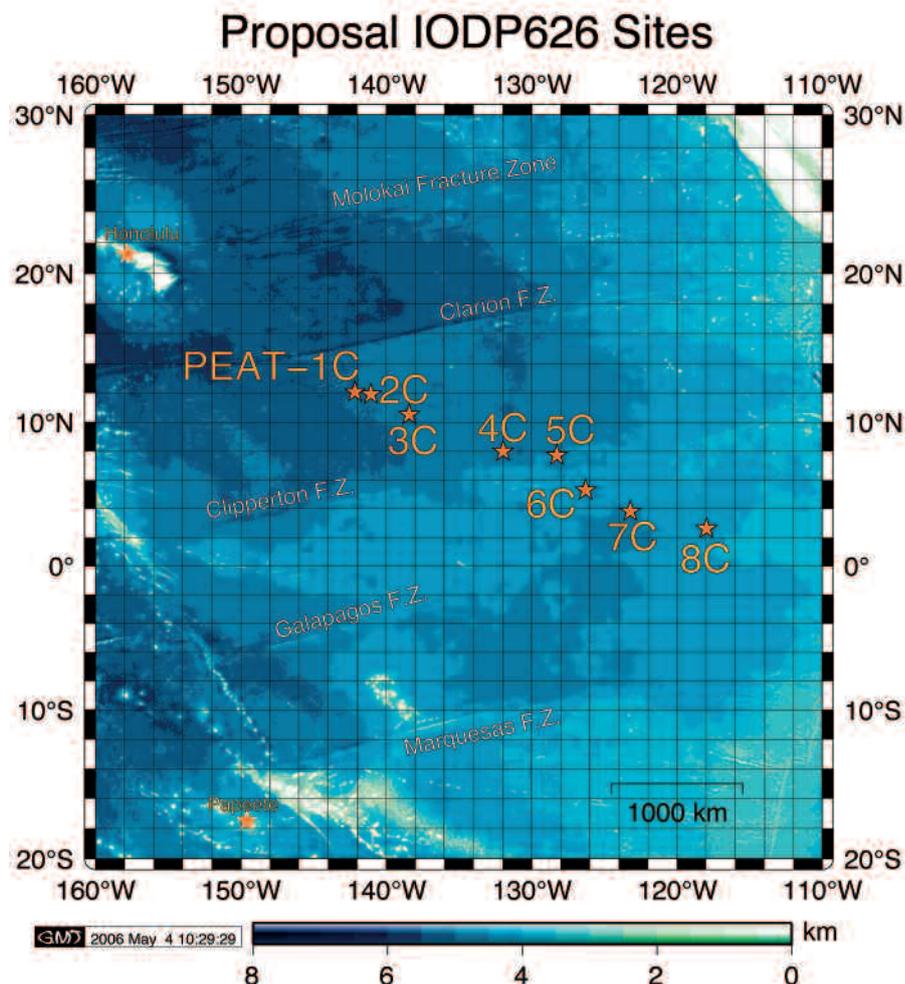


Figure 1. Locations of approved drill sites for PEAT. The sites will be split between the two combined expeditions. The detailed operational plan depends on a combination of time constraints.

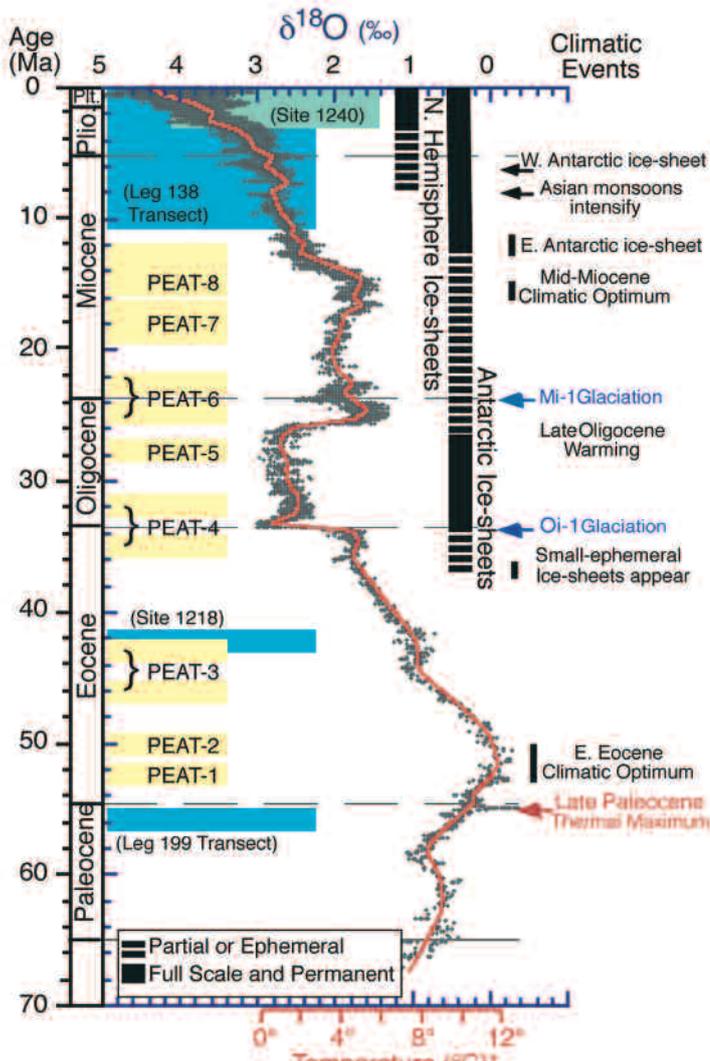


Figure 2. Selected time slices of palaeoceanographic interest for PEAT (Isotope curve modified from Zachos et al., 2001)



Figure 4. Some of the Proponents for PEAT (left to right: Ted Moore, Jan Backman, Heiko Pälke, Steve Hovan, Mitch Lyle).

paleo-equator in order to study the changing patterns of sediment deposition across equatorial regions. As we have gained more information about the past movement of plates, and when in time “critical” climate events took place, we now propose to drill an age-transect (“flow-line”) following the position of the paleo-equator in the Pacific, targeting selected time-slices of interest where calcareous sediments have been preserved best (Figures 2 and 3).

The Expeditions aim to obtain a unique sedimentary biogenic carbonate archive for time periods just after the Paleocene–Eocene boundary event, the Eocene cooling, the Eocene/Oligocene transition, the “one cold pole” Oligocene, the Oligocene–Miocene transition, and the Miocene (Figure 2). A very shallow CCD prior to the Oligocene/Eocene transition makes it difficult to obtain well preserved sediments.

Recovered cores will contribute towards (1) resolving questions of how and why paleo-productivity of the equatorial Pacific changed over time, (2) provide rare material to validate and extend the astronomical calibration of the geological time scale for the Cenozoic, (3) determine sea-surface and benthic temperature and nutrient profiles and gradients, (4) provide important information about the detailed nature of calcium carbonate dissolution and changes of the CCD, (5) enhance our understanding of bio- and magnetostratigraphic datums at the equator, as well as (6) provide information about rapid biological evolution and turn-over during times of climatic stress. (7) As our strategy also implies a paleo-depth transect, we hope to improve our knowledge about the reorganization of water masses as a function of depth and time. (8) Integrated with detailed site-survey data, we intend to make use of the high level of correlation between tropical sediment sections and seismic stratigraphy to develop a more complete model of equatorial circulation and sedimentation. (9) Due to the northward component of the Pacific plate

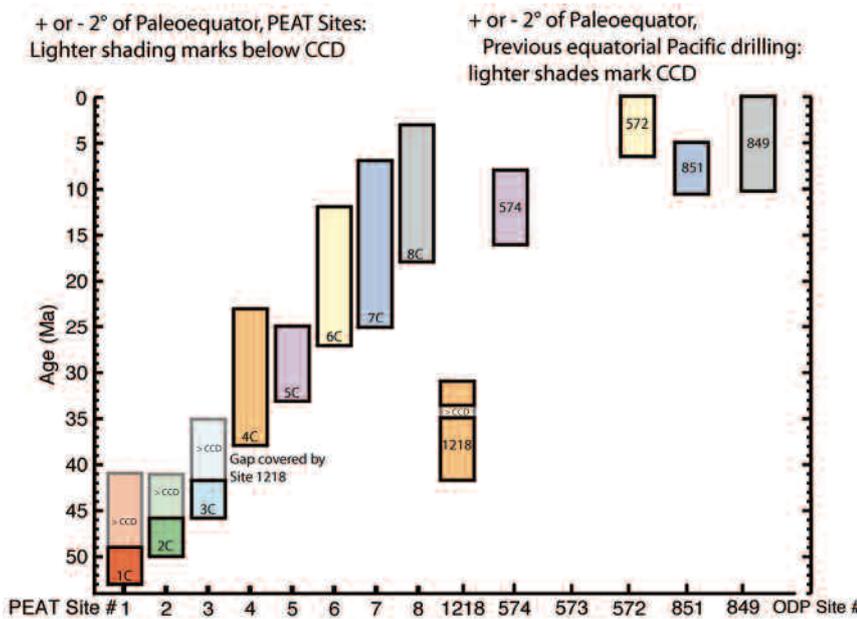


Figure 3. Time windows when PEAT sites are within Palaeo-equatorial region.

Table 1. Proposed Site details.

Site Name	Position	Water Depth (m)	Penetration (m)		Site-specific Objectives
			Total	Approved	
PEAT-1C	12°04.089'N 142°09.698'W	5132	192	250	Obtain calcareous sediments along an paleo-equatorial age-transect to decipher paleoceanography and paleoclimatology from the: earliest Eocene (~53 Ma crust) middle Eocene (50 Ma crust) middle/late Eocene (46 Ma crust) E/O boundary (~38 Ma crust) Oligocene (~32 Ma crust) O/M boundary (~27 Ma crust) Miocene (~24 Ma crust) Miocene (~18 Ma crust)
PEAT-2C	11°54.711'N 141°02.744'W	4941	167	250	
PEAT-3C	10°30.997'N 138°25.175'W	4874	179	250	
PEAT-4C	07°59.999'N 131°58.396'W	4809	273	300	
PEAT-5C	07°42.075'N 128°15.254'W	4311	258	300	
PEAT-6C	05°18.736'N 126°16.997'W	4362	367	400	
PEAT-7C	03°50.009'N 123°12.352'W	4491	457	480	
PEAT-8C	02°36.327'N 117°59.412'W	4330	460	480	
Alternates:					
PEAT-3D (Alt.)	10°32.720'N 138°20.183'W	4889	186	250	middle/late Eocene
PEAT-5D (Alt.)	07°42.069'N 128°06.068'W	4400	301	330	Oligocene



Figure 5. Sediment piston corer before deployment (in horizontal orientation). The empty tubing is lowered vertically on a steel wire to the sea-floor at approximately 5km depth, before capturing approximately 14m of sediment from the upper part of the sea-floor. Coring operations were performed by a crew from Oregon State University onboard the R/V Roger Revelle.

motion, our siting strategy also implies a limited N-S transect across the paleo-equator for some of the proposed time slices, providing additional information about N-S hydrographic gradients.

To fulfil the main objective of obtaining well preserved biogenic sediments despite the shallow carbonate compensation depth, sites are sited within a ±2° zone centered on the calculated position of the paleo-equator (Figure 1). Currently the plan is to core each target interval with multiple holes to ensure stratigraphic continuity and overlap, as well as using wireline tools to obtain logs for

correlation. There is a possibility of thin chert layer occurrences for the Eocene sites near the basal section, which will make recovery more challenging. Table 1 lists the proposed site positions and objectives, together with the estimated age for the oceanic crust on which the sedimentary section rests. Based on prior drilling expeditions (ODP Legs 138 and 199) the plan is to core the sedimentary sections using APC and XCB technology, allowing for the determination of palaeomagnetic orientations where APC can be deployed for the upper ~200m.

The current tentative schedule consists of two expeditions, with the first expedition targeting a subset of PEAT-1C through 4C

(mostly Eocene objectives), followed by a second expedition with mainly Oligocene and Miocene objectives. The current operational plan can be found at the IODP web site (www.iodp.org/expeditions/), subject to change.

The success of this drilling proposal upto the present would not have been possible without the excellent collaboration between NERC and NSF, providing the means for a successful site survey cruise, as evidenced by some of the happy proponents (Figure 4), and beautiful piston coring conditions (Figure 5), which were then expertly described and sampled by undergraduate and postgraduate students (Figure 6).



Figure 6. After site-survey sediment cores were retrieved, the cylindrical cores were split, and described for sedimentological features. This was done very professionally by the students on the survey cruise under the supervision of Steve Hovan. Visible are Kirsty Edgar (front left, University of Southampton), David Spofforth (front right, University of Southampton), Rebecca Reese (middle right, Undergraduate Student, Indiana University of Pennsylvania), Marcus Badger (far right, University of Cardiff), and Maite Hernandez (very far right, University of Bristol).

Reports on recent IODP expeditions

Expedition 310: Tahiti Sea Level

Ed C. Hathorne (The Open University, now at RCOM, University of Bremen, Germany) Alex Thomas (University of Oxford) and the Expedition 310 Scientists

Integrated Ocean Drilling Program (IODP) Expedition 310 to the reef terraces around Tahiti, French Polynesia, was only the second mission-specific platform (MSP) expedition conducted by the European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO). During October and November 2005 successive reef terraces seaward of the living barrier reef were cored using a dynamically positioned vessel. A total of 37 boreholes across 22 sites were cored in water depths ranging from 41.65 to 117.54m. The length of recovered core was some 630m with a recovery of 57%, although this value was calculated in the traditional manner and does not account for voids which are common in reef structures. Considering the nature of the reef structure drilled (average porosity: 30–35%), recovery was good to exceptional. Three areas around Tahiti were targeted (Figure 1) and because of the range of water depths covered it is thought that most if not all of the postglacial sequence from the LGM to the present day was recovered. Site survey and previous investigations have demonstrated the occurrence of successive reef

terraces at water depths of 100, 90, 60, and 40–50 m around Tahiti and these terraces were the drilling targets. For example, the Tiarei drill sites were mostly targeting a terrace at ~100m water depth (Figure 2). The Expedition 310 report is due to be published in March 2007 so this report will present a general summary and concentrate on research in progress by UK participants. Please see the expedition report for a more detailed description of the material recovered.

Scientific Objectives of Expedition 310:

1. Establish the course of postglacial sea level rise at Tahiti (i.e., define the exact shape of the deglaciation curve for the period 20.00–10.00 ka).
2. Define SST variations for the region over the period 20.00–10.00 ka.
3. Analyse the impact of sea level changes on reef growth and geometry.

Only three deglaciation curves based on coral reef records have been accurately dated for times reaching back to the

Pleistocene/Holocene boundary. These records are from Barbados (Fairbanks, 1989, 1990; Bard et al., 1990a 1990b; Peltier and Fairbanks, 2006) New Guinea (Chappell and Polach, 1991; Edwards et al., 1993), and Tahiti (Bard et al., 1996). To date, the Barbados curve is the only one to cover the whole deglaciation because it is based on offshore drilling. New Guinea is located in a tectonically active area so tectonic movements can be large and discontinuous potentially biasing sea level records by tectonic uplift. Tahiti was chosen as a site to study sea level because the tectonic movements are considered slow and regular and it was also located far from the melting ice sheets and their outflows during the deglaciation (far-field).

The recovery of a potentially complete postglacial sequence from the LGM to the Holocene at the far-field tectonically stable Tahiti will enable the refinement and confirmation of deglacial sea level history. Reconstruction of sea level relies on radiometric dating of in situ corals using methods like $^{230}\text{Th}/^{234}\text{U}$ by multi-collector inductively coupled plasma (MC-ICP-MS) or thermal ionization (TIMS) mass spectrometry and ^{14}C by accelerator mass spectrometry (AMS) in conjunction with paleobathymetric information deduced from biological communities (corals, algae, and molluscs) with a sufficiently narrow or specific water depth habitat.

The coring of massive *Porites* colonies provides the opportunity to gain sub-annual climatic information for the south Pacific during the last deglaciation. In the tropics the most debated points are: (1) the quantification of SSTs and the identification of climatic variations during the last deglaciation and (2) the timing of postglacial warming in the two hemispheres. Techniques for SST reconstruction will include $\delta^{18}\text{O}$ and Sr/Ca

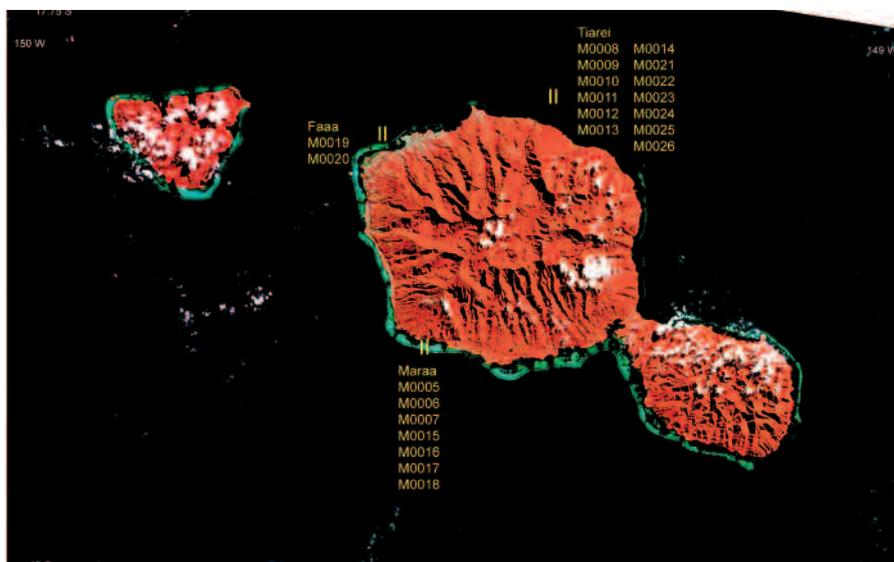


Figure 1. Landsat image composite showing the location of Expedition 310 operations around Tahiti (Source <http://landsat.gsfc.nasa.gov>).

