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UK newsletter 31



ODP Highlights

Leg 304 and 305: Oceanic Core Complex Formation, Atlantis Massif 1 and 2

Hole U1309D drilled during the course of these Expeditions is 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.

Leg 306: North Atlantic Climate 2

- A total of 4656 metres of high quality core were recovered to sample and study the climate records that record North Atlantic Pliocene-Quaternary climate
- The successful installation of a CORK with a 150m thermistor string in a cased borehole close to ODP Site 642.

Leg 307: Porcupine

18 day 'mini-leg' with a total of 1530m drilled, with 1398m recovered, in 12 days.

Leg 308: Gulf of Mexico Hydrogeology

 First time that downhole pressure and lithology were monitored in real time (MWD) and weighted mud used as a tool to drill through overpressured regimes.

Leg 309: Superfast Spreading

Successfully deepened existing Hole 1256D and penetrated for only the second time in scientific ocean drilling, the extrusive-intrusive boundary and recovered the transition from seafloor-dominated alteration to high temperature hydrothermal alteration.

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

Front Cover: JOIDES Resolution rounding Ponta Delgada Lighthouse, Azores at the end of Expedition 305 (image courtesy of IODP/TAMU). Expedition 306 began in Ponta Delgada on the 2nd March 2005.

Foreword

Heather Stewart, UK IODP Science Coordinator

would like to take this opportunity to write a short note by way of introduction to this latest edition of the UK IODP Newsletter. Since the last edition of the newsletter there has been a significant amount of activity to report as can be seen by the number of articles in this edition.

The Community was sad to see the JOIDES Resolution finish its last Expedition in December 2005 following a busy year. We eagerly wait to see what the replacement Scientific Ocean Drilling Vessel (SODV) is capable of. More information on this state-ofthe-art, riserless drilling research platform can be found on their newly launched website (www.joiscience.org/sodv/). There has also been another successful Mission Specific Platform Expedition in Tahiti and the Proceedings of the IODP Volume 302 have just been published online detailing at last the results from the successful ACEX drilling in 2004 (www.ecord.org). At the time of writing the EUROForum meeting has just taken place. It was the turn of the UK to host this European event and the ESSAC Office organised this in Cardiff on the 8th-9th of May. More than 100 students and individuals from academia and industry attended.

The programme began with an interesting series of presentations by co-chief scientists from Expeditions 302 and 305-311. This was a unique opportunity for the UK community to hear direct from the co-chief scientists how successful the expeditions were and to present some of the science coming out of the drilling. The following day keynote presentations highlighted the new drilling opportunities available through IODP: the Chikyu, Mission Specific Platforms and the SODV. This was followed by a drilling proposal writing workshop where members of the UK Community with a drilling proposal in the system or an idea for a proposal could speak to members of the SAS Panels and present their ideas.

I would like to take this opportunity to thank the ESSAC Office for organising this successful event - Dr Federica Lenci, Dr. Chris MacLeod and Dr Julian Pearce.

UKIODP is planning a series of visits to universities in Autumn 2006. The aim will be to discuss the opportunities available through UK-IODP and methods of realising them. At the same time encouraging interest from groups in neighbouring fields such as the biological sciences. I will be accompanied by scientists who have recently sailed on an IODP Expedition allowing the audience to get a taster of the exciting science that comes from these activities. As dates and venues are confirmed they will be posted on the UKIODP website.

Finally, I hope that you enjoy this edition of the newsletter.

Best regards Heather.

Professor Sir Nicholas Shackleton

An inspirational pioneer of the study of past climates whose research identified ice age cycles and the role of greenhouse gases, with lessons for future climate change

Harry Elderfield

N icholas John Shackleton, Palaeoclimate scientist: born London, 23 June 1937; Senior Assistant in Research, Cambridge University 1965-72, Assistant Director of Research sub-department of Quaternary Research 1972-87, Director 1988-94, Director Godwin Institute of Quaternary Research 1995-2004; Research Fellow, Clare Hall Cambridge 1974-80, Fellow 1980-2006; married Judith Carola Murray 1967 (marriage dissolved 1986) 1986 Vivien Anne Law (died 2002); died Cambridge 24 January 2006.

Nicholas John Shackleton, the son of Professor Robert Millner Shackleton, FRS, an eminent field geologist, graduated from Clare College, Cambridge, in physics in 1961 after which, as a result of what he later called "a series of random events", he followed his father into geology but in a different direction. The random events were associated with the suggestion made, at about 1960, by Edward Bullard that Harry Godwin, the then head of the sub-department of Quaternary Research, should set up a laboratory in Cambridge to measure stable isotopes. Nick Shackleton was the person selected to get the project started.

The reason for Bullard's suggestion related to the work of Nobel Laurate Harold Urey. In 1947 Urey published calculations which predicted that the heavy isotope of oxygen (¹⁸O) would be fractionated from its light isotope (¹⁶O) as a function of temperature. He suggested that this would provide a method to estimate temperatures in the geological past

from analysis of fossil shells composed of calcium carbonate minerals. He assembled a group of talented scientists who designed a mass spectrometer to test his theory and in the early 1950s demonstrated it was correct. Among this team was Cesar Emiliani who, because of his background in micropalaeontology (the study of microscopic fossils), went on to apply the techniques developed to tiny microfossils called foraminifera recovered from deep-sea cores. Emiliani identified cycles of warm and cold sea-surface temperatures back to over half a million years; because of this work, Emiliani is often thought of as the founder of paleoceanography.

The work carried out by Emiliani was



extremely laborious and Shackleton realised that to set up a successful laboratory he needed to develop a mass spectrometer an order of magnitude more sensitive than that developed by Urey's team. He accomplished this as part of his thesis work and in 1967 he received his PhD for a dissertation titled "The Measurement of Palaeotemperatures in the Quaternary Era". Shackleton made oxygen isotope measurements on shells of fossil foraminifera that lived in bottom waters and those from surface waters and from a comparison he saw a fatal flaw in Emiliani's work. The changes in isotopic composition were about the same, yet Emiliani had interpreted his results as an eight degrees change from the last ice age to today. This was clearly impossible: the deep sea water temperature today is less than about two degrees Celsius; the dominant cause of oxygen isotope variations was not temperature but was changes in the oxygen isotope composition of the oceans caused by removal of isotopically depleted water to form the ice sheets. In a spirit that typified Shackleton's generosity throughout his career he wrote in his 1967 Nature paper reporting this crucial result: "It should be emphasised that the time sequence which Emiliani has been able to obtain...remains of inestimable value...in a sense it is enhanced by the certainty that it is a time sequence for terrestrial glacial events rather than oceanographic events".

One such application for this time sequence was to identify the horizon of the last ice age in ocean cores worldwide which provided the temporal framework for a large US driven project in which Shackleton participated called CLIMAP to generate a global map of seasurface temperature. The map was used by modelers to reconstruct atmospheric circulation in glacial times and as a boundary condition in models that explored changes in atmospheric temperature, of crucial importance for modeling future climate. Another very important application was to place within a known time scale the fluctuating oxygen isotope signals that Emiliani and he had defined by generating a long core record that extended to a reversal in the Earth's magnetic field seen in sediment cores and known to be at 780 thousand years ago.

This set the stage for the most important application of the oxygen isotope method: the reconstruction of the history of global ice volume through the ice ages. Milutin Milankovitch in the 1920s had hypothesised that ice ages were caused by changes in distributions of solar radiation at the earth's surface in turn driven by changes in movement of the earth's orbit. Shackleton and his coworkers Jim Hays and John Imbrie generated long climate records from different ocean regions and subjected the patterns to



mathematical analysis. The result was the famous 1976 paper in Science (Variations in the earth's orbit: pacemaker of the ice ages) where they showed that the three periodicities with which the earth's orbit changes (100,000 years, 40,000 year and 21,000 years) were all present just as predicted. This clear recognition of orbital control is also now revolutionising the whole of stratigraphy (the study of geological strata) because it provides in principle a means of correlating beds at separated parts of the Earth to a precision of 20,000 years at a time of hundreds of millions of years ago, and of determining precise "orbitally tuned" age-calibrated stratigraphies back to about 30 million years.

Shackleton also pioneered the use of carbon isotopes in palaeoclimate studies. Oxygen isotope determinations are made by extracting carbon dioxide gas from the microfossils and the method also generates data for carbon isotopes, which previously was not examined. Recognising that the carbon isotopic composition of the oceans is affected by the amount of carbon stored on land, he used carbon isotopes to assess the changing land reservoir of carbon between glacial and interglacial times.

