IODP
INTEGRATED OCEAN DRILLING PROGRAM

UK newsletter 33

April 2008

NATURAL ENVIRONMENT RESEARCH COUNCIL

ECORD
European Consortium for Ocean Research Drilling

IODP Highlights

Expedition 314: Stage 1 NanTroSEIZE 'LWD Pilot'

- First leg of Stage 1 of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) and the maiden voyage of the Japanese research vessel *Chikyu* for the IODP.
- Sediments identified included hemipelagic mud, silty turbidites and some sand bodies.
- Extensive fracturing and faulting were observed from the image data and changes in physical properties, but few major deformation zones were identified.

Expedition 315: Stage 1 NanTroSEIZE 'Megasplay Riser Pilot'

- Deformation structures were observed at the core scale.
- Structural on-board results suggest three phases of stress field changes.
- The LWD data on Expedition 314 correlated with the detailed rock and fluid record observed on core acquired during Expedition 315.

Expedition 316: Stage 1 NanTroSEIZE 'Shallow Megasplay and Frontal Thrusts'

- Site C0004 successfully targeted the shallow portion of the megasplay fault in the older part of the prism.
- The frontal thrust was encountered at about 430 metres below sea floor at site C0007.
- Sites C0008 and C0004 recovered almost an almost continuous section of the slope basin stratigraphy giving vital clues about the sediment and fluid being incorporated into the accretionary prism.

Editor:
H A Stewart, British Geological Survey, Edinburgh, EH9 3LA

Front Cover: *Chikyu* leaving Shingu Port at the beginning of Expedition 314. *(Photo credit: IODP)*

Foreword

John Ludden, Executive Director, British Geological Survey
IODP-MI Governor for the European Consortium for Ocean Research Drilling (ECORD)

Firstly I must congratulate the UK community on the successful renewal of the UK contribution to IODP. This comes at the same time as the IODP science advisory structure (SAS) is setting up a committee to discuss the role of scientific drilling after the end of IODP. Ten years ago I participated in the Concord workshop when the community started discussions on the use of a riser drilling vessel and as we are about to start the first riser drilling experiment we are also invited to look into the future again. European countries were influential in setting up IODP and in particular, through ECORD, emphasising the need for Europe to provide a drilling capability as part of the programme. We do need to think beyond 2013 and we also need to make sure that IODP delivers what it promised. As a governor on IODP Management International (IODP-MI) my role as part of the Board is to ensure that IODP delivers the best science as part of a yearly programme plan including a forward look to future years.

The Governors help develop the annual program plan and approve budgets for science operations, for logging and for the annual publication and information service plan. They also approve budgets for technical developments, education, outreach and promotion. All of this advice is based on input from the SAS and the implementing organisations. As you will no doubt be aware, the cost of IODP has skyrocketed due to increased fuel prices and generally high costs of marine operations. The lead agencies who operate the vessels are considering a partial programme in which the *Chikyu* or the JOIDES *Resolution* replacement vessel may be subcontracted for part of their yearly operations. This will clearly affect the scientific delivery of the programme and our role is to ensure the efficiency of IODP through looking at efficiencies in operations and also new ways of funding the science. IODP was set up as an 'Integrated' programme, but funding schemes, operational attitudes and co-funding mechanisms with third parties all vary widely between the USA, Japan and Europe. There is no problem getting a critical mass of scientists to work on a key science problem and a joined-up approach to science development must remain a mainstay of IODP or any future ocean-drilling programme. Nonetheless, the different means of delivering science infrastructure may mean that we should start to think about an association, rather than integration of operators. Europe should continue to pursue an agenda of science infrastructure leadership. We have done well in undertaking two very high-profile scientific expeditions utilising mission specific platforms (MSP) in which the British Geological Survey has acted as the ECORD Science Operator. This year we will be completing the New Jersey Shallow Shelf Expedition 313 (see UK-IODP Newsletter 32). All of these MSP expeditions were proposed as part of the Ocean Drilling Program, some 10 years prior to drilling. If the scientific community were to be guaranteed at least two MSP operations (in the Arctic or in shallow marine environments) per year for the remaining years of the programme, I am convinced that there would be enormous pressure for US and Japanese scientists to take part in our European operation.

As it stands it appears that IODP programme planning is almost full until the end in 2013. The scientific projects to be undertaken are exciting and challenging, but how do we maintain a flow of new blood, new ideas, new technology in a long term adventure? The deep sea floor plays a pivotal role in the Earth system and it is a frontier which integrates multiple aspects of environmental and biological sciences. To this end we have convinced Europe to create a Deep Sea Frontier Initiative www.ecord.org/enet/dsf-june2007.pdf. The requirement to install sea floor observatories and to core is an expensive part of this initiative to which European countries should be actively involved in providing more than our knowledge by building infrastructure. UK-IODP has just won the funding for the next operational phase, but, even now, we need to start planning for post 2013. This sort of long-term planning is second nature to planetary scientists, astronomers and particle physicists, but NERC is starting to understand the need for such planning for environmental infrastructure in creating a NERC - National Capability Advisory Group. The UK-IODP community needs to keep NERC and this group informed on long-term planning.

Meanwhile enjoy the ride on some exciting science adventures and let's build an active community to lead in the future.

Reports on recent IODP Expeditions

Expedition 314: Stage 1 NanTroSEIZE 'LWD Transect'

Lisa McNeill (National Oceanography Centre, Southampton), Joanne Tudge (University of Leicester) and the Expedition 314 Shipboard Scientific Party: Masataka Kinoshita (Co-Chief Scientist), Harold Tobin (Co-Chief Scientist), Moe, Kyaw Thu (Expedition Project Manager), Philippe Gaillot (Logging Staff Scientist), Sylvain Bourlange, Chandong Chang, Marianne Conin, Sean Gulick, Maria José Jurado Rodriguez, Kylara Martin, Ayumu Miyakawa, Greg Moore, J. Casey Moore, Yasuyuki Nakamura, Saneatsu Saito, Dale Sawyer and Yasuhiro Yamada.

Introduction

Expedition 314 was the first leg of Stage 1 of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) and the maiden voyage of the Japanese research vessel Chikyu for the IODP. The aim of the NanTroSEIZE Project is to drill into the seismogenic zone of the Nankai subduction zone (Figure 1) and parts of the shallower fault system, to investigate fault mechanics, fault development and the seismogenic process and to ultimately install long-term observatories. Stage 1 will be followed by two stages of riser drilling which will access the seismogenic parts of the major thrust fault at the prism-forearc basin boundary ("megasplay") and of the plate boundary, by drilling to ~3km and ~6km, respectively (Figure 2). As the first of many expeditions for NanTroSEIZE, the primary goal of Expedition 314 was to perform logging while drilling (LWD) at sites across the active accretionary prism and forearc basin off the Kii peninsula. The main aims were to sample in situ properties of the sediments, rocks and fault zones from different fault systems within the prism, from the shallow parts of the megasplay system and from the forearc basin and underlying older prism.

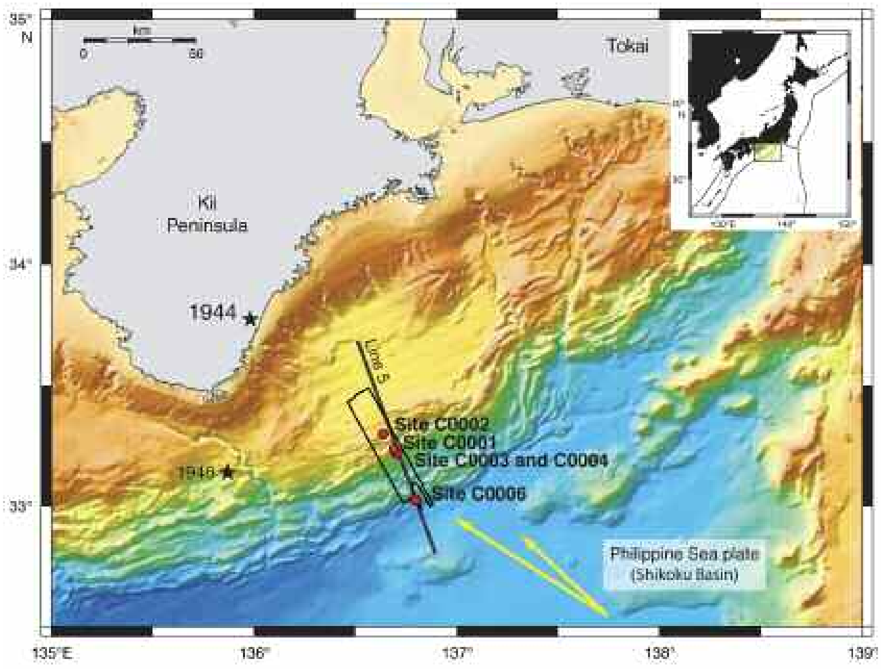


Figure 1. Map of the Nankai Trough showing the NanTroSEIZE transect including Expedition 314 site locations. Inset shows tectonic setting. Convergence vectors between Philippine Sea plate and Japan show range from Seno et al. (1993), Miyasaki and Heki (2001), and Heki (2007).

Chikyu sailed from Shingu port on 21st September 2007 (Figure 3) with a large crowd of well-wishers, including interested locals, scientists, dignitaries and the media. Media coverage included live interviews with the Co-Chief Scientists and television helicopters following *Chikyu's* departure from port. Interest in *Chikyu's* scientific progress continued throughout the expedition, culminating in a press conference in Tokyo by the Co-Chiefs at the end of the cruise.

The clearest difference between *Chikyu* and the JOIDES *Resolution* is size. Everything is on a much larger scale from the length of the ship (210 m) to the height of the derrick (~120 m above sea level) and to individual en suite cabins for all personnel. Both personal and laboratory space is ample and comfortable and the ship's laboratories are extremely well equipped, including a state-of-the-art CT scanner for non-invasive 3D core analysis. *Chikyu* is also equipped with the highest standard of automated drilling technology and a highly sophisticated DP (dynamic positioning) system. The latter was put to the test during this expedition as we contended with the high velocity Kuroshio Current. Another difference is the changing crew throughout this expedition and others in the Nankai Trough, aided by regular helicopter visits. The helicopters were used for final disembarkation by the science party of Expedition 314 during a changeover day with Expedition 315 scientists.

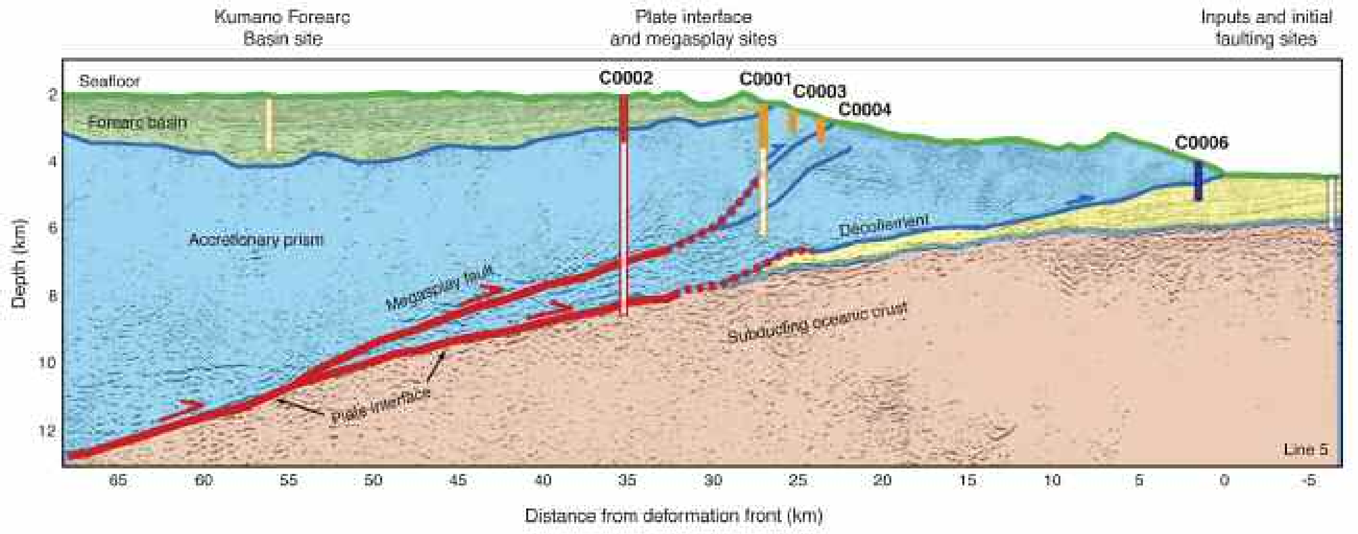


Figure 2. A seismic profile section showing the location and depth of the five sites across the subduction zone during Expedition 314, and the planned future riser and non-riser sites. Location shown on Figure 1 (Line 5).

Science Overview

Five sites were drilled using LWD with the deepest hole (C0002) sampling the forearc basin sediments and the underlying accretionary prism (Table 1). Four sites were drilled within the active accretionary prism; one sampled the shallow part of the major megasplay thrust fault (C0004), whilst another sampled its hangingwall at greater depths (C0001), and a third collected real-time data in the megasplay hangingwall (C0003). The final site was drilled into the toe of the accretionary prism (C0006), sampling the frontal thrust fault (Figures 1, 2).

Logging While Drilling Tools and Measurements

The following Schlumberger MWD (Measurement While Drilling) and LWD (Logging While Drilling) tools were used during Expedition 314:

MWD: Recording and transmission of data about drilling conditions and selected data from the LWD tools to the surface in real-time.
adnVISION: Azimuthal density neutron tool providing neutron porosity, density (including azimuthal measurements and images) and ultrasonic calliper measurements.
geoVISION: Resistivity and natural gamma ray data, with five different resistivity measurements (bit resistivity, ring resistivity and three button resistivity measurements: shallow, medium, deep). The button measurements can be shown as 360° oriented borehole images.
sonicVISION: P-wave sonic velocity data.
seismicVISION: Interval velocity from seismic check shots.

Summaries for Individual Sites

Site C0001

Site C0001 drilled 974m LSF (logging while drilling metres below sea floor) into the outer arc high controlled by the "megasplay fault system" and just seaward of the Kumano forearc Basin. This fault system branches off the plate boundary and extends to the seafloor where it marks the boundary between the active accretionary prism and the forearc basin. This site provided the measurement of properties of rocks which have been uplifted from significant depths and incorporated into the hangingwall of branches of the megasplay fault system. This fault system is hypothesised to accommodate some of the seismogenic slip during great plate boundary earthquakes, thus potentially influencing tsunami generation, and will be one of the targets of future deep riser drilling. Velocities, densities and drilling conditions (and samples retrieved during loss of the BHA, see C0003) indicate well indurated and probably relatively old rocks within the uplifted thrust sheet of the megasplay fault. The hangingwall thrust sheet was deformed by fractures with a variety of orientations, including unusually evidence of normal faulting in deeper parts of the borehole.

Site C0002

Site C0002 successfully drilled 1401m LSF at the Kumano forearc basin, and down into the underlying older accretionary prism. A complete suite of the LWD logs were obtained, sampling through the forearc basin sediments, which are predominately composed of sandy-muddy turbidites. The seismic profile suggests the presence of a BSR and the LWD logs confirmed the presence of gas hydrates and free gas, mostly within the porous, permeable sandy layers of the turbidite sequences. A clear change in properties was observed at the base of the basin and boundary with the older accretionary prism, with sharp increase in resistivity, density and gamma ray values, and corresponding decrease in data quality. Faults, fractures and bedding planes identified in resistivity images can be correlated well with features (including multiple landward-dipping normal faults) in the forearc basin from the 3D seismic reflection dataset.

Site C0003

Site C0003 aimed to drill though and sample the shallow part of the megasplay fault system. However, due to poor drilling conditions in the hanging-wall of the fault the hole began to degrade and at ~500m LSF the tool string became separated from the drill pipe. After spending a week attempting to retrieve the BHA, including all five LWD tools, the hole was abandoned and cemented and therefore we were unable to reach the target depth of ~1000m LSF. As a result the remaining holes were completed with the back-up tools, which did not include nuclear measurements. At this site, partial analysis was possible using the real-time data sent up by the tools as pressure pulses within the drilling fluid.

Site C0004

Site C0004 was a second attempt to reach the major megasplay thrust fault targeted at Site C0003, but at a shallower depth. The site is located at the tip of the deformed thrust sheet, and the site penetrated the megasplay fault at a depth of ~ 300m LSF and reached a total

Figure 3. Chikyu leaving Shingu Port at the beginning of Expedition 314.

depth of 400m LSF. The lithology of this hole was interpreted as predominantly homogeneous fine-grained sediments, with no major change across the fault, suggesting the sediments above and below the fault are similar in nature. Structure at this site was characterised by three distinct Structural Domains (the slope sediments, hanging-wall thrust sheet and footwall underthrust sediments) and several clear conductive fractured zones, particularly within the hanging-wall thrust sheet. Some of these zones can be correlated directly with fault splays within the 3D seismic data.

Site C0006

Site C0006 targeted the main frontal thrust, at the toe of the accretionary prism. Drilling penetrated the frontal thrust hanging-wall, the frontal thrust itself at ~ 700m LSF and partially into the footwall underthrust trench sediments to a total depth of 886 m LSF. The frontal thrust site sediments were weakly deformed compared to those of the more established megasplay fault system upslope. Fracture and bedding orientations appear to be affected by local factors, such as gravitational failure, as well as tectonic convergence. Distinct sandy beds appear to be displaced and repeated downhole by a series of subsidiary thrusts which are also imaged in the 3D seismic data. The frontal thrust fault zone itself is subtle in resistivity images but its base may be marked by an abrupt decrease in resistivity.

Summary of Stratigraphy and Lithology Results

One of the main aims of Expedition 314 was to document the lithology and physical properties of the sediments using the LWD data, primarily the resistivity images, resistivity, density and velocity data. Overall the sediments identified during Expedition 314 were hemipelagic mud, silty turbidites and some sand bodies, occurring across the different environments. Each site could be divided up into sections that corresponded to slope sediments, forearc basin sediments and accretionary sediments (Figure 4).

The slope deposits draping the accreted sediments were identified at all of the drilled sites, and all corresponded well to the seismic profiles. These deposits are interpreted as hemipelagic muds, with some gamma rays cycles suggesting the occurrence of silty turbidites. The thickness of these overlying sediments varied between the sites, from a few 10's metres to a couple of hundred metres. In all cases the base of these was interpreted as an unconformity, often due to change in bedding dip across the boundary as well as a changes in log properties.

The accretionary prism sediments were sampled at several sites and consist of multiple lithologies, varying from site to site. Overall the older accretionary prism sediments associated with the mega-splay fault and outer-arc region (sites C0001, C0003 & C0004) are dominated by compacted hemipelagic muds with occasional silty layers. Near the toe of the accretionary prism at the frontal thrust (sites C0006) the prism sediments are interpreted as muddy (potentially weakly lithified hemipelagic deposits) and sandy deposits, with cyclic profiles thought to be sequence repetitions across thrust faults. The underthrust sediments at the accretionary prism toe (site C0006) are distinct as they exhibit very low gamma ray values indicative of sand-rich lithologies.