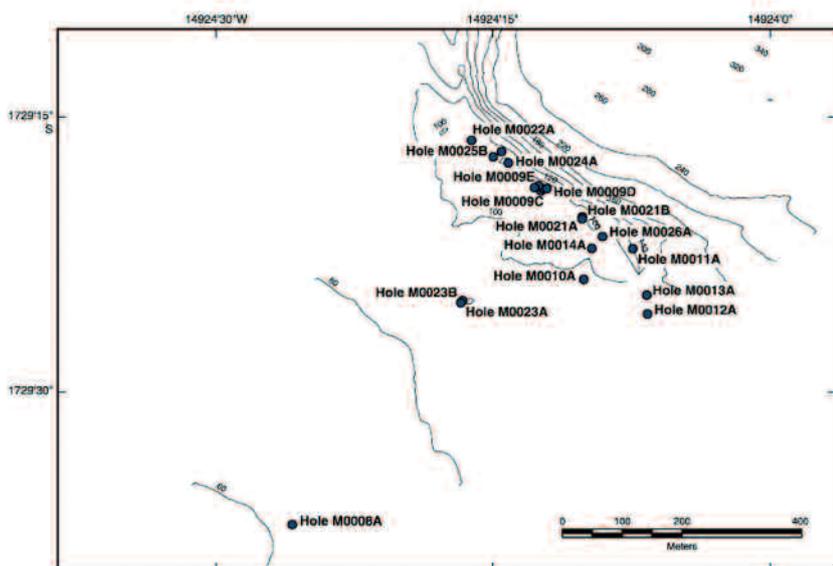


Figure 2. Location of Expedition 310 Holes in the Tiarei area. Contours represent depth below sea level in metres (Expedition 310 Scientists, 2006).

measurements on well preserved *Porites* skeletons. Such data will be the first for the early deglacial (perhaps even the LGM) in the south Pacific and will supplement records from other regions (e.g. Guilderson et al., 1994) and other deglaciations (McCulloch et al., 1999).

The sedimentary sequences recovered will allow the assessment of the impact of glacial meltwater phases (identification of reef drowning events) and the morphological and sedimentological evolution of the foreslopes (highstand versus lowstand processes). Numerical models simulating reef building will be used to study the effect of a sea level jump on reef geometry and to qualitatively assess the effect of sea level fluctuations on the reef shape and age–depth relationships.

Operations

Drilling offshore reef terraces has only been attempted in Barbados (Fairbanks, 1989) and Kiritimati Atoll (Fairbanks et al., 2005) previously so the Tahiti 310 drilling represented a technical challenge. The shallow water depths made a MSP necessary and the environmental impact of drilling on the modern reef ecosystems was of prime consideration. A drill pipe camera was utilised at most sites to conduct pre and post drilling sea floor surveys to establish no living corals were disturbed by the drilling. The void filled nature of coral reef frameworks posed a problem for recovery but the abundant microbialites filling some gaps between massive coral colonies proved extremely helpful in recovering corals in original position. Borehole logging operations in 10 boreholes produced continuous geophysical

information for the drilled strata and could prove vital for correctly placing pieces which have moved vertically in the core barrel. Pore water samples were obtained shipboard, from mostly sandy unconsolidated units, utilising Rhizon sampling (Seeberg–Elverfeldt et al., 2005). Microbiology sampling was undertaken on ship and the early results are promising (Expedition 310 Scientists, 2006).

The space restrictions of the MSP meant that only a handful of scientists were on ship during drilling and the cores were not split at sea. Instead the recovered material was shipped from tropical Tahiti to temperate Bremen and

the state of the art core repository located there for the onshore science party.

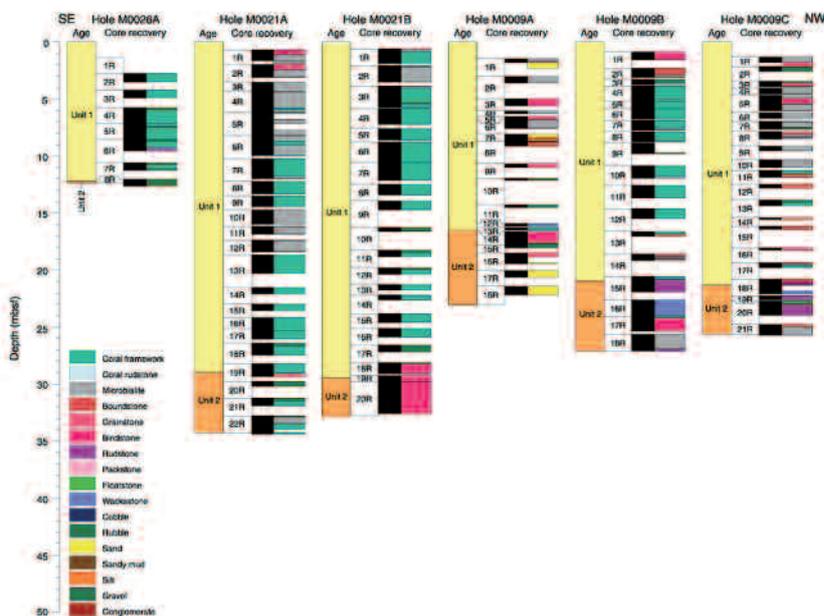
Onshore Science Party

On February 13th 2006, 26 scientists including the co–chiefs (or die Fahrleiter in German), from all corners of the Earth, assembled in Bremen for a scheduled 4 weeks of hard description and sampling. Most of the cores when split looked like a barcode with light massive corals alternating with darker microbialites, representing a succession of reef drowning events. The hard working team made quick work of 630m of core, describing the complex sediments (e.g. Figure 3), making additional measurements such as physical properties and elemental analyses of pore waters, and taking high quality samples for post cruise research to fulfil the objectives of the expedition. If it were not for the interruption of various TV crews (none from the U.K.) the work would have been finished a full week before schedule. After becoming television stars, most of the scientists then took part of Tahiti back to their labs for further study.

Research In Progress

Palaeoclimate from Last Deglacial Porites
Expedition 310 recovered some 30m of massive corals from the drowned reefs of Tahiti. Many of these corals are of the genus *Porites* and the annually banded aragonite skeletons of such corals represent an unique archive of seawater chemistry and environmental conditions during the last deglaciation in the South Pacific. Although there were not as many long continuous *Porites* recovered as all would have liked and

Figure 3: Lithostratigraphic summary of Holes on the Tiarei outer ridge. Unit 1 is the Postglacial Sequence and Unit 2 is the Older Pleistocene Sequence (Expedition 310 Scientists, 2006).



there is extensive bioerosion of many samples, there are still many pieces which hold great promise for reconstructing snap-shots of sub-annual climate variability. Figure 4 shows an example of a X-ray radiograph and a digital photograph of a sample which is undergoing laser ablation (LA)-ICP-MS analysis for trace element/Ca ratios and has been micro-drilled for $\delta^{18}\text{O}$ and solution trace element/Ca measurements. Sampling has been conducted along the clearly visible maximum growth axis and the initial data are very promising. The high resolution (<100 microns) LA-ICP-MS technique has revealed high amplitude variations in trace element ratios, such as U/Ca and Mg/Ca, superimposed on the seasonal fluctuations. Such high amplitude variability is thought to be related to biomineralization processes and not to external environmental conditions in modern corals (e.g. Meibom et al., 2007). This suggests that the samples analysed so far are well preserved as secondary alteration is likely to have removed such high amplitude biomineralization signals.

Radiometric Dating of Corals

Along with providing a temporal framework for the study of paleoclimate reconstruction and reef development, absolute dating of coralline material through U-series forms part of the principle objective of the expedition. The pre-existing sea level record from Tahiti (Bard et al., 1996) has been extended to at least 17.5 ka, with ongoing measurements potentially extending it further. The material dated so far has enabled the global significance of Melt-Water-Pulse 1A (Fairbanks, 1989) to be confirmed. The timing and magnitude of this event at Tahiti will – through collaboration with isotopic modelling groups from the Expedition 310 Scientists – enable the source of melt-waters during the deglaciation to be further investigated.

The lead area of the UK's involvement in the dating of material from Expedition 310 is the investigation of corals that are older than 20 ka. Though the preservation of this material is often poor, as much of it may have been exposed to meteoritic water during subsequent sea level low-stands, significant results have been obtained. It appears that some of the sites at Tahiti are recording sea level low-stands with material recovered and dated to Marine Isotope Stage IV and the end of MIS VI. Older corals have also been successfully dated although the closed system model of U-Th systematics no longer holds true for these samples. Although uncertainties on the ages and palaeo-depths of these older corals are large it will be possible to put better constraints on the subsidence of Tahiti, which at present is poorly constrained.

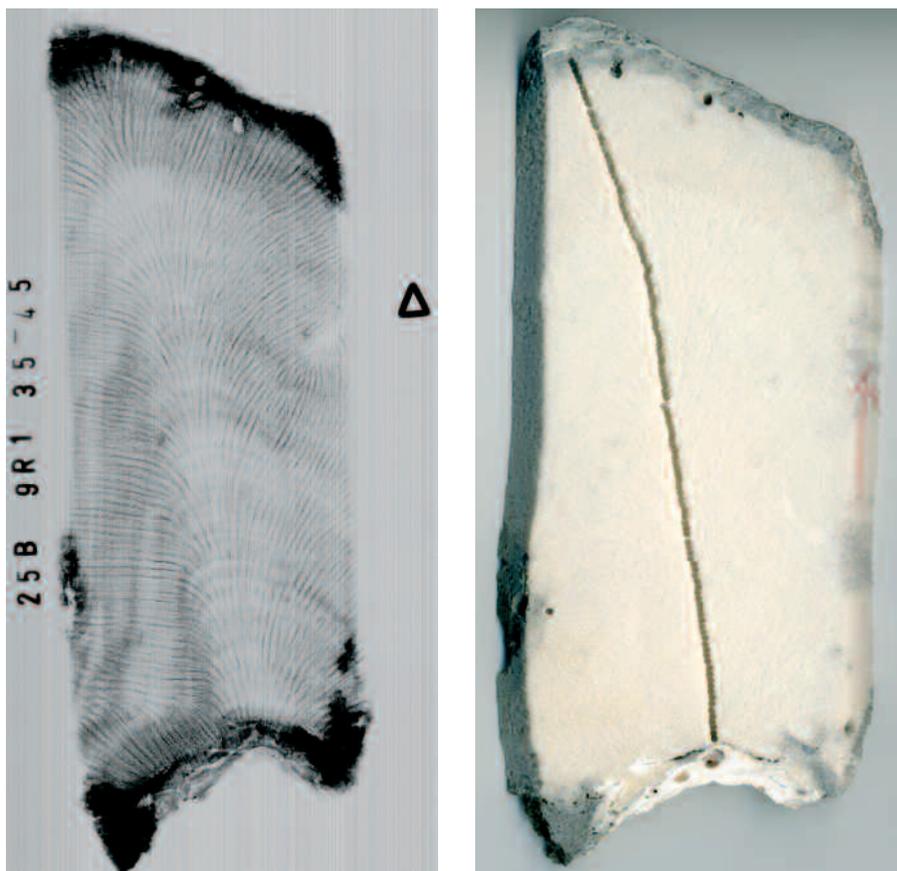


Figure 4. X-ray radiograph (left) and digital photograph (right) of a deglacial Tahiti *Porites* coral recovered by Expedition 310. Note the prominent growth axis visible in the X-ray and the coralgal (white) and microbialite crusts (grey) at the top and bottom of the piece visible in the photo. The growth axis which has been sampled by micro-drilling is 12cm long and this sample should provide a sub-annual climate record for a period of ~10 years during the last deglaciation.

Concluding Remarks

Although the science using the Expedition 310 samples is far from complete, the samples obtained from Tahiti are truly unique and will contribute greatly to the knowledge of sea level and climate change during the last deglaciation. Much work will be done before the post cruise meeting in November 2007 which will be a much needed opportunity to compile and integrate data and ideas. Expect to see Expedition 310 data at a conference or in a journal near you soon, for example there are 5 presentations (Session CL 36, oral and poster) from Expedition 310 scientists at the EGU in Vienna 15–20 April 2007.

References

- Bard, E, Hamelin, B, Arnold, M, Montaggioni, L, Cabioch, G, Faure, G, and Rougerie, F. 1996. Deglacial sea-level record from Tahiti corals and the timing of global meltwater discharge. *Nature*, Vol. 382, 241–244. doi:10.1038/382241a0
- Bard, E, Hamelin, B, and Fairbanks, R G. 1990a. U-Th ages obtained by mass

spectrometry in corals from Barbados: sea level during the past 130,000 years. *Nature*, Vol. 346, 456–458. doi:10.1038/346456a0

Bard, E, Hamelin, B, Fairbanks, R G, and Zindler, A. 1990b. Calibration of the ^{14}C timescale over the past 30,000 years using mass spectrometric U-Th ages from Barbados corals. *Nature*, Vol. 345, 405–410. doi:10.1038/345405a0

Chappell, J, and Polach, H. 1991. Post-glacial sea-level rise from a coral record at Huon Peninsula, Papua New Guinea. *Nature*, Vol. 349, 147–149. doi:10.1038/349147a0

Edwards, R L, Beck, J W, Burr, G S, Donahue, D J, Chappell, J M A, Bloom, A L, Druffel, E R M, and Taylor, F W. 1993. A large drop in atmospheric $^{14}\text{C}/^{12}\text{C}$ and reduced melting in the Younger Dryas, documented with ^{230}Th ages of coral. *Science*, Vol. 260, 962–968.

Expedition 310 Scientists. 2006. Tahiti Sea Level: the last deglacial sea level rise in the South Pacific: offshore drilling in Tahiti (French Polynesia). IODP Preliminary Report Vol. 310.

doi:10.2204/iodp.pr.310.2006

Fairbanks, R G. 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature*, Vol. 342, 637–642. doi:10.1038/342637a0

Fairbanks, R G. 1990. The age and origin of the Younger Dryas climate “event” in Greenland ice cores. *Paleoceanography*, Vol. 6, 937–948.

Fairbanks, R G, Mortlock, R A, Chiu T-C, Cao, L, Kaplan, A, Guilderson, T P, Fairbanks, T W, and Bloom, A L. 2005. Marine Radiocarbon Calibration Curve Spanning 10,000 to 50,000 Years B.P. Based on Paired $^{230}\text{Th}/^{234}\text{U}$ and ^{14}C Dates on Pristine Corals. *Quaternary Science*

Reviews, Vol. 24, 1781–1796.

Guilderson, T P, Fairbanks, R G, and Rubenstone, J L. 1994. Tropical temperature variations since 20,000 years ago: modulating interhemispheric climate change. *Science*, Vol. 263, 663–665.

McCulloch, M T, Tudhope, A W, Esat, T M, Mortimer, G E, Chappell, J, Pillans, B, Chivas, A R, and Omura, A. 1999. Coral record of equatorial sea-surface temperatures during the penultimate deglaciation at Huon Peninsula. *Science*, Vol. 283, 202–204. doi:10.1126/science.283.5399.202

Meibom, A, Mostefaoui, S, Cuif, J-P, Dauphin, Y, Houlbrequé, F, Dunbar, R, and Constantz, B.

2007. Biological forcing controls the chemistry of reef-building coral skeleton. *Geophysical Research Letters*, Vol. 34, L02601. doi:10.1029/2006GL028657

Peltier, W R and Fairbanks, R G. 2006. Global glacial ice volume and Last Glacial Maximum duration from an extended Barbados sea level record. *Quaternary Science Reviews*, Vol. 25, 3322–3337.

Seeberg-Elverfeldt, J, Schlüter, M, Feseker, T, and Kölling, M. 2005. Rhizon sampling of porewaters near the sediment-water interface of aquatic systems. *Limnol. Oceanogr.: Methods*, Vol. 3, 361–371.

Geotek Travelogue: IODP Expedition 311, Cascadia Margin Gas Hydrates

Melanie Holland (Geotek Ltd.), Peter Schultheiss (Geotek Ltd.), and IODP Expedition 311 Shipboard Scientific Party

About five weeks into any IODP Expedition, scientists start asking themselves why they ever agreed to come to sea on this crazy ship. Peter and I are repeat ODP offenders (Peter's four to my two) and we congratulated ourselves with the thought that this time around we were being directly paid as contractors! Geotek sailed the two of us on IODP Expedition 311, together with two HYACINTH coring engineers from Fugro, Martin Rothfuss and Roeland Bass, funded by the United States Department of Energy (US DOE) through the Joint Oceanographic Institutions to obtain pressure cores and to perform specialized core analysis on gas hydrate cores. Neither Geotek nor IODP are strangers to hydrate drilling; IODP Expedition 311 was ODP/IODP's fourth dedicated gas hydrate leg (after Legs 146, 164, and 204) and Geotek's third of five gas hydrate drilling expeditions to date. With two more major gas hydrate expeditions to come in 2007 for Geotek, it is becoming quite a habit for us!