He also applied the carbon isotope method to test an idea suggested by Wally Broecker to explain changes in the carbon dioxide content of the atmosphere between ice ages and today. The first reports had appeared from air trapped as bubbles in ice cores that carbon dioxide concentrations at glacial times were about 190 parts per million compared to 280 parts per million in pre-industrial times. Broecker argued that the only way this could have occurred was by transferring carbon to the deep ocean by increased biological productivity. Because this process preferentially enriches the lighter ¹²C isotope in organic matter that sinks to the sea floor it should produce larger differences in the heavier ¹³C between surface and deep seawater at glacial times as recorded in the foraminifera shells. Shackleton's record published in 1983

predicted how atmospheric carbon dioxide has changed over the past 100,000 years and was found to be very similar to that obtained from bubbles in the Antarctic Vostok ice core.

Shackleton has worked with co-workers from over 20 countries and his contributions were invariably characterised by a mass of new high quality isotope data collected with the help of his laboratory manager Mike Hall. One recent paper published in 2005 is unusual in showing no new data but is one of Shackleton's most interesting and daring contributions. Having shown early in his career that the ice volume component of the marine oxygen isotope records is dominant over temperature, there had been no way of knowing precisely what the contributions are. By comparing ice core and deep records in a complex manner he was able to separate the two contributions and showed that the ice volume component lags behind (it responds with a delay) the changes in carbon dioxide. In other words, changes in the ice sheets do not cause changes in atmospheric carbon dioxide. Shackleton's analysis showed the reverse: carbon dioxide played a major role in causing the changes from glacial to interglacial conditions. This is an extremely profound analysis with potentially very important ramifications for our future climate.

Nick Shackleton was was awarded many honours including the Crafoord, Vetlesen and Blue Planet prizes, FRS and the Royal Medal, Foreign Associate of the US Academy of Sciences and the Urey medal of the European Geophysical Association. He encouraged and inspired both young researchers and his colleagues and co-workers by his unselfish collaboration and through his immense influence on the field of palaeoclimatology.

As well as his many scientific accomplishments, Nick Shackleton excelled in another area, that of music which was almost as important to him as science. He was a very accomplished clarinet player. He combined both loves in the musicology concert held at each International Conference of Palaeoceanography at which he will be sadly missed.

Nick Shackleton was very attached to his college Clare Hall where he organised many events. He strongly supported music, art exhibitions and a Quaternary discussion group. He invited many Visiting Fellows to Clare Hall to work with him in palaeoclimate research.

Nick obtained great happiness from his partner Ingrid Pearson who was with him and his family and friends when he died. Shortly before the time of his death he initiated the foundation of the Sir Nicholas Shackleton Fund to support Visiting Fellows in the general field of palaeoclimate research to continue his work in Cambridge.

First published in the Independent on 8 Feb 2006

Reports on recent IODP Legs

Expedition 305: Oceanic Core Complex 2

Angela Halfpenny (University of Liverpool), Roger Searle (University of Durham), Andrew McCaig (University of Leeds), Tony Morris (University of Plymouth) and the Expedition 307 Shipboard Scientific Party

ceanic core complexes (OCC, a.k.a megamullions), often found at the inside corners of ridge-transform intersections, are one of the most important discoveries in oceanic tectonics of the last 10 years (Cann et al., 1997). They are a prime target for IODP because they provide a window into lower crustal and mantle rocks, and because formation of such complexes is one of the primary modes of lithosphere formation at slow and ultra-slow spreading ridges. The location chosen for Expeditions 304 and 305 was the Atlantis Massif, which exposes serpentinized peridotite and lesser 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).

Atlantis Massif has several key features that made it an ideal target for OCC drilling.

- The massif is <2 Ma, so weathering and erosion have not degraded (macro) structural relationships.
- The corrugated, striated central portion of this domal massif displays morphologic and geophysical characteristics inferred to be representative of an OCC exposed via long-lived detachment faulting
- The hanging wall is in contact with the footwall, so the detachment zone could be cored and logged at both exposed (footwall, core) and unexposed (beneath the adjacent hanging wall) sites to address the characteristics of strain localization and the effects of fluid flow.
- The core of the massif is dominated by variably serpentinized peridotite exposed at the surface (Blackman *et al.*, 2004), mantle seismic velocity has been reported in refraction experiments at depths < 1000m (Detrick and Collins, 1998), and gravity anomalies suggest fresh peridotite at shallow levels several hundred meters down (Blackman *et al.*, 1998). It was

therefore anticipated that an alteration gradient and/or an alteration front into fresh mantle could be studied through drilling and coring.

IODP Expeditions 304 and 305 was unusual in being the first of a new style of IODP expeditions in which drilling extends continuously over two or more adjacent drilling legs. A decision was taken early on to treat the two legs as a single project. Although the science parties on the two legs comprised different people, they were treated as on combined science party. One result of this was that all sampling for post-cruise research was postponed to a single shore-based sampling party which followed Expedition 305. So far this arrangement has worked well, and the increased size of the science party has sometimes provided a broader perspective and wider range of expertise than would otherwise have been achieved.

The Expeditions, which were at sea from November 2004 to March 2005, aimed to drill two main holes in the Atlantis Massif. One, on the crest of the Massif, aimed to drill into the footwall of the detachment fault, giving the best chance of intersecting fresh mantle rocks. The other aimed to drill through the basaltic hanging wall of the fault in order to intersect the fault zone at depth. In the event, Hole U1309D into the footwall is, at 1415m, 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.

Scientific Objectives

The hypotheses to be tested by drilling during Expeditions 304 and 305 were (Expedition Scientific Party, 2005a,b):

- 1. A major detachment fault system controlled the evolution of Atlantis Massif.
- 2. Significant unroofing occurred during formation of this OCC.



Figure 1. Base map of Atlantis Massif showing prior geological and geophysical data coverage and the location of Integrated Ocean Drilling Program (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 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.

- Plate flexure (rolling hinge model) is the dominant mechanism of footwall uplift.
- The nature of melting and/or magma supply contributes to episodes of longlived lithospheric faulting.
- 5. Expansion associated with serpentinisation contributes significantly to uplift of core.
- 6. The Mohorovicic discontinuity (Moho) at Atlantis Massif is a hydration front.
- 7. Positive gravity anomalies at Atlantis Massif indicate relatively fresh peridotite.

Drilling Operations

None of the British participants on Expeditions 304 and 305 had sailed on the Joides Resolution before, and for Angela and Tony it was their first research cruise. I think it is fair to say that we were all deeply impressed by the efficiency and calm purpose with which the whole ship functions on site. It truly is a team effort, from the Transocean crew shifting pipe for 12 hours at a time during a bit change, the small army of technicians sawing, grinding, photographing, analyzing powders and making more thin sections in 7 weeks than most university departments can manage in a year, and then the scientists, cheerfully (mostly!) working 12 hour shifts every day for 7 weeks in teams that had never met before. On Expedition 304 the highlight had to be the sterling efforts of the Catamar crew (sadly no longer employed by Transocean), who prepared the most sumptuous feast 3 times on Christmas day and were rewarded back in the Azores by the presentation of a signed wooden spoon and a bottle of malt whisky each, following a collection on board.

Expedition 304 sailed from the Azores on the evening of 20th November 2004 after a pleasant few days walking over volcanoes, visiting hot springs and "crossing over" with

of each lithology per core.

Figure 2. Stratigraphic distribution of lithologic proportions of cores recovered

300

400

500

from Hole U1309D, including Expedition 304 data. A. 20m running average of

lithologic proportions (white = no recovery). B. Each bar represents the percentages

the participants of Expedition 303. It took 3 days to get on site, which gave us all a chance to get to know each other, decide how we were going to log core, and get used to shift work. Operations started with a 102m pilot hole (U1309B) on the crest of the Massif, which slightly surprisingly turned out to be mainly gabbro with some diabase intrusions, and just one thin sliver of harzburgite giving us hope of the Moho just a little deeper. The fault rock on top of the Massif was not sampled in core, with only a few pieces of talc-tremolite schist giving a clue as to its nature (see Schroeder and John, 2004 for a description of the fault rock at the top of the south wall of the Massif). The hole was logged with a full array of downhole tools, and then we moved a few metres away to start the main footwall hole. A new hard rock re-entry system (HRRS) was tried which involved using a hammer drill pulling a 133/8 inch casing to start the hole. The idea was to insert 30m of casing and then drop a re-entry cone onto it. The first attempt was abortive, but the next was almost completely successful, with 20m of casing inserted and only 4.5m protruding above the seabed. Once the cone was dropped onto it, it looked like some sort of crinoid, but Hole U1309D was ready to go and by the end of

Expedition 305 was deepened to 1415.5mbsf, with around 15 re-entries for bit changes.