At site C0002 the older accretionary prism sediments underlying the forearc basin are again dominated by hemipelagic muds but seem to be much more deformed than at the other sites, with steeply dipping bedding, and abundant fractured zones. This is presumably a function of the extended period of deformation. Overlying this section are the Kumano forearc basin sediments. Here muddy-sandy turbidite deposits dominate, where the sand-rich layers can be easily identified by gamma ray and resistivity measurements and resistivity images. A thick (~100m) unit unconformably overlying the accretionary prism sediments exhibits a much more homogeneous signature, suggesting a more clay-rich compacted mudstone. Within the basin sediments, a gas hydrate-bearing zone is identified from resistivity data, with the hydrate apparently concentrated in sandy turbidite layers. This zone overlies the BSR (bottom simulating reflector, at ~400m LSF) seen in seismic data. A second deeper zone is potentially gas bearing, based on the sonic log response and is again associated with sandy layers.

Overall the logs consistently show a dominance of hemipelagic muds/mudstones and turbidites, but with some sand, particularly at the toe of the accretionary prism (site C0006). The accretionary prism

Figure 4. Lithological summary of Expedition 314 LWD sites, indicating changes in lithology and setting across the NanTroSEIZE transect.

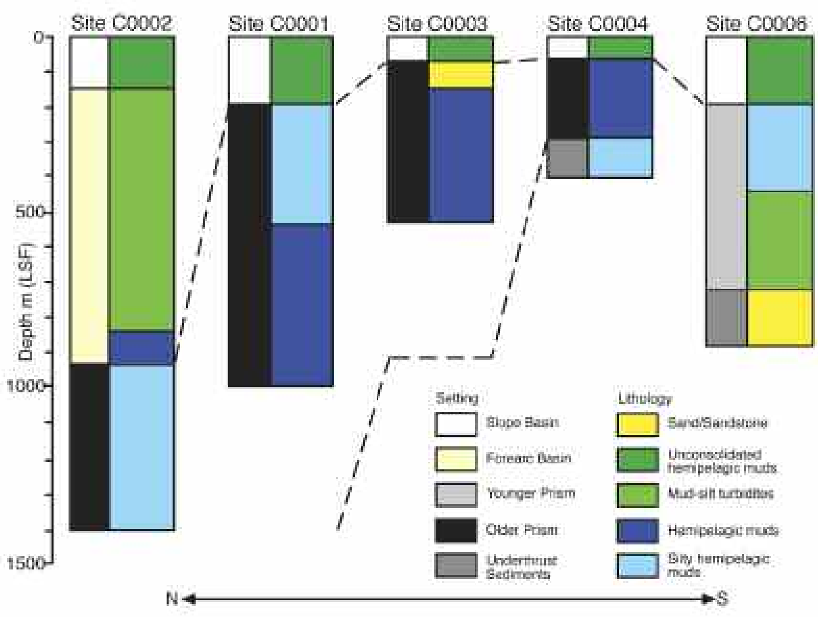


Table 1. Expedition 314 site locations

Site	Depth (m LSF)	Location and Comments
C0001	974	Hangingwall of the megasplay fault system. Future site for riser drilling to the megasplay fault
C0002	1401	Forearc Basin and inactive underlying accretionary prism Future site for riser drilling to the seismogenic plate boundary
C0003	526	Accretionary prism, targeting the "mega-splay" fault Real-time data only (no LWD)
C0004	400	Accretionary prism, targeting the "mega-splay" fault
C0006	886	Frontal thrust fault at toe of active accretionary prism

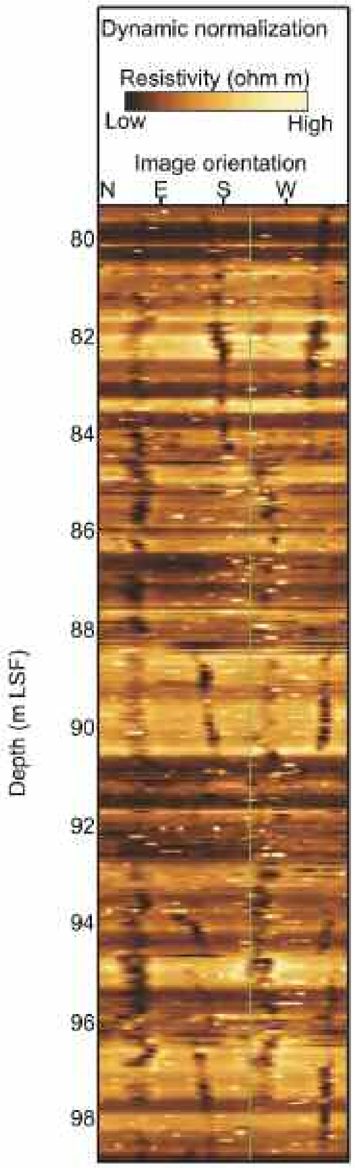


Figure 5. Resistivity image at Site C0001 showing borehole breakouts (vertical conductive lines at NE and SW) and drilling-induced tensile fractures (near-vertical conductive lines at SE and NW) indicating shortening at ~335° or perpendicular to the margin and plate boundary.

sediments in the hanging wall of the mega-splay fault are interpreted to have undergone significantly more lithification than those sampled at the prism toe. Now Expeditions 315 and 316 have been completed, a more extensive correlation between logs, cores and seismic data will allow further analysis and interpretation.

Structural Geology

Resistivity images were the primary data source for determining deformation and structural development of the prism and forearc basin (in the form of faults, fractures and bedding at the borehole and integrating with regional scale seismic data) and for assessing *in situ* stress conditions.

Borehole breakouts induced by drilling, along with drilling-induced tensile fractures in many cases, were produced at all of the sites and imaged within the resistivity images (Figure 5). We were able to use them to determine the orientation of the maximum horizontal stress as the borehole opens preferentially along the minimum horizontal stress direction. In some cases, stress magnitude could be estimated from breakout widths and tensile fractures and therefore likely stress regime (normal, thrust or strike-slip faulting) predicted. At the active prism sites (C0001, C0004, C0006), the breakouts indicated prism-normal shortening (NW-SE) with a deviation from the convergence direction. This suggests that the oblique convergence must be accommodated elsewhere either as right-lateral faulting or on the plate boundary. Landward of the megasplay outer-arc area and within the forearc basin (C0002), the shortening direction (NE-SW) contrasts strongly with that of the prism and is more compatible with extension in the basin (consistent with normal faults observed in the borehole images and seismic data) extending down into the underlying inactive prism.

Fractures, faults and bedding plane orientations are generally consistent with subduction-related convergence within the prism sites. However, in many cases there is significant scatter of orientations or a change in orientation with depth in the borehole. This may be a function of local effects (both local stress conditions and non-tectonic factors such as gravitational failure) superimposed on the regional tectonic convergence. In most cases, the average trend of fractures and bedding was in agreement with that observed and interpreted in the 3D seismic data. At several sites, namely C0001 and C0002, faults with clear offset of either bedding planes or older fracture sets could be interpreted in resistivity images. In both cases, normal faulting was interpreted. At C0002, this style of faulting was in agreement with both borehole breakouts and seismic data, confirming margin-normal extension of the forearc basin probably due to backtilting in the hanging-wall of the megasplay fault. At C0001, this was not the expected mode of faulting within the megasplay thrust hanging-wall, but appears to be in agreement with the stress magnitude analysis of tensile fractures.

Extensive fracturing and faulting were observed from the image data and changes in physical properties, but few major deformation zones were identified. This might be expected as the major faults penetrated by drilling were either the shallow parts of fault zones (the megasplay fault at C0004) or juvenile fault zones (the frontal thrust at C0006). A zone of deformation and disruption at ~500-600m LSF at Site C0001 (hanging-wall of the megasplay fault) is interpreted as a fault zone and produced difficult drilling conditions. The megasplay fault at C0004 is marked by a transition from the fractured conductive hanging-wall with well developed breakouts to a relatively weakly deformed footwall. The frontal thrust at C0006 is not marked by a major fractured zone in resistivity images, but its position coincides with the transition from faulted(repetition of sequences and marker beds) hanging-wall sediments to distinct coarse turbiditic trench-fill sediments in the underthrust footwall.

Conclusions

In spite of difficulties expected in challenging drilling conditions and on a new vessel, the entire scientific party were more than satisfied with both the technological and scientific achievements of *Chikyu's* first scientific expedition. It was the result of teamwork involving hundreds of personnel onboard and onshore (science, drilling and logistics) and planning over many years. We all look forward to building on these successes. As we write, the final expedition of Stage 1 has recently been completed: a total of 3 expeditions to date. We can now look forward to additional non-riser drilling and then the start of riser drilling in the Nankai trough and eventually the target seismogenic zone.

References

HEKI, K. 2007. Secular, transient and seasonal crustal movements in Japan from a dense GPS array: Implications for plate dynamics in convergent boundaries. In: T. Dixon and J.C. Moore (Editors), The Seismogenic Zone of Subduction Thrust Faults. Columbia University Press, New York, pp. 512-539.

KINOSHITA, M, TOBIN, H, and THU, M K. 2008. Integrated Ocean Drilling Program Expedition 314 Preliminary Report, NanTroSEIZE Stage 1A: NanTroSEIZE LWD Transect.

MIYAZAKI, S, and HEKI, K. 2001. Crustal velocity field of southwest Japan: subduction and arc-arc collision. Journal of Geophysical Research, 106, B3, 4305-4326.

SENO, T, STEIN, S, and GRIPP, A E. 1993. A model for the motion of the Philippine Sea plate consistent with NUVEL-1 and geological data, J. Geophys. Res., 98, 17941–17948.

IODP Expedition 315: Stage 1 NanTroSEIZE 'Megasplay Riser Pilot'

Gérôme Calvès (University of Aberdeen) and IODP Expedition 315 Shipboard Scientific Party.

IODP Expedition 315, which began on November 16th and ended December 19th 2007 was one of three Nankai Zone Trough Seismogenic Zone Experiment (NanTroSEIZE) expeditions – Stage 1. One main site C0001 (Proposed site: NT2-03) was scheduled for the preparation of casing for the future riser drilling operation during the next stage of NanTroSEIZE.

At the start of our leg the Japanese riser ship Chikyu was already on site for IODP Expedition 314 in the Nankai Trough offshore the Kii peninsula, Japan. The Scientific Party therefore joined the vessel via helicopter. We met some of the scientists from Expedition 314 onshore during the transfer by three helicopter trips. Co-chiefs J. Ashi (University of Tokyo), S. Lallemant (University of Cergy-Pontoise), Expedition Project Manager H. Masago (CDEX) and some of the scientists were already onboard in order to familiarize themselves with the staff of Expedition 314 and the operations team. Expedition 315 was the first coring operation for the *Chikyu* under IODP operations.

After arriving a few days before the port call from the deep Scottish winter I had to go through a 'HUET' (Survival Training in case of a helicopter crash – just in case!). This day was an excellent opportunity to discover the warm welcome from our host in Yokohama – JAMSTEC–CDEX and to 'break the ice' with scientists from different parts of the world (spending a day simulating survival situation greatly changes images between scientists, for the best and the fun of it, of course). After this day at JAMSTEC we went south to the Kii peninsula to join the temporary heliport base.

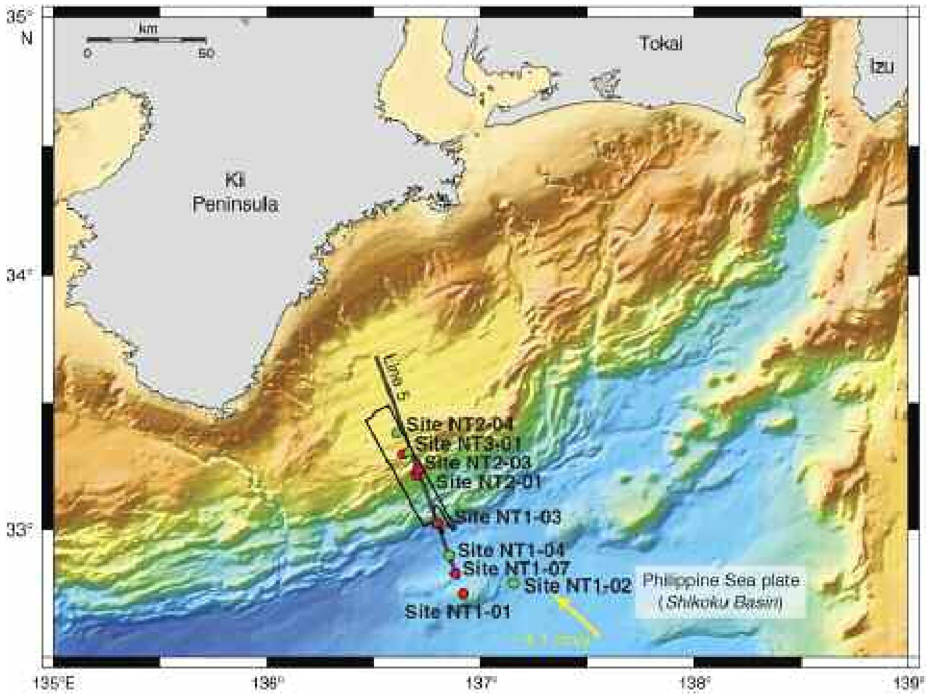


Figure 1. Map of Kumano Basin region with planned Stage 1 drill sites (Ashi et al., 2007; Scientific prospectus, Expedition 315).

Well fed the night before and with a good night of sleep we took a ride over the ocean to hunt for the *Chikyu*. I have to confess that arriving by helicopter on such a gigantic ship was stunning! From that moment our mission was making sense, excitement and raised the first question: 'So, where is the lab and do we have cores to describe?'

Scientific Objectives

The SE Margin of Japan has already hosted DSDP and ODP expeditions (DSDP Leg 31, 87 and 131; ODP Leg 190 and 196). The NanTroSEIZE transect is designed to derive the most complete record for understanding the construction of an accretionary prism and to reveal the driving mechanisms of seismogenic zones.

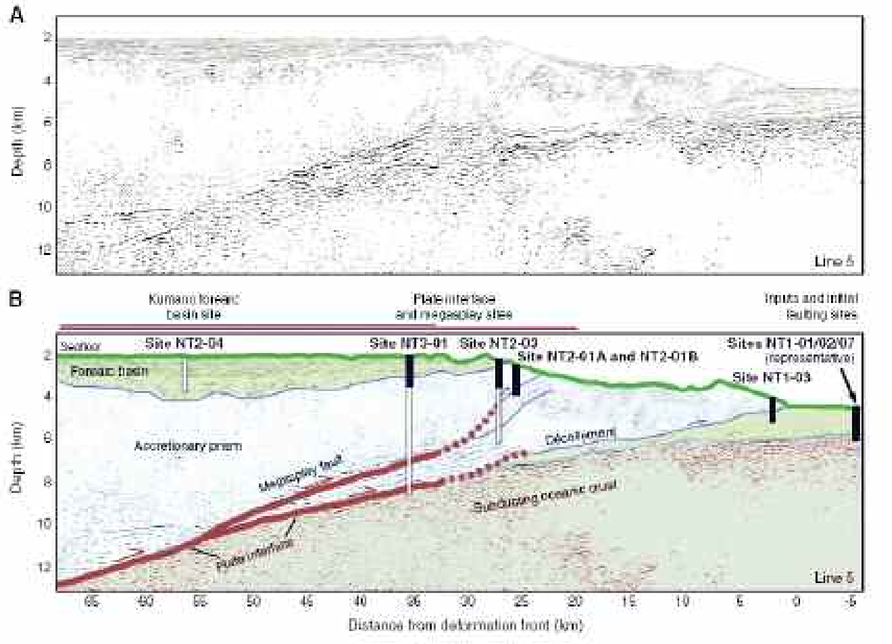


Figure 2. Line KR0108-5 (see Fig. F1). A. Uninterpreted (prestack, depth migration) shows structure of Nankai Trough accre-tionary prism (from Park et al., 2002). B. Interpretation shows locations of Stage 1 sites slated for LWD, coring, and downhole measurement/CORK installation (after Tobin and Kinoshita, 2006). Solid rectangles = TD planned for Stage 1, open rectangles = TD planned for future operations. The extent of coseismic rupture in the 1944 Tonankai (M 8.2) great earthquake determined from tsunami (red arrows) (Tanioka and Satake, 2001) and seismic (blue arrows) (Kikuchi et al., 2003) waveform inversions are shown above the seismic lines (Ashi et al., 2007; Scientific Prospectus, Expedition 315).

This expedition targeted the shallow branching faults and the tectonostratigraphy of the Kumano forearc basin (Ashi *et al.*, 2007). The four main objectives were as follows: (1) acquisition of geotechnical data and establishment of core-log-seismic integration for deep riser drilling, (2) structural investigations of strain partitioning between the prism and the forearc basin in oblique subduction, (3) geochemical investigations of migrating fluids through splay faults and (4) reconstruction of the prism and the forearc basin evolution based on stratigraphic records.

Drilling Operations

Drilling with the *Chikyu* allows access to the most recent generation of offshore drilling equipment and the most advanced onsite scientific measurement lab in earth sciences history (X-Ray CT scan, XRD, XRF, ICP-MS, magnetometer, organic and inorganic geochemistry, microbiological measurement). We had the good fortune to follow the experience of Expedition 314 during which precious LWD data from the sites planned for Stage 1 were collected, as well as industry operations from the past year offshore Kenya and NW Australia for oil industry exploration boreholes. One challenge at that time was that the drilling and coring team on *Chikyu* had never been tested. We thus attempted to answer the question 'How good is the recovery with the Rotary Core Barrel Sampling System (RCB assembly)?'

The first site drilled was C0001 (Proposed site: NT2-03) in a water depth of 2188.5 m. Coring started in Hole E on the night of 20th November by Hydraulic Piston Core Sampling System (HPCS) reaching a depth of 118.1m below seafloor. This was then followed by Hole F which recovered the depths below the seafloor from 108.0 m to 229.8m (HPCS) and 229.8m to 248.8m with the Extended Shoe Coring System (ESCS). Another site was planned after the poor recovery and bad quality of cores recovered by ESCS. Hole G had to be abandoned due to the cable of the Remotely Operated Vehicle (ROV) becoming tangled with drill string immediately after the start of coring by RCB. After recovery to a normal situation with the ROV, the drillship was moved slightly to run Hole H with RCB in a water depth of 2197m. We collected samples by RCB between 240.0 and 458.0m below seafloor. The LWD results from Expedition 314 identified a zone of 'sensible' drilling operations, the 'so called Sticky Zone'. The plan was to skip coring over the difficult portion and try to collect samples from 600m below seafloor or deeper. However, because the borehole wall was unstable we had to move to the next site. Hole I encountered the same problem, so that the decision was made by onshore staff and the NanTroSEIZE community to abandoned the site and move to contingency sites.