So what's the big deal with gas hydrate, and why are so many different groups of people interested in this ice-like solid made of methane (or other light hydrocarbons) encased in a water lattice? Between its awkward stability—it only exists at high pressures and low temperatures—and the flammability and greenhouse gas potential of the methane locked inside, there are many fascinating aspects to gas hydrate. Most scientists funded by national science programs study gas hydrate in the context of global biogeochemical cycles

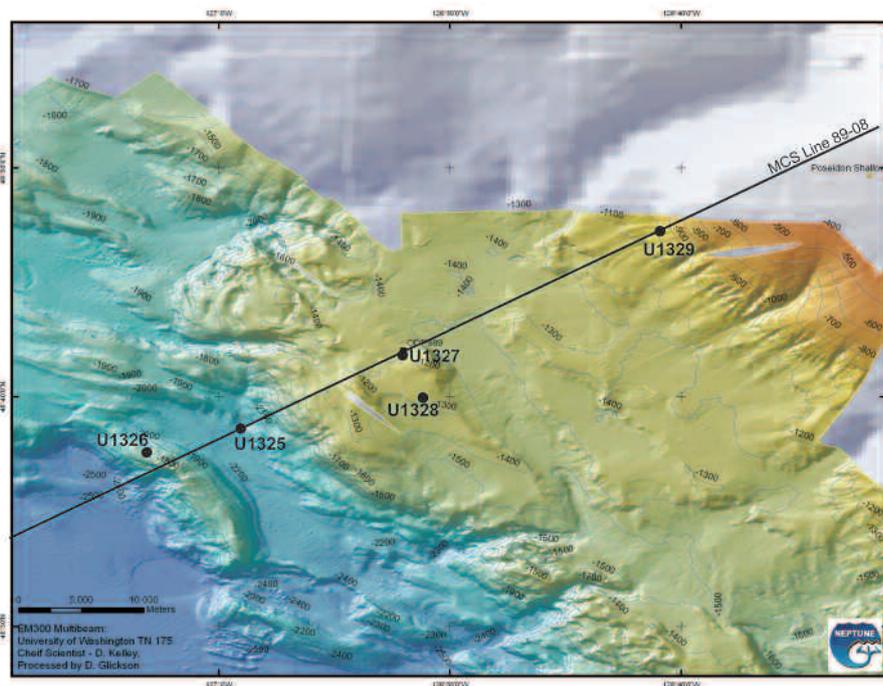


Figure 1. Map of drilling locations for IODP Expedition 311; bathymetry courtesy of D. Kelley & the NEPTUNE program.

and climate change, but nations such as Japan, India, China, and Korea are seriously considering marine gas hydrate as a potential hydrocarbon fuel reserve. On the flip side, major oil companies are interested in gas hydrate so that they can avoid the danger of accidentally dissociating (melting) sedimentary hydrate during oil recovery, leading to well instability, slope failure, or loss of a rig.

Geotek was contracted to perform analysis both on pressurized cores, where hydrate remains stable, and conventional cores, where pressure is released during core recovery and hydrate begins to dissociate. Natural gas hydrate, kept under pressure, can be identified by its low density and high velocity compared to surrounding sediments. Using the Pressurized Multi-Sensor Core Logger

(MSCL-P; Figure front cover), both the ODP Pressure Core Sampler (PCS) cores and the HYACINTH Fugro Pressure Corer (FPC) & HYACE Rotary Corer (HRC) cores were X-rayed while under in situ temperature and pressure; hydrate in these cores was stable, so gas hydrate-sediment structures could be examined. HYACINTH pressure cores, designed to be analyzed under pressure (Schultheiss et al., 2006), also had both gamma density and ultrasonic P-wave velocity measured in the MSCL-P.

Perversely, the detection of gas hydrate in conventional cores relies on its destruction. The most rapid method of detection uses infrared cameras to find cold spots in cores (pioneered during ODP Leg 201; Ford et al., 2003), which are generated by the endothermic dissociation of gas hydrate. The Geotek infrared imaging track runs a FLIR infrared camera along a 9.5-m core in 2.5 minutes, showing the composite infrared image of the core in real time on monitors along the catwalk. The concatenated core images are used for immediate core sampling and are then saved along with the corresponding two-dimensional temperature array for further analyses.

Scientific Objectives

IODP Expedition 311 examined the geological controls on gas hydrate formation within the accretionary wedge of an active margin. The goal of the program was to test contrasting models of gas hydrate formation in sediments: dispersed pervasive upward flow vs. focused flow in fault zones, and to constrain model parameters with real data. The margin-perpendicular transect sites drilled on Expedition 311 (Figure 1) represented different stages in the evolution of the gas hydrate across the accretionary prism (Figure 2). The transect was supplemented by a site at an active cold vent to ensure that one site was influenced by focused flow.

Specifically, IODP Expedition 311 concentrated on finding out, for each site

- the distribution of gas hydrate
- the nature of the seismic Bottom Simulating Reflector (BSR)
- baseline geochemical and microbiological profiles
- ground-truth data for remote techniques (e.g., seismic or electromagnetic surveys)

IODP Expedition 311 was in many ways a follow-on to ODP Leg 146 (Westbrook et al., 1994), which drilled the same area of the Cascadia Margin. Gas hydrate was found at Sites 889 & 890 (soon to be reoccupied as Site U1327) but many questions remained about the quantity of gas hydrate within the sediment. Gas hydrate was quantified on ODP

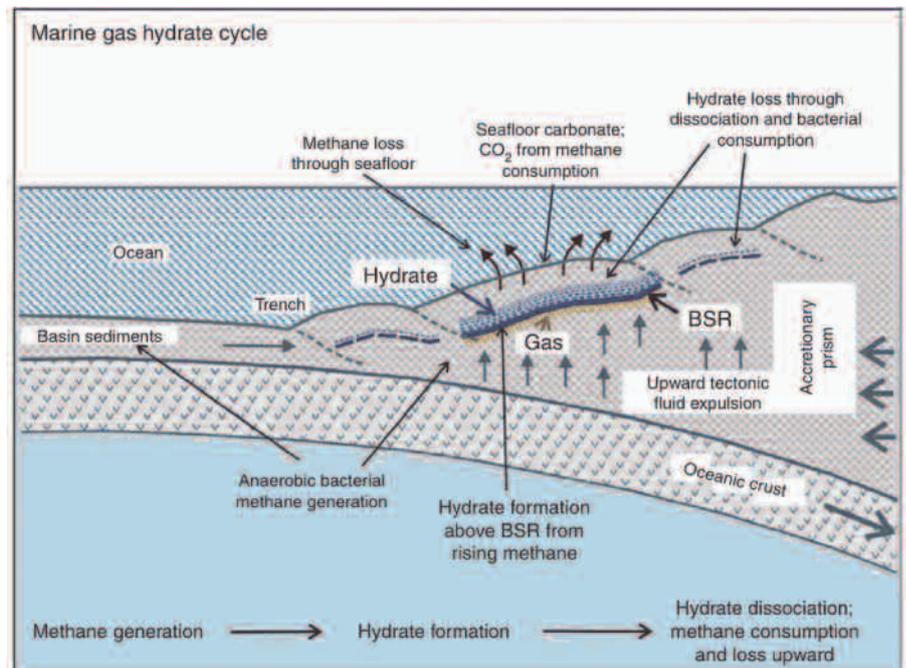


Figure 2. Marine gas hydrate cycle (after Hyndman and Davis, 1992). BSR = bottom-simulating reflector.

Leg 146 using electrical resistivity and porewater freshening. Borehole logs of electrical resistivity in sediments have been used in the oil industry to calculate water saturation in porous sandstones using Archie's relationship; the remaining porosity is assigned to resistive materials like oil—or in this case, gas hydrate. However, there is much less data concerning the use of Archie in clays, and the gas hydrate saturations calculated on Leg 146 lacked the necessary ground-truth data to calibrate them. Gas hydrate quantification via porewater freshening is a much more direct method of assessing hydrate concentration; after all gas hydrate has dissociated in a sediment sample, the concentration of conservative tracers in pore fluid are measured (e.g., chloride) and the amount of fresh water contributed from gas hydrate is calculated. To use this method, however, one must be certain of the in situ chlorinity and a variety of different assumptions were tested, inconclusively, on data from Leg 146 (Westbrook et al., 1994; Kastner et al., 1995).

Pressure coring was used on IODP Expedition 311 as the "gold standard" for gas hydrate quantification. Dickens et al. (2000) showed that if a pressure core, which captures and retains all constituents of a core, is slowly depressurized and the gas collected and analyzed, a mass balance approach will allow the total gas hydrate within the core to be calculated. Methane collected is partitioned into that which is dissolved in the pore fluids vs. methane above and beyond what can be dissolved, based on the calculated in situ solubility, and then the excess methane that cannot be contained in solution is assigned to

gas hydrate or free gas as dictated by thermodynamic equilibrium conditions. This mass balance approach was applied to pressure cores on IODP Expedition 311, enhanced by indirect measurements and X-ray observations of core at in situ temperatures and pressures, both prior to and during depressurization.

Drilling Operations

We boarded the *JOIDES Resolution* for IODP Expedition 311 in Astoria, Oregon, at the beginning of the port call to load and install the pressure coring and core analysis equipment. Geotek's software guru, Richard Chamberlain, joined us for the Astoria port call to ensure the smooth installation of the new infrared imaging track. As a treat for a job well done, we took Richard for a trip up to Mt. St. Helens—and ran into a group of our soon-to-be shipmates. You can't get away from these people even if you go climb a mountain!

We left port on the 19th of September, 2005, and immediately began the Logging While Drilling (LWD) phase of the expedition using the Schlumberger LWD toolset. One hole at each site was drilled with the LWD tools, and to satisfy safety requirements, gas influx into the borehole was monitored by the annular pressure from the EcoScope tool and the fluid velocity and waveform coherence from the SonicVISION tool. Site by site the data was printed out and hung in the lab, while the bulk of the science party drank tea and debated the magnitude of the resistivity anomalies. LWD lulls shipboard scientists into a false sense of security; we had an entire week to fuss and settle in, and it came as a shock to

some people when, on 27 September, we finally heard...

Core on Deck! Or might it be Hydrate on Deck? All eyes were on the infrared track (Figure 3), which would tell the intrepid explorers whether gas hydrate was concealed within the core. The lack of any thermal anomalies at Site U1329 was disappointing after the long wait, but morale was high with the promise of massive hydrate saturations at sites to come, courtesy of the LWD Resistivity-At-Bit (RAB) tool and Archie's relationship. Five holes were drilled at Site U1329 to a maximum depth of 220mbsf. Core was processed with smooth efficiency; gas-hydrate-related data collected included the thermal image taken on the catwalk, chloride concentrations in porewater which might indicate freshening, gas compositions from voids, and sedimentological textures which were closely examined for indications of moussy or soupy sediments. Peter and I were pleased that other Geotek systems on board the JOIDES Resolution, such as the Digital Imaging System that provides the split-core images, were so routinely used as to be unremarkable.

Pressure coring operations settled into a

routine: the PCS was assembled above the core tech shop, and the 11-meter-long HRC & FPC tools were assembled on the port side of the piperacker. Tools were deployed, and upon recovery were stabbed into a 3-meter-long ice-water-filled bath hanging in the moonpool for 30 minutes to chill the core at the bottom of the tool and keep any hydrate stable. The tool autoclaves were removed and brought into the 20-foot refrigerated Geotek pressure core analysis van over the core tech shop. PCS cores were X-rayed directly through the autoclave, which was remanufactured in aluminum especially for this analytical capability, and carried to another 20-foot refrigerated van atop the lab stack for depressurization analysis. Depressurization, supervised by organic geochemist Verena Heuer, took place while the core underwent repeated gamma density scans in the Vertical Multi-Sensor Core Logger (MSCL-V) to pinpoint zones of gas production. HYACINTH autoclaves, when brought into the pressure core analysis van, were connected to the MSCL-P system and the core was removed from the autoclave, under pressure, and transferred into the MSCL-P for X-rays, ultrasonic P-wave velocity measurements, and gamma density

analysis. HYACINTH cores were then stored for further analysis and subsampling on shore.

The original plan at each site was to drill one LWD hole (already done, at this point), drill one continuously cored hole, and based on the data from those two holes, deploy "special tools" in the third hole, which would then be wireline logged. "Special tools" included the Davis-Villinger Temperature Probe (DVTP) and the three pressure coring tools: the PCS and the HYACINTH FPC & HRC. However, the North Pacific had other ideas. Our first wait on weather was on the 29th of September, and we could see the weather window closing in front of us. The pragmatic goal became to drill one cored hole at each site, with "special tools" included, and log this hole if possible. This conserved time, which was not on our side, but meant that pressure coring targets were no longer chosen with the benefit of core data.

LWD resistivity data became our guide. Highly resistive, "bright" layers could indicate gas hydrate, and these layers became targets for both pressure and conventional coring. Alas, they proved elusive; one of the lessons re-learned on IODP Expedition 311 is that gas hydrate is difficult to recover. Logging scientist Alberto Malinverno put his

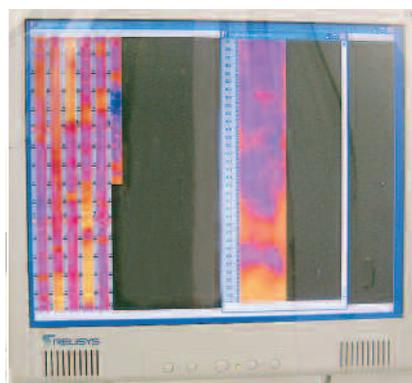


Figure 3. Below: Geotek infrared imaging track set to image an APC core, using the US DOE FLIR infrared camera. Lisa Hawkins is shown for scale. Left: Monitors along the track showed the complete infrared image of the core in real time along with a scale marked in meters. Cold (blue) spots indicate hydrate dissociation.



quantitative mind to the problem and showed that conventional core recovery was inversely proportional to electrical resistivity! Unfortunately, this trend extended to pressure cores as well, and between the deteriorating weather and the difficult coring targets, the pressure coring tools did not perform as well as had been hoped. However, the pressure cores that were recovered provide invaluable ground-truth and novel observations of hydrate (see “Scientific Results”).

After Site U1329, the closest to shore, the ship moved on the 2nd of October to Site U1327, the central site in the transect and a near-reoccupation of Site 889/890. A total of five holes were drilled at Site U1327, to a maximum depth of 300 mbsf. Infrared anomalies were greeted with sighs of relief, two excellent HRC cores showing hydrate-related velocity anomalies were stored for further work, and the Vertical Seismic Profile (VSP) was a success. Spirits remained undamped even after ship heave increased to 3.5m, curtailing a pressure coring hole and forcing the first of many uses of “armless” logging tool strings.

The 11th of October found the science party clustered around the televisions, watching the camera survey of the Bullseye vent area (Site U1328) which showed many carbonate outcrops (which later took their toll

in two bent APC barrels) but no clam colonies. Whew—no problems with animal rights activists! This site was expected to produce the most hydrate and did not disappoint, showing infrared thermal anomalies throughout the section and pieces of the real article, white hydrate—but again, the zone of highest electrical resistivity (0–40 mbsf) was practically unrecoverable. Five holes were drilled at Site U1328 to a maximum depth of 300mbsf as the weather continued to deteriorate, with periods of ship heave over 7m recorded on the drill floor.

Site U1325, the slope basin, was reached on the 17th of October and we drilled four holes to a maximum depth of 350mbsf. Fine sands made drilling and core recovery more difficult at this site. Infrared anomalies, while present, were no longer unusual enough to bring the entire science party out to the catwalk. We grimly drilled and deployed more armless logging tool strings in sustained ship heave of 5m, when four weeks ago we had been waiting on weather in calmer conditions.

The final site drilled, U1326, was begun on the 23rd of October, eventually drilling four holes to a maximum depth of 300mbsf. This location on an uplifted ridge was the most seaward in the transect and contained some notable thermal anomalies, which were dissected under infrared cameras for detailed

porewater analysis by Phil Long, Marta Torres, and Miriam Kastner, who retained their hydrate enthusiasm to the very end of the cruise.