After drilling to 131mbsf we left Site U1309D to try and start the hanging wall hole (Figure 1). Thus commenced a frustrating week of tool failures and abortive holes, with only a few fragments of totally fresh basalt to show for it. No deep holes have ever been started in young basalts because of their friable nature. It was hoped that if we could only get a good start with the shallow part of the hole cased, progress would be possible. Various designs of specialised drill bit including a hammer drill were tried, and although the HRRS showed some promise, in the end it proved unequal to the task. Nevertheless, much was learned, and the experience will be used to continue developing a hard rock spudin capability. For the scientists and technicians this week gave us a welcome break from logging core, a chance to write reports and compare the results of the 2 holes we had so far achieved in gabbro 20m apart (hard to correlate, which was not a great surprise to anyone who has worked in ophiolites). It was like a Penrose conference lasting a week, and probably greatly improved our interpretation of the whole Site. It was also a chance for people to practise carol singing and hone those

Figure 3. Whole rock alteration profile based on visual core descriptions. Note the very low levels of alteration between 800 and 1100 mbsf. Higher levels below that mostly correspond to serpentinised olivine-rich rocks







performances for the Christmas revue (of which the less said the better!).

Eventually we returned to Hole U1309D and rapidly cored down to 401.3mbsf, with an average recovery of 59%. After an unsuccessful and then successful logging runs, and a couple of shallow penetration holes which recovered pieces of fault rock, we set off for Ponta Delgada (Azores) on 4th January, arriving on the 7th.

After a moderately riotous crossover, the 304 party (apart from Donna Blackman and staff scientist Jay Miller who were to remain for Expedition 305) made their way home and the 305 participants, including Angela Halfpenny, had their chance for a bit of R&R in Ponta Delgada. That was the last rest they had, since once on site Hole U1309D was reentered and after that they just kept coring! The hole was deepened by 1014m between 17th January and 23rd February, surely a new record for hard-rock drilling. The only break was a logging run in the middle. A further logging run and downhole seismic experiment completed operations at the end. The science party were pretty tired on arrival back in the Azores on 2nd March.

The drilling and core recovery phase of the expeditions was a great success due to the quality and quantity of core recovered; high recovery of hard rock is very unusual. Good recovery means nearly continuous data and the potential to meet the scientific objectives; the final average for Hole U1309D was 74.8%. Coupled with the superb logging data using a variety of tools, and palaeomagnetic data, this offers a real chance to reorient core into a geographical reference frame over long intervals. The logging data will also be combined with physical properties measurements made on board and post-cruise to relate the cored material to the seismic

sections over the Massif. Hole U1309D is the third deepest borehole in the hard rock oceanic crust, and the second deepest hole in lower crustal and upper mantle rocks. At the end of the expedition, the hole was open and in good condition for further work.

Scientific results

Hole U1309D was dominated by lower crustal rock types (Figure 2); interlayered gabbros of varying grain size and modal mineralogy made up approximately 91% of the core. Basaltic rocks like diabase made up nearly 3% and the rest was ultramafic rock types (olivine rich troctolite and peridotite, almost entirely magmatic rather than residual in origin). For many the biggest disappointment of the expeditions was the failure to reach fresh mantle rocks as predicted, meaning that objectives 6 and 7 above could not be tested. This has been much discussed, but the most likely explanation for the discrepancy between geophysical and geological data is that the lower crust and upper mantle at slow spreading ridges are extremely heterogeneous (eg. Cannat et al., 1987), and a continuous sub-horizontal Moho simply does not exist, particularly near transform faults. In these circumstances geophysical survey results can only be extrapolated over short distances, although the origin of continuous reflectors in seismic sections (Canales et al., 2004) remains uncertain. It was also disappointing that the failure of the hanging wall holes meant that no good sections of the fault rock were recovered. Despite these disappointments, the recovery of such continuous core through an oceanic gabbro must be viewed as a considerable success, likely to influence ideas about the formation of gabbros, fluid circulation, and tectonic processes in young ocean crust of Atlantic type for many years to come.

Figure 4. Spectacular double rainbow over the Joides Resolution, Expedition 304. Photo taken by Bill Crawford, IODP Imaging Specialist.

Highlights include:

A complete suite of gabbroic rocks is present ranging from layered olivine-rich troctolites through olivine gabbros and gabbronorites to oxide gabbros and late felsic veinlets. This offers a unique opportunity to study magma chamber processes at a slow spreading ridge, and shows detachment faulting can be accompanied by significant magmatism (objective 4).

Geochemical analysis for major and trace element concentrations revealed that the gabbroic rocks are some of the most primitive sampled along the MAR, as indicated by high Mg# ranging from 67 to 87.

A superb alteration profile is preserved (Figure 3), with samples above about 400mbsf being pervasively altered, while some intervals below 800mbsf are almost completely fresh. The profile records downward penetration of alteration in the low amphibolite and greenschist facies at progressively decreasing temperatures. Zeolite facies metamorphism is still occurring in fractures in the lower part of the hole, where temperatures exceed 120°C. The existence of amphibolite and greenschist facies metamorphism in both diabase dykes and gabbros at the top of the hole, coupled with the extremely fresh basaltic hanging wall, supports the hypothesis that tectonic unroofing has occurred in the massif (objective 2)

There is abundant textural evidence for volume increase during alteration of olivinebearing gabbros and troctolites. These reactions occurring in gabbroic rocks are the counterpart of serpentinisation in peridotites, and are relevant to objective 5 above.

Palaeomagnetic measurements reveal several areas of core where two or more phases of magnetisation have occurred in fields of opposite polarity, perhaps reflecting different ages of magmatism or alteration. In the majority of the hole, magnetic inclinations are within 200 of the ambient field. This restricts the net amount of tectonic rotation that can have occurred since the remanences were fixed in the rocks during cooling and/or alteration. The rolling hinge model (objective 3) may only apply to a limited extent, or may be accompanied by other tectonic rotations (e.g. about a horizontal axis parallel to Atlantis Transform).

On-board measurements of seismic velocity revealed values consistent with crustal lithologies (Vp <6.8 km s⁻¹). Measured

densities range from ~2.6 to >3.2 kg m-³, with higher values corresponding to oxide gabbros and some olivine-rich troctolites. Continuous measurements of magnetic susceptibility reflected mostly the magnetite content (up to 8% by volume in some oxide gabbros).

Several diabase sills occur in the upper 130m of Hole U1309D and can be correlated with Hole U1309B 20m away. Emplacement of sills at this level is an important indicator of stress orientations.

Although weak magmatic fabrics are present in 22% of the core, solid-state deformation is restricted to a few thin granulite-facies shear zones (< 3% of the core), and to late brittle breccia zones formed in the greenschist facies. This lack of deformation contrasts with ODP Hole 735b on the southwest Indian Ridge, which is similarly situated on a massif close to a transform fault (Dick et al., 2000). Ductile deformation in the granulite and amphibolite facies is dominant in Hole 735b, leading to the idea that the detachment fault roots deeply into the magmatic zone at that ridge crest. The deformation in the Atlantis Massif is much more similar to a detachment fault and footwall studied at 15° 45' N (Escartin et al., 2003) in the Atlantic. The lack of high temperature deformation places severe constraints on the geometry of the detachment fault at depth (MacLeod et al., 2002).

The oceans are the last great frontier for geological investigation of the Earth's crust – we really do know very little about the ocean crust compared to the continents. In view of this it should hardly be a surprise that our findings were in many respects unexpected! Expeditions 304 and 305 are a significant step towards a better understanding of processes at slow spreading ridges.

References

BLACKMAN, D K, CANN, J R, JANSSEN, B, and SMITH, D K, 1998. Origin of extensional core complexes: evidence from the MAR at Atlantis Fracture Zone. Journal of Geophysical Research, Vol. 103, 21315-21334.

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'N). Earth and Planetary Science Letters, Vol. 222, 543–560.

CANN, J R, BLACKMAN, D K, SMITH, D K, MCALLISTER, E, JANSSEN, B, MELLO, S, AVGERINOS, E, PASCOE, A R, and ESCARTIN, J. 1997. Corrugated slip surfaces formed at ridge-transform intersections on the Mid-Atlantic Ridge. Nature, Vol. 385, 329–332.

CANNAT, M, LAGABRIELLE, Y, BOUGAULT, H, CASEY, J, DE COUTURES, N, DMITRIEV, L, and FOUQUET, Y. 1997. Ultramafic and gabbroic exposures at the Mid-Atlantic Ridge: geological mapping in the 15 degrees N region. Tectonophysics, Vol. 279, 193–213.