Around the same time the Kuroshiro Current was not at its slowest speed, so that the casing operation planned for future riser operation was also cancelled. This decision was hard to manage. The on and offshore members in charge of the project had to make the critical decision to postpone this operation.

During that period of time those scientists with 'high' moral ('always look at the bright side!') took the time to sample for future analysis, prepare reports, exchanges ideas and initiate research plans concerning those samples collected. Talks were also given at 'controversial' times in the day. The 12-24 hour shift noticed that talks and meetings were always held during 24-12 hour shift. We were maybe getting into the critical stressful period of time seen on regular two months legs, even if Expedition 315 was only one month long.

After discussion between all NanTroSEIZE members, the *Chikyu* moved to drilling site C0002 (Proposed site: NT3-01).

Figure 3. Expedition 315 Shipboard members include marine crew, drilling engineers, lab technicians and scientists. (Photo credit: Jamstec/IODP)

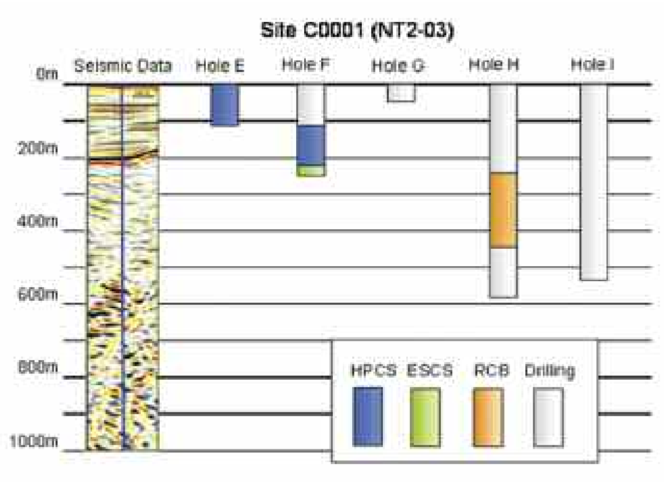


Figure 4. Summary of Coring Operation at site C0001 (NT2-03).

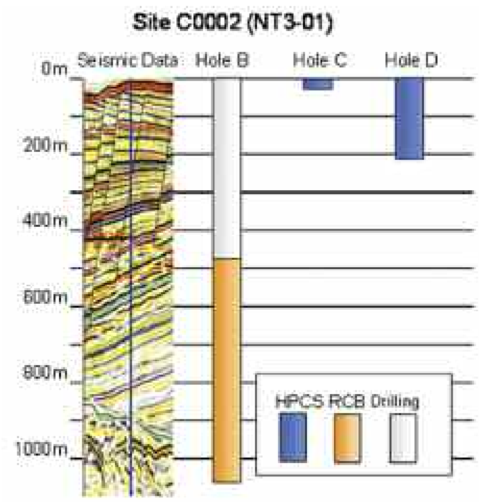


Figure 5. Summary of Coring Operation at site C0002 (NT3-01).

We arrived on site on 9th December. Drilling of Hole B (water depth 1937.5 m) penetrated to 475m and coring (RCB) reached a depth of 1057m below sea floor. This decision was made for the time left to the end of this expedition, to secure operation by drilling below the bottom-simulating reflector (BSR) and trying to reach the base of the Kumano forearc basin. Two shallow Holes C and D were cored with HPCS, reaching the depth of 204m below sea floor.

On the night of 12th to 13th December, we had our 'last meeting' with all the scientists to celebrate this challenging month. Luckily for me that meeting happened on my birthday, so I had the pleasure to raise my 'dry' glass and cheers all my colleagues for this amazing experience. Most of us left the following morning, reaching the Japenese shore and spreading around Japan on our way back home.

Scientific Results

The preliminary scientific results of IODP Expedition 315 revolve around the following points (Expedition 315, Preliminary Report, 2008).

The use of X-ray CT scan allowed important decisions to be made concerning critical time measurements such as interstitial waters. Downhole temperature measurements using APCT3 was first applied to the *Chikyu* operation and was successfully recorded in shallow intervals to 171m LSF at Site C0001 and to 159m LSF at Site C0002. RCB coring was a success during its first use on *Chikyu* with a recovery of 30–40%. At Site C0001 a very good record of the slope basin sequence and its thick basal sand layer underlain by the accretionary prism was recovered. Micropaleontological and paleomagnetic stratigraphies give a new age perspective on prism growth. The geochemical signal through the splay fault seems to suggest minor fluid flow and/or diagenetic influence. At Site C0002 the depositional ages revealed rapid sedimentation rates in the forearc during the Quaternary and sediment-starved conditions in the basal slope basin during the Pliocene.

Deformation structures were nicely observed at the core scale, such as steepened bedding, faults, breccia, shear zones and vein structures. The structural on-board results suggest three phases of stress field changes: (1) a NW-SE shortening by thrust faulting and possibly strike-slip faulting, (2) NE-SW extension by normal faulting and (3) N-S extension by normal faulting. The LWD data on Expedition 314 correlated with the detailed rock and fluid record observed on core acquired during Expedition 315.

The results of this Expedition 'Megasplay Riser Pilot' are regarded as satisfactory especially considering the experience of drilling operation of *Chikyu*. I do believe that NanTroSEIZE and the *Chikyu* will play an important role in the stated mission of IODP and for the Earth system knowledge over accretionary prism construction, as well as for seismicity driving mechanisms.

Future

Once all the scientists returned home and the samples reached labs worldwide the detailed work could start. There is still a lot to do to unreveal the signals recorded in this expedition.

Stage 2 expeditions will drill the first of two planned deep riser holes using the drill ship *Chikyu*, targeting the megasplay fault zone at 3,000–3,500m below the sea floor for the first time in the history of scientific ocean drilling.

References

Ashi, J, Lallement, S, and Masago, H. 2007. NanTroSEIZE Stage 1: NanTroSEIZE megasplay riser pilot. IODP Sci. Prosp., 315. doi:10.2204/iodp.sp.315.2007

Expedition 315 Scientists. 2008. NanTroSEIZE Project Stage 1: NanTroSEIZE Megasplay Riser Pilot. IODP Prel. Rept., 315. doi:10.2204/iodp.pr.315.2008

Internet Sites

www.jamstec.go.jp/chikyu/eng/Expedition/NantroSEIZE/exp315.html

www.jamstec.go.jp/chikyu/eng/Expedition/NantroSEIZE/exp315_pg.html

Expedition 316: Stage 1 NanTroSEIZE 'Shallow Megasplay and Frontal Thrusts'

Uisdean Nicholson (University of Aberdeen) and the Expedition 316 Scientists

Introduction

In all, twenty-seven scientists from nine different countries spent seven weeks between December '07 and February '08 participating in Expedition 316 on the IODP drillship *Chikyu*, offshore of the Kii peninsula in southeast Japan. The targets of drilling were the tsunamigenic megasplay fault and frontal thrust of the accretionary complex of the seismically active margin between the Eurasian plate and Phillipine Sea Plate. This expedition forms part of the Nankai Trough Seismogenic Experiment (NanTroSEIZE) aimed at improving the understanding of seismogenesis and tsunamigenesis in this region and is one of IODP's primary objectives in ocean drilling during the next few years. The fundamental aim of the experiment is to set up a seismic observatory to monitor seismogenic behaviour and to characterize the active plate boundary fault zone. Expedition 316 was the third expedition in the first stage in the experiment, with a focus on understanding the fault behaviour at shallow levels and investigating the sedimentary and fluid inputs to the seismogenic zone.

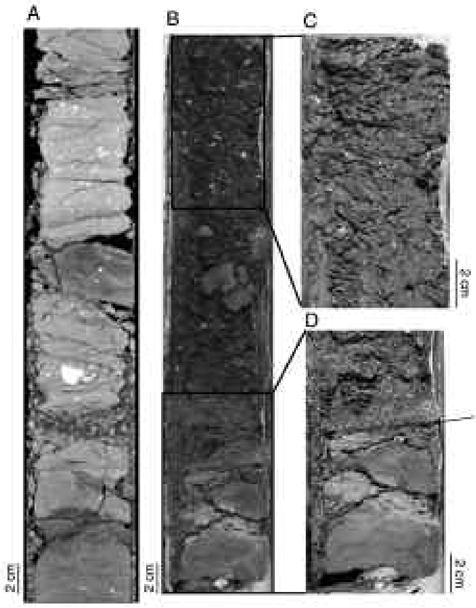
The Nankai Trough is one of the most intensively studied subduction zones in the world, with a long history of tsunamigenic earthquakes over at least 1300 years. In contrast with other subduction zones the Nankai Trough has relatively shallow water depths (<5km everywhere) and the shallow depth of the tsunamigenic megasplay fault make this an ideal candidate for ocean drilling. The Japanese government has also invested heavily in improving the understanding of the margin, given the high risks to life and property faced in all the large cities on the eastern seaboard of the islands.

Several DSDP and ODP legs have targeted this prism already, including ODP Legs 131 and 190 which drilled several sites in the Muroto and Ashizuri transects to the southwest. Four sites were drilled during Expedition 316: one in the shallow megasplay, one in the slope basin which has been partially underthrust beneath the megasplay and two intended to reach the frontal thrust within the leading edge of the prism.

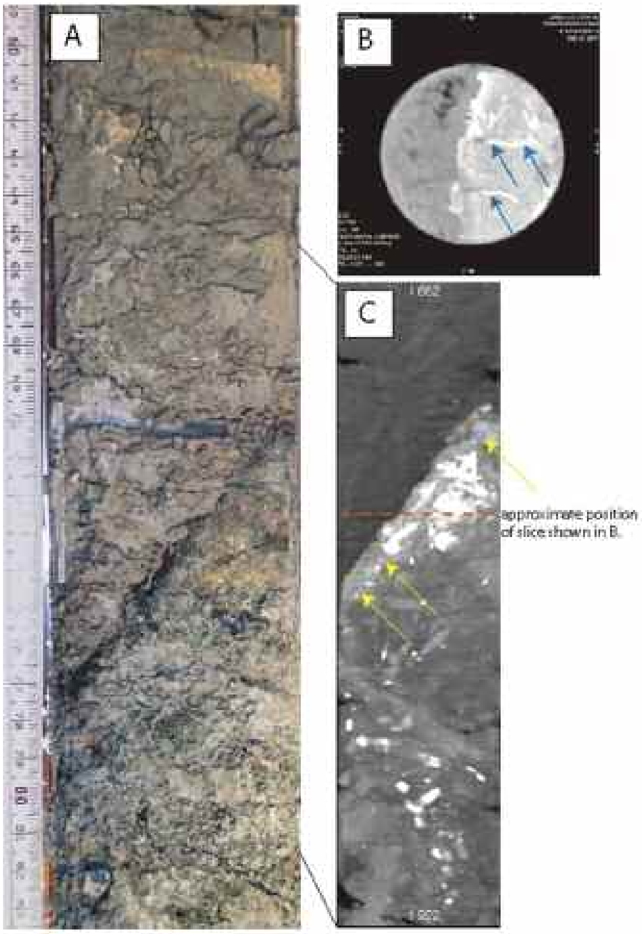
Scientific Objectives of Expedition 316

The most important scientific objective of the NanTroSEIZE experiment is to improve understanding of the processes that govern the strength, nature and distribution of slip along convergent plate-boundary fault systems, where over 90% of global earthquakes (and associated tsunamis) are generated. Current models of plate-boundary faulting are limited by a lack of information on the physical conditions and the mechanical properties of these faults at seismogenic depths. The experiment is focused on understanding the mechanics of seismogenesis and rupture propagation along the various faults that make up the subduction plate boundary, by in-situ sampling of the fault zones and installation of a multi-component fault observatory system in the subsurface (Tobin & Kinoshita, 2006a, b).

While the ultimate aim of the project is to set up this long-term seismic monitoring system in the up-dip limit of the seismogenic zone, there is also a great deal that can be learned from drilling and sampling the shallow (and possibly aseismic) part of the fault zone. In particular the sediments that are being incorporated into the prism, as well as the fluids they contain and transmit, have a crucial role in the seismic behaviour of the prism. With this in mind, Expedition 316 had two specific drilling targets in the shallow part of the prism: (1) the frontal thrust at the seaward side of the prism and (2) the megasplay fault, an out of sequence thrust which may have slipped and generated tsunamis during various large tremors in Japan, such as the 1944 Tonankai earthquake.



The frontal thrust is the youngest part of the prism and represents an area of active accretion and lateral growth of the prism. This expedition aimed to answer fundamental questions about the nature of movement along this fault, such as whether the frontal thrust grows by slow interseismic creep, or by episodic coseismic movements associated with large earthquakes and possibly tsunamis. There are also key questions regarding the role of fluid and sediment type in the deformation



processes in the fault zone (Tobin & Kinoshita, 2006a,b).

The second target, the megasplay fault, is one of the key drilling targets of the NanTroSEIZE project due to its potential as the source of many of the great earthquakes that have occurred in this region. Fault geometries observed on seismic data and slope morphology suggest that this thrust is active and that the thrust has steepened over time. This makes the fault a prime candidate for tsunamigenesis due to the great potential for vertical uplift of the seafloor during slip (Moore *et al* 2007, Park *et al* 2002). The seismogenic zone of this fault will be the target of the main, 7km deep, record-breaking well which is to be drilled in a later stage of the project. Expedition 316 however was aiming specifically at the shallow portion of the fault with several fundamental questions regarding its potential as a tsunami-generator: is this an active blind thrust and is there any evidence for recent seismogenic slip? If so, what are the relationships between fluid behaviour, slip and deformation in the fault zone?

Drilling Operations

After a day's helicopter survival training at the JAMSTEC (Japanese Agency for Marine-Earth Science and Technology) headquarters in Yokahama, and a 5-hour train journey to the helipad in Ugata, we boarded the *Chikyu* on the afternoon of the 19th of December to join the members of our party who were already onboard, having formed part of a week-long crossover team with Expedition 315. We were immediately impressed with the size of the ship and the range of facilities available to us. The *Chikyu*, at 210 metres in length and with a gross tonnage of approximately 57, 087 tons, is the biggest Japanese owned vessel and the world's largest and most advanced scientific drill ship. It has the tallest derrick (drill tower) of any drill platform in the world, standing more than 100 metres above the sea floor allowing and is fully equipped to carry out deep riser drilling to depths of up to 7km beneath a sea-floor of several thousand metres. This includes a 16 metre high, 380 ton blow out preventor (BOP), designed to withstand up to 1000 times atmospheric pressure. The relatively shallow wells drilled during Expedition 316 however, allowed for riserless drilling which is faster and more cost-effective in such environments. The shipboard laboratory, which is distributed over three floors near the front of the ship has a wide range of analytical facilities including a newly installed X-Ray CT scanner, the first time such an instrument has been used in ocean drilling.

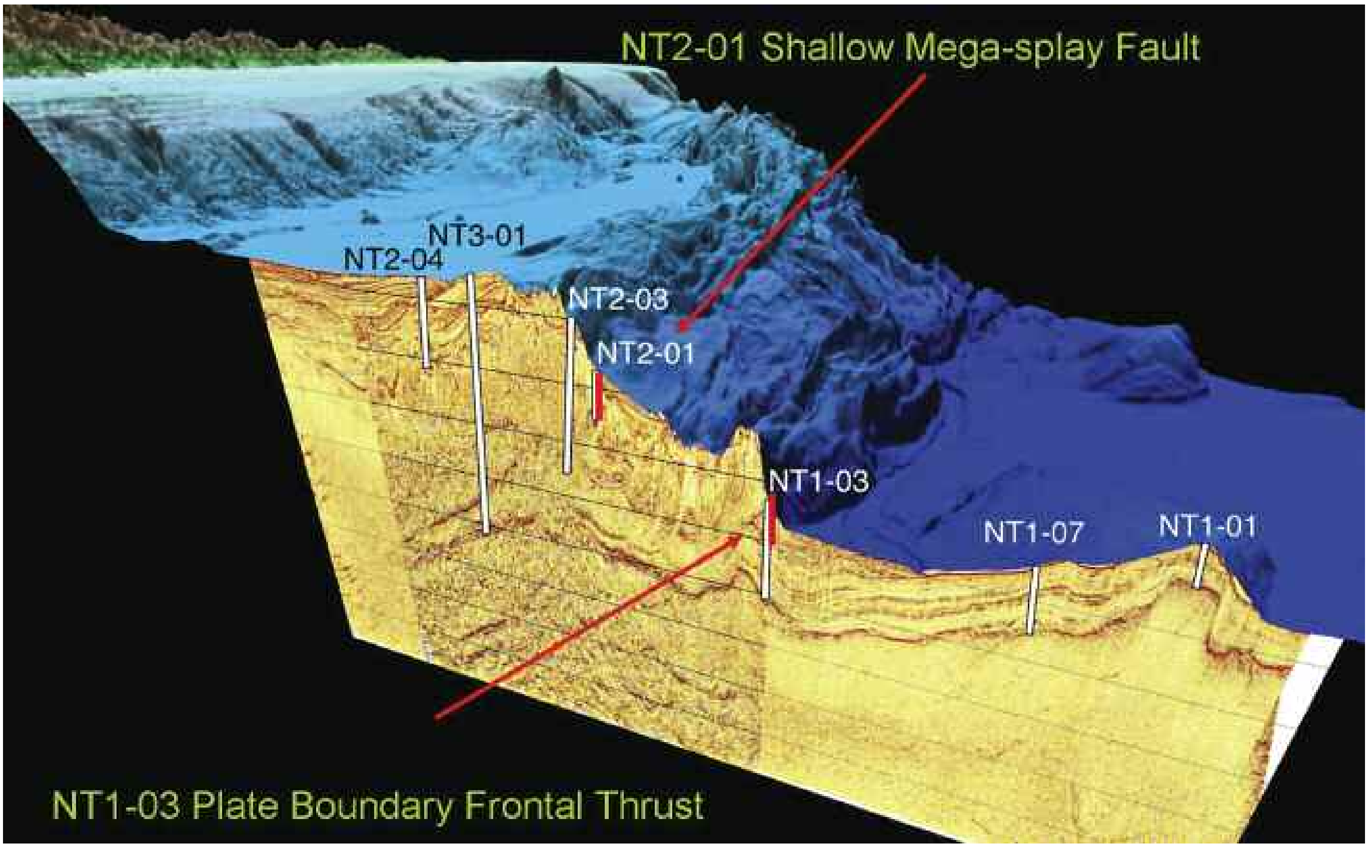
Despite the state of the art technology on the *Chikyu*, there are significant challenges to drilling in this area. As well as typhoons in the late summer, there is also the problem of one of the world's strongest ocean currents. The Kuroshio current (literally 'Black Stream'), which carries warm, tropical water from offshore Taiwan to the northern Pacific, intermittently flows past the NanTroSEIZE drill sites at a rate of up to 4 knots, posing a major challenge to the crew. A specially designed GPS system, aided by six adjustable thrusters, allows the ship to remain stable in the face of the current. Despite this, sites had to be chosen very much with the current in mind, as the full force of the current causes significant vibrations potentially resulting in significant damage to the ship.