On the 27th of October, IODP Expedition 311 turned tail and ran for Victoria as the weather window slammed shut, with 40–45 knot winds gusting to >50 knots. I got soaked by the top of a wave that sailing over the DP shack and landed on me while I was trying to move samples out of the cold van on top of the lab stack! Both the storm and IODP Expedition 311 continued at the Pacific Geosciences Centre (PGC) in Sidney, British Columbia, with the help of Fred Wright & Scott Dallimore and courtesy of the US DOE. In the damp, a trailer park sprung up like a fairy ring in the corner of the PGC yard; the cold vans from the ship were joined by other refrigerated containers to accommodate the University of Berlin’s PRESS pressure core subsectioning equipment and the University of Cardiff pressure core subsampler, both of which are designed to operate on HYACINTH cores under pressure. While waiting for the vans to be hooked up to base electricity, Peter and I saw the local wildlife which including salmon leaping upstream and a deer committing suicide in the rain by jumping into the path of our rental car. Over the next week, four HYACINTH pressure

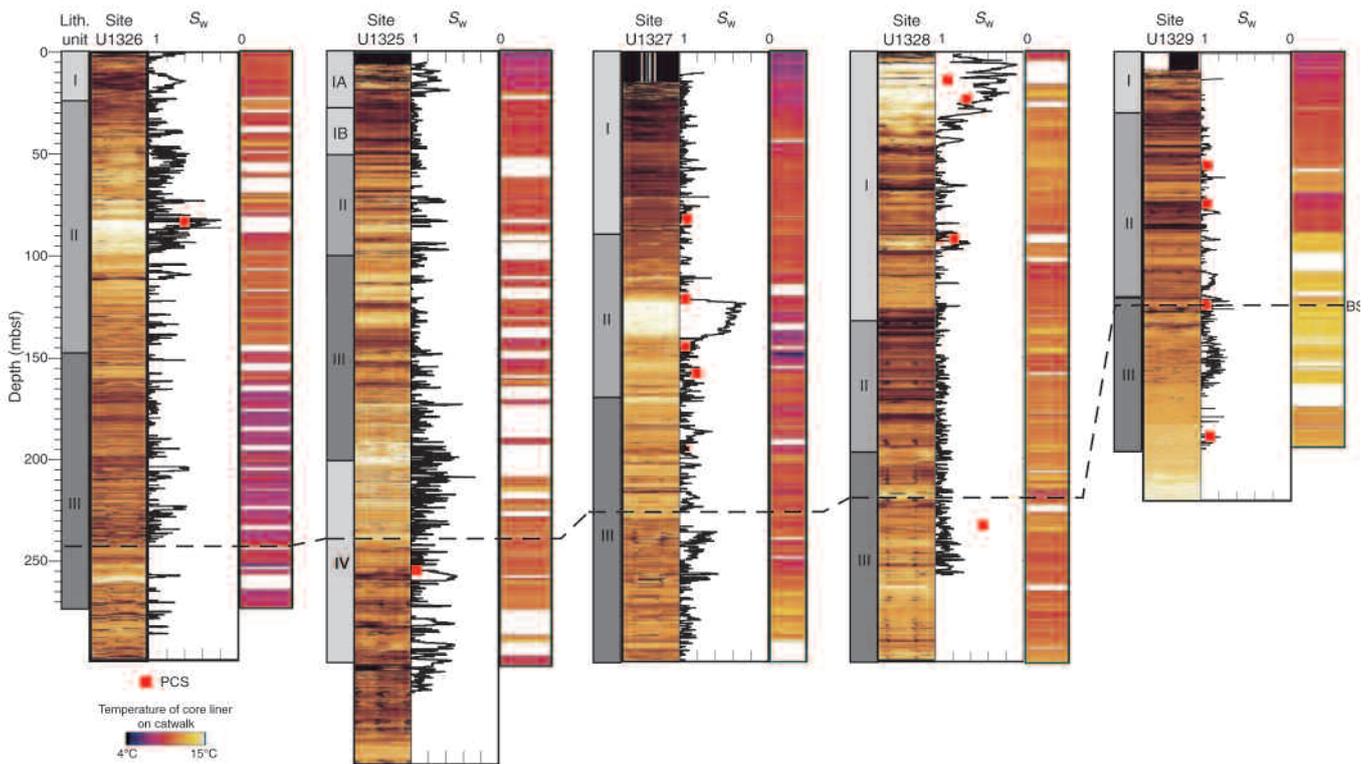


Figure 4. Summary of IODP Expedition 311 infrared images of core liner temperature. Also shown are lithostratigraphic units, dynamically scaled LWD RAB images (light=more resistive), pore water saturation from Archie’s relationship (S_w), and location of the bottom-simulating reflector (BSR). PCS = pressure core sampler.

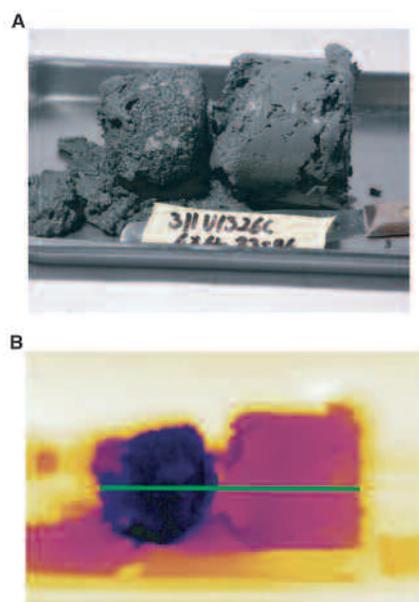


Figure 5. A) Sample of a sand layer containing gas hydrate in Sample 311-U1326C-6X-4, 83-96 cm. B) Infrared thermal image of the same sample, showing that the hydrate-containing sand layer was cold (blue).

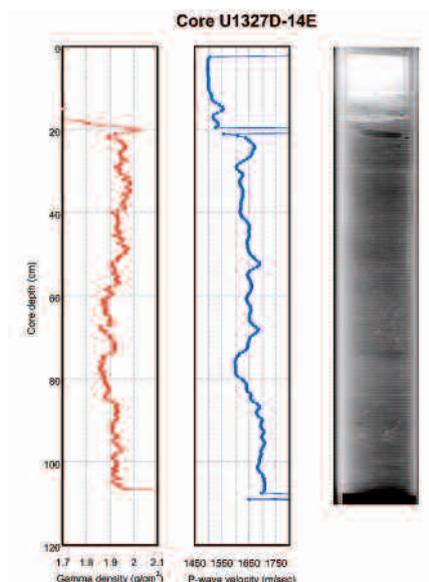


Figure 6. Data collected at 120 bar and 7°C for Core 311-U1327D-14E, showing gamma density, P-wave velocity, and X-ray image. This core had anomalously high P-wave velocities throughout the core, as well as showing low-density (white) wispy structures (see Figure 7). The X-ray image has been stretched 250% in the cross-core direction to show detail.



Figure 7. Portion of gas hydrate vein, approximately half a millimeter thick, removed from the core catcher of Core 311-U1327D-14E following rapid depressurization. These were the low-density wispy structures seen in the X-ray image (Figure 6).

cores which had been stored under pressure were variously subsectioned and subcored aseptically under pressure for microbiological studies, slowly depressurized while gamma density was repetitively measured, or rapidly depressurized and rapidly repressurized for transport to other researchers.

Scientific Results

What did we learn out there, after collecting 1217m of core, 21 pressure cores, and logging 11 holes—other than it's difficult to recover hydrate? The most easily assimilated observations had to do with the distribution of gas hydrate. Tim Collett & Michael Riedel, our illustrious co-chiefs, created a series of composite plots for gas hydrate distribution, showing the LWD resistivity images along with gas hydrate proxies, such as infrared thermal images (Figure 4) and chloride concentration, as well as the quantitative data from pressure core analysis. When all the data is examined together, once again our observations show that, from the largest to the smallest scales, the real world is more complicated than we imagined.

The sediments at all sites drilled were predominately clay, with interbedded silts and sands, and gas hydrate showed a distinct preference for these silty and sandy layers, even when the intervals were as small as one centimeter. Sandy intervals that showed up as cold in the original infrared thermal scan turned out to be up to 80% gas hydrate as a

percent of pore space (Figure 5). However, gas hydrate was also present throughout the clay, as shown in nondestructive measurements from pressure cores (Figure 6). This gas hydrate took the form of thin (0.5mm) subvertical veins, which were directly observed after the rapid depressurization of Core 311-U1327D-14E (Figure 7). Both of these observations will create headaches for the tireless interpreters of downhole logs, as the simple Archie's relationship between downhole resistivity and gas hydrate saturation of sediments must be modified to include horizontal or vertical layers of highly resistive material.

The presence of sandy intervals high in the sediment column might explain why gas hydrate was not found nestled above the BSR as had been predicted by models; alternatively, the vertical distribution of gas hydrate could reflect more than simple vertical diffusion. Complex fracturing and fluid flow was certainly evident at the Bullseye vent, Site U1328, but there was also evidence for gas hydrate present along fractures at Site U1327. At Site U1327, the zone of maximal infrared thermal anomalies in cores from Hole U1327C were offset in depth by 10m from the zone of maximal resistivity in Hole U1327A, drilled for LWD measurements, only 15m distant. Subsequent Holes U1327D&E, drilled for wireline logging, showed resistivity profiles that did not match those at U1327A. Site U1325 in the slope basin showed evidence

of faulted sediments, lateral inhomogeneities from hole to hole, and evidence for advection of a deep fluid in the porewater geochemistry. Site U1326, atop the westernmost uplifted ridge, showed pronounced faults in the seismic data and the potential for enhanced vertical or lateral fluid flow. Drilling an active margin as we were, I guess it's not surprising that we did not sample a static sedimentary environment to provide the wholly diffusive endmember in the model (see Tréhu et al., 2006, for a discussion of the endmembers, with IODP Expedition 311's sites in context).

Of course there were other exciting finds during IODP Expedition 311. There was possible Structure II gas hydrate at U1328, and maybe even at U1326, based on the gas composition as well as thermal anomalies found below the calculated base of Structure I methane hydrate stability. The top of the sediment column at Site U1328 (Bullseye vent) was notably salty (850 mM chloride), showing that this site is actively producing gas hydrate and excluding salts. The background, hydrate-unaffected geochemical profiles gleaned from both conventional and pressure cores show that both fresh and salty deep fluids exist in the region. For more extensive data, please see the Expedition report (Riedel et al., 2006), though with the second postcruise meeting around the corner in April, I'm sure that fresh insights into gas hydrate at accretionary margins will be coming soon!

References

- Dickens, G R, Wallace, P J, Paull, C K, and Borowski, W S. 2000. Detection of methane gas hydrate in the pressure core sampler (PCS): volume–pressure–time relations during controlled degassing experiments. In Paull, C.K., Matsumoto, R., Wallace, P.J., and Dillon, W.P. (Eds.), *Proceedings of the ODP, Scientific Results, Vol. 164: College Station, TX (Ocean Drilling Program)*, 113–126.
- Ford, K H, Naebr, T H, Skilbeck, C G, and the Leg 201 Scientific Party. 2003. The use of infrared thermal imaging to identify gas hydrate in sediment cores. In D'Hondt, S.L., Jørgensen, B.B., Miller, D.J., et al., *Proceedings of the ODP, Initial Reports, Vol. 201, 1–20 [CD-ROM]*. Available from: Ocean Drilling Program, Texas A&M University, College Station TX 77845–9547, USA.
- Hyndman, R D, and Davis, E E. 1992. A mechanism for the formation of methane hydrate and seafloor bottom–simulating reflectors by vertical fluid expulsion. *Journal of Geophysical Research*, Vol. 97, 7025–7041.
- Kastner, M, Kvenvolden, K A, Whiticar, M J, Camerlenghi, A, and Lorenson, T D. 1995. Relation between pore fluid chemistry and gas hydrate associated with bottom–simulating reflectors at the Cascadia margin, Sites 889 and 892, *Proceedings of the ODP, Scientific Results, Vol. 146 (Pt 1): College Station, TX (Ocean Drilling Program)*, 175–187.
- Riedel, M, Collett, T S, Malone, M J, and the Expedition 311 Scientists. 2006. *Proceedings of the IODP, Expedition Reports, Vol. 311. College Station, TX (Ocean Drilling Program)*.
- Schultheiss, P J, Francis, T J G, Holland, M, Roberts, J A, Amann, H, Thjunjoto, Parkes, R J, Martin, D, Rothfuss, M, Tyunder, F, and Jackson, P D. 2006. Pressure coring, logging and sub–sampling with the HYACINTH system. 151–165 in *New Ways of Looking at Sediment Cores and Core Data*, Rothwell, R G (Editor). Special Publication of the Geological Society of London, No. 267.
- Tréhu, A M, Ruppel, C, Holland, M, Dickens, G R, Torres, M E, Collett, T S, Goldberg, D, Riedel, M, and Schultheiss, P. 2006. Gas hydrates in marine sediments: lessons from scientific ocean drilling. *Oceanography*, Vol. 19(4), 124–142.
- Westbrook, G K, Carson, B, Musgrave, R J, et al. 1994. *Proceedings of the ODP, Initial Reports, Vol. 146 (Pt. 1). College Station, TX (Ocean Drilling Program)*.

IODP Expedition 312: Superfast Spread Crust III Gabbros for Christmas....

John MacLennan (University of Cambridge)

One of the long-term goals of scientific ocean drilling has been to determine the nature of the oceanic crust. While 2/3 of the outer solid shell of the Earth is composed of this oceanic crust, we have only gained a rudimentary understanding of its overall structure, and how this structure might vary within and between the ocean basins. Models of the lithological structure of oceanic crust have so far been based on marine geophysics, mapping and sampling of the ocean–floor lavas that form the uppermost surface of the crust, and scattered exposures of deeper parts of the crust that have been exhumed in unusual tectonic environments. Ophiolite complexes are the most spectacular of such exposures, and observations from ophiolites in Oman and Cyprus have been central to the development of current models of oceanic crustal structure. Many have sought to link the lithological layering of ophiolite complexes to the vertical variations in the physical properties of the crust observed in the ocean basins. Despite the synthetic appeal of these parallels, the significance of the observations from ophiolites has been called into question because ophiolites can only form in unusual tectonic settings. Their relevance to the open ocean basins which host almost all of the oceanic crust is equivocal. Therefore, in order to knit together the geological observations from ophiolites with the geophysical observations from the oceans there has been a long and outstanding need for the

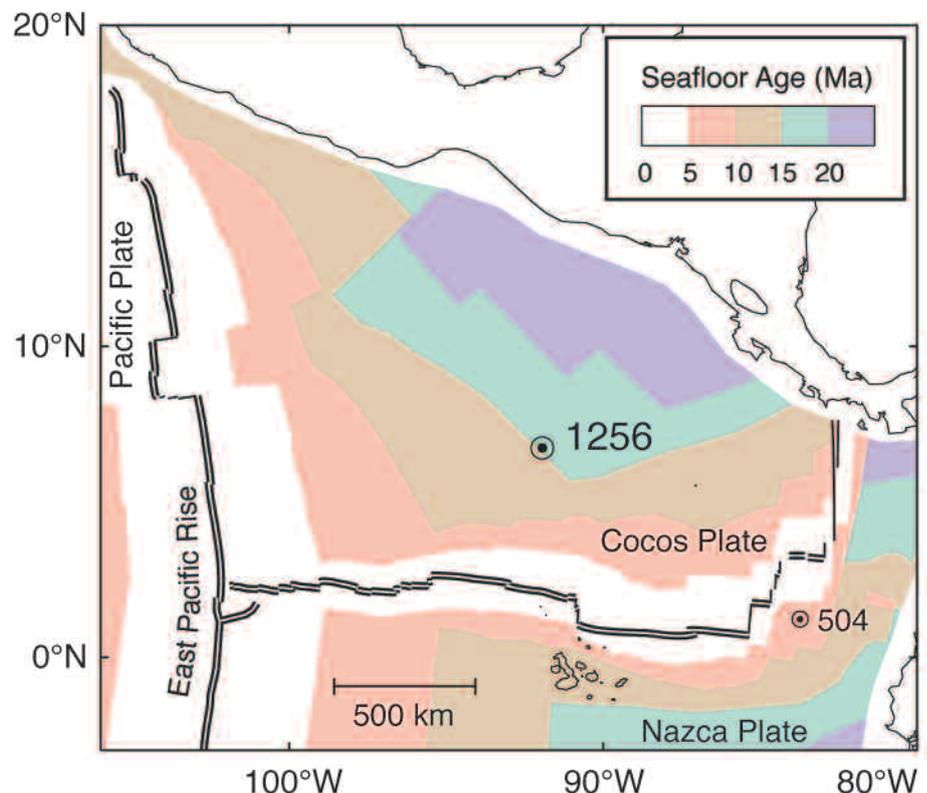


Figure 1. Location map showing the position of Site 1256 in the Guatemalan basin, and the age of the oceanic crust. The N–S structure about 800km to the west of Site 1256 is the fast–spreading northern East Pacific Rise. Other sites with penetration into basement are shown. From (Wilson et al., 2003).

recovery of a complete section of oceanic crust from an open ocean basin. Preferably this section should sample a part of the crust that is well understood in terms of its tectonic history and geophysical structure. Welcome onto the road to the Moho, or, The Highway to Hell. This has been the principal aim of the Superfast Campaign, a sequence of scientific ocean drilling cruises to drill a complete section of upper oceanic crust formed at a (super-)fast spreading rate.

Ocean Drilling Program Hole 1256D now provides our most representative sample of different lithological units of the oceanic crust, having penetrated sediments, lava flows (ODP Leg 206), dikes (IODP Expedition 309) and the uppermost part of the plutonic section (IODP Expedition 312). Site 1256 is located in the Guatemalan Basin at 6°44.2'N, 91°56.1'W (Figure 1). Inspection of the crustal ages on Figure 1 reveals that the Site 1256 crust formed about 15 Ma during superfast spreading (200–220mm yr⁻¹ full rate) on part of the Northern East Pacific Rise. These spreading rates are significantly higher than those found on the Southern East Pacific Rise, which is the fastest spreading ridge at the present day (~150mm yr⁻¹). It makes sense to target deep drilling in crust formed at superfast spreading rates. Firstly, fast-spreading crust is thought to have a better developed layered structure than crust formed at slow-spreading ridges, such as the Mid-Atlantic Ridge. Therefore, lithological variations reported from a single drill core are likely to reflect variations with significant lateral extent and that can be correlated with geophysical constraints on the layered structure of the crust. Secondly, systematic studies of magma chambers at active mid-ocean ridges have found a broad relationship between spreading rate and the depth of stable magma chambers beneath the ridge axis. While magma chambers found at ridges spreading at intermediate or slower rates (<80mm yr⁻¹) are found to lie at depths of 3km or more beneath the sea-floor, those at fast spreading ridges lie <2km beneath the seafloor. Extrapolation of this relationship to the superfast spreading rates applicable to the Hole 1256D crust indicates that the magma chamber would have been located approximately 1km beneath the ridge axis. It is likely that this magma chamber would have solidified to form gabbros and other rocks of the plutonic section of the crust. Therefore, the location of Hole 1256D was chosen in order to provide access to the lower lithological units of the oceanic crust with the minimum depth of penetration and drilling time. Furthermore, Hole 1256D is located close to the coast of central America and the Panama canal, allowing for straightforward and rapid access.

Expedition 312 started on October 28th

2005 in Victoria, Canada. A team of educators, the 'School of Rock', sailed south on the MRV *JOIDES Resolution* along the Pacific Coast as far as Acapulco, learning about IODP activities and wondering how to transmit their fascination to their students and the public. Then, on the 12th of November, the educators swapped for the Expedition 312 science party, many of whom had arrived in Mexico only hours before. Indeed, one of the party's luggage arrived in Acapulco several hours after departure of the *JOIDES Resolution*! The last line was dropped at 0958 on the 12th November 2005, and the vessel began the journey to site 1256. On board, the UK contingent were Damon Teagle (NOCS, metamorphic petrologist), Sally Morgan (Leeds, metamorphic petrologist), Roz Coggon (NOCS/Michigan, metamorphic petrologist), Mark Reichow (Leicester, logging) and John Maclennan (Cambridge, igneous petrologist). Damon and Roz had already been to 1256D with ODP Leg 206 and IODP Expedition 309: Damon sailed as a co-chief on both Leg

206 and Expedition 309. For Sally and John, however, Expedition 312 was the first taste of scientific ocean drilling.