BLACKMAN, D K, KARSON, J A, KELLEY, D S, CANN, J R, FRÜH-GREEN, G L, GEE, J S, HURST, S D, JOHN, B E, MORGAN, J, NOONER, S L, ROSS, D K, SCHROEDER, T J, and WILLIAMS, E A. 2004. Geology of the Atlantis Massif (MAR 30°N): implications for the evolution of an ultra-mafic oceanic core complex. Marine Geophysical Research, Vol. 23, 443-469.

DETRICK, R S, and COLLINS, J A. 1998. Seismic structure of ultramafics exposed at shallow crustal levels in the Mid-Atlantic Ridge rift valley at 15°N. EOS, Transactions American Geophysical Union, Vol. 79, F800.



DICK, H J B, NATLAND, J H, ALT, J C, BACH, W, BIDEAU, D, GEE, J S, HAGGAS, S, HERTOGEN, J G H, HIRTH, G, HOLM, P M, ILDEFONSE, B, ITURRINO, G J, JOHN, B E, KELLEY, D S, KIKAWA, E, KINGDON, A, LEROUX, P J, MAEDA, J, MEYER, P S, MILLER, D J, NASLUND, H R, NIU, Y-L, ROBINSON, P T, SNOW, J, STEPHEN, R A, TRIMBY, P W, WORM, H-U, and YOSHINOBU, A. 2000. A long in situ section of the lower ocean crust: results of ODP Leg 176 drilling at the Southwest Indian Ridge. Earth and Planetary Science Letters, Vol. 179, 31–51.

ESCARTIN, J, MÉVEL, C, MACLEOD, C J, and MCCAIG, A. 2003. Constraints on deformation conditions and the origin of oceanic detachments, the Mid-Atlantic Ridge core complex at 15°45'N. Geochem., Geophys., Geosyst., Vol. 4, 10.1029/2002GC000472.

EXPEDITION SCIENTIFIC PARTY. 2005a. Oceanic core complex formation, Atlantis Massif—oceanic core complex formation, Atlantis Massif, Mid-Atlantic Ridge: drilling into the footwall and hanging wall of a tectonic exposure of deep, young oceanic lithosphere to study deformation, alteration, and melt generation. IODP Preliminary Report, Leg 304. http://iodp.tamu.edu/publications/PR/304PR/30 4PR.PDF.

EXPEDITION SCIENTIFIC PARTY. 2005b. Oceanic core complex formation, Atlantis Massif—oceanic core complex formation, Atlantis Massif, Mid-Atlantic Ridge: drilling into the footwall and hanging wall of a tectonic exposure of deep, young oceanic lithosphere to study deformation, alteration, and melt generation. IODP Preliminary Report, Leg 305. http://iodp.tamu.edu/publications/PR/305PR/30 5PR.PDF.

MACLEOD, C J, ESCARTIN, J, BANERJI, D, BANKS, G J, GLEESON, M, IRVING, D H B, LILLY, R M, MCCAIG, A M, NIU, Y, ALLERTON, S, and SMITH, D K. 2002. Direct geological evidence for oceanic detachment faulting: the Mid-Atlantic Ridge, 15'N. Geology, Vol. 30:10, 879–882.

SCHROEDER, T, and JOHN, B E. 2004. Strain localization on an oceanic detachment fault system, Atlantis Massif, 30°N, Mid-Atlantic Ridge. Geochem., Geophys., Geosyst., Vol. 5, 10.1029/2004GC000728.

Expedition 306: North Atlantic Climate 2. March-April 2005.

Ian Bailey (NOC, Southampton), Patrizia Ferretti (University of Cambridge) and the IODP Expedition 306 Scientists

xpedition 306 was based on two separate proposals. The first of these objectives, shared with Expedition 303, was to establish a Neogene-Quaternary chrono-stratigraphic template from strategic sites in the sub-polar north Atlantic to elucidate sub-millennial- to orbital-scale phasing of environmental change. The second aim was to install a CORK (circulation obviation retrofit kit) to reconstruct bottom water temperature change on time scales of decades to a century in the Norwegian Sea. The drilling locations selected (Figure 1) are known, either from previous Ocean Drilling Program (ODP)/Deep Sea Drilling Project (DSDP) drilling or from conventional piston cores to be key regions that today are influenced by, or potential sources of, North Atlantic Deepwater (NADW) with long

continuous records of millennial-scale environmental variability from the North Atlantic region.

Scientific objectives

Stratigraphy is the fundamental backbone of our understanding of Earth's history, and stratigraphic resolution is the main factor that limits the timescale of processes that can be studied in the past. Sub-Milankovitch-scale climate studies face the challenge of finding a stratigraphic method suitable for correlation at this scale. The overarching objective of the expedition was therefore to generate a palaeointensity-assisted chronology (PAC) for the North Atlantic region from the integration of geomagnetic palaeointensity and stable isotope data with palaeoceanographic proxies and, in so-doing, allow for the correlation of millennial-scale stratigraphies to other parts of the globe for the last few million years.

Geomagnetic palaeointensity records from marine sediment cores have been shown to contain a global signal suitable for fine-scale correlation (see Guyodo and Valet, 1996), at least for the last glacial cycle. Beyond the range of AMS 14C dating, geomagnetic palaeointensity data may provide viable means of sub-Milankovitch-scale long-distance correlation. Palaeointensity records have been applied to stratigraphic correlation throughout the North Atlantic for the last 75 k.y. (Laj et al., 2000), and for the Atlantic realm for the last 110 k.y. (Stoner et al., 2000). As variations in geomagnetic palaeointensity control atmospheric production of 10Be and 36Cl isotopes and the flux of these isotopes is readily measurable in ice cores, palaeointensity

Figure 1: Locations of Expeditions 303 and 306 sites (from Expedition Scientists, 2005).



records in marine cores may also provide an independent link between marine sediment and ice core records.

Fundamental to the objectives of Expeditions 303/306 is to improve our understanding of the mechanisms and causes of abrupt climate change. To this effect, the expeditions proposed to collect records of climate variability from key regions and compare the response and timing of climate change among sensitive regions. They follow the premise that understanding the phase relationship of environmental variability on millennial timescales via the global export of PACs is an essential step to defining the underlying mechanisms of abrupt climate change.

A persistent ~1500 y cycle, apparently independent of glacial or interglacial climate state, has been observed for the past 80 k.y. (Bond et al., 1999). The presence of this cyclicity in previous interglacials, with the same Ice Rafted Debris (IRD) petrology that defines it in the Holocene, indicates that the cyclicity does not reflect ice sheet instability but rather changes in sources of drifting ice, driven by changes in the size and intensity of the subpolar cyclonic gyre possibly related to solar forcing (Bond et al., 2001). The implication is that the 1500 y cycle may have been a dominant feature of the Earth's oceanatmosphere climate over a very long time. How far back in time does the ~1500 y cycle extend? Do Dansgaard/Oeschger cycles simply represent an amplification of this? Do distinct modes of variability persist through other glacial and interglacial intervals? If so, is the pacing always the same or does millennial-scale variability evolve during the late Pleistocene?

The best evidence for the 1500 y cycle during interglacials seems to originate from IRD proxies that monitor changes in the subpolar gyre in the North Atlantic. Our proposed drilling sites are positioned to monitor such changes. The Expedition 303 and 306 sites are located well within or close to the main present-day routes of iceberg transport into the North Atlantic and therefore are well suited to capture faint interglacial signals in shifting ocean surface circulation. Connecting the 1500 y cycle to palaeointensity records, will provide a means of directly comparing both signals with climate records from well outside the North Atlantic.

Drilling operations

The operations schedule for Expedition 306 was based on the original Scientific Prospectus for Expeditions 303/306 (Channel *et al.*, 2004), in consultation with the preliminary results and accomplishments from Expedition 303 (Shipboard Scientific Party 2005). During Expedition 303, drilling at Site U1307

(proposed Site LAB8C) established the feasibility of recovering the older Pliocene-Miocene sedimentary section on the Eirik Drift. Consequently, in addition to proposed primary Sites IRD3A and IRD4A, two sites on Eirik Drift were selected to become the primary expedition sites. Continuous weather observations performed throughout Expedition 306 showed, however, that coring operations on Eirik Drift were not possible at any time because of extremely bad weather conditions in the Labrador Sea. Thus, the alternate proposed Site GAR1B was elevated to a primary site instead. In total, 10 days were lost because of severe weather conditions in the first part of the expedition. Therefore, only three of the planned four sites related to the North Atlantic palaeoceanography study were drilled during Expedition 306: Sites U1312 (proposed Site IRD4A), U1313 (proposed Site IRD3A) and U1314 (proposed Site U1314), located between 40 and 56°N in a water depth between 2800m and 3500m. The coring strategy remained the same as on Expedition 303, consisting of advanced piston coring (APC) utilizing the "drillover" technique to maximize penetration at each site to ensure complete and undisturbed recovery of the stratigraphic section. Non-magnetic core barrels were utilized to preserve the primary sedimentary geomagnetic signal.