Before drilling commenced at a new site the transponders positioned on the seafloor during Expedition 314 had to be located. After this, the ROV was deployed in order to provide live images of the drill bit at the seafloor, so that the bit could be located exactly at the mudline for the first core. The deeper sites C0006 and C0007 proved to be slightly more difficult. The enormous pressure at 4km water depth is too great for ROVs to operate and the drillers had to find the mudline 'blind' by shooting the piston core when they estimated the drillbit was close enough to the sea bed.

Different coring systems were used depending on the state of consolidation or lithification of the sediment being drilled. Shallow, unconsolidated sediment was drilled using the hydraulic piston coring system (HPCS) which allowed rapid recovery and minimal drilling disturbance. Once the consolidation state of the sediment increased and rate of penetration and core recovery with the HPCS dropped, the extended shoe coring system (ESCS) was employed. This allowed the drilling to penetrate more consolidated sediments although drilling disturbance also often increased significantly. A change to the rotary core barrel (RCB) was necessary when rate of penetration decreased and/or core condition deteriorated due to drilling disturbance; this change required a pipe trip and time to make up the RCB assembly on the drill floor – usually about a day's delay. RCB coring typically resulted in lower recovery than HPCS or ESCS, particularly when drilling through sand or breccia.

When the target depth had been reached in the last hole several hours ahead of the end of drilling, a new method of ESCS that pushed, rather than rotated the coring shoe ahead of the bit (yet to be given a suitable acronym) was tested. This proved to be a great success with high recovery and reduced drilling disturbance in comparison to the standard ESCS coring at shallow to moderate depths and low levels of consolidation. It is likely that this technique could replace ESCS coring in suitable formations of future IODP expeditions.

Once core had been recovered, it was treated on the drill floor and cut into 1.5 metre sections then left to warm to room temperature before being taken through to the shipboard lab. Each core section was then sent through the X-Ray CT scanner to generate 3D images of the internal core structures. This was the first time such a tool had been used on an IODP leg, and it proved to be an invaluable tool, with superb, high resolution images of the core allowing detailed analysis of fault structures as well as mineralogical and lithological changes in the core. It seems likely



that this will come to be an integral part of any future IODP cruise, particularly in structurally complex areas.

After the CT scan and before the sections were split, measurements of thermal conductivity were taken, sensors recorded various whole core parameters, and whole-round were samples were taken from suitable sections to analyze the interstitial water in the core. Samples were also taken for palaeontological analysis, microbiology, XRD analysis of bulk elements, carbon content, and various other geochemical analyses. Sections were then split into archive and working halves so that the internal structure of the core could be examined. The archive half was examined by the lithostratigraphy team and then carefully photographed and measured for paleomagnetic parameters, colour reflectance before being removed for storage. The working half was first analysed by the structural geologists and the physical properties specialists took samples for measurements of moisture and density (MAD), velocity, porosity and other geotechnical analyses. Palaeomagnetists also took samples for magnetostratigraphy as well as to orientate the structural geologists' observations. The remaining core was then open to individual scientists to collect samples for post-cruise analysis, after careful discussion and debate over which methods would get the maximum amount of information from each core.

Initial site summaries

C0004

The first site, C0004, was aimed at recovering the shallow portion of the megasplay fault in the older part of the prism. About 400 metres were drilled in total at Site C0004 and the section was divided into four units based on contrasts in dominant lithology, presence or absence of minor lithologies, petrography, fossil assemblages, structural data, seimic interpretation, XRD data and geochemistry.

The first unit encountered belonged to the slope apron overlying the accretionary prism and consisted mostly of nannofossil-bearing hemipelagic mud, some of which showed signs of soft sediment deformation and slumping indicative of unstable slope conditions up-slope. These features were often much more clearly recognizable in the CT scan than in the core, which begs the question of how often these features have gone unrecognized in previous ocean drilling expeditions, particularly in poorly lithified core.

Unit II is dominated by mud, although there is a sharp decrease in the nannofossil content and a significant increase in consolidation at the boundary. This unit is typically brecciated and one of the difficult issues we had to face was to distinguish sedimentary breccias from drilling induced breccias in the core. The CT image again proved to be an invaluable tool for this and a clear set of criteria was developed to distinguish the two. Recovery was much lower in this unit than the first, partly due to the extent of brecciation and due to the necessity of using the RCB coring system.

Unit III is also dominated by mud but was bound at the top and bottom by thrust faults which correspond to biostratigraphic age reversals in the core. Recovery of this unit was excellent and continuous samples were obtained of the bounding faults, as well as the numerous smaller faults which dissected the unit.

Unit IV was interpreted on seismic data as belonging to the underthrust sediment sequence and is dominated by mud with thin interbedded sand and minor ash.

C0006 and C0007

Both of these sites aimed to penetrate the frontal thrust zone which is particularly shallow at this site. Drilling conditions were often difficult with a high sand content often causing problems in the stability of the hole.

Site C0006 was drilled to a depth of 600 metres, several hundred metres short of the frontal thrust, before the hole condition deteriorated and the hole had to be aborted. Site C0007 was then drilled approximately 800 metres downslope in order to try to intercept the frontal thrust fault at a shallower level. Again, due to deteriorating hole conditions in the clastic rich succession at this site, the hole had to again be abandoned. A second hole was drilled at the same site, this time washing down to 175 metres and drilling on from there. The frontal thrust was encountered at about 430 metres below sea floor, and the well was killed at 500 metres after successfully recovering a small amount of the underthrust sand-rich trench deposits.

The section cored in these wells was divided into four units using the same criteria as Site C0004. Unit I, the muddy slope apron, is very thin at this Site and consists largely of nannofossil-bearing mud with thin interbedded sand and ash. Unit II belongs to a coarsening-upwards sequence of mud and sand, with sand beds becoming increasingly thick and frequent up-section. This may represent a gradual movement of the subducting plate towards the sand-rich trench channel before accretion into the frontal thrust. Unit III consists of a mudstone sequence with no sand and minor volcanic ash layers. Unit IV, which was only encountered in one hole at Site C0007, consists largely of coarse volcaniclastic sand although recovery was very limited in this interval.

Heat flow measured at these sites was considerably lower than preliminary models would predict, particularly at site C0006.

C0008

Site C0008, located about a kilometre downslope of C0004, was drilled in the last week of the cruise and was chosen in order to sample the slope basin which is being underthrust beneath the megasplay fault. Drilling rate was very rapid due to the largely unconsolidated nature of the sediment and we quickly penetrated to the target depth of 350 metres. As at site C0004, the dominant lithology is nannofossil-rich mud, although in this case the interbedded sands are thicker and better developed, and have a cyclic nature; graded sand beds are underlain by thin ash horizons again suggesting that sedimentation in this basin has been strongly influenced by tectonics. The rapid rate at which this hole was drilled allowed an extra hole to be drilled at the same site, but targeting a normal fault a few hundred metres downslope of the first hole. Recovery in both holes was excellent, resulting in more or less continuous coverage of the slope basin stratigraphy and giving vital clues about the nature of sediment and fluid being incorporated into the prism.

Concluding remarks

We returned to Shingu port on the 5th of February 2008 to a crowd of journalists, cameras and 100 small children in brightly coloured hats, drawing an end to Phase 1 of the NanTroSEIZE experiment. Expedition 316 proved to be a great success, with excellent recovery from most of the targeted fault zones and many interesting and often unexpected discoveries. These will be the subject of intensive post-cruise research and results made public in the near future. However, it should be remembered that this is just the first stage in the NanTroSEIZE experiment, and there promises to be many exciting challenges and discoveries ahead over the next four or five years of drilling.

References

KINOSHITA, R, VON HUENE, M, MOORE, G, TOBIN, H, and RANERO, C R. 2006. The seismogenic zone experiment, Oceanography, 19, 28-38.

MOORE, G F, BANGS, N L, TAIRA, A, KURAMOTO, S, PANGBORN, E, and TOBIN, H J. 2007. How Three-Dimensional Splay Fault Geometry Fosters Tsunami Generation. Science.

TOBIN, H J, and KINOSHITA, M. 2006a. NanTroSEIZE: the IODP Nankai Trough seismogenic zone experiment. Scientific Drilling, 2:23–27.

TOBIN, H J, and KINOSHITA, M. 2006b. Investigations of seismogenesis at the Nankai Trough, Japan. IODP Scientific Prospectus, NanTroSEIZE Stage 1.

PARK, J, TSURU, T, KODAIRO, S, CUMMINS, P R, and KANEDA, Y. 2002. Splay Fault Branching Along the Nankai Subduction Zone. Science.

Scientific results from past expeditions

Expedition 305: Post-cruise Results

Angela Halfpenny (Australian National University, previously at the University of Liverpool)

An Oceanic Core Complex (OCC) is a domal bathymetric high often found at the inside corners of ridge-transform intersections and have been recognised along both slow and ultra slow spreading ridges (Cann *et al.*, 1997; Cannat *et al.*, 2006; Ohara *et al.*, 2007; Ohara *et al.*, 2001; Okino *et al.*, 2004; Smith *et al.*, 2006; Tucholke *et al.*, 1998). OCCs expose gabbroic rocks on the sea floor via detachment faulting, often associated with serpentinized peridotite (Ildefonse *et al.*, 2007). Geophysical interrogations of OCCs have been used to infer that the internal structure is dominated by mantle peridotite (Blackman *et al.*, 1998; Blackman *et al.*, 2002; Canales *et al.*, 2004).

The Atlantis Massif OCC exposes serpentinized peridotite and a smaller amount of gabbro, in a domal high at the inside corner of the eastern intersection of the Mid-Atlantic Ridge (MAR) at 30°N and the Atlantis Fracture Zone (Figure 1). The Atlantis massif formed within the last 1.5-2 my, therefore weathering and erosion have not degraded the structural relationships this made it a perfect target for the IODP Expeditions 304 and 305 (Blackman *et al.*, 1998; Blackman *et al.*, 2002). The corrugated, striated portion of the domal massif displays morphologic and geophysical characteristics inferred to be representative of an OCC exposed via long-lived detachment faulting.

The IODP Expeditions 304 and 305 was designed to provide a greater understanding of the formation and evolution of OCCs via drilling through the Atlantis Massif OCC. The expeditions drilled a combined total of 1415.5m through the footwall of the central dome of the Atlantis Massif OCC at site U1309D and is by far the deepest hole ever drilled in young ocean crust, the third deepest ever drilled in hard rock ocean floor, and the deepest in the Atlantic.

The drill core of Hole U1309D was dominated by lower crustal rocks consisting of

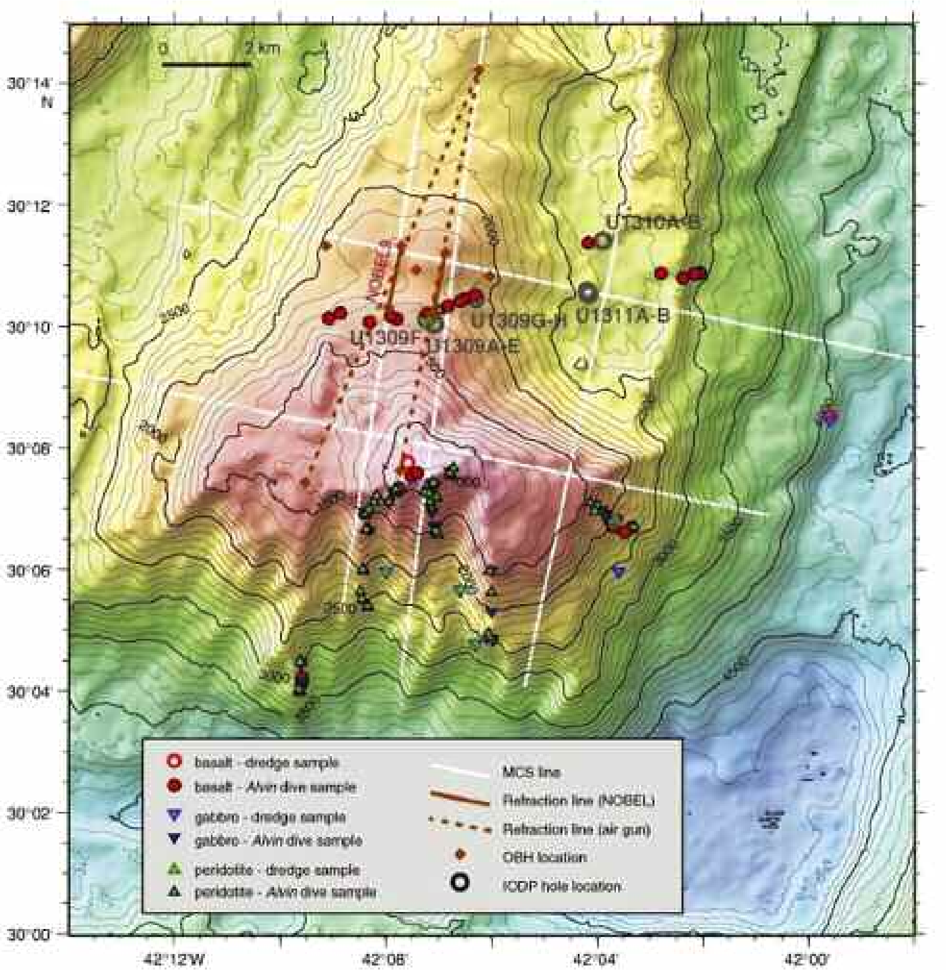


Figure 1. Base map of Atlantis Massif showing prior geological and geophysical data coverage and the location of IODP drill sites (circles). Bathymetry is contoured at 20m intervals, based on a 100m grid. Seismic reflection and refraction lines and seafloor mapping/sampling sites are shown. Spreading-parallel multichannel seismic (MCS) Line Meg-9 follows the Southern Ridge; Meg-10 crosses the central dome. Line Meg-5 crosses the southeast shoulder of the massif and then runs sub-parallel to the trend of the adjacent volcanic block. The corrugated detachment surface capping the central dome is inferred to extend beneath this eastern block, thereby making the upper crustal volcanics a hanging wall to the fault. OBH = ocean bottom hydrophone.

interlayered gabbroic lithologies with basaltic rocks such as diabase and other ultramafic rock types. A complete suite of gabbroic rocks was recovered, ranging from olivine-rich to oxide-rich and exhibiting variations in grain size from mm to tens of cms. A superb alteration profile was also recovered from the core (with the alteration of the core changing down hole). High strain crystal plastic deformation was observed in discrete shear zones, which varied in thickness from millimetres to a few meters (Ildefonse *et al.*, 2007); however such deformation was recognised in just 3% of the recovered core volume. The majority of the shear zones were located in gabbroic lithologies.

Expeditions 304 and 305 were at sea from November 2004 to March 2005. The joint expeditions allowed for an increased size of the science party and provided a broader perspective and wider range of expertise than would otherwise have been achieved. Since disembarking, each on-board scientist has continued to study the rocks collected based upon their particular area of interest and expertise. Each member of the scientific party wrote a proposal for post-cruise (shore-based) research and put in a request for samples from the core at the post-cruise sampling party.

Post-cruise Sampling Party

All sampling for post-cruise research was performed at a single shore-based sampling party at Texas A&M University in May 2005, which is the headquarters for the IODP. This was the first time the sampling had been performed at a shore-based sampling party and the arrangement worked well. Initially there was an overall discussion about what each scientist would like to achieve from their post-cruise research. This enabled areas of overlap and collaboration to be identified. Each scientist met with their separate ship board disciplines (such as structure, metamorphic, igneous etc) and viewed the entirety of the core and discussed it within their group. This enabled everyone to get a general overview of the entire core, which was beneficial since previously each scientist had only seen the core drilled on their particular expedition.

After the general overview, each scientist went down the core identifying locations of areas of interest for their research (where they would like to take a sample of the core for further analysis), which were labelled with a sticker. This was also complicated by the fact that people wanted different amounts of the core depending upon what research they would be performing, from a small section for a thin section billet to cubes to half rounds. Once everybody had finished selecting their sites of interest, the co-chief scientist from the boat went through all of the sample site requests to check for possible problem areas

Figure 2. Photograph of core 270r3 section 101 to 111cm (from the top of the core). The piece of the core exhibits red makings which show the boundaries of each sample. So the core will be cut into one half slab (red sticker saying Toru) and two thin section billets (one for me and one for AD). The arrows mark the orientation of core up.

and to confirm that the samples could be taken. Possible problem areas were where more than one person was selecting a sample from the same section of the core. These problems were easily solved by people taking samples next to each other or underneath each other (Figure 2).

Once all the sample sites had been given approval by the co-chiefs, the scientists then marked up the sample locations giving the outside lines to be cut along and marking the samples with an orientation arrow that represented the up direction of the core. Everybody then returned home to wait for their samples to be delivered, as it takes the IODP staff a while to cut out a few thousand rock samples. At the start of July 2005, I received my thin section billets, small pieces of rock approximately 3 to 4cm long by 2cm wide and 0.5cm thick. The billets were used to create standard thin sections (a glass slide with a 30μm thick piece of rock glued onto it). Thin sections are used to study the optical properties of the rock and its constitutive mineral phases (Figure 3).

Post-cruise Scientific Objectives

The samples I selected at the post-cruise sampling party from down the core length were located in gabbroic lithologies and exhibited ductile (plastic) deformation. The main aims of my post-cruise research are to:

- Measure mineral crystallographic preferred orientations (CPO).
- Quantify variations in microstructure such as grain size and boundary irregularity.
- Contrast and compare samples which exhibit varying amounts of deformation from the same shear zone.
- Study exsolution textures and use as a constraint of temperature.
- Constrain deformation, recovery and recrystallization mechanisms.
- Use inferred mechanisms and CPOs to estimate deformation conditions.
- Infer deformation histories and deformation mechanism pathways.

Scientific techniques

Characterisation of shear zone microstructures from the Atlantis Massif can provide extra information about the areas deformation history and insight into the formation of oceanic core complexes. Using optical microscope techniques, orientation contrast imaging and electron backscatter diffraction (EBSD), the petrofabrics and microstructures have been compared between the centre and

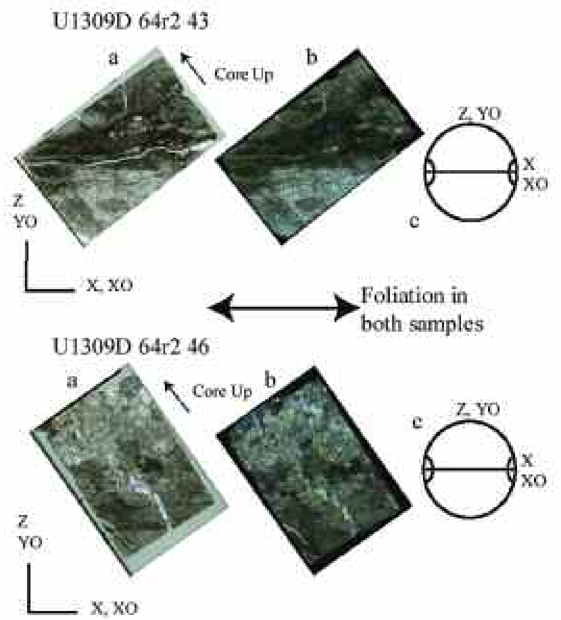


Figure 3. Samples 64r2-43 and 64r2-46. Reference frames marked onto each thin section. XZ reference frame represents the semi-kinematic reference frame of the thin section (foliation known but not lineation). X0Y0 reference frame represents the reference frame of the maps produced by the HKL Channel software. (a) plane polarised light of the full thin section (b) cross polarised light of the full thin section (c) stereonet reference frames corresponding to the thin section reference frames. The orientation of the foliation in the thin sections is marked, as well as the orientation of up in the core reference frame.