Less than 3 days out of Acapulco, the first pieces of coring equipment were in the water over Hole 1256D. The cone was re-entered on the evening of November 15th, and the drill string passed easily to 927mbsf, where the first resistance was encountered. For the next five days, the operations team put all their efforts into preparing the hole for further coring. Meanwhile, the science party were getting used to their shift times, new colleagues and the wonderful laundry system. Everybody wanted to get their hands on those gabbros, which we knew had to be lurking only metres from the bottom of the hole. Within hours an empty log chart had been placed in the science lounge, with everybody invited to enter their best guess at the depth of the dike/gabbro transition. Some optimists put the contact within 10m of the base of Hole 1256D after the end of Expedition 309, their courage strengthened by the rising

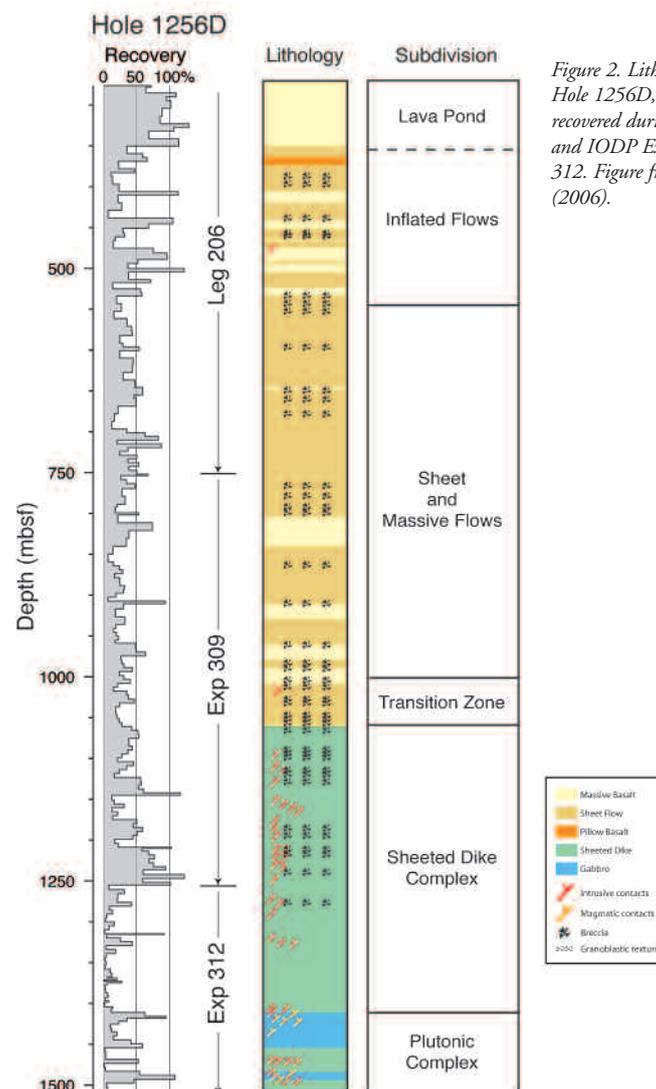


Figure 2. Lithological structure of Hole 1256D, based on core recovered during ODP Leg 206, and IODP Expeditions 309 and 312. Figure from Teagle et al. (2006).



Figure 3. Photograph showing used C-7 bit missing all of its cones. Note a small fragment of one cone remains. New C-7 bit shown for comparison.

metamorphic grade noted towards the end of 309. Others chose a more conservative approach, waiting until Doug Wilson had used his knowledge of the seismic data from the site survey and the extrapolation of the relationship between magma chamber depth and spreading rate to pick a dike/gabbro transition depth. Stropky stick-in-the-muds predicted that we would not find gabbro on Expedition 312, citing uncertainty in the thickness of accumulated off-axis lava for their pessimism. After extensive washing and reaming, coring of Hole 1256D recommenced at 0730 on November 21st. Over the next 12 days, the hole was deepened from 1255.1 to 1372.8 mbsf with neither incident nor recovery of gabbro. We enjoyed a superb Thanksgiving dinner.

All of the material recovered during this period was from the sheeted dike section, and, in common with Expedition 309, we found a number of spectacular glassy basaltic dike margins, commonly showing evidence for extensive brecciation and focussing of hydrothermal mineralisation. The presence of such margins, and other variations in the texture and geochemistry of the recovered basalts were used to inform the choice of boundaries between units. Much of the scientific debate onboard centred on the rapid evolution of metamorphic grade and textures with increasing down-hole depth. The increasing incidence of chlorite, actinolite, secondary hornblende and plagioclase indicated a steep increase in preserved alteration temperatures with depth. In a similar fashion, original igneous intergranular textures were found to have been increasingly overprinted, eventually evolving to an annealed texture which had never been

previously reported in rocks from the ocean floor and was referred to as granoblastic (Figure 2). These mineralogical and textural indications of increasing temperature, and their comparison with very similar rock types found in ophiolite sections, raised hope that we were within hours of striking gabbro, but progress remained frustratingly slow.

Then, on 4th December, the fifth coring bit suffered a catastrophic failure somewhere in the baked dykes, when 3_ of the 4 cones sheared from the bit, and were left in the hole (Figure 3). Several days of fishing with magnets and mills ensued. These were tough times for the Expedition. We had not hit gabbro, and the hole looked almost broken. Scientists picked through the material in the junk basket, and noted a dominance of fragments of granoblastic dike material, which had readily fractured into chips of 3–4cm length. These hard chips must have been at the root of the drilling problems. We also recovered a variety of fragments of felsic rocks, presumably from small intrusive veins. Such veins are also known to be commonplace near the dike–gabbro transition in ophiolite complexes. The two on-board educators were busy interviewing scientists about their motivation, trying to take their minds off the bitter disappointment of the lack of core and lack of gabbro.

Then, on the 8th of December, Hole

1256D was re-entered with the 6th rotary coring bit of the expedition. Despite the tough drilling conditions in the granoblastic dikes, no further technical difficulties were encountered and drilling continued smoothly until the hole reached a depth of 1507.1 mbsf on the 19th December. The next few days saw recovery of increasingly altered dykes, with the appearance of secondary pyroxenes and notable incidence of felsic veins implying further proximity to underlying gabbro.

At long last, history was made on 0800h on 13th December 2005. Core 312–1256D–213R arrived on deck carrying the first ever in-situ dike/gabbro contact recovered from an intact section of oceanic crust (Figure 4). The Expedition only had a few moments to bask in the glory of this discovery and reflect on its scientific significance. Along with efforts of Leg 206 and Expedition 309, we had obtained the first complete section through the upper oceanic crust. Furthermore, we sat at the top of the plutonic section of the oceanic crust, whose structure is of vital importance for testing models of generation and evolution of the ocean basins. Drilling conditions improved substantially in the gabbros, with recovery rates and rates of penetration higher than anything that we had experienced on Expedition 312 (Figure 5). The next six days saw a period of intense activity, with detailed

Figure 4. Roz Coggon, disregarding international collaborative nature of scientific ocean drilling, plants the Union Jack on the dike–gabbro transition!





Figure 5. Assembled scientists and operational staff celebrate 100% recovery of a 5m long core of gabbro. Damon Teagle is grinning at the extreme left.

description of highly heterogeneous gabbro bodies and intervening dike screens fully engaging the petrologists.

The gabbros showed many textural similarities with the parts of the uppermost plutonic section found in ophiolites, most notably in their textural heterogeneity! Two principal plutonic intrusive units were found, separated by a screen of highly altered granoblastic dike material. The upper gabbro commonly had a patchy appearance due to the presence of millimetric clinopyroxene oikocrysts surrounded by veins of apparently more evolved material. The upper gabbro persisted for about 50m of core. If the margins of this body are close to horizontal, then its geometry is similar to that preferred for the shallow melt lenses imaged at super-fast spreading ridges (Wilson et al., 2006; Singh et al., 1998). Critically, the compositions of the gabbros correspond to those of trapped basaltic melts, rather than cumulate materials that have separated from their liquid. Therefore, bodies such as gabbro 1, and possibly the shallow melt lens at active ridges, cannot be the location where the compositional stratification of the oceanic crust into upper basaltic liquids and lower cumulates occurs. Gabbro 2 has a vertical extent of 20m in the hole, and shows spectacular assimilation features near its margins in the form of 5–10cm long xenolithic fragments of the host dike screen

that have been extensively altered and bear abundant orthopyroxene.

After just six days of drilling and ~100m penetration into the plutonic sequence we were sad to see the end of coring, and hope that one day we will be able to drill deeper into these gabbros. The core acquired will allow the Science Party to address a host of fundamental questions relating to our understanding of the structure of oceanic crust. For instance, how does the distinctive vertical compositional structure found in the extrusive section of Hole 1256D relate to the lateral distribution of compositions observed in detailed studies of the sea-floor at active fast-spreading ridges? Can such a comparison be used to develop a unified general model of the compositional structure of the upper oceanic crust? The physical properties of the Hole 1256D core will also give new insight into the significance and cause of the layering of the crust that has been observed by marine geophysical surveys. We will continue to identify and isolate those features of crustal accretion that appear to be common to all spreading centres, developing and refining models of the structure and genesis of the oceanic crust.

References

Singh, S C, Kent, G M, Collier, J S, Harding, A J, and Orcutt, J A. 1998. Melt to mush

variations in crustal magma properties along the ridge crest at the southern East Pacific Rise. *Nature*, Vol. 394, 874.

Teagle, D A H, Alt, J C, Umino, S, Miyashita, S, Banerjee, N R, Wilson, D S, and the Expedition 309/312 Scientists. *Proceedings of the IODP, Vol. 309/312. (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.309312.101.2006

Wilson, D S, Teagle, D A H, Acton, G D, et al. 2003. *Superfast Seafloor Spreading I. Proceedings of the ODP Initial Reports, Vol. 206. College Station, Texas, USA.*

Wilson, D S, Teagle, D A H, Alt, J C, Banerjee, N R, Umino, S, Miyashita, S, Acton, G D, Anna, R, Barr, S R, Belgoul, A, Carlut, J, Christie, D M, Coggon, R M, Cooper, K M, Cordier, C, Crispini, L, Durand, S R, Einaudi, F, Galli, L, Gao, Y, Geldmacher, J, Gilbert, L A, Hayman, N W, Herrero-Bervera, E, Hirano, N, Holter, S, Ingle, S, Jiang, S, Kalberkamp, U, Kerneklian, M, Koepke, J, Laverne, C, Vasquez, H L L, MacLennan, J, Morgan, S, Neo, N, Nichols, H J, Park, S-H, Reichow, M K, Sakuyama, T, Sano, T, Sandwell, R, Scheibner, B, Smith-Duque, C E, Swift, S A, Tartarotti, P, Tikku, A A, Tominaga, M, Veloso, E A, Yamasaki, T, Yamazaki, S, and Ziegler, C. 2006. *Drilling to gabbro in intact ocean crust. Science, Vol. 312, 1016–1020.* doi:10.1126/science.1126090

Scientific results from past expeditions

Faunal Constraints for the Timing of the Fram Strait Opening: The Record Of Miocene Deep-Water Agglutinated Foraminifera From IODP Hole M0002a, Lomonosov Ridge

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Introduction

The Arctic Ocean is the last remaining frontier for deep-ocean drilling. The pre-Quaternary record of the Central Arctic Ocean is virtually unknown below the last few glacial/interglacial cycles, as so few piston cores have penetrated into older sediments. The primary goal of the Integrated Ocean Drilling Program Expedition 302, Arctic Coring Expedition (ACEX) (August 7 – September 14, 2004), was to core a complete sedimentary section on the Lomonosov Ridge in the Central Arctic, to study the Arctic's sedimentary, climatic, and biotic history (Figure 1). This major aim was successfully achieved – drilling during the ACEX cruise recovered a composite section of Cenozoic sediments overlying Campanian-age sedimentary basement.

The overall goal of scientific drilling on the Lomonosov Ridge was to decipher the paleoenvironmental evolution of the Central Arctic Ocean over the Cenozoic. One of the specific initial scientific objectives of the ACEX cruise was to “investigate the development of the Fram Strait and deepwater exchange between the Arctic Ocean and the Norwegian–Greenland Sea” (Expedition 302 Scientists in Backman *et al.*, 2006). The purpose of this study is to obtain new information about the Neogene of Hole M0002A, with an aim to (1) document the foraminiferal assemblages recovered from the hole; and (2) interpret the environmental significance of the deep-marine claystone unit of Lithological Subunits 1/3 and 1/4, by comparison with the Miocene record of Hole 909C in the Fram Strait.

Methods

Standard methods of sample processing were applied to 125 samples collected from Hole M0002A, from Lithological Subunits 1/3 and 1/4. The average sample volume was 20 cc, and two samples were collected from each core section. Samples processed in the shorebased

laboratory were first dried overnight at about 40–50°C and then boiled in water with sodium carbonate (Na₂CO₃) until disaggregated, then washed over a 63-µm sieve. The residues were retained and dried at about 40–50°C. Foraminifera were picked from the entire >63-µm residue, mounted on cardboard slides.

To study the timing of the influx of Atlantic species into the Arctic Ocean, we compared the deep water agglutinated foraminiferal assemblages from the Lomonosov Ridge with previously studied Miocene assemblages from ODP Hole 909C in the Fram Strait, Norwegian–Greenland Sea (Kaminski *et al.*, 2005).

Results

Biostratigraphy

The ACEX cruise recovered a 198-m thick section of Neogene sediments in Hole M0002A. Owing to corrosive pore waters the sediments in this hole contain no calcareous microfossils below approximately 20mbsf, but they do contain assemblages of agglutinated foraminifera similar to the Pleistocene assemblages described by Evans and Kaminski (1998) from long piston cores collected nearby. Initial examination of shipboard core-catcher samples revealed that the agglutinated foraminifera constitute the only microfossil group continuously present in this noncalcareous interval of Lithological Unit 1 (Subunits 1/3 and 1/4). A major hiatus occurs at 193.13mbsf, spanning a 25 m.y. interval from the early Miocene to the middle Eocene.

The foraminiferal record of Hole M0002A consists entirely of agglutinated benthic species, largely sparse assemblages containing *Cyclammina pusilla* and *Alveolophragmium polarensis*. The faunal succession in Hole M0002A is subdivided into three assemblages based on the stratigraphic ranges of characteristic taxa: (1) a relatively diverse assemblage at the base of Lithological Subunit

1/4 (Cores 44X–1 to –38X), with abundant agglutinated foraminifera including *Reticulophragmium pusillum* and *Ammolagena clavata*, indicating connections with the North Atlantic; (2) A less diverse assemblage characterised by *Alveolophragmium polarensis* with *Adercotryma agterbergi*, in the lower part of Lithological Subunit 1/3 (Cores 38X to 35X); (3) a sparse residual assemblage within Lithological Subunit 1/3 with *Rhabdammina* spp., *A. polarensis* and *R. pusillum* indicating poor preservation of organically-cemented DWAF in Cores 34X to 10X.

Paleobiogeography of Agglutinated Foraminifera and the Opening of the Fram Strait

Presently, the Fram Strait constitutes the only deep marine passageway for the exchange of deep waters between the Arctic Ocean and the Norwegian–Greenland Sea. Today, the West Spitsbergen Current carries warm, salty Atlantic Water northward into the Eurasian Basin.

A long-standing debate has existed in the literature regarding the timing of the opening of the Fram Strait passageway. Previously published faunal evidence suggests that the establishment of a marine connection may have begun as early as the Early Oligocene, based on the appearance of Atlantic species in the Beaufort Sea – MacKenzie Delta region (Schroder–Adams and McNeil, 1994b, Kaminski & Gradstein, 2005). In this basin, cosmopolitan species (such as *A. clavata*, *Reophax pilulifer*, *R. elongatus*, *Cyclammina cancellata*, and *Psammimopelta gradsteini*) that are known from the Atlantic–Tethyan region appeared successively during the Oligocene.

The plate tectonic reconstructions are more controversial. The reconstructions published by Lawver *et al.*, (1990) show a middle Miocene age for the separation between Svalbard and Greenland. Lawver *et al.* were of the opinion that a shallow water

connection may have existed during the Middle Miocene, but stated that the corridor of ocean crust in the Fram Strait was not wide enough to allow deep water circulation until the late Miocene (7.5 to 5 Ma). These authors speculated that until then “the Arctic Ocean may have been isolated with respect to deep–water passages”. Kristoffersen (1990), on the other hand, preferred an earlier (mid–Oligocene) opening for the Fram Strait, stating that a 2 km deep passage was in place by the middle Miocene.

Drilling in the Fram Strait during ODP Leg 151 was carried out with the goal of determining the age of the thick sequence of marine sediments preserved there. At Site 909, located near the Fram Strait sill, a thick Miocene sequence was cored that contains diverse DWAF assemblages with Atlantic/Norwegian Sea affinities. This occurrence suggested to us that the estuarine circulation pattern of the Arctic Ocean had been in place since the Early Miocene (Kaminski *et al.* 2005), which favours Kristofferson’s interpretation of the geophysical data suggesting an early opening of the Fram Strait.