Site Summaries

Site U1312

Site U1312, a reoccupation of DSDP Site 608, is located northeast of the Azores islands, on the southern flank of the King's Trough tectonic complex at a water depth of 3554m. It is within the central Atlantic IRD belt and provides a distal record (relative to Expedition 303 Sites) of Laurentide Ice-Sheet instability through Neogene-Quaternary times. The overall objective of Site U1312, therefore, was to explore the phase relationships between surface and deepwater characteristics and ice sheet instabilities as far back as the upper Miocene.

The sediment sampled at the site consists of varying mixtures of biogenic and detrital components, primarily nannofossils, foraminifers, and a clay- to silt-sized clastics. Unfortunately, severe weather conditions meant that only two holes could be drilled and, although recovery in these holes was very good, a complete splice of the entire sedimentary section could only be obtained between 68 and 159 mcd. The upper 68 mcd of Hole U1312A was affected by coring disturbance and below 159 mcd both holes are of high quality but splicing the two records was not possible because of a very uniform sediment composition. At this site, sedimentation rates are quite low, especially in

the late Miocene, the major target at Site U1312 (<1–2 cm/k.y.). Thus, high-resolution studies cannot be performed at this site. The almost-complete sedimentary sequence from Site U1312 representing the last ~11 m.y., however, will allow the study of short- and long-term climate variability and oceanatmosphere interactions under very different boundary conditions, such as the closure and reopening of Atlantic/Mediterranean connections at the end of the Miocene (6–5 Ma), the closing of the Isthmus of Panama (4.5–3 Ma), and the onset of major northern hemisphere glaciation near ~2.7 Ma.

The severe weather conditions that resulted in a premature end to drilling operations at Site U1312 forced the Joides Resolution to spend 8 days sheltering in the lee of the Azores islands, an unprecedented period of 'waiting on weather' in ODP/IODP history. With sanity still intact the ship set sail to Site U1313 in late March. While on route to Site U1313, (-240 miles northwest of the Azores Islands) sea-state conditions were still somewhat marginal but continuously improved over time.

Site U1313

Site U1313 is a reoccupation of DSDP Site 607, and is located at the base of the upper western flank of the Mid-Atlantic Ridge at a water depth of 3426m. DSDP Site 607, together with DSDP Site 609 re-drilled during Expedition 303, is a benchmark site for longterm (millions of years), as well as short-term surface and deep ocean climate records from the subpolar North Atlantic. These sites, today situated under the influence of the NADW, have been very important for generating benthic d18O and d13C records for the Pleistocene (Ruddiman et al., 1989, Raymo et al., 2004)), the Late Pliocene (Ruddiman et al., 1986; Raymo et al., 1989) and for interpreting these records in terms of ice sheet variability and changes in NADW circulation.

The sediment recovered at Site U1313 consists primarily of nannofossil ooze with varying amounts of foraminifers and clay- to gravel-sized terrigenous components. Four holes were drilled, permitting the generation a composite splice (0-250 mcd) spanning the Pliocene-Pleistocene. Correlation between the holes was excellent in the upper ~170 mcd because of pronounced variations in nearly all physical properties measured. In particular, Lightness (L*) from colour reflectance measurements mimics variations in the global benthic oxygen isotope stack during the last 3.4 Ma (Lisiecki and Raymo, 2005) and a preliminary age model was constructed by matching sharp L* variations with glacial and interglacial transitions back to Marine Isotope Stage MG1. This age-model, together with bio- and magnetostratigraphy, indicate nearly

constant sedimentation rates of ~4-5 cm/k.y. throughout the Pliocene–Pleistocene time interval, whereas in the late Messinian sedimentation rates were ~13–14 cm/k.y. Moreover, of special note is the consistent linear correlation of downhole natural gamma radiation (upper 225 mbsf) with the recent Lisiecki and Raymo (2005) benthic oxygen isotope record during the last 5.4 m.y. The consistency of downhole logging data with both core data and benthic oxygen isotope stack will allow mapping of the spliced core record to actual depth, resulting in more accurate sedimentation rate calculations as well as more detailed age-depth models.

Real-time ship-board alkenone-derived sea surface temperatures show variability from ~13° to 19°C during the Pleistocene, whereas temperatures of ~20° and 22°C are obtained for the Late Pliocene and the latest Miocene, respectively. Given the sedimentation-rates, this site will allow an optimal reconstruction of the phasing of the temperature records and its relationship to ice sheet instability and changes in deepwater circulation at a (sub)millennial-scale throughout the last 5 m.y. High sedimentation rates of 13–14 cm/k.y. will allow a high-resolution study of palaeoenvironmental change during the late Messinian.

Site U1314

Site U1314 was drilled on the southern Gardar Drift in a water depth of 2820m in early April. This site is close enough to the IRD belt to record Heinrich-type detrital layers that monitor ice sheet instability; in addition, its water depth makes it suitable for a high-resolution monitoring of NADW and its short-term (sub)millennial variability. Site U1314 was not in the initial plan for Expedition 306, but was occupied when proposed drilling of the Eirik Drift was not possible due to extremely bad weather conditions in the Labrador Sea.

A complete Upper Pliocene to Holocene sequence, characterized by high sedimentation rates of 7 to >11 cm/k.y., was recovered The sedimentary sequence consists of an alternation of predominantly nannofossil oozes enriched in biogenic and terrigenous components, and terrigenous silty clay with varying proportions of calcareous and siliceous organisms. This alternation is also reflected in the carbonate content which varies between ~5 and 70 wt-%. Sand- and gravel-sized sediment, common at Site U1314 from 0 to 240 mbsf, provides direct evidence of ice rafting and documents the influence of Pliocene-Pleistocene glaciations on this region. Mafic igneous and felsic igneous dropstones, as well as sand-sized, hematite-stained quartz suggest Iceland and Greenland as probable source areas of the IRD material. The mcd

scale is well resolved, and the spliced section is complete down to 281 mcd. The sediment yields abundant moderately well to wellpreserved assemblages of calcareous and siliceous microfossils throughout the section and an excellent palaeomagnetic record of the Brunhes, Matuyama, and the upper part of the Gauss Chrons. Even several short geomagnetic reversals are present in the palaeomagnetic record, indicating that an environmental record of sea-surface and bottom water characteristics and a detrital (Heinrich type) stratigraphy for the past ~2.7 m.y can be placed into a reliable and precise PAC.

Site U1315

Site U1315 was reached by mid-April after a ~1200 nmi transit from Site U1314. At this site, a borehole observatory was successfully installed in a new hole ~180m deep close to ODP Site 642, consisting of a CORK to seal the borehole from the overlying ocean and a thermistor string/data logger unit to document bottom water temperature variations and monitor its subbottom diffusion over a 5 y period. To assess current background thermal conditions in the region, logging down to almost 600 mbsf was performed in Hole 642E using the TAP tool in combination with the triple combo and the FMSsonic tool strings. The upper 10m of the borehole has a very steep thermal gradient (~2500°C/km). Below this depth, the borehole has a relative low gradient of ~22°C/ km. At a depth of ~500 mbsf, a strong positive temperature excursion to ~42°C may indicate inflow. The downhole logging in Hole 642E was extremely useful and another highlight of the expedition. FMS logging yielded very good results and allows correlation to existing core data (from ODP Leg 104) and filling of coring gaps (60% of the formation!). Together with the other downhole logging data, detailed information about permeability, fluid flows, and temperature gradients of the area will be available.

Although the weather in early spring provided a challenging environment in which to perform drilling operations in the North Atlantic (10 days were lost to severe weather conditions in the first part of the expedition, and three sites drilled instead of the planned four), Expedition 306 was completed successfully and the objectives outlined fulfilled. More than 2.3km of high quality sediment cores were recovered at the three sites. From the multidisciplinary (i.e., sedimentological, micropalaeontological, and geochemical) studies to be performed on these cores (together with cores from Expedition 303) in the coming years, new milestones in the understanding of mechanisms and causes of abrupt climate change as one of the major challenges in global climate change research

today are expected to be reached. In addition, the successful installation of a CORK with a 150m thermistor string in a cased borehole close to ODP Site 642 will provide for the first time a directly measured record of bottom water temperatures over approximately the last 100 y from a palaeoceanographically very important key area of the North Atlantic.