Table 1. Summary of statistical calculations for various ways of measuring the 'middle' of a data set performed for each phase of the two samples such as the mean, standard deviation, median, quartiles and the interquartile range (equals quartile 4 minus quartile 1). Data have been calculated using a statistical data file where grains smaller than 4x step size have been removed. These small grains have been removed as most errors created during the data collection, noise reduction and data manipulation phases show up as small grains.

Centre of Shear Zone Sample 64r2 43

Phase	Mean	Standard Deviation	Median	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Interquartile Range
Plagioclase	45.5	35.7	34.2	19.4	34.2	58.6	440.3	420.9
Enstatite	33.3	28.1	22.5	14.4	22.5	39.8	160.0	145.6
Diopside	43.9	40.7	34.4	19.4	34.4	50.1	366.9	347.5
Ilmenite	18.4	6.1	16.2	14.0	16.2	20.0	38.6	24.6

Edge of Shear Zone Sample 64r2 46

Phase	Mean	Standard Deviation	Median	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Interquartile Range
Plagioclase	26.7	24.2	20.3	15.5	20.3	29.9	409.5	394.0
Enstatite	24.8	19.1	19.7	14.4	19.7	29.8	166.7	152.3
Diopside	35.7	29.9	26.4	18.2	26.4	43.9	418.4	400.1
Ilmenite	15.5	2.9	14.8	13.1	14.8	17.0	24.4	11.3
Hornblende	21.5	8.0	19.4	15.5	19.4	25.3	98.9	83.4

the edge of the gabbroic shear zone samples (shear zones are areas where deformation has been concentrated into a particular zone and has altered the original igneous rock texture) collected from Hole U1309D.

The optical microscope was the first technique applied to the thin sections and was used to identify and locate the main mineral phases, as well as textural relationships. Optical microscopy was also used to identify possible locations for further study using more advanced techniques, such as orientation contrast imaging and EBSD.

Orientation contrast imaging and EBSD are both performed in the scanning electron microscope (SEM). An SEM is a type of electron microscope that creates various images by focusing a high energy beam of electrons onto the surface of a sample and detecting signals from the interaction of the incident electrons with the sample's surface. The type of signals gathered in a SEM varies, including secondary electrons and back scattered electrons (Lloyd, 1987). Depending upon the type of SEM, the resolution is between less than 1nm to 20nm.

EBSD is a microstructural technique used to study the crystallographic texture of any crystalline or polycrystalline material, such as geological materials, ceramics or metals (Prior *et al.*, 1999). EBSD measures the full crystallographic orientation and as such, it is applied to crystal orientation mapping, defect studies, phase identification, grain boundary identification and deformation studies, plus much more (Prior *et al.*, 1996). In this study, EBSD has been used to map the choosen areas of interest from the thin sections. The sample area was designated and collection parameters selected. The HKL Channel 5 software then automatically controls the electron beam and indexed the orientation at each point (Schmidt and Olesen, 1989) and the information is stored in a dataset. These datasets contain the raw information of the project and from these numerous maps, charts and plots can be generated. Some of these include grain orientation maps, grain boundary maps, image quality maps, grain size charts, misorientation charts and texture plots showing the CPO.

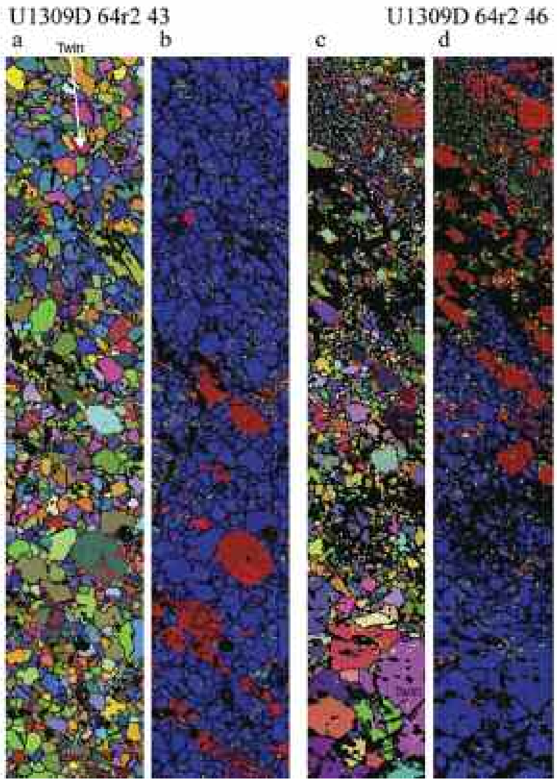


Figure 4. (a) All Euler (full crystallographic orientation) for 64r2-43, with the grain boundaries marked on. 2°= yellow, 5°= lime green, 10°= blue, 20°= pink and >30°= black. Boundaries between the phases are marked in red. (b) Phase map showing each mapped phase in a different colour for 64r2-43, with the grain boundaries marked on. 2° = yellow, 5° = lime green, 10°= blue, 20°= pink and >30° = black. Phase colours are blue = Plagioclase, red = Diopside, purple = Enstatite, green = Hornblende, yellow = Ilmenite. Boundaries between the phases are marked in red. (c) Same display as (a) but for sample 64r2-46. (d) Same display as (b) but for sample 64r2-46.

Scientific results

Microstructural Characteristics

The microstructure of each sample exhibits deformed original grains, which are elongated in the same orientation as the foliation (Figures 3 and 4). All of the mapped phases in each sample exhibit some deformation (grains are elongate or contain some internal low angle grain boundaries or substructure).

Sample 64r2 43 represents the centre of the shear zone and is dominated by plagioclase grains (blue grains in Figure 4b). The plagioclase grains exhibit some internal deformation in the form of low angle grain boundaries, but they are mostly concentrated in specific grains. Also, some of the plagioclase grains exhibit twins, which can be spotted by looking for grains which are mainly one colour, but contain a thin boundary across it which is coloured differently (Figure 4a). Twins can be formed as the grain grows or due to deformation of the grain. In plagioclase, they represent a 180° rotation of the crystal lattice around a specific axis. The grain sizes of the phases, except diopside, are larger in sample 64r2 43 (centre of shear zone) than in sample 64r2 46 (edge of shear zone) (Table 1).

Sample 64r2 46 shows a better development of sub-grain boundaries inside the plagioclase and hornblende, but overall the sample does not show much substructure (Figure 4c). The sample exhibits a clear change in the grain size of the plagioclase from coarse to fine grained (from the bottom to the top of the section). Also, the sample shows a dominance of other phases at the top of the section after the fine grained plagioclase (Figure 4d). All phases are aligned with the foliation in both samples. Most of the high angle grain boundaries exhibit 30° or more misorientation across them (black coloured boundaries).

Orientation Data

The two samples show a similar CPO (Figure 5). Comparison of the plots of Figure 5 shows that the concentrations are in similar locations, but the concentration or strength (max number) varies. <100>, [001] etc are numerical representations (Miller indexes) of important planes and axes in the crystal, which are based upon the symmetry of the crystal phase (plagioclase is monoclinic or orthorhombic depending upon the chemistry of the crystal). Sample 64r2 43 exhibits a stronger texture (higher maximum number) than sample 64r2 46.

In Sample 64r2 43, the <100> forms a distinct cluster 10°-20° from the y direction on the upper hemisphere stereonet. <010> is dispersed along a great circle on the lower hemisphere (a curved swath of data from the top to the bottom of the stereonet). <001> is dispersed around the periphery or edge of the upper hemisphere stereonet. In Sample 64r2 46, the <100> forms a distinct cluster 5°-15° from the y direction. <010> is dispersed along a great circle on the lower hemisphere and <001> is dispersed around the periphery of the stereonets.

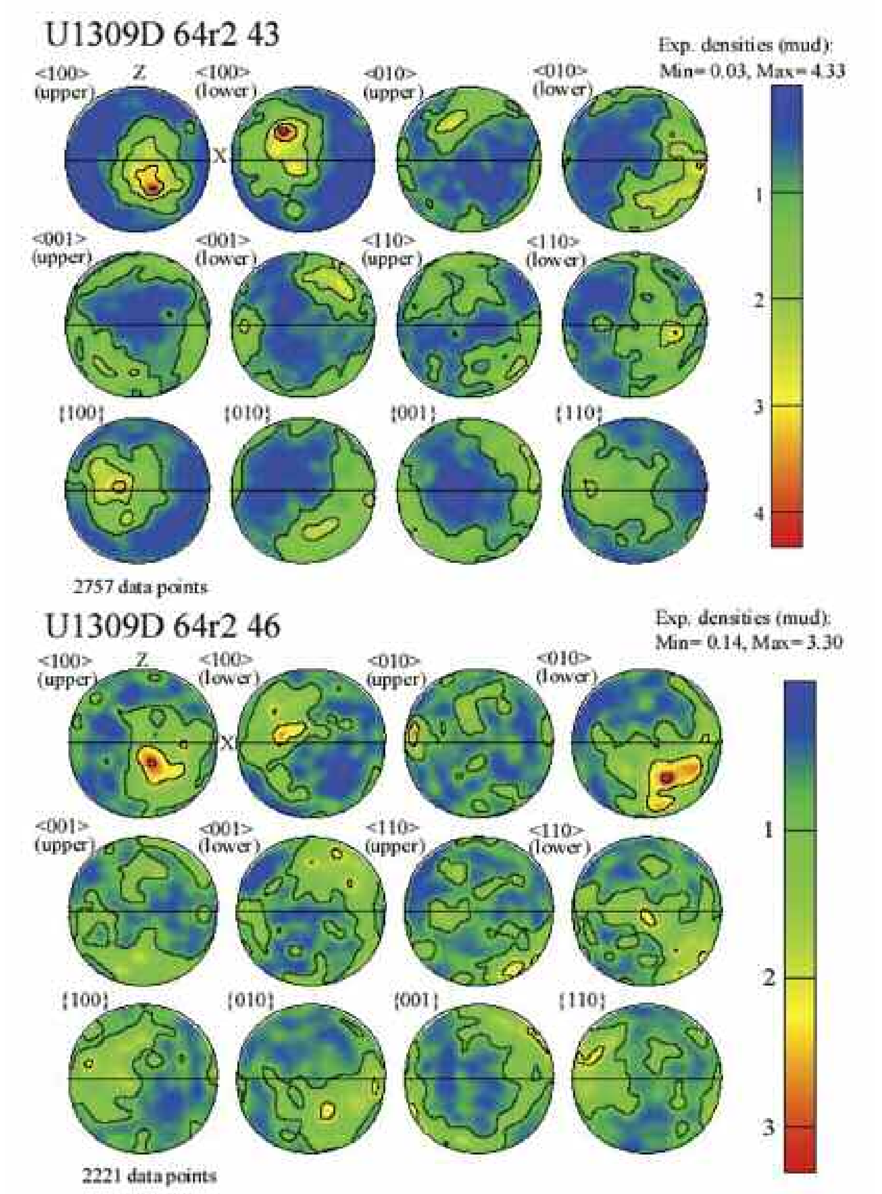


Figure 5. Equal area, lower hemisphere contoured stereonets plotted for only the plagioclase grains of each sample (half width 15° and cluster size 5° used for contouring). (a) one point per grain (ensures a false CPO is not shown due to the over sampling of one large grain) for sample 64r2 43. (b) one point per grain (ensures a false CPO is not shown due to the over sampling of one large grain) for sample 64r2 46. The first stereonet also shows the kinematic framework where foliation is E-W perpendicular to the page (Z = pole to foliation). The number of data points in each plot is also shown as well as the maximum and minimum values for the contouring.

Misorientation Data

A good way of quantifying the microstructure is to study the angle of misorientation (angle between two crystal orientations next to each other), which can tell you about the controlling deformation, recovery and recrystallization mechanisms. A misorientation angle distribution (MAD) plots the relative frequency of misorientation angles in 5° bins (such as 175 to 180°) for the actual sample data and for a random textured sample. Also shown is the theoretical random line (how the data would plot if there was no texture or preferred orientation).

The MAD for plagioclase in both samples is dominated by a peak at 180° (Figure 6),

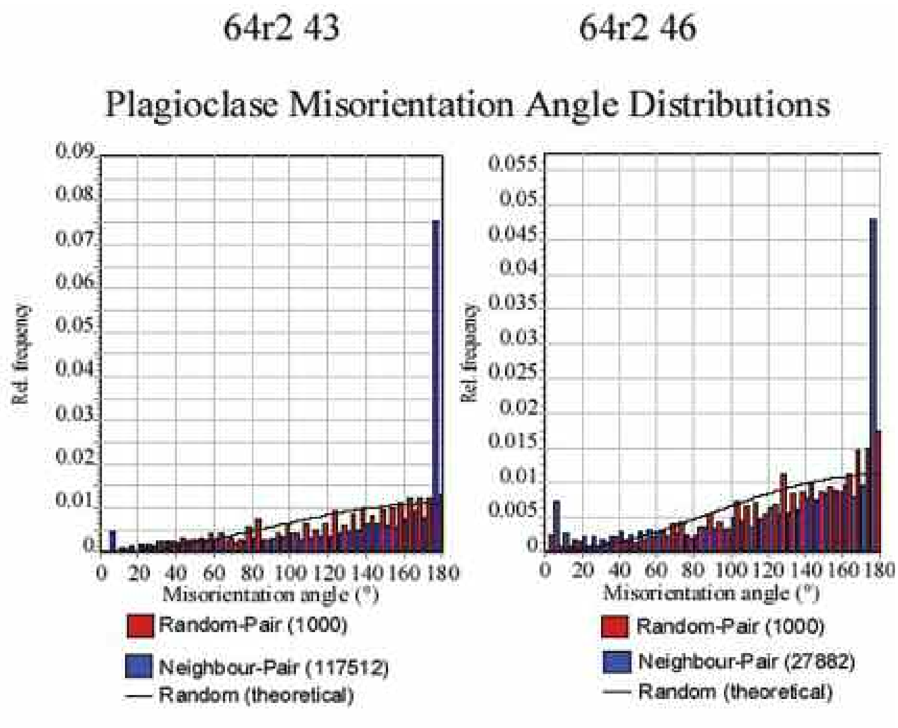


Figure 6. Misorientation angle distributions for 64r2 43 and 64r2 46 are plotted as frequency histograms for neighbour-pairs and random-pairs. The black line represents the theoretical random distribution. 64r2 43, random-pairs 1000 data points and neighbour-pairs 117512 data points. 64r2 46, random-pairs 1000 data points and neighbour-pairs 27882 data points.

which represents the rotation of the twin laws. The maps show that the grains do contain twins as previously identified in Figure 4a and 4c. A comparison between the actual sample data (neighbour-pair data) and the theoretical random line shows that both plots also exhibit a small increase in the number of low angle grain boundaries. Both MAD neighbour-pair distributions show low relative frequencies of boundaries with misorientation angles in the range of 10° to 30° for 64r2 43 and in the range of 15° to 35° for 64r2 46.

Summary

The data show that the concentration of strain into a shear zone has controlled deformation and the formation of the texture shown by both samples, rather than a preservation of the original igneous crystallization texture. The shear zones exhibited a maximum thickness of a few meters and could not have been responsible for the uplift of the OCC. As such small shear zones would not have been able to accommodate the movement necessary to uplift the OCC. These shear zones were formed to accommodate late phase pulses or injections of magma into the gabbroic body and are not linked to the larger scale uplift mechanisms, but help us understand the emplacement mechanisms of a gabbroic body.

There is still much more information to be obtained from these samples and the samples taken by the other scientists. The post-cruise data gathered by the Expedition 304 and 305 scientists will help with the goal of obtaining a greater understanding of Ocean Core Complex formation, exhumation and deformation. There is still much to be learned about these unique phenomena and the ocean crust in general.

References

BLACKMAN, D K, CANN, J R, JANSSEN, B, and SMITH, D K. 1998. Origin of extensional core complexes: Evidence from the Mid-Atlantic Ridge at Atlantis Fracture Zone. Journal of Geophysical Research-Solid Earth, 103(B9): 21315-21333.

BLACKMAN, D K, ET AL. 2002. Geology of the Atlantis Massif (Mid-Atlantic Ridge, 30 degrees N): Implications for the evolution of an ultramafic oceanic core complex. Marine Geophysical Researches, 23(5-6): 443-469.

CANALES, J P, TUCHOLKE, B E, and COLLINS, J A. 2004. Seismic reflection imaging of an oceanic detachment fault: Atlantis megamullion (Mid-Atlantic Ridge, 30 degrees 10 ' N). Earth And Planetary Science Letters, 222(2): 543-560.

CANN, J R, ET AL. 1997. Corrugated slip surfaces formed at ridge-transform intersections on the Mid-Atlantic Ridge. Nature, 385(6614): 329-332.

CANNAT, M, ET AL. 2006. Modes of seafloor generation at a melt-poor ultraslow-spreading ridge. Geology, 34(7): 605-608.

ILDEFONSE, B, ET AL. 2007. Oceanic core complexes and crustal accretion at slow-spreading ridges. Geology, 35(7): 623-626.

LLOYD, G E. 1987. Fabric Analysis Using Sem Electron Channeling. Journal of the Geological Society, 144: 678-678.

OHARA, Y, OKINO, K, and KASAHARA, J. 2007. Seismic study on oceanic core complexes in the Parece Vela back-arc basin. Island Arc, 16(3): 348-360.

OHARA, Y, YOSHIDA, T, KATO, Y, and KASUGA, S. 2001. Giant megamullion in the Parece Vela Backarc Basin. Marine Geophysical Researches, 22(1): 47-61.

OKINO, K, MATSUDA, K, CHRISTIE, D M, NOGI, Y, and KOIZUMI, K. 2004. Development of oceanic detachment and asymmetric spreading at the Australian-Antarctic Discordance. Geochemistry Geophysics Geosystems, 5: 22.

PRIOR, D J, ET AL. 1999. The application of electron backscatter diffraction and orientation contrast imaging in the SEM to textural problems in rocks. American Mineralogist, 84(11-12): 1741-1759.