The new sedimentological and micropaleontological results from the ACEX Expedition mean that timing of the Fram Strait opening and appearance of Atlantic immigrant species in the Arctic is now much better constrained. It seems likely that the shift from the gray–blue (sub–oxic) sediments to the brown (oxidized) sediments found near the top of Core section 302–M0002A–44X–1 (Figure 1) is associated with the presence of North Atlantic waters at the Lomonosov Ridge

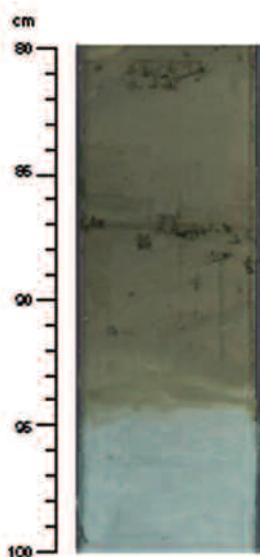


Figure 1. The boundary between Subunits 1/4 and 1/5 in Core –44X–1, 80–100cm. Brown clays above the colour change contain a rich assemblage of agglutinated foraminifera with North Atlantic affinities, whereas the blue clays below are barren of foraminifera.

(Moore *et al.*, 2006).

This is documented by the appearance of DWAF species with Atlantic/Norwegian Sea affinities just above the colour change. In Core M0002A–43X, we recovered a relatively well–preserved fauna with a mixture of cosmopolitan species such as *Ammolagena clavata* (Figure 2), *Adercotryma agterbergi*, and *Reticulophragmium pusillum* alongside Arctic endemics such as *Reticulophragmium projectum*. The “cosmopolitan” species are known from the Early Miocene record of Hole 909C in the Fram Strait, but are not known from older Paleogene sediments of the

Beaufort Sea. In particular, *A. clavata* is regarded to be a deep–water indicator (Kaminski and Gradstein, 2005), and its first appearance on the Lomonosov Ridge would therefore indicate the presence of deeper water of Atlantic origin. This species is common in the Eocene at ODP Site 643 on the Vøring Slope (Kaminski *et al.* 1990) and occurs in the Lower Miocene at Site 909. Although some intermittent shallow–water connections between the Arctic and the Atlantic/Tethys may have taken place earlier in the Paleogene over epicontinental seaways that allowed the exchange of neritic faunas (e.g., McNeil, 1997; Podobina, 2000), deep marine connections were only effected through the Fram Strait. The presence of bathyal DWAF such as *Ammolagena*, *Psammosiphonella*, *Cyclammina*, and *Reticulophragmium* just above the colour change in Core section –44X–1 represents the “smoking gun” that documents the first appearance of deep water of Atlantic origin.

We now believe that the opening of a deep passage in the Fram Strait and the onset of the current fully marine conditions at the Lomonosov Ridge took place in the early Miocene. The oldest fully marine sediments with cosmopolitan DWAF present on the Lomonosov Ridge are dated to the latest early Miocene (approx 17 Ma) based on magnetostratigraphy (Shipboard Scientific Party, 2006). Consequently, since the late early Miocene, the Arctic Ocean has experienced open connections with the Norwegian–Greenland Sea to the south.

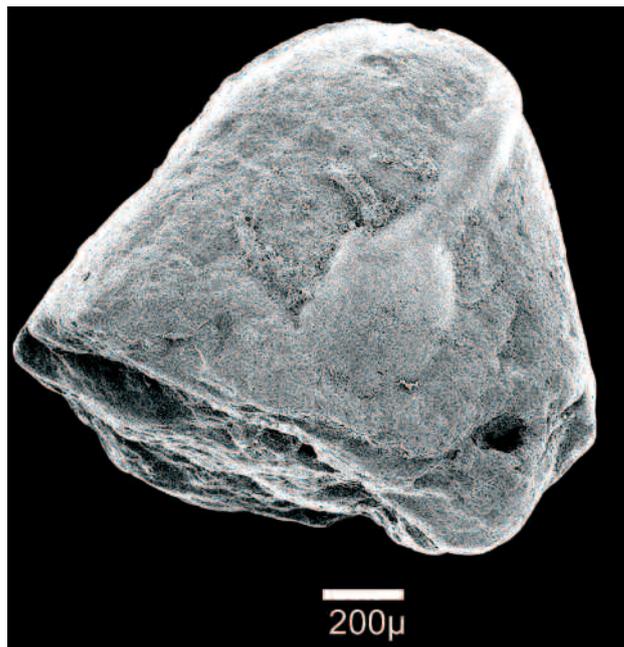


Figure 2. *Ammolagena clavata* (Jones & Parker) from Core section 302–M0002A–43X. Its first appearance in the Arctic Ocean marks the influx of deep water of Atlantic origin.

Acknowledgements

I wish to thank the Integrated Ocean Drilling Program and Co–chiefs Jan Backman and Kate Moran for the opportunity to participate on the ACEX Expedition and the NERC IODP committee for funding the current project (Grant NE/C516928/1).

References

- Expedition 302 Scientists. 2006. Sites M0001–M0004. In: Backman, J., Moran, K., McInroy, D.B., Mayer, L.A., and the Expedition 302 Scientists, Proc. IODP, 302: Edinburgh (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.302.104.2006
- EVANS, J.R. and KAMINSKI, M.A. 1998. Pliocene and Pleistocene chronostratigraphy and paleoenvironment of the central Arctic Ocean, using deep–water agglutinated foraminifera. *Micropaleontology*, Vol. 44, 109–130.
- KAMINSKI, M.A. and GRADSTEIN, F.M., 2005. *Atlas of Paleogene Cosmopolitan deep–water Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, No. 10, 547 pp.
- KAMINSKI, M.A., GRADSTEIN, F.M., GOLL, R.M., and GRIEG, D., 1990. *Biostratigraphy and paleoecology of deep–water agglutinated foraminifera at ODP Site 643, Norwegian–Greenland Sea*. In: Hemleben, C., Kaminski, M.A., Kuhnt, W. and Scott, D.B., (Editors), *Paleoecology, Biostratigraphy, Paleocyanography and Taxonomy of Agglutinated Foraminifera*, NATO ASI Series, Kluwer Acad. Publ. 345–386.

KRISTOFFERSON, Y., 1990. *On the tectonic evolution and paleoceanographic significance of the Fram Strait Gateway*. In: Bleil, U. and Thiede, J. (Editors), *Geological History of the Polar Oceans: Arctic vs. Antarctic*. NATO ASI Series C:308; Kluwer Academic Publishers, Dordrecht, pp. 63–76.

LAWVER, L.A., MÜLLER, R.D., SRIVASTAVA, S.P., & ROEST, W. 1990. *The opening of the Arctic Ocean*. In: Bleil, U. and Thiede, J. (Editors), *Geological History of the Polar Oceans: Arctic vs. Antarctic*. NATO ASI Series C:308; Kluwer Academic Publishers, Dordrecht, pp. 29–62.

MCNEIL, D.H., 1997. *New foraminifera from the Upper Cretaceous and Cenozoic of the Beaufort–MacKenzie Basin of Arctic Canada*. *Cushman Foundation for Foraminiferal Research, Special Publication, Vol. 35*, 1–95.

MOORE, T.C., and the Expedition 302 Scientists, 2006. *Sedimentation and subsidence history of the Lomonosov Ridge*. In: Backman, J., Moran, K., McInroy, D.B., Mayer, L.A., and the Expedition 302 Scientists, *Proceedings of the IODP, Vol. 302 (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.302.105.2006.

PODOBINA, V. 2000. *Paleogene agglutinated foraminifera of the Western Siberian biogeographical province*. In: Hart, M.B., Kaminski, M.A., & Smart, C. (Editors), *Proceedings of the Fifth International Workshop on Agglutinated Foraminifera*. Grzybowski Foundation Special Publication, No. 7, 387–396.

SCHRÖDER–ADAMS, C.J. and MCNEIL, D.H., 1994. *Oligocene to Miocene agglutinated foraminifera in deltaic and deep–water facies of the Beaufort–MacKenzie Basin*. *Geological Survey of Canada Bulletin, Vol. 477*, 67 pp.

News

EuroForm 2006

Julian Pearce (Cardiff University)

A EuroForum is held every two years so that European scientists involved in ocean drilling science can meet and discuss their work and so that others, young scientists in particular, can find out what is going on and how to participate. The 2006 EuroForum was held in Cardiff at the National Museum of Wales on 8th and 9th May to take advantage of the fact that the ESSAC office in Cardiff would be able to assist in preparations. The timing of the EuroForum, in the gap between the just-completed Phase 1 of IODP and the upcoming Phase 2, provided the perfect opportunity to summarize past successes of IODP (the theme for the first day) and look ahead to future opportunities (the theme for the second day).

The 'Past Successes' day began with a set of keynote lectures by European co-chief scientists or their representatives from the IODP expeditions completed to date. Expeditions covered were: 301 (The Arctic Coring Expedition, ACEX, presented by Jan Backman), 304/305 (Oceanic Core Complex Formation, by Benoit Ildefonse); 306 (Late Neogene/Quaternary North Atlantic Paleooceanography, by Rudiger Stein); 307: (Porcupine Carbonate Mounds, by Tim. Ferdelman); 308 (Gulf of Mexico Hydrogeology, by Jan Behrmann); 309/312 (Superfast Spreading Crust, by John. MacLennan); 310 (Tahiti Sea Level, by

Gilbert. Camoin); and 311 (Cascadia Gas Hydrates, by Barbara Teichert). This was followed by a screening, introduced by Henk Brinkhuis, of a DVD of the Arctic Drilling Expedition, and by poster presentations highlighting some of the science already carried out on past IODP expeditions. Prof. Sir Geoffrey Allen (on behalf of UK–IODP) and Prof. Mike Bassett (on behalf of the National Museum of Wales) hosted a reception in the Great Hall to accompany the poster displays.

The 'Future Opportunities' day began with updates on the capabilities of the three drilling platforms. This was again timely as Phase 2 of IODP will have significantly enhanced drilling capability. Kiyoshi Suyehiro represented Japan in highlighting the capabilities of the new Chikyu riser drilling ship. Peggy Delaney represented the U.S.A. in summarizing plans for the refitting, and renaming, of the JOIDES Resolution. Dan Evans had a shorter journey from Edinburgh to represent Europe (ECORD) in explaining the concept of Mission Specific Platforms.

The Future Opportunities theme continued with a Drilling Proposal Workshop. As preparing drilling proposals requires funding, John Ludden and Bernard Avril gave details of European initiatives to support IODP science. For the drilling proposal to be successful, knowledge of the workings of the IODP proposal review process is important.

Kier Becker (Chair of the Science Planning Committee) presided over presentations by Mike Bickle (SASEC representative), Rudiger Stein (SSEP representative), Hermann Kudrass (SPC representative) and Roger Searle (SSP representative) designed to help proponents optimise their chances of getting having an Expedition approved for drilling. The EuroForum concluded with a series of short presentations by scientists with proposals that have recently been submitted, each of which was followed by a discussion on ways to improve their chances of success.

The EuroForum ran smoothly, thanks to a lot of people from museum staff to speakers, but particular thanks are due to the sponsors (UK–IODP, the National Museum of Wales, EMA and ESF) and the local organising team ('Team Federica' comprising Federica Lenci, the ESSAC Office Science Co-ordinator, aided by Federica Tamburini, Lizzie Molyneux, Sarah Dare, Helena Evans Catherine Burgess, Elena Colmenero Hidalgo and Paula Diz). UK–IODP can now relax, and save some money, as the EuroForum will likely not be back in the UK for another eight years if the present format continues.

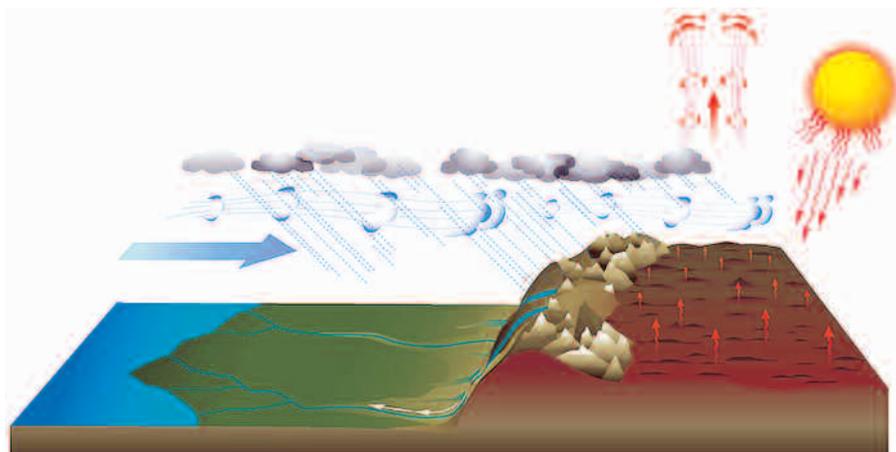
Reports on recent meetings

Planning Climate–Tectonic Drilling in the Asian Marginal Seas Kochi, Japan, June 2006

Peter Clift (School of Geosciences, University of Aberdeen)

Understanding the evolution of the global climate system is a major scientific goal for Integrated Ocean Drilling Program (IODP). While the influence of orbital forcing on climate has been the subject of numerous earlier, high-resolution drilling legs the influence that the solid Earth has had on climate development is less well documented. Together with the opening and closure of oceanic gateways the uplift of orogenic plateaus is believed to have a major impact on regional and even global climate, a hypothesis underlined by increasingly sophisticated numerical modelling. Of all the proposed interactions the effect of topographic uplift of the Tibetan Plateau on the intensity of the Asian monsoon is regarded as the classic example of climate–tectonic coupling. In its simplest form it is suggested that rapid uplift of Tibet, possibly triggered by loss of dense mantle roots, caused monsoon intensification recorded in the Arabian Sea and South Asia around 8 Ma. However, advances in palaeo–altitude studies across the Tibetan Plateau make this intensification hard to correlate in detail with solid Earth processes because southern and central Tibet appear to have been close to their modern altitude by at least 15 Ma and possibly as early as 35 Ma. Unfortunately existing monsoon records in South Asia only extend to around 18 Ma, making detailed correlation of climatic and tectonic histories impossible over truly tectonic timescales. The new drilling capabilities of IODP compared to Ocean Drilling Program (ODP) now allow this science to progress, because for the first time the community has the technology to recover climatic and erosional records from the thick sedimentary sequences that have accumulated on the Asian margins during the Cenozoic.

A proper resolution of how solid Earth tectonism controls monsoon intensity requires long duration monsoon climate records, coupled with matching tectonic and erosion reconstructions. Six proposals presently exist in the IODP system addressing this issue, spanning a variety of timescales and geographic regions. The Bengal Fan attracts particular attention as the world's largest sediment body and possible repository of enough carbon to have strongly affected



Cenozoic global climate. Quantifying the rate of sediment and carbon burial on the Bengal Fan is central to understanding climate–tectonic interactions in Cenozoic Asia. Although studying “core” areas of the monsoon is important this does not diminish the need for drilling in “far field” regions, which are particularly sensitive to changes in the strength and extent of the monsoon. The Arabian Sea has long been a key area for monsoon studies because it was in this region, on the Oman margin, that the initial indications for an 8 Ma monsoon were derived following ODP Leg 117. As a result the erosion record preserved in the Indus submarine fan can be readily interpreted using the existing climate records, which nonetheless need to be extended to tectonic timescales, i.e., as old as the India–Asia collision ~50 Ma, not the 14 Ma available at present.

At the other end of the monsoon's sphere of influence scientific drilling is planned in the Sea of Japan. However, in NE Asia it is the winter rather than summer monsoon that dominates the marine sedimentary record, because the westerly jet transports eolian dust from the deserts of central Asia into the Sea of Japan and North Pacific. In addition, the enclosed nature of the Sea of Japan makes its oceanography highly sensitive to continental run-off, supplied by river swollen by summer monsoon rains. Future IODP operations target both the relationship between winter and summer monsoon strength, as well as the links between East and South Asian

monsoons. Although both monsoons are influenced by Tibetan topography the East is also affected by the intensity of the Western Pacific Warm Pool, itself a Miocene feature, while the South Asian monsoon is modelled as being partly controlled by African topography, and localized uplift in the Karakoram.

Monsoon drilling has been planned for several years and is largely based on the results of ODP operations in the Arabian and South China Seas (Legs 117 and 184). Workshops on East Asia ocean–continent interactions and the Indian Ocean submarine fans were convened in 2002 and 2003 respectively. More recently a workshop sponsored by UKIODP, JOI and JAMSTEC was held in June 2006 in Kochi, Japan to discuss plans for climate–tectonic drilling in SE Asia. This region is of special interest because it is an area where the summer monsoon is especially strong, and the rivers of the region incise the edge of the Tibetan Plateau, but crucially the clastic sediment budget is not influenced by the immense sediment flux from the Himalaya, which masks Tibetan erosion into the Indian Ocean. The proposed drilling strategy is based on the idea that plateau uplift must influence the rate of erosion because of gorge incision and as a result of monsoon intensification. The meeting reviewed recent research advances in the marine geology of the South China Sea, as well as the tectonics of eastern Tibet. Existing plans proposed to IODP were discussed, together with needs for further proposals to fill gaps in the existing

proposals. Proposed drilling targets the temporal evolution of the delta and fan sediments of the Mekong and Red Rivers, as these record the evolving continental climate and the erosional response to a changing monsoon. Changing provenance of the rivers can also be used to examine the change in regional topography. It has been suggested that the unusual, non-dendritic drainage patterns seen in eastern Tibet and SW China relate to the disruption of an ancestral river system that was forced to reorganize as regional topographic gradients changed and headwaters were transferred from one river basin to another. Several of major rivers now discharging sediment into deltas in the South China Sea including, the Mekong, Red and Pearl Rivers are central to the evolving drainage model. Drill sites within their offshore deposits will test the nature and timing of this drainage evolution through

detailed provenance studies.