References

BOND et al., 1999, Geophysical Monograph Series, 112: 35-58

BOND et al., 2001, Science, 294: 2130-2136. doi:10.1126/science.1065680

CHANNELL, J E T. et al., 2004 IODP Scientific Prospectus, 303/306. http://iodp.tamu.edu/publications/SP/303306SP. PDF

EXPEDITION SCIENTISTS (2005). IODP Preliminary Report, 306. doi:10.2204/IODP.PR.306.2005

GUYODO and VALET, 1996 Earth and Planetary Science Letters, 143:23–36. doi:10.1016/0012-821X(96)00121-5

LAJ et al., 2000. Philosophical Transactions of the Royal Society of London, 358: 1009-1025.

LISIECKI and RAYMO, 2005, Paleoceanography, 20, doi:10.1029/2004PA001071.

RUDDIMAN et al., 1986, Earth and Planetary Science Letters, 80:117–129, doi:10.1016/0012-821X(86)90024-5

RUDDIMAN et al., 1989 Paleoceanography, 4:353–412.

RAYMO et al., 1989, Paleoceanography, 4:413–446.

RAYMO et al., 2004, *Paleoceanography*, 19. doi:10.1029/2003PA000921

SHIPBOARD SCIENTIFIC PARTY, 2005 IODP Preliminary Report, 303. http://iodp.tamu.edu/publications/PR/303PR/30 3PR.PDF

STONER et al., 2000. Earth and Planetary Science Letters, 183: 161-177. doi:10.1016/S0012-821X(00)00272-7

Drilling recent deep-water coral banks: Expedition 307, Porcupine Basin Carbonate Mounds

Veerle A I Huvenne (NOCS), Barry A Cragg (Cardiff University) and the Expedition 307 Shipboard Scientific Party

onday, 2 May 2005, 22.00h. The crew and scientific party on board the JOIDES Resolution, although still processing cores from the previous hole, are preparing for an historical moment in deep-sea research: the first ever scientific drilling operation on a recent deep-water carbonate mound.

Carbonate mounds are structures known from several locations around the world, and have occurred at several periods in geological history. They are often studied, even to microscopic detail, in the fossil record (e.g. Riding, 2002). However, so far not many modern analogues have been investigated. The drilling in the Porcupine Seabight created a unique opportunity.

Background: mounds and deep-water corals

The presence of large mounds on the seabed of the Porcupine Seabight has been known for a long time. In 1948, for example, Le Danois described large 'massifs coralliens' in the area. However, scientific interest in the topic was only renewed fairly recently, in the wake of hydrocarbon exploration moving into deeper waters. Hovland et al. (1994) were the first to publish seismic profiles picturing the mound structures of up to 150 m high and more than 1500 m long. This initiated a significant scientific interest, expressed by a large number of national and international projects (e.g. the suite of EU 5th Framework projects GEOmound, ECOmound and ACES). The mounds were studied with a wide range of techniques, including multibeam bathymetry (Beyer et al., 2003), sidescan sonar (Huvenne et al., 2005), high resolution 2D- and industrial 3D-seismics (De Mol et al., 2002; Huvenne et al., 2003; Van Rooij et al., 2003), several types of coring operations (Dorschel et al., 2005; Rueggeberg et al., 2005), video surveys and ROV operations (Foubert et al., 2005; Wheeler et al., 2005). Through the large number of resulting datasets, the mounds could be characterised to a certain extent. It appeared that all mounds are seated on a clear unconformity, and both simple, conical and more complex, elongated morphologies were found. Some mounds, especially in the Magellan mound province (Figure 1), are now buried, while others still partly protrude above the present-day seabed. Deep-water corals such as Lophelia pertusa (L.) (Figure 2a) and Madrepora oculata (L.) were encountered on

their flanks and tops, and coral pieces were found in the upper 10 to 20 m of the mounds using traditional piston and gravity coring techniques. Corals and coral reefs are generally associated with shallow tropical waters, but extensive research during the last decade has shown that deep-water, ahermatypic coral types, which are filter-feeders and do not live in symbiosis with algae, can also build up large structures on the seabed (e.g. Freiwald and Roberts, 2005). Although our understanding of these large mound structures has increased quickly over the last decade, no one has been able to characterise the nature of the mound base and of the mounds internally. This lack of information has left much debate about the mound origin and initial build-up processes.

Hypotheses and objectives

In the hypothesis originally presented by Hovland *et al.* (1994), the mounds were linked to hydrocarbon migration from greater depth. Different mechanisms of migration have since been proposed by different authors, such as seepage along faults or through the broken-up strata of a buried submarine slide (e.g. Hovland *et al.*, 1994; Henriet *et al.*, 2001; 2002; Naeth *et al.*, 2005). Essentially,



Figure 1. Overview map of the Porcupine Basin, indicating the target sites for IODP Expedition 307 and the 3 mound provinces in the area. Figure after Expedition Scientists (2005).



the different authors suggest that migrated hydrocarbons could initiate a range of microbial processes and/or that microbial communities could form the base of a food chain to which the corals would also belong. Over a sequence of different phases, possibly involving different biota and processes (e.g. microbial mats, bryozoans and/or in the final stage deep-water corals), a mound would be formed and stabilised (Henriet *et al.*, 2002). Additionally, methane seepage could cause the formation of authigenic carbonates that could act as settling grounds for the deep-water corals.

As an alternative hypothesis, it was suggested that the mounds in the Porcupine Seabight may be entirely built up by deepwater corals, their growth and formation being controlled by environmental parameters such as nutrient input and the interaction of current speed and sediment dynamics (De Mol et al., 2002). Deep-water corals prefer areas with enhanced current velocities that can increase the nutrient flux and keep the polyps of the filter-feeders free of sediments (Freiwald, 2002). Enhanced currents of tidal frequencies have been registered in the Porcupine Seabight (Pingree and Le Cann, 1989). They may result from internal tides, enhanced at the boundary between water masses with different densities, such as the Mediterranean Outflow Water (MOW) and Eastern North Atlantic Water (ENAW) at ca. 800 m depth. It is possible that a paleoceanographic change-over, such as the re-entry of the MOW in the NE Atlantic in the Late Pliocene caused a period of erosion and non-deposition, and later on triggered the correct conditions for the initiation of the coral growth (De Mol et al., 2005). Further mound development would then have been due to sediment baffling between the coral

Figure 2. Coring deep-water corals. (a) Live Lophelia pertusa recovered from the Porcupine Seabight (photo courtesy A. Freiwald); (b) Well-preserved fossil coral fragments in a muddy matrix (floatstone), showing variations in coral density over short intervals. This core section was split in frozen state. (c) Coral packstone overlying wackestone. The matrix contains a higher amount of CaCO3, which may indicate different environmental conditions during the mound build-up and/or different amounts of dissolution. (d) The firmground representing the mound base under Challenger Mound, overlain by ca. 2 cm of packstone, followed by floatstone. The coral fragments in the latter are partly shattered, also due to the core splitting (using the rock saw on a non-frozen section).

framework, and to further coral growth to stay ahead of this sediment deposition. Studies on shallow cores showed that glacial/interglacial cycles most probably affected the coral growth and mound formation (Dorschel, 2003; Rueggeberg *et al.*, 2005)

Monday, 2 May 2005, 23.45h. With the wellknown shipboard announcement 'core on deck, core on deck', the first core drilled on Challenger Mound in the Belgica mound province arrives on the catwalk of the Joides Resolution. It contains coral fragments embedded in a muddy matrix. Although corals were also encountered in shallow piston and gravity cores on different mounds in the Porcupine Seabight, everybody on board is excited about this finding. A major question now is how much of Challenger Mound consists of this facies, and if any major changes will be encountered further downhole.

Considering the debate described above, the IODP Leg 307 gave the unique opportunity

to answer some of the most prominent questions about the Porcupine Carbonate Mounds. The actual drilling objectives included the following (Expedition Scientists, 2005):

- Establish whether the mound base rested on a carbonate hardground of microbial origin and whether past geofluid migration events acted as a prime trigger for mound genesis.
- Define the relationship, if any, between mound initiation, mound growth phases, and global oceanographic events.
- Analyze geochemical and microbiological profiles that define the sequence of microbial communities and geomicrobial reactions throughout the drilled sections.
- 4. Examine high-resolution paleoclimatic records from the mound section using a wide range of geochemical and isotopic proxies.
- Describe the stratigraphic, lithologic, and diagenetic characteristics, including timing of key mound-building phases, for establishing a depositional model of deepwater carbonate mounds and for investigating how they resemble ancient mud mounds.