PRIOR, D J, TRIMBY, P W, WEBER, U D, and DINGLEY, D J. 1996. Orientation contrast imaging of microstructures in rocks using forescatter detectors in the scanning electron microscope. Mineralogical Magazine, 60(403): 859-869.

SCHMIDT, N H, and OLESEN, N O. 1989. Computer-aided determination of crystal-lattice orientation from electron-channeling patterns in the SEM. Canadian Mineralogist, 27: 15-22.

SMITH, D K, CANN, J R, and ESCARTIN, J. 2006. Widespread active detachment faulting and core complex formation near 13 degrees N on the Mid-Atlantic Ridge. Nature, 442(7101): 440-443.

TUCHOLKE, B E, LIN, J, and KLEINROCK, M C. 1998. Megamullions and mullion structure defining oceanic metamorphic core complexes on the mid-Atlantic ridge. Journal Of Geophysical Research-Solid Earth, 103(B5): 9857-9866.

News and reports on recent meetings

UPDATE March 2008: IODP U.S. Implementing Organization and the U.S.-sponsored JOIDES *Resolution*

The new and improved JOIDES *Resolution* continues undergoing a complete refurbishment in a Singapore shipyard.

What's been done?

The demolition including deckhouse and lab stack has been completed as well as the drydocking for underwater work and hull painting. Steel construction is essentially complete with the new deckhouse and all the new lower decks fabricated and mounted. After refurbishment, equipment such as the derrick, drilling equipment, thrusters, propulsion motors and emergency generator have been re-installed. Equipment foundations, stairs, handrails, etc. have also been fitted. New equipment such as anchor windlass, water maker, incinerator, motor generator set, and fans has been installed and more is underway. A new wireline heave compensator for logging has been developed, constructed and land based tested.

What about Labs and Accommodations?

The all new labs and accommodations are being outfitted with insulation, plumbing, WCs/showers, ducting, electrical cable, exterior doors and windows. This will be followed by interior partitions and doors, lighting, ceilings, floor coverings, furnishings, lab equipment, and other outfitting. The purchase and development of most laboratory analytical systems and IT equipment has been completed and testing and integration is underway. The few remaining science equipment items are nearing completion.

When will the JOIDES Resolution be done?

Delivery from the shipyard is currently anticipated in August 2008. After installation of science equipment, loading of supplies, at-sea testing and transit, the JOIDES *Resolution* is currently scheduled to begin IODP operations in November 2008.

Why have there been so many delays?

Demand for time in shipyards is at all-time high levels. Labor is stretched among too many large ship projects worldwide therefore the shipyard cannot keep up with the schedule agreed to when the project began. This is a global problem and projects large and small are many months behind schedule and over budget. Recently, Bob Gagosian, president and CEO of Consortium for Ocean Leadership, and Steve Bohlen, Ocean Leadership's president for the JOI Division, met with the vice president for western hemisphere operations for Transocean – the world's largest offshore drilling contractor and manager of the refurbishment of the JOIDES *Resolution* – to discuss specific actions Transocean will be taking in the coming weeks to ensure that the ship is ready for IODP as soon as possible. All senior managers for scientific ocean drilling programs at Ocean Leadership are committed to doing everything possible to achieve an on time delivery of the ship on our current schedule.

Where can I see the progress?

This site includes a photo chronology of initial demolition and ongoing renovation work: www.oceanleadership.org/sodv/status

What is happening to IODP expeditions on the JOIDES Resolution?

Because we now anticipate the JOIDES Resolution to be ready for IODP expeditions in November 2008, the program is still committed to implementing the Canterbury Basin and Wilkes Land expeditions within the timeframes currently identified (November 2008 to January 2009 and January to March 2009, respectively).

However, the Pacific Equatorial Age Transect/Juan de Fuca expedition will have to be pushed back. The Bering Sea expedition will be returned to the Operations Task Force for future scheduling consideration.

In FY 2009 and FY 2010, IODP expects to implement four expeditions on the riserless platform JOIDES *Resolution*. Program officials are working to secure long-term solutions to the budget shortfalls that impact our ability to conduct operations. Efforts are underway by program administrators to organize an industry consortium that will work on the JOIDES *Resolution* and make use of its facilities while the ship is not carrying out IODP expeditions. Other long-term alternatives to fill the gaps are also being investigated for FY 2009 and beyond, and if an industry consortium were successfully established, it would begin operating in FY 2010 at the earliest.

What are we looking to the community for?

We welcome all input from friends of the program. It takes the engaged involvement of past, present and future participants in IODP to make this succeed, and we want to hear from you with your ideas. Please feel free to contact IODP U.S. Implementing Organization staff at Ocean Leadership with questions or comments.
www.oceanleadership.org/about/staff

Understanding Ocean Redox and Formation of Organic Carbon Rich Sediments From the Shelf to Deep Oceans and Their Significance for the Deep Biosphere

Thomas Wagner (University of Newcastle), Nick Stronach (Fugro-Robertson Ltd.), Howard Armstrong (Durham University), Darren R. Gröcke (Durham University), Ian Head (University of Newcastle) and Ute Mann (SINTEF Petroleum Research)

Background

Low oxygen facies in the ocean have long intrigued earth scientists, petroleum geochemists and microbiologists, because of their widespread distribution at certain times in the past and their early recognition as potential hydrocarbon source rocks. It is now recognized that the deposition of major marine black shales and the enhanced storage of organic carbon in the geological record indicate fundamental changes in the functioning of biogeochemical cycles and their feedbacks during extreme climate modes and climate transitions. Black shale and similar C_{org}-rich sediments are also hotspots for extreme microbial life in the deep biosphere posing fundamental challenges and insights into the limitations of extreme life and factors governing its evolution, size, distribution, activity and geochemical significance.

Controversy surrounds the origin of C_{org}-rich sediments and a number of key questions remain to be answered.

What are the relative importance of primary productivity versus preservation mechanisms (water column anoxia and sedimentation rate) and, how does the development of ocean anoxia respond to changing climate, terrestrial and ocean processes, and possible feedbacks between these systems?

Is the original Oceanic Anoxic Event (OAE) concept from Schlanger and Jenkyns from the seventies still appropriate given the growing evidence from high resolution marine records that anoxia or even euxinia was not a permanent feature of the ocean?

Is there one single mechanism (or succession of mechanisms) driving the ocean into anoxia; can we distinguish regional from global scale anoxia; how can we overcome limitations in chronology?

What is the relationship between C_{org} and anoxia cyclicity with atmospheric composition and in particular what is the role of methane as a strong greenhouse gas in driving ocean anoxia; how rapid were climate changes in the geological record and to what extend can we resolve this information from the record of open ocean sediments; what were the regional variations to global trends in climate; what are the relationships between data and modelling; and how can interpretations of past greenhouse conditions be better used for the current climate debate?

Finally, how can improved modelling aid petroleum exploration in, for example, the prediction of petroleum source rock distribution?

Role of the IODP

Rare modern analogues, and a general lack of critical sedimentological and geochemical proxy data has resulted in a limited testing of the cause and effect relationships of the atmosphere-land-ocean system and a still incomplete understanding of temporal responses of marine environments and spatial changes in ocean redox from shallow to the deep ocean and from the tropics to the poles. These remain a major challenge to Earth System Science research and it is generally accepted that progress can only be made from cross-disciplinary studies of new, continuous and high time-resolution marine records combined with modelling.

Ideally provided through IODP, these records cover bathymetric and latitudinal gradients to ensure full insights into the fundamental connections linking climate and oceanography. It is now established from both sub-seafloor sediments and petroleum reservoirs that the deep biosphere is stimulated at geochemical interfaces where energy rich compound interact with deep fluids. Deep C_{org}-rich sediments therefore are potential “hot-spots” for the deep biosphere. Biological alteration of deep organic carbon also has implications for the generation of labile substrates such as acetate and hydrogen that may fuel the deep biosphere and potentially alter source-rock properties. Studies of C_{org}-rich sediments with a range of thermal histories can also be used to test hypotheses about the thermal limit for life in the deep subsurface, which data from biodegraded petroleum systems and some other circumstantial evidence implies is around 80 to 90°C. Extrapolations from the generally exponential decay of deep biosphere prokaryote numbers with depth however suggest that substantial microbial populations may be found at greater depth and temperature and data from sediments associated with active hydrothermal systems such as Blake Ridge, suggest that prokaryotes may survive in deep sediments above the 80-90oC limit suggested by the palaeopasteurization hypothesis.

There are also clear industrial applications of this focal point of research. As existing oil reserves decline, the increasing focus on deeper-water petroleum potentials means a fuller understanding of the origin, spatial distribution, and lateral and bathymetric variation of organic-rich sediments is vital for the development of offshore exploration strategies. Data points provided by the IODP and its precursor programmes (DSDP and ODP) have been vital in extrapolating from conventional exploration datasets on the continental shelves, but importantly and increasingly the high resolution proxy datasets provided by this research have become more widely relevant in calibrating and validating predictive modeling, on both regional and global scales.

The Workshop

With this broad scientific and industrial frame, 25 representatives from academia and petroleum industries joined for a two-day workshop at Durham University (30th and 31st January 2008), supported by the NERC Science and Innovations programme and the UK-IODP Industrial Liaison Panel (UK-ILP), to outline and discuss potential drilling targets for IODP. The final goal of the workshop was to develop a workflow that leads to the submission of new IODP drill proposals with strong involvement and leadership of UK scientists based around specific drilling targets. With almost similar shares between academic and industrial representatives the Durham workshop was the first of its kind creating a new spirit and dialogue at the interface between both communities. It was jointly felt that this new concept was highly stimulating and successful, at the same time identifying areas where communication and collaborative work needs to be developed to ensure synergies and optimal use of resources and expertise.

Following a general shelf-basin transect strategy, potential research targets were discussed at the workshop with regard to their scientific and industrial merits but also possible shortfalls in data availability and scientific or industrial scope. One concrete outcome of the workshop was a ranking of the proposals with respect to maturity and clarity showing demand for further cross disciplinary discussions on how to pursue individual target areas to develop competitive IODP proposals.

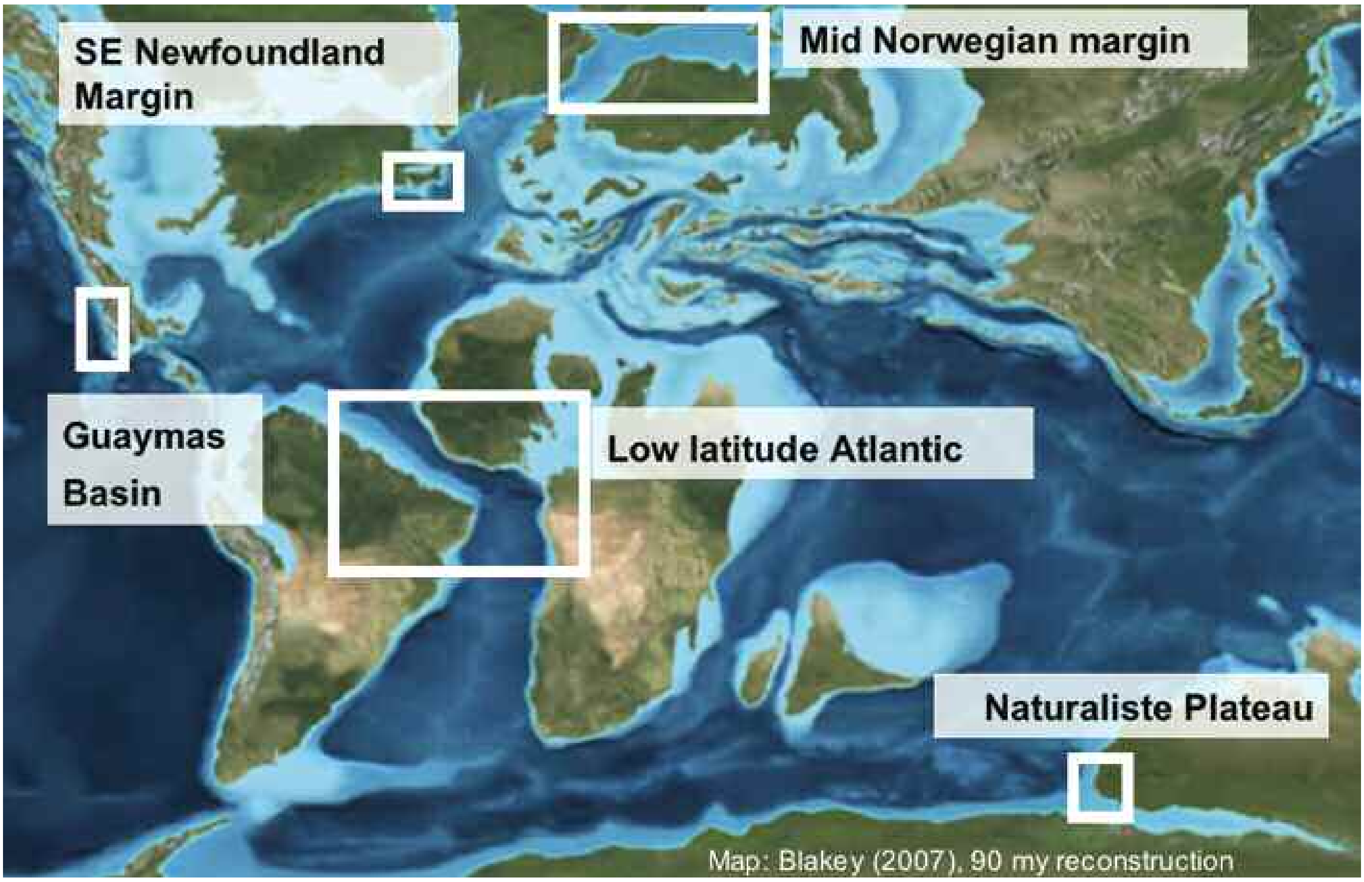
The discussed drilling targets cover a wide range of latitude and depositional settings, from tropical to the high (southern) latitude at about 60°S and shallow high productive shelves to more oligotrophic central deep ocean basins. The stratigraphic focus of the drill targets combines modern microbial processes with past situations of extreme carbon burial and ocean anoxia, focusing on the Jurassic-Cretaceous Oceanic Anoxic Events (OAEs) and other intervals of preferential Corg enrichment, but also covering other major global climate transitions including the Eocene-Oligocene Transition and the Mid-Miocene 'Monterey' interval.

The first day was used to introduce the academic and industrial scope of the workshop and to present the five proposed drilling areas. Building on that the second day was used for an open forum discussion where strengths and possible lacks and risks of each individual proposal were identified and workflows to the development of the proposals were specified.

Proposals

The Naturaliste Plateau, offshore Western Australia, introduced by Darren Gröcke (Durham), is a rare opportunity to drill a Cretaceous high-latitude site in the southern hemisphere open ocean; a setting to investigate both local models of high latitude organic carbon productivity and those of global temperature gradients. There is a general lack of high-latitude, southern hemisphere oceanic records for the Cretaceous and the fact that currently there is only one IODP proposal under consideration to study the Cretaceous (co-investigator, Hugh Jenkyns, Oxford, IODP 691 Full) justified a very high priority for this proposal. The Naturaliste Plateau and its adjacent Mentelle Basin, originally thought to be associated with the Kerguelen Large Igneous Province (LIP), has recently been suggested to be a continental fragment from Australia. This region has received very little scientific attention up to know despite that 1.5 to 2 .5km of Late Jurassic to Early Cretaceous sediments have been deposited in the rift basins. The main objectives to be addressed at this area cover a series of climate events (Mid-Miocene Event, PETM, Cenomanian–Turonian OAE 2, Albian OAEs (1c & 1d), Valanginian OAE, and potentially, Jurassic & Paleozoic intervals) and critical ocean-atmosphere boundaries including southern deep-water formation, and the gateway opening between Australian and Antarctica. Of particular interest also seemed the opportunity to directly combine a continental ICDP drilling proposal targeting the Southern Perth Basin where up to 15km of sediment dating back to the base Permian have been confirmed. Although this basin is not likely to have major petroleum potential, this data point will be important in establishing palaeo-oceanographic models, which could be significant in the exploration of other frontier basins in the region.

The drilling area in the **eastern to central low latitude Atlantic**, introduced by Howard Armstrong (Durham), aimed to investigate the Upper Cretaceous Hadley Cell dynamics by comparing equatorial signatures where marine productivity was dominated by continental run-off with sub-tropical sites on both sides of the equator where (trade) wind induced upwelling dominated climate-ocean processes and enhanced carbon burial. Critical climate events to be targeted in the subtropic-tropical sector cover the Cretaceous OAEs in their most 'extreme' mode, the PETM, the Eocene greenhouse world and onset of rapid Antarctic glaciation at 34-33 Ma (Oi-1 event), the Mediterranean outflow during Tethys Gateway closure (Arabia-Eurasia collision) from ~35 Ma, and the Mid-Miocene 'Monterey' Event. Critical ocean-atmosphere boundaries to be investigated include the history and dynamics of the ITCZ and of the thermal equator, and the deep water connection between the South and North and Atlantic. Drilling in this area



builds on an extensive existing onshore and offshore database possibly extending to the western side of the tropical Atlantic (ODP Leg 207 at Demerara Rise and the South American Querecual-La Luna formations). Specific drill sites at both tropical and subtropical end points of the Hadley cell are to be identified within well-defined climate and bathymetric corridors, including further discussion about the possible issues of drilling in licensed acreage with operator and government permissions.

The proposed drill area offshore **Mid-Norway**, introduced by Ute Mann (SINTEF Petroleum Research, Norway), suggests to focus on the Helgeland Basin and its adjacent areas to drill high resolution sections of the Kimmeridgian-Volgian organic-rich mudstones, with possible upside in drilling section of Permo-Triassic Ravnefjeld Formation. As for the other drilling proposals critical climate events to be targeted include the high resolution cyclicity in the Kimmeridge Clay equivalent of the Spekk Formation, in the central Helgeland Basin approximated to be up to 120m C_{org}-rich section, and potentially sediments covering the Permian-Triassic boundary. Taking advantage of the large amount of seismic data available via the Norwegian Petroleum Directorate (NPD) the mid-Norwegian continental margin bears potentially highly important regional implications for Upper Jurassic source rocks in particular when contrasted with the British Kimmeridge Clay RGGE and IFP boreholes in Dorset and Yorkshire respectively. Despite general positive feedback on this proposal and its significance for regional Late Jurassic petroleum source rock models, it was jointly felt that more work is required to develop a globally significant hypothesis to be tested off the Norwegian margin and further north towards Svalbard.