Future workshops aimed at IODP climatic-tectonic science are now planned. 26–28th September 2007 will see a European Magellan workshop on climate-tectonic drilling hosted at the University of Bremen, Germany. European scientists are at the forefront of the science and this workshop is designed to bring this community together to best exploit the opportunities for advance within the framework of IODP. The meeting is also open to the wider ocean and Earth science community in an attempt to involve new workers, both in marine and terrestrial geology. Because monsoon-tectonic studies necessarily draw on both marine and terrestrial data the meeting will invite those working on the geology of continental Asia, as well as the marginal seas to develop a coherent and integrated science plan. The results of the Magellan workshop will further shape a

mission proposal for climate-tectonic drilling across Asia. The “Monsoon and Tectonics” mission, submitted in spring 2007 aims to bring together the six existing monsoon-related proposals into a single science plan, spanning the entire geographic range of the monsoon, as well as providing long duration climate records. A dedicated, IODP-funded workshop designed to provide further community input to the mission plan is being planned for early 2008, to be held in Shanghai, China. Climatic-tectonic drilling represents a key area of study that will ensure the success of IODP and fulfilment of its stated science plan. At the same time this initiative provides multiple research opportunities for UK-based scientists to contribute to a truly interdisciplinary science project that will require contributions from a wide range of sub-disciplines within the Earth, ocean and atmospheric sciences.

Scientific drilling of the Chicxulub Impact Crater Joint IODP/ICDP workshop GeoForschungsZentrum, Potsdam, Germany, 11–12 September 2006

Joanna Morgan (Imperial College London)

The purpose of this workshop was to discuss future drilling of the Chicxulub impact crater, with the objective of advancing our understanding of Chicxulub, large impact craters in general, and the mass extinction event 65 million years ago. Fifty scientists from eleven countries attended the workshop. The UK participants included Joanna Morgan and Gareth Collins (Imperial), Penny Barton (Cambridge University), and Charles Cockell (Open University). During the first day 10 keynote speakers reviewed the current state-of-knowledge, showed results from previous drilling, and presented new seismic data acquired across the crater in 2005. On the second day we discussed potential new drill sites, their scientific priority and associated logistics.

Summary of Presentations on Day 1

The Chicxulub impact structure, Mexico, is unique in the terrestrial impact record. The Chicxulub catastrophe represents a critical event in the evolution of the Earth. Understanding Chicxulub's formation is, thus, critical to understanding its immediate effects on the Earth's environment and ecology. Chicxulub is also unique in the larger planetary context in that it is the only known large terrestrial impact basin with a demonstrable topographic peak ring. Peak rings are a diagnostic characteristic of large impact structures on the other terrestrial

planets, but details of their nature are limited to information based on remote sensing from planetary missions. Understanding peak ring formation is particularly important as numerical models suggest that peak-ring diameter is diagnostic of impact energy.

Chicxulub is the best-preserved large impact crater on Earth, and the only known terrestrial impact structure to have impactites within the crater, proximal ejecta deposits outside the crater, and distal ejecta deposits around the entire globe. Hence, the entire impactite and ejecta sequences of a large impact event with global consequences for the Earth are available for examination.

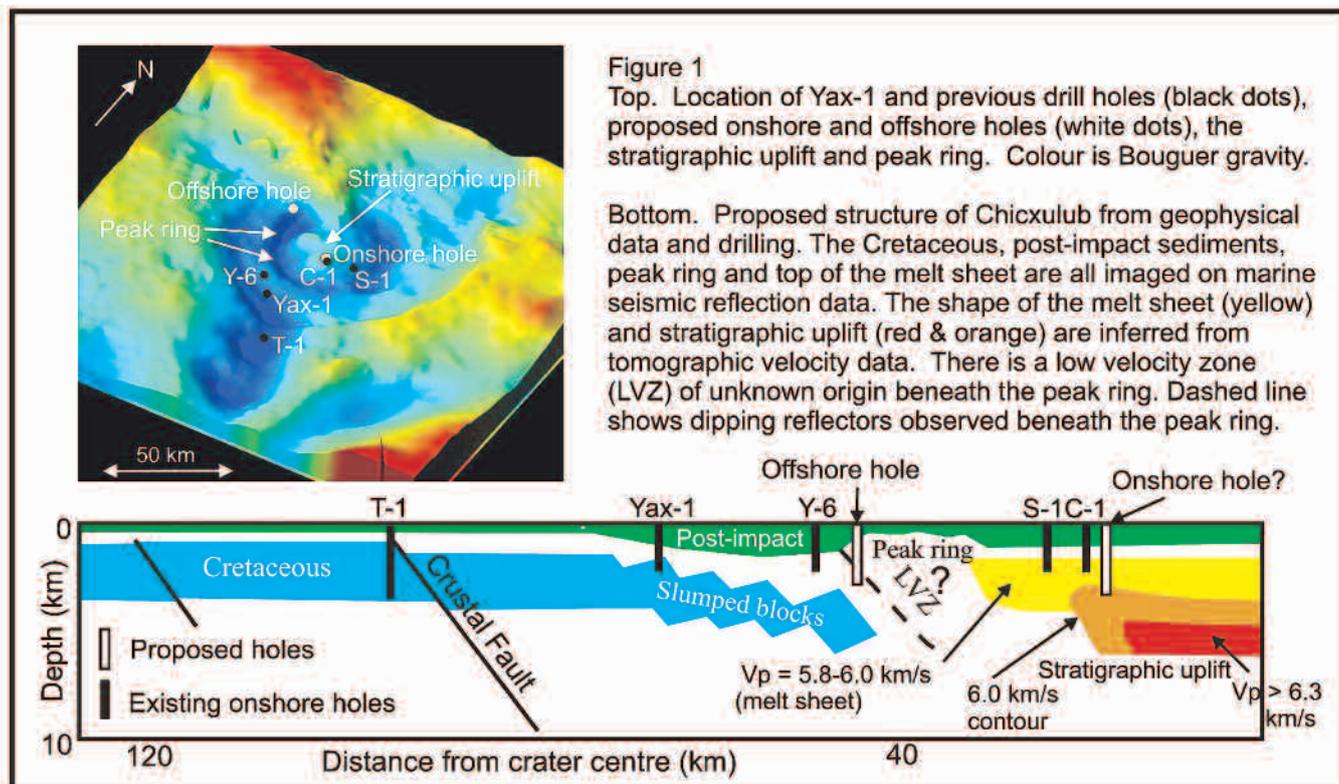
A wealth of geophysical data now exist across and beyond the crater structure, which, along with a number of oil industry drill holes and a drilling campaign by UNAM (Universidad Nacional Autónoma de México) and ICDP, have provided invaluable insight into the structure of Chicxulub (Figure 1). Participants agreed that, following the successful Yaxcopoil-1 (Yax-1) drilling in 2002 and NERC/NSF funded seismic experiment in 2005, we now had a better understanding of this impact structure, and were well placed to identify future targets for a focused drilling campaign.

Summary of Discussions on Day 2

Two holes were identified as critical in advancing our understanding of cratering

mechanisms: one onshore through the melt sheet in the central basin and one offshore through the structure's topographic peak ring (Figure 1). The offshore hole is targeted at understanding peak rings, for which there is currently no direct knowledge of their material make-up or precise formational mechanism. The onshore hole is targeted at understanding impactite formation and emplacement at a large impact structure, and at determining the total volume of melt produced by this impact. This will improve energy-scaling laws, which are poorly defined for large crater sizes but vital for assessing the environmental effects of this impact.

The proposed offshore IODP hole is aimed at providing understanding of the internal structure of the peak ring and the nature of important inward-dipping seismic reflectors (Figure 1). The minimum depth of this hole was considered to be 3km. The lithologies expected include ~700m of post-impact sedimentary fill, and 2.3km of peak-ring forming material. At depths of >2.35km the hole will intersect a suite of dipping reflectors that can be traced downward and inward from the outer edge of the peak ring to the inner edge of the slumped blocks at depth. If the peak ring material displays inverted stratigraphy, as predicted by some numerical models, these reflectors may represent the boundary between outward collapsed materials from an originally



overheightened central uplift and inward collapsed materials from the transient crater rim. This hole will, therefore, determine the fundamental character of the lithologies above and below the dipping reflectors, the physical state of the peak ring material, the cause of the seismic reflectivity, and the fundamental properties of a peak ring structure.

The proposed onshore ICDP hole is near the crater centre through the entire impactite sequence, in particular the suevite, the underlying coherent melt sheet, the crater floor materials, and the crystalline rocks of the stratigraphic uplift (Figure 1). The minimum depth of this hole was also considered to be about 3 km, to ensure penetration of the entire melt sheet. Major scientific targets of this hole are to mineralogically and geochemically characterize the entire suevite and coherent impact melt rock sequence, and to determine variations in the amount, composition and degree of shock of clasts in both of these impactite layers with depth (to be compared with results of ICDP drilling at Yax-1). We will also investigate the degree to which the coherent melt sheet is differentiated, search for a projectile component, and document the lithologies above and below the melt sheet, including any mineralization due to post-impact hydrothermal activity. Core logging and physical properties measured within the hole, together with existing seismic, magnetic, and gravity data, will facilitate the production of a well-constrained 3D

geophysical model of the interior of the crater, including a much improved estimate of total impact melt volume.

In both holes we will encounter thick sequences of post-impact rocks, and these will be used to reconstruct the sedimentological history and paleo-sea level and paleo-climate changes throughout the Cenozoic, including post-impact subsidence and modification of the original crater topography. Biota analysis will allow us to study the post-impact recovery of life and also provide an understanding of how the deep subsurface biosphere can be influenced by geological and geochemical changes induced by impact long after the impact itself. Geochemical data will be used to investigate the nature and timing of impact-generated hydrothermal systems, which are predicted to be significant within the peak ring and central basin.

There was unanimous support for a joint IODP-ICDP planning and execution of the entire drilling efforts, including sample and data handling.

Actions taken following the workshop

In October 2006 we submitted an addendum to drilling proposal IODP-548 outlining the scientific targets of the peak ring hole, and in January 2007 we submitted new site survey data to the IODP databank. In January 2007 we submitted a full proposal to ICDP to request financial support for the onshore hole.

Acknowledgments

The workshop was jointly sponsored by the International Continental Scientific Drilling Program (ICDP) and the Integrated Ocean Drilling Program Management International, Inc. (IODP-MI). NERC IODP provided travel support for U.K. participants.

Investigating Continental Break-Up and Sedimentary Basin Formation Pontresina, Switzerland, 15–18 September 2006

Donna Shillington, National Oceanography Centre, Southampton

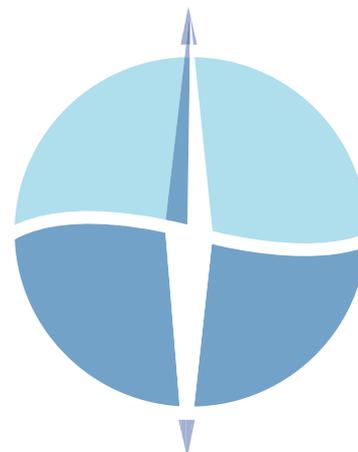
In September 2006, fifty-five scientists from all over the world, including three participants from the UK, gathered in Pontresina, Switzerland for an IODP Workshop on continental breakup (Coffin et al., 2006). The purpose of this meeting was to discuss strategies for pursuing research on continental rifting and breakup using the platforms of the IODP: the new Japanese riser ship *Chikyu*, the US riserless ship formerly known as the JOIDES Resolution, and the mission-specific platforms of the European Consortium for Ocean Research Drilling (ECORD). Continental rifting throughout Earth's history has resulted in a broad range of margins with variable architectures, sedimentation, and amounts of magmatism. Consequently, a complete understanding of rifting cannot be addressed at only one or two locations. Furthermore, the processes that accommodate extension appear to change through time, from the initiation of extension to late-stage rifting and rupture, thus requiring investigations of rifts at different stages in their evolution. The meeting participants decided that the best way to advance our understanding of rifting with drilling was to develop a proposal for an IODP mission, which will be led by John Hopper (Texas A&M, USA). An IODP mission represents an integrated strategy from the scientific community for addressing a key part of the IODP Science Plan that requires multiple drilling legs.

The meeting was organized by Dale Sawyer (Rice University, USA) and Millard Coffin (University of Tokyo, Japan) to bring together observational scientists and numerical modelers from both academia and industry who are studying various aspects of rifting. Key-note speakers gave overviews of magmatic (Sverre Planke, Volcanic Basin Petroleum Research, Norway) and magma-poor rifting (Timothy Reston, University of Birmingham, UK), the role of IODP in addressing scientific questions regarding rifting (Tony Watts, Oxford University, UK), and the drilling capabilities of the IODP platforms (Greg Myers, IODP Management International). Other participants also gave presentations on their research and ideas for drilling. Gianreto Manatschal (University of Strasbourg, France) led a field trip to examine the exhumed mantle rocks of the ancient Adriatic margin of the Tethys ocean, an example of a highly extended, magma-poor margin. Further discussions took place both in breakout groups and as an entire group. The scientific questions

that arose in presentations, during the field trip and in discussions could be divided into six themes: 1) rift initiation, 2) tectonic and dynamic aspects of rift development, 3) magmatic aspects of rift development, 4) sedimentary, paleoenvironmental, and oceanographic aspects of rift evolution, 5) initiation of seafloor spreading, and 6) consequences and impact. As these themes cover the fundamental processes and consequences of rifting, they will serve as a framework for designing the mission proposal. The participants also made a tentative list of key localities for drilling extensional systems, including the active rifts of Gulf of California and Woodlark Basin, highly magmatic margins (e.g., the conjugate east Greenland–Norwegian margins or the Western Australian margin), the highly extended, magma-poor margins of Newfoundland–Iberia, and the margins of the South Atlantic. A mission break-up proposal is currently under development by a team led by John Hopper and will be submitted for the 1 April 2007 IODP deadline.

References

Coffin, M F, Sawyer, D S, Reston, T J, and Stock, T M. 2006. *Continental Breakup and Sedimentary Basin Formation*. *EOS*, Vol. 87, 528–529.



Getting involved in IODP

Application forms and instructions are available at the websites of each Implementing Organization. For UK scientists and scientists from other ECORD countries applications must be submitted to the ECORD Science Support Advisory Committee (ESSAC). ESSAC has been appointed by ECORD as the “National Office” for ECORD participation in IODP.

Staffing decisions are made in consultation with, co-chief scientists, the implementing organizations (JOI Alliance for the non-riser vessel, ECORD Science Operator for mission-specific platforms, and CDEX for the riser vessel Chikyu), and reviewed by the IODP Central Management Office. Final staffing authority lies with the respective implementing organization.

The IODP is a unique scientific endeavour. One of the most unusual aspects is the opportunities it presents for people at all stages of their academic careers to be involved, from distinguished professor to undergraduates.

Applying

Anyone interested in participating in an expedition is encouraged to complete an application as instructed on the ESSAC website (www.essac.ecord.org/participation). Calls for applications to sail are made regularly and interested parties are asked to consult the ESSAC and IODP websites for information on upcoming expeditions.

All UK applicants must complete the online application to sail on the ESSAC website. Please inform the UK IODP Science Coordinator (ukiodp@bgs.ac.uk) when you make your application. Applicants will be notified in due course.

If you have any comments or questions then please do not hesitate to contact the UK Science Coordinator (ukiodp@bgs.ac.uk).

EXPEDITIONS

Currently scheduled expeditions

These dates are not fixed and are subject to change

Expedition	Dates
USIO	
Equatorial Pacific Transect	November – December 2007
NanTroSEIZE (Stage 1) – Subduction inputs	January – February 2008
NanTroSEIZE (Stage 1) – Kumano Basin Observatory	March – April 2008
Bering Sea	May – June 2008
Juan de Fuca Hydrogeology	July – August 2008
Equatorial Pacific Transect 2	September – October 2008
Canterbury	TBD
Wilkes Land	TBD

The scheduling for Wilkes Land and Canterbury is subject to change pending the result of the Canterbury hazard assessment.

CDEX

NanTroSEIZE (Stage 1) – LWD Transect	September – October 2007
NanTroSEIZE (Stage 1) – Mega-Splay Riser Pilot	November – December 2007
NanTroSEIZE (Stage 1) – Thrust Faults	January – February 2008
Maintenance	March – May 2008
NanTroSEIZE (Stage 2) – Mega-Splay Riser	June 2008 TBD

ESO

New Jersey Shallow Shelf	~May – July 2007
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For more information please visit www.iodp.org/expeditions/

Forthcoming events

Large Igneous Provinces Workshop

21–26 July 2007, Coleraine, Northern Ireland

This international workshop will guide the Integrated Ocean Drilling Program in addressing the objectives in the Initial Science Plan regarding processes associated with and consequences of large igneous province (LIP) emplacement.

Workshop participants will define key scientific objectives of investigating transient large igneous provinces through drilling, establish an integrated and interdisciplinary, long-term, global strategy for addressing fundamental LIP science questions, and identify the technological requirements for achieving these objectives. Problems associated with intraplate and rifted margin LIPs will be considered. Participants will include scientists with a broad range of expertise including geophysics (geodynamics, tomography, seismology, paleomagnetism, remote sensing), paleoclimatology, paleoceanography, environmental modeling, micropaleontology, physical volcanology, planetary geology, tectonics, geochemistry (high- and low-temperature, geochronology, biogeochemistry), and petrology. Research methods range from field and laboratory observation to simulation. Drilling engineers will participate and provide information about enhanced drilling, logging, and long-term borehole monitoring capabilities of IODP.

Based in Coleraine, Northern Ireland, the workshop will include a one-day field trip to spectacular exposures of the Tertiary North Atlantic large igneous province, including Giant's Causeway. Selected participants will be notified by the steering committee.