The drilling strategy consisted of 3 sites in an across-slope transect, containing one drill site on Challenger Mound in the Belgica province, one site just downslope of this as a comparison, and one site further upslope to investigate the overall sedimentation in the area (Figures 1 and 3). Previous site surveys on Challenger Mound had shown that this

Figure 3. Lithostratigraphy of the 3 sites projected on an interpreted seismic profile of Challenger Mound (figure from Expedition Scientists, 2005; seismic interpretation after De Mol et al., 2002).



mound is 'dead' in a sense that no living communities of deep-water corals and associated fauna were found on its flanks or top. This made it a suitable target for drilling operations, as it was also unlikely that pockets of methane would be encountered causing a safety problem.

Practical matters: Leg 307 peculiarities

Tuesday, 3 May 2005, 7.20h. On site U1317, hole A, the drilling operations have now advanced to 92 mbsf. The 10 cores recovered so far each contained coral fragments, in varying densities.

Expedition 307 was a so-called mini-leg: it took 'only' 18 days. The original proposal for the area was more extensive, but it was scaled down to the most essential operations, which allowed swift and adaptable planning, and resulted in a maximum amount of new information obtained in a record short time. The cruise was like many IODP cruises- very intensive, also due to the fact that the target sites were located in relatively shallow water depths (up to 960 m) and were closely spaced, so transit times were reduced to a minimum. The weather stayed fine for the entire cruise, which meant the operations could continue without downtime. Before the cruise there was concern about possible limited core recovery on the mound site because the exact nature of the material to be drilled was not known, but the results were more than impressive: more than 100% recovery in the interval above the mound base, and a total of 1530 m drilled, with 1398 m recovered, in 12 days.

Compared to a 'standard' IODP cruise, there were some more unusual aspects. The core flow was altered in a significant way. First of all, upon arrival on deck, every core was checked for the presence of corals, while headspace gases were checked as quickly as possible for the presence of light hydrocarbons and/or H₂S. Furthermore, at regular intervals (generally once per core within one hole per site) entire 1 or 1.5 m sections were taken away immediately into the 10°C reefer, where they were cut into WRC of varying lengths and stored in the correct way for a variety of microbiological analyses. Generally, they were packed into gas-tight aluminium bags with a chemical oxygen scrubber and stored at 10°C. This is because many deep sediment prokaryotes respond to temperature changes and most are poisoned by oxygen. The samples will be used for, amongst others, rateprocess work investigating methanogenesis using 14C radiotracers and assessing prokaryote growth rates using tritiated thymidine. In addition microbial diversity using 16SrRNA and DGGE plus the presence of functional gene 'mcrA' for methanogenesis are being



Figure 4. Microbiological results at mound flank Site U1316, (a). Prokaryote depth profile. Dotted line and two dashed lines represent the global sediment prokaryote profile and 95% prediction limits respectively (Parkes et al, 1994), Blue dots on the y-axis indicate samples that have yet to be processed. (b). Dividing cells profile. (c). Geochemical profiles of sulphate (red) and methane (green).

investigated. Due to the short length of the cruise, combined with the rapid acquisition of core, there was very little time during the leg to process samples and generate data. However, basic geochemistry was obtained from the interstitial water and gas samples taken from each core, and a limited amount of microbiology was obtained from small samples taken on the catwalk as the core sections were being cut.

Additionally, as microbiology was an important component of this leg, the geochemists and microbiologists also undertook contamination studies using a perfluorocarbon tracer and fluorescent microbeads respectively to determine if core material could be contaminated by seawater and, more importantly, the prokaryotes contained within the seawater. This was particularly important where there were large amounts of coral fragments in the sediments as these tended to make the cores looser and the lumens within the coral branches acted as conduits for seawater into the interior of a core.

Finally, except for Holes U1317A and D, the cores recovered from the mound were frozen to -50° C before being split. Using a cheese-wire to split cores containing rigid coral fragments in a muddy matrix results in severe core disturbance, while splitting such cores with a rock saw causes the coral fragments to shatter. Splitting the cores in a frozen state gives much better results, but it also complicates and slows down the workflow. Due to the short time-frame of the cruise, most of the frozen cores were split on land.

Results

Tuesday, 3 May 2005, 10.55h. Core 14H of hole 1317A comes on board. Finally the base of the mound is reached, and at least one of the questions is solved : the entire mound, here 130 m deep, consists of coral-bearing strata.

Some first results have been obtained on board already; they are described in the Preliminary Report (Expedition Scientists, 2005). Challenger Mound consists of an accumulation of at least 155 m of coralbearing floatstone, packstone, wackestone and rudstone, in strata of varying thickness and varying degrees of coral preservation, and with a carbonate content ranging from 16 to 75% (Figure 2). However, the most remarkable observation is that the entire mound is largely unlithified, with only small amounts of the wackestone facies showing limited lithification. Within the mound, at least 10 successions of coral-bearing strata can be identified, which may correspond to different phases of coral growth. They can also be recognised in some



Figure 5. Microbiological results at mound Site U1317, (a). Prokaryote depth profile. Dotted line and two dashed lines represent the global sediment prokaryote profile and 95% prediction limits respectively (Parkes et al, 1994), Blue dots on the y-axis indicate samples that have yet to be processed. (b). Dividing cells profile. (c). Geochemical profiles of sulphate (red) and methane (green).

of the physical properties measured on the mound core sections (e.g. natural gamma radiation, magnetic susceptibility and gamma density). It is possible that they are related to glacial/interglacial cycles, but further study is necessary to confirm this.

The mound initiated on a sharp erosional unconformity, expressed by a firmground and a strong hiatus in the biostratigraphy. This horizon corresponds to the unconformity identified on the seismic profiles, and was encountered in the cores from all three sites. The interval of the hiatus under the mound was estimated at longer than 1.65 Ma, ranging from the early Pliocene to the early Pleistocene. No hardgrounds or authigenic carbonates were encountered. Overall, no indications were found on board for a possible role of hydrocarbons in the initiation or subsequent formation of Challenger Mound, and no significant quantities of hydrocarbons were found in the mound or sub-mound sediments.

The unit below the mound base consists of glauconitic and in some places sandy siltstones of Miocene to Pliocene age. Its carbonate content increases with depth. At some specific locations lithified layers are encountered, caused by dolomite precipitation. They can easily be recognised in the physical property data and the downhole logs by the increased p-wave velocity and density values.

Just beside Challenger Mound, at Site U1316, we first recovered the drift sediments (containing variable amounts of dropstones) in which the mound is partly embedded (Figure 3). They consist of silty clays, including finingupwards sandy beds in the lower subunit. Also the physical properties are typical for siliciclastic-rich sediments. However, below 40-45 mbsf, a 10-13 m thick coral-bearing unit was found, resting on the mound base unconformity (located at 52-58 mbsf). The floatstones in the lowest part may represent corals being buried in situ, indicating that Challenger Mound may have initiated on a rather broad base. The upper part of the coralbearing unit, however, most probably contains a deposit that originated from mass wasting on the steep mound flanks (Figure 3).

At the upslope off-mound site, U1318, a sediment drift package was encountered similar to that found at U1316. It is followed by 4-6 m of fine sands interbedded with silty clays that rest unconformably on what can be interpreted as the continuation of the mound base unconformity (at ca. 86 mbsf, Figure 3). This boundary is further marked by a basal conglomerate and a 10-20 cm thick oyster bed. Below the boundary, this upslope site also penetrated a seismically low-amplitude layer, which appears to be eroded away below Challenger Mound, and which may contain more paleo-environmental information of the pre-mound period.