The **SE Newfoundland Ridge**, introduced by Thomas Wagner (Newcastle) in collaboration with Richard Norris (SOI, USA), targets the history of the North Atlantic deep waters during the late Cretaceous; in particular abyssal chemistry, vertical structure and flow strength of the Deep Western Boundary Current and outflow from the Arctic and Nordic Sea. The main Cretaceous objectives to be addressed at this site cover the OAEs from ~100-80 Ma (OAE 2 and 3) as well as the Mid Cenomanian Event (MCE), a bathymetric depth transect of about 2km to the surface ocean at ~100-70 ma, a detailed record of Aptian-Albian reef drowning, and oceanographic or tectonic controls on the transition from black shale to the open North Atlantic. Given the nature of the sediments as drift deposits it is likely that expanded records of extreme climate events including the mid-Cretaceous OAE's (about 500 m Cretaceous section approximated from seismic data at ~150m burial depth) and Palaeogene and younger ones (targeted by ODP 661, Full 2, currently in front of operations panel) can be recovered in this area. Previous work at J Anomaly Ridge encountered Aptian-Albian reef rocks at DSDP 384 and, more recently, ODP Leg 210 identified most of the OAEs in the much deeper buried Newfoundland Basin, just north of the proposed SE Newfoundland Ridge. Possible excessive sediment reworking within the 'drifts' and a better tie with the ODP Leg 210 drill sites, possibly linked with exploration wells on the shelf, were issues to be discussed and explored when developing the drill proposal. Preliminary data from this location also indicated that organic rich sequences with different thermal maturity would be ideal for investigating the effects of thermal maturity of organic matter on its potential to provide an energy source for deep biosphere microorganisms and may also shed light on the generality of the palaeopasteurization hypothesis which suggests that at least part of the deep biosphere is inactivated at temperatures well below the currently accepted thermal limit for surface life of 121°C.

The last proposal aimed for the **Gulf of California**, a well established hotspot for geomicrobiological research, but for which there has been little exploration of the deep biosphere, despite the remarkable thermal gradients and active hydrocarbon generation associated with the Guaymas Basin. Ian Head (Newcastle) together with John Parkes (Cardiff) introduced the Guaymas Basin in the Gulf of California where the thermal limit of life in the deep biosphere, which may be lower than in high temperature surface environments can be tested in the context of the palaeopasteurization hypothesis developed on the basis of data on the occurrence of biodegraded oil fields. In addition exciting recent developments that indicate there a biologically enhanced thermal cracking process may result in the release of labile energy sources such as acetate and hydrogen from recalcitrant organic matter, fueling the deep biosphere. It has been proposed that the energy starved nature of much of the deep biosphere may lead to the observed lower thermal maximum for deep subsurface life. The varied thermal gradient conditions and variation in levels of energy rich reduced chemicals in the hydrothermal fluids will allow the interplay between energy availability and the upper thermal limit for life in the deep subsurface to be investigated.

Key actions identified from the workshop include further refinement of the proposals' objectives and contents, clearer definition and integration of industrial objectives and suggestions as to data acquisition and analysis that could strengthen the proposals. In a more mature phase of the proposals' development it is planned to circulate the results from the workshop more widely within UK-ILP and to other international networks identified.

Mantle extrusion on the Mid-Atlantic Ridge near 13ºN

Roger Searle (Durham University)

The first scientific cruise of the new NERC research ship RRS *James Cook* (March 5 to April 17, 2007) was funded by UK-IODP as part of its Site Survey Investigations theme, the aim being to allow UK scientists to acquire the site survey data required to support an IODP drilling proposal. It was jointly led by myself, Chris MacLeod (Cardiff University) and Bramley Murton (National Oceanography Centre, Southampton).

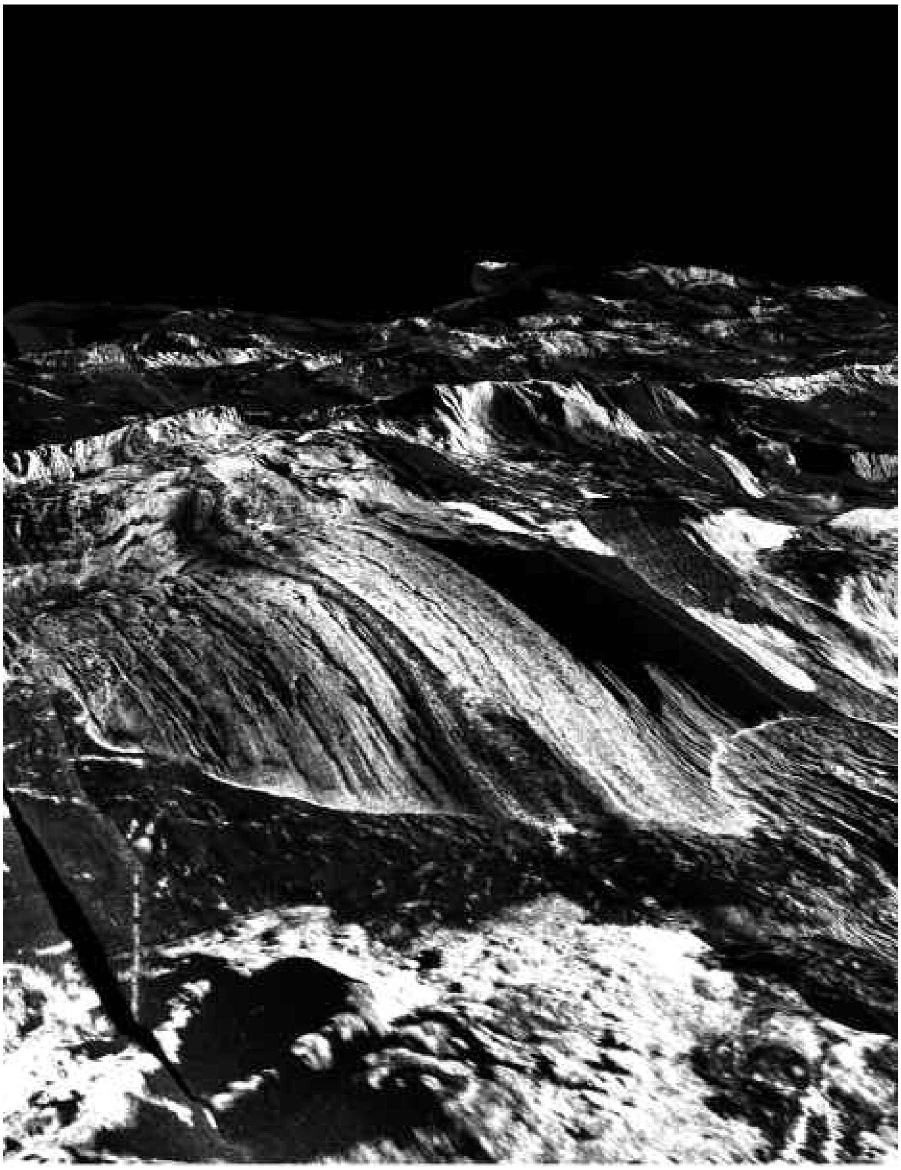
Our scientific objectives were 1) to test whether mantle upwelling and melting is focused in diapiric structures at the centres of slow spreading ridge segments or rises in more uniform sheets along whole segments; 2) to test whether plate accretion and separation mechanisms are fundamentally different in 'magma-starved' and 'robustly magmatic' areas; and 3) to test mechanisms of detachment faulting and extensional strain localisation in the lower crust and upper mantle.

We selected our study area based on prior work by many scientists, which had shown this to be an area where there is a clear transition from robustly magmatic seafloor spreading north of 14.0°N to over 100km of ridge between 14.0°N and 13.0°N where evidence for extensive seafloor volcanism was sparse and there appeared to be an excellent opportunity for sampling mantle rocks over an extensive length of ridge.

We began with a 1-week survey using the deep-towed geophysical instrument TOBI, which provided an outstanding side-scan sonar image of the seafloor over a 70km square area, and at the same time acquired multibeam bathymetric data to make an improved map of seafloor depth. Using the visualisation software Fledermaus® we then draped the sidescan image over a 3D model of the topography, and could "roam" around this virtual image to choose our sampling sites.

We used a combination of the British Geological Survey oriented rock-drill and traditional dredging to obtain samples from 18 drill sites and 30 dredge sites. Of these, 14 yielded samples of mantle rocks, 25 yielded basalts, and seven yielded gabbro, although only minor amounts of the latter.

We focussed particularly on one Oceanic Core Complex, where we were able to show that the detachment fault is actively slipping and has exhumed mantle rocks that we believe now underlie the smooth, corrugated part of the dome; stratigraphically above this is a high fractured plateau consisting of upper crustal rocks such as dolerite and pillow basalt, with little or no gabbro in between. We also recovered evidence of extensive active or recent high-temperature hydrothermal activity near the toes of two active core complexes. These observations have enabled us to build a stratigraphic model of an Oceanic Core Complex that can be tested by IODP drilling. We have also been able to propose mechanisms for the initiation and termination of core complexes, and have obtained the data needed to test our hypotheses on mantle upwelling and spreading processes.



The figure shows the Earth's mantle being exhumed from beneath the volcanic crust at the axis of the Mid-Atlantic Ridge in an active Oceanic Core Complex. View to the northwest, and ridge axis runs N-S. The bright (high-backscatter) area in the foreground is part of the axial volcanic ridge at the Mid-Atlantic Ridge axis, which is advancing from the south to cut off the active core complex. Note that this volcanism is absent immediately in front of the dome: a state that is thought to allow core complexes to develop. Middle ground shows the striated dome of the core complex, which our sampling shows to be composed primarily of peridotite. Above this, separated by a sharp break of slope, is a highly deformed summit massif composed of upper crustal rocks (basalt and dolerite). In the near background at the far left is an eroded fault scarp which is the uppermost part of the detachment fault (the "breakaway") where the detachment initiated. The "termination", at the boundary between the footwall and the hanging wall, is marked by a variable band of high-backscatter curving around the foot of the dome which we infer is a band of talus spalling off the footwall.

DRILLS
Distinguished scientists reporting on scientific ocean drilling achievements

Robert Gatliff (British Geological Survey)

DRILLS is a new scientific lecture series sponsored by the Integrated Ocean Drilling Program. This year, three scientists, one from Japan, one from Europe and one from the USA each undertook a lecture tour in different regions. Dr Yoshiyuki Tatsumi from the Institute for Research on Earth Evolution (IFREE), Japan Agency for Marine-Earth Science and Technology was the first DRILLS lecturer to undertake a tour of Europe. He visited 12 institutions in seven countries across Europe in just over three weeks. We were lucky in the UK to have Dr Tatsumi visit the University of Edinburgh, Durham University, University of Leicester and the National Oceanography Centre, Southampton.

Dr Tatsumi spoke about the Japanese-led programme based on island arc and ocean trench drilling with the riser vessel *Chikyu*. Dr Tatsumi described the capabilities of the new ship and its current programme, the NanTroSEIZE Complex Drilling Project. This includes drilling a series of holes through the accretionary prism to provide new evidence to understand the development of accretionary prisms, the formation of splay faults, the thermal structure and fluid migration in the arc and mechanisms of large earthquakes. He concluded his talk with a detailed look at the proposed IBM (Izu-Bonin-Mariana) Arc project. This is an ambitious proposal that will last for several years with a focus on probing the roots of juvenile oceanic arcs to develop our understanding of the origin of 'andesitic' continental crust. Dr Tatsumi highlighted the many opportunities for European researchers to get involved in the project.

A recording of the lecture will be available on the IODP website. For further details of how to get involved in the IODP programme please contact the UK IODP Science Coordinator (ukiodp@bgs.ac.uk)

IODP DRILLS is the topical scientific lecture series to feature prominent, internationally known scientists describing scientific results derived from samples retrieved from beneath the ocean floor. DRILLS will actively engage future generations of scientists in ocean drilling, while highlighting scientific ocean drilling's major accomplishments to the scientific community and beyond. For more information about hosting an IODP DRILLS Scientist, please contact Nancy Light (nlight@iodp.org) or go to www.iodp.org/drills.

Dr Yoshiyuki Tatsumi (centre) with Dr Dan Evans (Science Manager, ECORD Science Operator), Heather Stewart (UK-IODP Science Coordinator), Robert Gatliff (Head of Marine Geoscience, BGS) and Alan Stevenson (Outreach Manager, ECORD Science Operator) at BGS in Edinburgh before Dr Tatsumi's presentation at the University of Edinburgh.

Rocks 'n' Beasts: an interdisciplinary conference on vent systems Leeds, UK, June 2007

Luciana Génio and Sally Morgan (School of Earth & Environment, University of Leeds)

The rocks 'n' beasts conference was held at the University of Leeds from 17-19 June 2007. The meeting brought together 24 academics and postgraduate students from 13 institutions across 6 countries (England, France, Germany, Greece, Portugal and Wales) for a two-day meeting. Areas of expertise covered by attendees spanned several disciplines of hydrothermal vents research, ranging from macro- and micro-biology, to fluid and rock chemistry and alteration processes and products.

The purpose of the meeting was to provide delegates with an understanding of vent systems from a variety of angles. This was accomplished with a series of keynote lectures given by experts in each field. Joe Cann (University of Leeds) opened the meeting with an introduction to vent systems providing some history as well as highlighting some of the questions that remain. Paul Dando (University of Bangor) and Steffen Kiel (University of Leeds) gave insight into vent biology and palaeontology respectively while Damon Teagle (University of Southampton) provided a look at fluid-rock interactions related to vent systems. Between them, the keynote speakers took the delegates on a journey from the discovery and history of hydrothermal vents to modern concepts, cutting-edge research and highlighted some of the outstanding problems. Another aim of the meeting was to give attendees the chance to present their own work in a more relaxed setting. Subjects presented included microbiology, population dynamics, molecular biology, geology, palaeontology and geochemistry. The participants covered both modern and ancient ocean crust vent systems as well as ophiolites. This led the group from the hydrothermal rootzone of vents and the associated geochemical reactions to sub-sea floor processes (specifically related to mineralization) and biogeochemical reactions. Ocean floor and water column studies also featured, covering isotope chemistry of the water and micro-organism studies. Faunal assemblages associated with these ecosystems were also discussed.

The meeting schedule was designed to promote interactions between all participants and to ensure plenty of time for discussion. The poster session and final group discussion held at the end of the meeting were very successful in getting people talking and highlighted the importance of a multi-disciplinary approach to studying vent systems.

The prize for best oral presentation at the meeting went to Kleopatra Detsi (National & Kapodistrian University of Athens) who presented her work on manganese biomineralisation in a seafloor palaeohydrothermal vent system. Teddy Castelain (University of Leeds) won the best poster prize for the presentation of his work on hydrothermal fluid flow in oceanic crust gabbros at IODP Site 1309, Mid Atlantic Ridge.

We would like to thank the sponsors, speakers and all participants who made Rocks 'n' Beasts a success!

For further information: www.see.leeds.ac.uk/misc/rnb/

Rift to Ridge '07: A UK-IODP workshop on the evolution of the NE Atlantic under the influence of the Iceland hotspot

Bramley Murton and Gavin Elliott (National Oceanography Centre, Southampton)

The Rift to Ridge '07 workshop was held at the National Oceanography Centre, Southampton (NOCS) at the end of June 2008 and attracted some 50 researchers worldwide. The conference was sponsored by the UK-IODP, primarily to support a UK-led IODP drilling proposal investigating the western flank of the Reykjanes Ridge. These funds were amplified by generous financial assistance from Statoil and sponsorship-in-kind from the NOCS.

The meeting identified the Iceland hotspot phenomena and its impact on spreading and ocean circulation in the NE Atlantic as an end-member for the investigating the influence of hotspots on the evolution of an ocean basin. The Iceland–NE Atlantic region is both unique in the World and the best, current, example of the fundamental interaction between plate-driven and intra-plate mantle convection, and its impact on ocean circulation. As a focus for these wide-ranging interests, planned and proposed academic and industrial expeditions, the Rift to Ridge '07 workshop has acted as a catalyst for a coordinated international effort.

Keynote speakers included Prof. Godfrey Fitton, Prof. Gillian Foulger, Dr. Stephen Jones, Prof. John Hopper, Dr. Tony Doré, Prof. James Wright, Prof. Garrett Ito, Dr. Bryndís Brandsdóttir, Dr. Nicky White and Dr. Michael Larsen. The consensus from the meeting was to renew efforts to get the IODP to drill the Iceland hotspot through pressure from existing drilling proposals and by submitting new drilling proposals. Additional discussion centred on complimentary sampling and seismic programmes.

ECORD Summer School on Paleoceanography

Maria Teresa Hernandez (School of Chemistry, University of Bristol)

In August 2007 the Marum building (University of Bremen) hosted the ECORD summer school on palaeoceanography. Over 30 people attended, mostly PhD students and post-doctoral researchers, coming mainly from European universities (Bremen, Bremerhaven, Heidelberg, Bergen, Glent, Dublin, Oulu, Zurich, Salamanca and the UK), with a few participants from China (Zhejiang University) and the USA (Syracuse University).

Palaeoceanographic research relies on the integration and synthesis of different proxies and techniques. Therefore, it is crucial to understand how they work in order to best interpret the sedimentary record. The summer school covered different theoretical aspects of the earth system, from ocean circulation to biogeochemical cycling and productivity. Those were supported with practical sessions and very flexible discussion groups. These discussion groups provided a good opportunity to question and understand a range of different proxy datasets. Furthermore, and very useful for people who have not participated on an ocean research cruise, the school provided the chance to simulate the work carried out on a research vessel. Core logging, digital imaging and XRD scanning were carried out on several IODP cores. This was one of the most exciting activities during the summer school, as it allowed the participants to work with real IODP cores from the core repository in Bremen; it was like being on board the JOIDES Resolution but just onshore. The data obtained during the practical sessions and other databases were used to carry out time series analysis. This is an important component of palaeoceanographic research, as an age model is needed at some point when working with sediment cores in order to interpret any climatic event. As well as the lectures and workshops, there was also the opportunity to write a real IODP drilling proposal and present it to the IODP scientific meeting. Finally, participants presented their own research at the end of the course, and two prizes were awarded.

The summer school included attendance at the IODP Topic symposium on North Atlantic and Artic climate variability, where different palaeoclimate research was presented. During this symposium summer school participants were offered the chance to present their own research in poster format and discuss it with scientists from all over the world.

ECORD Summer School in Palaeoclimatology – two (happy!) reports

Melanie Bugler (University of Plymouth) and Richard Abell (University of Bristol)

A chance to attend a summer school in palaeoclimatology, especially in a country with beautiful scenery, good food and a little sunshine should never be cast aside. Therefore we would firstly like to thank the UK-IODP for giving us the opportunity and funding to attend the IODP/ECORD summer school in palaeoclimatology, Urbino, Italy, during the summer of 2007. Additional thanks go to the organisers Dr. Schellenberg, Dr. Brinkhuis, Dr. Galeotti and the USSP consortium. At the start of the journey to Italy we were unprepared for the three weeks of highs and a few momentary lows that we were about to face. Arriving at the hotel, we were greeted with food and wine, much needed after a day of travelling. It was certainly an 'ice breaker' and allowed people to relax and mingle with a mix of students, scientists, and organisers gathered from a variety of backgrounds, cultures and scientific interests encapsulated by the broad title of palaeoclimatology.