Please see the website for more information: www.iodp.org/lips

Addressing geological Hazards Through Ocean Drilling

26–30 August 2007, Portland, Oregon, USA

This workshop is designed to establish the current state of community knowledge and activity in the area of submarine geologic hazards, and to address a series of focused questions. In particular, investigations of geologic hazards through scientific ocean drilling still face many obstacles. We have an incomplete understanding of the necessary conditions and triggers for catastrophic geologic events (e.g., landslides, earthquakes, and tsunami), and limited instruments for making in-situ or remote measurements of the geotechnical and other material properties of the rocks and sediments involved. Moreover, there is a need to define tractable scientific questions, and to design realistic science and engineering plans that can actually answer them. Key goals of the workshop are to define outstanding research questions that can be addressed through scientific ocean drilling, establish scientific priorities, identify potential drilling targets, evaluate existing technologies and scientific approaches, and formulate strategies to overcome anticipated scientific and engineering challenges. We hope the workshop will enhance international collaborations and stimulate teams of proponents who will then be expected to develop competitive IODP proposals addressing oceanic geologic hazards.

Please see the website for more information: www.iodp.org/geohazards

Other Conferences and Meetings

International Union of Geodesy & Geophysics XXIV

2–13 July 2007, Perugia, Italy
www.iugg2007perugia.it/

The Arctic Conference Days 2007

3–7 September 2007, Tromsø, Norway
www.icamv.org/

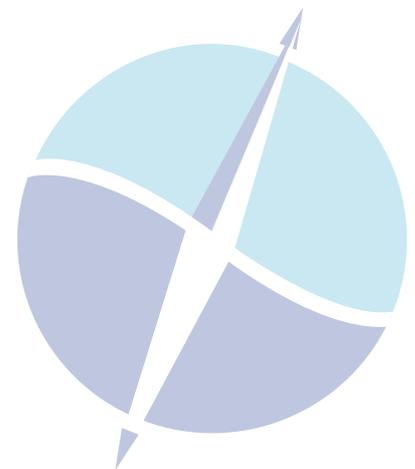
Submarine Mass Movements and their consequences – 3rd conference

1–3 October 2007, Santorini, Greece.
www.ncmr.gr/submarinemove2007/index.html

33rd International Geological Congress

6–14 August 2008, Oslo, Norway
www.33igc.org/

If you have an event related to Ocean Research Drilling you would like to see listed in the April 2008 edition of the UKIODP Newsletter then please contact ukiodp@bgs.ac.uk





Rift to Ridge '07: 28th-29th June 2007 National Oceanography Centre, Southampton

A workshop dedicated to North Atlantic rift - drift evolution under the influence of the Iceland Hotspot

Fundamental scientific question to be addressed:

How does a hotspot influence the development of an oceanic basin from rifting through to mid ocean ridge spreading?

Objectives:

- Mantle influence on rifting and break-up geometries
- Understanding mantle circulation and hotspot phenomena
- Consequences for crustal-scale horizontal and vertical tectonics
- Influence on the structure of oceanic crust and the geometry of seafloor spreading
- Determine linkages between basin evolution and oceanographic circulation, and thus to climate change

Outcomes:

- To coordinate proposed and planned IODP efforts aimed at addressing North Atlantic evolution.
- To stimulate new proposals and identify mechanisms to lever funding.
- To address the the hotspot phenomenon and its influence on ocean basin evolution in a 'joined-up' fashion

Key-note speakers:

Godfrey Fitton, University of Edinburgh
Erik Lundin, Statoil
Garrett Ito, University of Hawaii
John Hopper, Texas A&M University

Gillian Foulger, University of Durham
Steve Jones, Trinity College Dublin
Jim Wright, Rutgers University, New York
Bryndis Bryndisdottir, University of Iceland

To participate:

Please register at: http://www.noc.soton.ac.uk/gg/rift_ridge07/

UK IODP Grants

Applicants should refer to the current conditions and eligibility requirements, which can be found on the NERC website at www.nerc.ac.uk/funding/application/forms.asp where application forms, procedural information and a research grant guideline booklet can also be obtained. Applicants may also wish to consult the IODP Science Programme that can be found at www.iodp.org/isp. All successful applicants are asked to fully acknowledge support from the UK IODP Programme in their work. If you would like any further information or advice on the funding opportunities discussed below please contact the Science Coordinator (ukiodp@bgs.ac.uk) or the Programme Administrator (snbl@nerc.ac.uk).

NERC IODP Small Research Grants

To support UK membership in the Integrated Ocean Drilling Program (IODP), NERC has established a Directed Science Programme to enable: UK Scientists to ensure that IODP carries out the best and highest priority science; UK Scientists to participate in and obtain material from drilling legs, and finally to allow UK scientists to capitalize on the results of IODP drilling and UK Technologies to benefit from technological advances in deep sea drilling.

UK IODP will have one further funding round closing date **1 May 2007**. Small grants provide funding for small discrete projects, proof-of-concept studies, pump-priming exercises etc. This scheme is not intended to extend research assistants' employment once a standard grant has ended.

Applications are invited for small research grants only.

IODP has a maximum of around £225k to spend in this funding round, to fund 80% of the full economic cost of proposals.

Up to £25 000 may be sought for the total directly incurred costs (i.e. the limit applies to 100% of costs under this heading). In addition, NERC will pay the standard proportion (80%) of directly allocated and indirect costs.

Completed forms should be sent to NERC. They will be reviewed by external referees and assessed by the UK IODP steering committee.

If you would like any further information or advice please contact the Science Co-ordinator (ukiodp@bgs.ac.uk) or the Programme Administrator (snbl@bgs.ac.uk).

UK IODP Rapid Response Grants

IODP Rapid Response Awards are for the purpose of supporting a limited number of small-scale, short research activities specifically related to IODP Leg objectives. Rapid research grants are typically awarded to assist with initial sample processing costs or small equipment purchases related to IODP involvement. Proposals (no more than 2 pages long) should clearly state the aims, deliverables and the case for support. Where relevant, the proposal should be supported by a statement from an IODP Leg Co-Chief Scientists and/or (for students) from an appropriate member of the departmental academic staff.

Please note that applications for Rapid Response Grants will now need to be costed under FEC requirements. The maximum amount, to include all FEC costings, is now £2,750 for Rapid Response Grants.

Rapid Response proposals will be reviewed by members of the UK IODP Committee and awards will be limited by the funds available for this scheme. Although there is no closing date, applications should be submitted by e-mail to the Science Coordinator (ukiodp@bgs.ac.uk) as early as possible in advance of the proposed starting date.

Post-cruise support for Post-Doctoral and Post-Graduate Research Assistants

This scheme provides additional support for Post-Doctoral Research Assistants (PDRA) and Post-Graduate Research Assistants (PGRA) who sail with IODP on behalf of the UK. The scheme aims to ensure that more PDRAs and PGRAs have access to funding to complete up to 6 months post-cruise research between IODP Special Topic grants rounds (1st May and 1st November). Application procedures (separate from the main IODP Special Topic grant rounds) are subject to the following conditions:

- As with applications to any other NERC grant scheme, applications must be led by a Principal Investigator from an eligible UK institution. The PDRA or PGRA should be named as the Recognised Researcher for the application. All eligibility criteria are the same as for all other NERC thematic grant applications.
- Applications must be on behalf of a PDRA or PGRA who has been accepted (not simply applied to) as a UK shipboard participant on a forthcoming IODP leg. No shore-based contributors will be

considered under any circumstances.

- Applications for both PDRAs and PGRAs will be subject to peer review.
- The application for this scheme must be a discrete body of work based only on material collected during an IODP cruise. It must not be a continuation of any other unrelated project funded by the NERC or other bodies.
- On return to port the candidate will have to write confirming that the necessary samples to complete the work have been successfully obtained during the cruise, otherwise funding will not be made available.
- Candidates should apply to the Science Coordinator Heather Stewart (ukiodp@bgs.ac.uk) for this funding prior to sailing. Applicants will need to give a brief description of the post-cruise work that they intend to perform using the NERC small grants application form. The deadline for an application is two months prior to the scheduled departure of the IODP leg.
- At least one first-authored peer-reviewed publication should result from the work.
- All other conditions and eligibility requirements are the same as for other NERC funding and can be found on the Forms and Handbooks section of this website

Special criteria for PDRA applications:

- Applications for Post Cruise Grants will now need to be costed under FEC requirements. The maximum amounts, to include all FEC costings is now £16,500 to cover up to 6 months of post-cruise research. Extra time will be allowed only if another funding source is procured.
- To be eligible for this funding, a PDRA must hold a recognised PhD. PhD students are entitled to apply for this scheme if they are close to submission or have submitted at the time of sailing but will not be eligible to receive any funding until they have successfully defended their PhD.
- UK IODP will fund two PDRA positions per year.

Special criteria for PGRA applications:

- Applications for Post Cruise Grants will now need to be costed under FEC requirements. The maximum amounts, to include all FEC costings is now £8,250 to

cover up to 6 months of post-cruise research. Extra time will be allowed only if another funding source is procured.

- To be eligible for this funding, a PGRA must be at least 18 months into their PhD before taking up the award.
- UK IODP will fund two PGRA positions per year.

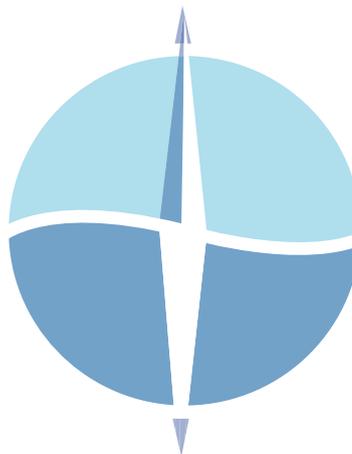
UK IODP Urgency grants

These allow researchers to exploit scientific opportunities where the normal grant application procedures are likely to be too slow.

Application procedures (separate from the main IODP Special Topic grant rounds) are subject to the following conditions:

- Topics must relate to IODP-supported science, and awards will be considered only in exceptional circumstances.
- Only small sums will be considered.
- Applications must be led by a principal investigator from an eligible UK institution. Eligibility criteria are the same as for all other NERC directed grant applications.
- You should contact the UKIODP Science Coordinator (ukiodp@bgs.ac.uk) with a brief resume of your case, to check whether an urgent application process is appropriate.
- Apply using NERC's small grant application forms (i.e. including a two-page case for support) under the published rules for research grants.

- You can apply at any time.
- No studentships will be awarded under this scheme.
- Only aspects of the research that are time-limited will be considered. For example, collecting data or samples during a window-of-opportunity could qualify for funding, whereas support for subsequent analyses, interpretation or publication would not.
- Your application should justify both the science and the resources sought. Only those applications that are urgent, receive a high science grade, and are likely to obtain resources for follow-up work and publication will be funded (later funding should either be in place or be sought subsequently through the normal application process).
- Submit your application via email to the UK IODP Programme Administrator at NERC (snbl@nerc.ac.uk).
- Applications will be sent to three external reviewers, and selected members of the UK-IODP Committee will make a final decision. The Programme Administrator will oversee the application/review process and ensure that it is completed promptly.
- All other conditions and eligibility requirements are the same as for other NERC funding, and can be found on the Forms and Handbooks section of the NERC website.



IODP UK contacts

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IODP Panel Members from the UK

Science Advisory Structure Executive Committee (SASEC)

Mike Bickle, Department of Earth Sciences, University of Cambridge

UK Industrial Liaison Panel Chairman and IIS-PPG liaison

Richard Davies, Director CeREES
Department of Earth Sciences, University of Durham

Science Steering and Evaluation Panel liaison (SSEP)

Tim Elliott, Department of Earth Sciences, University of Bristol

Scientific Technology Panel liaison (STP, Co-Chair)

Mike Lovell, Department of Geology, University of Leicester

Science Planning Committee

Julian Pearce, School of Earth, Ocean and Planetary Sciences, Cardiff University

Engineering Development Panel liaison (EDP)

Peter Schultheiss, Managing Director, Geotek Ltd

Site Survey Panel liaison (SSP, Co-Chair)

Roger Searle, Department of Earth Sciences, Durham University

Environmental Protection and Safety Panel liaison (EPSP)

Bramley Murton (NOCS) will continue to report to the Steering Committee in his role as

ECORD Science Operator Science Manager

Dan Evans, British Geological Survey

Useful websites

Integrated Ocean Drilling Programme (UK) – www.ukiodp.bgs.ac.uk and www.nerc.ac.uk/research/programmes/ukiodp/

ECORD Sites

European Consortium for Ocean Research Drilling (ECORD) – www.ecord.org
ECORD Science Support Advisory Committee – www.essac.ecord.org

IODP Central Sites

IODP Management International Inc. – www.iodp.org
Initial Science Plan for IODP – www.iodp.org/isp
JAMSTEC – www.jamstec.go.jp/jamstec-e/odinfo/index.html
IODP Science Advisory Structure – www.iodp.org/sas

IODP Implementing Organisations

Centre for Deep Earth Exploration (CDEX) – www.jamstec.go.jp/jamstec-e/odinfo/cdex_top.html
ECORD Science Operator – www.eso.ecord.org
JOI–Alliance US Implementing Organisation – www.iodp-usio.org

IODP National Offices

Canada – <http://web.uvic.ca/~iodp/>
Finland – <http://iodpfinland.oulu.fi/>
France – www.iodp-france.org/
Germany (in German) – www.iodp.de/
Italy (in Italian) – www2.ogs.trieste.it/iodp/
Netherlands – www.iodp.nl/
Norway (in Norwegian) – www.geo.uib.no/IODP/
Portugal (in Portuguese) – <http://e-geo.ineti.pt/ecord/>
Switzerland – www.swissiodp.ethz.ch

IODP China – www.iodp-china.org/chs/
IODP Korea – www.kodp.re.kr
ODP Australia – www.odp.usyd.edu.au

IODP Related Sites

European Science Foundation (ESF) – www.esf.org
Japan Drilling Earth Consortium (J-DESC) – www.j-desc.org/
International Continental Scientific Drilling Program (ICDP) – <http://icdp.gfz-potsdam.de>
Lamont Doherty Earth Observatory – www.ldeo.columbia.edu
MEXT Ministry of Education, Culture, Sports, Science and Technology – www.mext.go.jp/english/
National Science Foundation – www.nsf.gov
Natural Environment Research Council – www.nerc.ac.uk
USSSP U.S. Science Support Program – www.ussp-iodp.org

ODP Legacy Sites

Joint Oceanographic Institutions for Deep Earth Sampling – www.ifm-geomar.de
Joint Oceanographic Institutions, ODP Program Manager – www.joiscience.org/
ODP Wireline Logging Services – [www.ldeo.columbia.edu/BRG/ODP/Science Operator Texas A&M University \(TAMU\)](http://www.ldeo.columbia.edu/BRG/ODP/ScienceOperatorTexasA&MUniversity(TAMU))
– www.odp.tamu.edu/index.html

Mid–Ocean Ridge Links

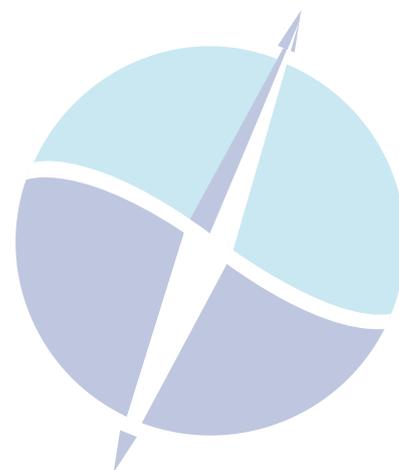
InterRidge Office – www.interridge.org
NOAA Vents Programme – www.pmel.noaa.gov/vents
RIDGE – <http://ridge2000.bio.psu.edu>
DeRIDGE – www.palmod.uni-bremen.de/FB5/Ozeankruste/DeRidge/deridge.html

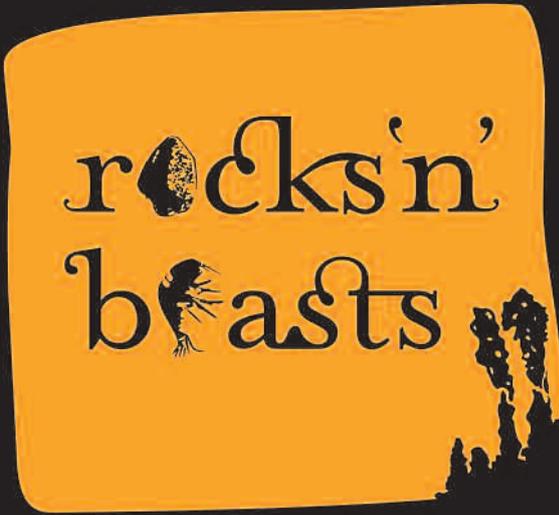
Margins Links

European Ocean Margin Initiative – www.geomar.de/euromargins
Stratagem – www.stratagem-europe.org/
US Margins Programme – <http://margins.wustl.edu>

NERC Marine Programmes

Autosub Under Ice (AUI) Programme – www.nerc.ac.uk/research/programmes/autosubunderice/
COAPEC (Coupled Ocean-Atmosphere Processes and European Climate) – www.nerc.ac.uk/research/programmes/coapec/
Ocean Margins LINK Programme – www.nerc.ac.uk/research/programmes/oceanmargins/
Rapid Climate Change (RAPID) – www.nerc.ac.uk/research/programmes/rapid/
Surface-Ocean/Lower-Atmosphere Study (SOLAS) – www.nerc.ac.uk/research/programmes/solas/





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further information available at:
<http://www.see.leeds.ac.uk/misc/rmb/index.html>
contacts:
sally@earth.leeds.ac.uk
luciana@earth.leeds.ac.uk

Back Cover: Close-up photographs of A, B and C, showing coralgal-microbialite frameworks composed of branching and columnar corals (light grey and red borders), laminated microbialites (grey) and angular Halimeda segments (white) where coral colonies are encrusted by coralline algae (white). Branching coralline algae are shown on photo D.
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INTEGRATED OCEAN
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UK newsletter 32

A



B



C



D