Our daily routine of intensive sessions on a variety of topics encompassed both marine and terrestrial environments, concentrating on the Cretaceous and Cenozoic. After a general introduction to palaeoclimate from proxy and modelling perspectives the course focused on detailed palaeoenvironmental and palaeoclimate reconstructions. The sessions were taken by an impressive selection of top scientific minds that added topical debates, hot of the press and pre- published data for our intellectual consumption. The diverse topics ranged through 'Holocene climate variability, and the danger of putting 'labels' on anomalies' by Eelco Rohling, to biotic presentations such as 'Morphological evolution of planktonic foraminifera' presented by Isabella Premoli-Silva. These sessions were set around a vast food intake including a selection of cakes and biscuits at coffee and a three course lunch, making concentrating in the afternoon particularly challenging. It was vital to keep brain cells well fed for these afternoon sessions consisting of more lectures as well as practical computer workshops on both age modelling and climate modelling. We too did our fair share of presentations showing the latest findings of our own research. We also formed working groups during the summer school to investigate and present our findings of a designated topic. Trawling through the literature was made considerably easier by having many key authors on hand to offer advice and their expertise. There was also the opportunity to explore some of our ideas using an Internet link to the latest GCM model housed on a computer in the USA.

Urbino Summer School group photo taken at the K/T boundary, Bottaccione Valley.

Evening 'socials by the pool' allowed time to relax and the brain a little time to reorganise itself after an overload of information. Often a greatly deserved de-stress, it also offered the opportunity to chat and put forward some ideas to the session presenters. Special evening talks were arranged for several evenings throughout the summer school, giving more information on the current and the future of palaeoclimatic research from around the world. Halfway through the summer school we were taken on a field trip for an overview of the local geology and a visit to the K/T boundary GSSP, rounded off by a superb lunch at the K/T boundary café.

The take home message from this experience was one of '*collaboration, out of the box thinking, combining modelling with hard palaeontological data, and that the top scientists are approachable!*' We would thoroughly recommend the summer school to other students as an opportunity to mix with likeminded people with similar ambitions and aspirations.

Jawad Afzal (University of Leicester)

Thanks to UK-IODP for sponsoring me to participate in the Urbino summer school in palaeoclimatology, from July 17 to August 3. I would also like to extend my thanks to the organizers: Simone Galeotti (University of Urbino), Henk Brinkhuis (Utrecht University), Stephen Schellenberg (San Diego State University) and Roderik van de Wal (IMAU Utrecht).

Firstly let me give a bit of background, I am a PhD student at the University of Leicester researching the control of environmental changes on the evolution of shallow marine benthic foraminifera to reconstructing environmental conditions in the tropical Eastern Tethys (Indus Basin, Pakistan) during the late Palaeocene–Early Eocene globally warm interval (PETM). My PhD research is closely related to the key aims of IODP/ECORD summer school course structure and my participation given me an opportunity to understand regional climate evolution in a global context and to see the 'bigger picture' and relate my findings to it.

The main focus of the summer school is on climate change: how and in which extent did the climate change, were these changes gradual or stepwise, what caused the warming and cooling and how can we investigate them? What happened with biota and with the ocean during these events? These questions were addressed by the key palaeoclimate scientific researchers who were on hand to present recent findings. The course was comprised of formal lectures by experts in stratigraphy, micropalaeontology, biogeochemical cycling, palaeoceanography, and climate modelling. Discussion sessions integrated geological data and modelling results for various geological intervals, including Cretaceous Oceanic Anoxic Events, Palaeocene–Eocene hyperthermals, and the Eocene–Oligocene transition. Student-centred investigations applied course content towards solving/constraining common questions in palaeoclimatological research.

A field trip to classic regional exposures recording cycles and events of the Cretaceous and Cenozoic took place during the summer school. In addition informal evening sessions and social events promoted discussion and collaboration. During these lectures, exercises, evening talks and discussions, we looked at possible mechanisms and forcing for climate changes, interpretation of proxies and different methods for building age models and correlation of different marine and terrestrial records.

The summer school is organized annually in the Natural Science Faculty of the University of Urbino, Italy. The city of Urbino located on the east coast of Italy is gifted with beautiful landscape, unique cultural options, excellent food and monuments which were good counterparts to the intensive science studies. I really enjoyed my participation and am very pleased to have had this opportunity during my PhD. A deep overview into the Cretaceous and Cenozoic climate development was presented, which will benefit me a lot in many aspects of my future research. The summer school also provided me with a link to palaeoclimate experts like Henk Brinkhuis and Appy Sluijs (Utrecht University) and I am benefiting from their expertise. I would recommend this summer school to any palaeoclimate research student as this will certainly provide an immense scientific learning experience and will be of great importance for their future research career.

Summer School 2008

The Deep Subseafloor Biosphere

September 1-12, 2008, University of Bremen, Germany

Lectures and interactive discussions on the deep sub-seafloor biosphere are combined with a virtual ship experience based on practical's on IODP shipboard logging and analytical work using the facilities of the IODP Bremen Core Repository (BCR). A focus of both lectures and discussions will be on key topics of sub-seafloor microbial communities, habitability and environmental conditions and the deep biosphere´s role in the global carbon cycle.

Location: University of Bremen, MARUM Building, Room 2070, www.marum.de
Closing date for registration: April 15th, 2008.
www.glomar.uni-bremen.de/

Past Climate Reconstruction and Modelling Techniques

July 15-August 3, 2008, Urbino, Italy

The Urbino Summer School in Paleoclimatology presents an advanced course co-sponsored by the European Consortium for Ocean Research Drilling (ECORD), the Darwin Center for Biogeology, the Institute for Marine and Atmospheric research Utrecht (IMAU), IMAGES, and the Netherlands Research School of Sedimentary Geology (NSG), in collaboration with IODP's School of Rock.

The 5th summer school of the USSP consortium will be focused on the evolution and dynamics of Cretaceous and Cenozoic climates. Experts will give lectures in the areas of stratigraphy, biogeochemical cycling, paleoceanography, climate models and integration of results.

Interactive discussions of case-studies (eg black shale deposition and carbon cycling including Cretaceous Oceanic Anoxic Events, Paleocene-Eocene hyperthermals and the Eocene-Oligocene transition) in classes, practicals and in the field will provide participants with an advanced working knowledge on the paleobiological and geochemical proxy data and their use in the reconstruction and modelling of past climates.

Location: University of Urbino, Urbino, Italy.
Closing date for registration: April 15th, 2008.
www.uniurb.it/ussp

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).

Currently Scheduled Expeditions

These dates are not fixed and are subject to change.

Expeditions	**Dates**
USIO	
Canterbury Basin	mid November 2008 – mid January 2009
Wilkes Land	mid January 2009 – mid March 2009
Pacific Equatorial Age Transect/Juan de Fuca	mid March 2009 – mid July 2009
CDEX	
NanTroSEIZE Input Sites	December 2008 – mid January 2009
NanTroSEIZE Riserless Observatory Preparation	mid January 2009 – February 2009
Riserless Expedition*	March 2009 – April 2009
ESO	
New Jersey Shallow Shelf	May – July 2008
Great Barrier Reef	September – November 2009

**Expedition schedule and implementation to be decided*

For more information please visit www.iodp.org/expeditions/

UK IODP 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 expeditions, 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.

There will be no further grant rounds in the current UK IODP NERC programme. The next phase of the UK IODP NERC programme commences in October 2008. An announcement of future grant rounds will be made in due course. In anticipation of this, please see below a summary of the grants available through UK IODP below. Please note that PDRA, PGRA, Urgency and Rapid Response Grants will be running outside normal grant rounds and can be applied for before the next phase of UK IODP begins.

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

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.

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 Expedition 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 Expedition 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.

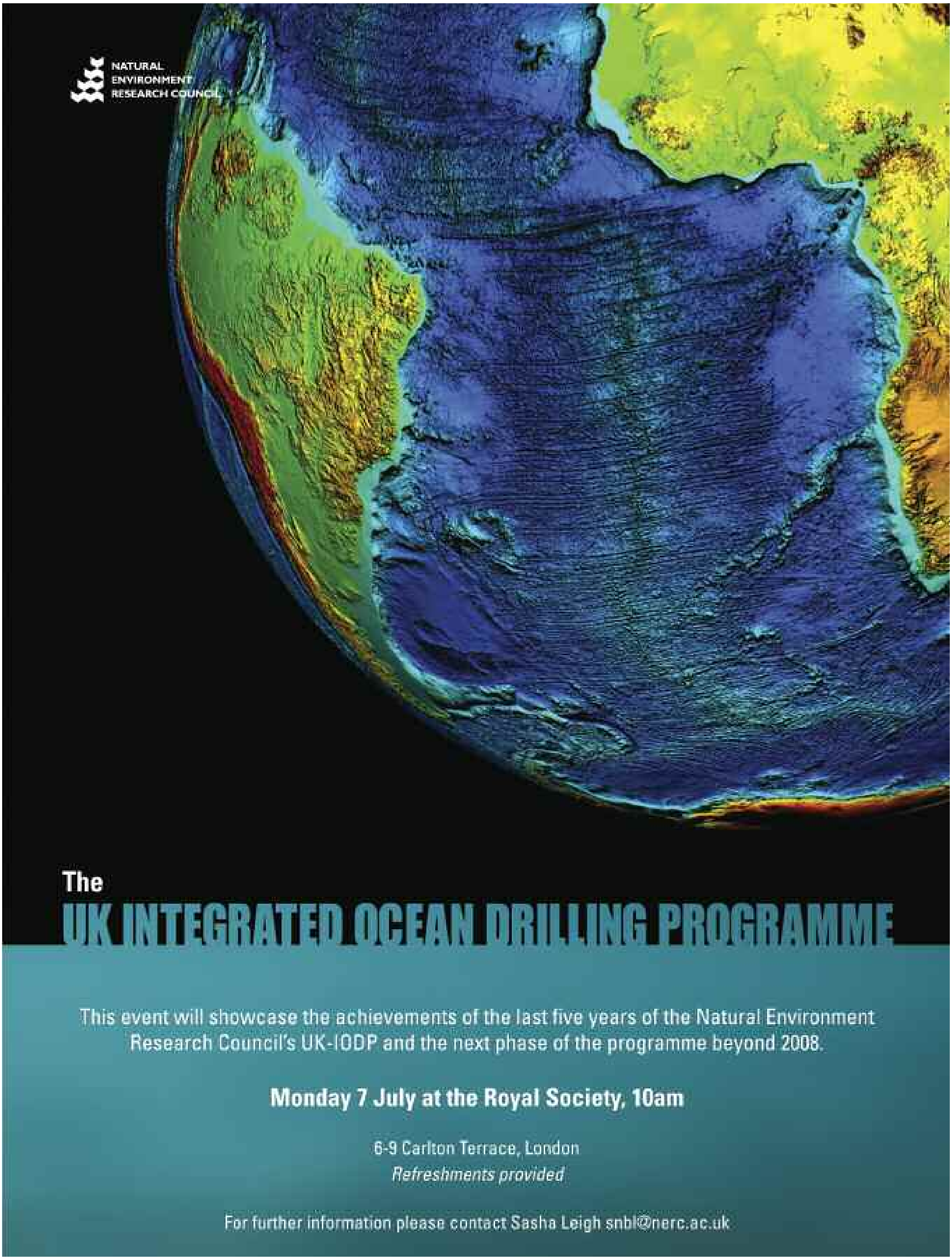
UK IODP Urgency grants

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.

Forthcoming event



IODP UK contacts

UKIODP Science Coordinator
Heather Stewart
British Geological Survey
Murchison House
West Mains Road
Edinburgh, EH9 3LA
Tel: +44 (0)131 6500259
Email: ukiodp@bgs.ac.uk

UKIODP Programme Manager
Chris Franklin
Science and Innovation Manager
Science and Innovation Programmes
Natural Environment Research Council
Polaris House
North Star Avenue
Swindon, SN2 1EU
Email: cfr@nerc.ac.uk

UKIODP Programme Administrator
Sasha Leigh
Natural Environment Research Council
Polaris House
North Star Avenue
Swindon, SN2 1EU
Email: snbl@nerc.ac.uk

ESO External Communication and Scientific Liaison
Alan Stevenson
British Geological Survey
Murchison House
West Mains Road
Edinburgh, EH9 3LA
Tel: +44 (0)131 6500376
Email: agst@bgs.ac.uk

IODP Panel Members from the UK

SPPOC - Science Planning and Policy Oversight Committee
Mike Bickle, Department of Earth Sciences, University of Cambridge

SPC - Science Planning Committee
Hugh Jenkyns, Department of Earth Sciences, University of Oxford

SSEPs - Science Steering and Evaluation Panel-Interior
Tim Elliott, University of Bristol

SSEPs - Science Steering and Evaluation Panel-Environment
Heiko Pälike, School of Ocean and Earth Science, National Oceanography Centre, Southampton

EDP - Engineering Development Panel
John Thorogood, formerly of BP Exploration Co Ltd.

STP - Scientific Technology Panel
Mike Lovell (co-chair), Department of Geology, University of Leicester

SSP - Site Survey Panel
Neil Mitchell, University of Manchester

EPSP - Environmental Protection and Safety Panel
Bramley Murton, School of Ocean and Earth Science, National Oceanography Centre, Southampton

IS-PPG - Industry Science Program Planning Group
Richard Davies (Cardiff, move to Durham in Janurary 2006), David Roberts (BP) and Harry Doust (Free University of Amsterdam)

UK Industrial Liaison Panel Chairman
Prof. Richard Hardman, Consultant

ECORD Science Operator Science Manager
Dan Evans, British Geological Survey

Useful websites

UK

NERC Integrated Ocean Drilling Program
www.nerc.ac.uk/research/programmes/ukiodp and
www.ukiodp.bgs.ac.uk

Europe

European Consortium for Ocean Research Drilling (ECORD)
www.ecord.org

ECORD Science Support Advisory Committee
www.essac.ecord.org

IODP central

IODP Management International Inc.
www.iodp.org

Initial science plan for IODP
www.iodp.org/isp

IODP science advisory structure
www.iodp.org/sas

IODP's implementing organisations

Centre for Deep Earth Exploration
www.jamstec.go.jp/chikyu/eng/index.html

ECORD Science Operator
www.eso.ecord.org

JOI-Alliance US Implementing Organisation
www.iodp-usio.org

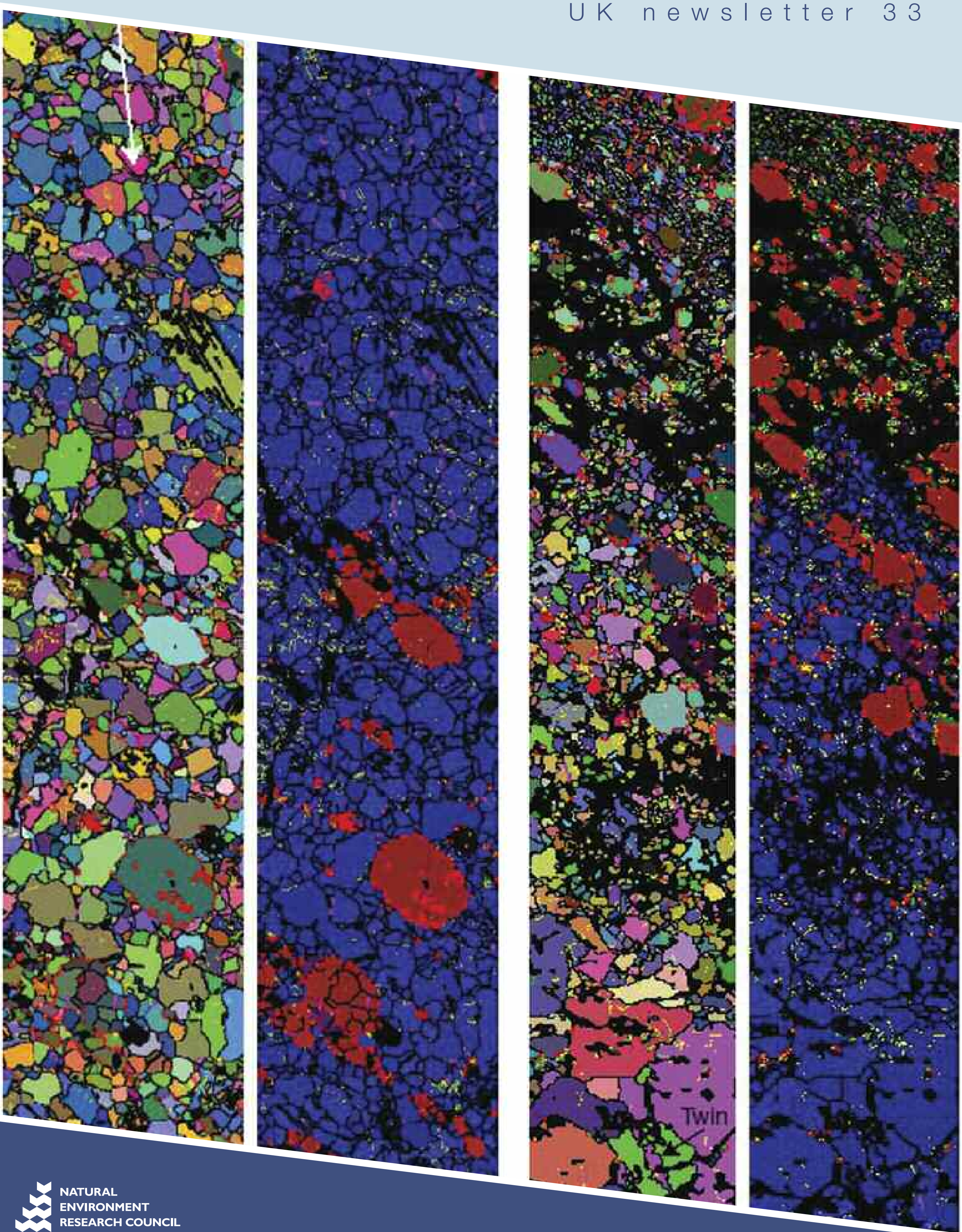
Back Cover: (a) All Euler (full crystallographic orientation) for 64r2-43, with the grain boundaries marked on. 2° = yellow, 5° = lime green, 10° = blue, 20° = pink and >30° = black. Boundaries between the phases are marked in red. (b) Phase map showing each mapped phase in a different colour for 64r2-43, with the grain boundaries marked on. 2° = yellow, 5° = lime green, 10° = blue, 20° = pink and >30° = black. Phase colours are blue = Plagioclase, red = Diopside, purple = Enstatite, green = Hornblende, yellow = Ilmenite. Boundaries between the phases are marked in red. (c) Same display as (a) but for sample 64r2-46. (d) Same display as (b) but for sample 64r2-46.

(Image courtesy of Angela Halfpenny, data examined as part of research on samples collected during IODP Expeditions 304 and 305)

IODP

INTEGRATED OCEAN DRILLING PROGRAM

UK newsletter 33



NATURAL ENVIRONMENT RESEARCH COUNCIL