Concerning the microbiology, prokaryote numbers near the surface at Site U1316 on the flank of the mound (Figure 4) were what would be expected from the global profile (Parkes et al, 1994). However, from around 50 mbsf they decreased rapidly and at the same time numbers of dividing cells (a measure of population growth rates) declined to zero, indicating that this was an unusually moribund zone. Low prokaryote activity can also be inferred from the very gradual decrease in sulphate concentrations with depth. In high activity sediments sulphate may be completely removed in the upper few metres. It is likely that the prokaryotes are organic carbon limited, as the population and numbers of dividing cells both increase significantly at the sulphate-methane transition zone at around 80 mbsf when methane becomes available to the prokaryotes. It is likely that anaerobic oxidation of methane (AOM) and methanogenesis are the dominant processes here

On the mound itself, Hole U1317A, the prokaryote profile was initially unusually low, following the lower prediction limit of the global profile (Figure 5). From about 65 mbsf prokaryote numbers indicated a trend of gradual increase. The reason for the "bump" in the profile between 35 and 65 mbsf is not yet understood, although, as it correlates with a significant increase in dividing cell numbers, it is clearly a response to something. The base of the mound is at 130 mbsf and this is also the depth of the sulphate/methane transition zone. Like the mound flank site, it seems that the prokaryotes in the mound are in relatively nutrient poor conditions. As soon as methane becomes available to them the population size increases more rapidly, passing above the global profile, and there is a substantial rise in the numbers of dividing cells from the zero percent observed just above the mound base. Unfortunately there was insufficient time to process all of the prokaryote count samples (Figure 5) so at the moment we have little data from below the mound base.

Overall these dead carbonate mounds seem to be ailing microbiologically. Prokaryote numbers are low, growth rates are often low or non-existent, sulphate reduction rates seem to be low and methanogenesis rates will probably be low as well. However, we are currently just at the start of the laboratory work on these samples and so it is not possible to draw any final conclusions yet.

Further work

The first drilling on a recent deep-water carbonate mound showed a unique system of high carbonate deposition in an essentially

siliciclastic sedimentary environment. The Porcupine mounds partly resemble the buried bryozoan mounds drilled during ODP Leg 182 (James et al., 2000), but the Porcupine Seabight does not contain carbonate platforms like the Great Australian Bight. Hence the deep-water corals keep amazing us, not only because they live in the cold and deep ocean, but also due to the fact that they build/concentrate a carbonate system outside the photic zone, apparently without the help of a microbial system or migrating geofluids. Extensive and in-depth further study now is necessary to fully understand this phenomenon. For example, until we have run the full suite of microbial investigations in sediment samples from within, below and around the mound, we will not understand the extent of the involvement of prokaryotes in mound formation. As we write, the scientific party of Leg 307 has just started work on additional core description and on core sampling at the new Core Repository in Bremen. The short time-frame of the cruise and the decision to freeze the coral cores made most sampling on board impossible. We now are only at the start of a wide range of detailed studies on the on-mound and off-mound facies, looking at the mound base, at carbonate chemistry, at microbial signatures, at isotopes, dating, climatic signals and more.

References

BEYER, A, SCHENKE, H W, KLENKE, M, and NIEDERJASPER, F. (2003). High resolution bathymetry of the eastern slope of the Porcupine Seabight. Marine Geology, Vol. 198, 27-54.

DE MOL, B, VAN RENSBERGEN, P, PILLEN, S, VAN HERREWEGHE, K, VAN ROOIJ, D, MCDONNELL, A, HUVENNE, V, IVANOV, M, SWENNEN, R, and HENRIET, J P. (2002). Large deep-water coral banks in the Porcupine Basin, southwest of Ireland. Marine Geology, Vol. 188, 193-231.

DE MOL, B, HENRIET, J P, and CANALS, M. (2005). Development of coral banks in the Porcupine Seabight: do they have Mediterranean ancestors. 515-533 in Cold-water corals and ecosystems. FREIWALD, A, and ROBERTS, J M. (Editors). (Springer-Verlag: Heidelberg)

DORSCHEL, B. (2003). Late Quaternary development of a deep-water carbonate mound in the Northeast Atlantic. PhD thesis, University of Bremen, 87pp.

DORSCHEL, B, HEBBELN, D, RUEGGEBERG, A, DULLO, W C, and FREIWALD, A. (2005). Growth and erosion of a cold-water coral covered carbonate mound in the Northeast Atlantic during the Late *Pleistocene and Holocene. Earth and Planetary Science Letters, Vol. 233, 33-44.*

EXPEDITION SCIENTISTS (2005). Modern carbonate mounds: Porcupine drilling, IODP Preliminary Report, 307, 58pp.

FOUBERT, A, BECK, T, WHEELER, A J, OPDERBECKE, J, GREHAN, A, KLAGES, M, THIEDE, J, HENRIET, J P, and SHIPBOARD PARTY. (2005). New view of the Belgica Mounds, Porcupine Seabight, NE Atlantic: preliminary results from the Polarstern ARK-XIX/3a ROV cruise. 403-415 in Coldwater corals and ecosystems. FREIWALD, A, and ROBERTS, J M. (Editors). (Springer-Verlag: Heidelberg)

FREIWALD, A, and ROBERTS, J M (Editors). (2005). Cold-water corals and ecosystems. (Springer-Verlag: Heidelberg)

HENRIET, J P, DE MOL, B, VANNESTE, M, HUVENNE, V, VAN ROOIJ, D, and THE 'PORCUPINE-BELGICA' 97, 98 AND 99 SHIPBOARD PARTIES. (2001). Carbonate mounds and slope failures in the Porcupine Basin: a development model involving fluid venting. 375-383 in The petroleum geology of Ireland's offshore basins. SHANNON, P M, HAUGHTON, P D W, and CORCORAN, D V (Editors.). Special Publication of the Geological Society of London, No. 188.

HENRIET, J P, GUIDARD, S, and THE ODP "PROPOSAL 573" TEAM. (2002). Carbonate mounds as a possible example for microbial activity in geological processes. 439-455 in Ocean margin systems. WEFER, G, BILLET, D, HEBBELN, D, JØRGENSEN, B B, SCHLÜTER, M, and VAN WEERING, T (Editors). (Springer-Verlag: Heidelberg)

HOVLAND, M, CROKER, P F, and MARTIN, M. (1994). Fault-associated seabed mounds (carbonate knolls?) off western Ireland and north-west Australia. Marine and Petroleum Geology, Vol. 11, 232-246.

HUVENNE, V A I, BEYER, A, DE HAAS, H, DEKINDT, K, HENRIET, J P, KOZACHENKO, M, OLU-LE ROY, K, WHEELER, A J, and THE TOBI/PELAGIA 197 AND CARACOLE CRUISE PARTICIPANTS. (2005). The seabed appearance of different coral bank provinces in the Porcupine Seabight, NE Atlantic : results from sidescan sonar and ROV seabed mapping. 535-569 in Cold-water corals and ecosystems. FREIWALD, A, and ROBERTS, J M. (Editors). (Springer-Verlag: Heidelberg)

HUVENNE, V A I, DE MOL, B, and HENRIET, J P. (2003). A 3D seismic study of the morphology and spatial distribution of buried coral banks in the Porcupine Basin, SW of Ireland. Marine Geology, Vol. 198, 5-25. JAMES, N P, FEARY, D A, SURLYK, F, SIMO, J A, BETZLER, C, HOLBOURN, A E, LI, Q, MATSUDA, H, MACHIYAMA, H, BROOKS, G R, ANDRES, M S, HINE, A C, MALONE, M J, and ODP LEG 182 SCIENCE PARTY. (2000). Quaternary bryozoan reef mounds in cool-water, upper slope environments: Great Australian Bight. Geology, Vol. 28, 647-650.

LE DANOIS, E. (1948). Les profondeurs de la mer. (Payot: Paris)

NAETH, J, DI PRIMIO, R, HORSFIELD, B, SCHAEFER, R G, SHANNON, P M, BAILEY, W R, and HENRIET, J P. (2005). Hydrocarbon seepage and carbonate mound formation: a modelling study from the Porcupine Basin (offshore Ireland). Journal of Petroleum Geology, Vol. 28, 147-166

PARKES, R J, CRAGG, B A, BALE, S J, GETLIFF, J M, GOODMAN, K, ROCHELLE, P A, FRY, J C, WEIGHTMAN, A J, and HARVEY, S M. (1994). A deep bacterial biosphere in Pacific Ocean sediments. Nature, Vol. 371, 410-413.

PINGREE, R D, and LE CANN, B. (1989). Celtic and Armorican slope and shelf residual currents. Progress in Oceanography, Vol. 23, 303-338.

RIDING, R. (2002). Structure and composition of organic reefs and carbonate mud mounds: concepts and categories. Earth-Science Reviews, Vol. 58, 163-231.

RUEGGEBERG, A, DORSCHEL, B, DULLO, W-C, and HEBBELN, D. (2005). Sedimentary patterns in the vicinity of a carbonate mound in the Hovland Mound Province, northern Porcupine Seabight. 87-112 in Cold-water corals and ecosystems. FREIWALD, A, and ROBERTS, J M. (Editors). (Springer-Verlag: Heidelberg)

VAN ROOIJ, D, DE MOL, B, HUVENNE, V, IVANOV, M, and HENRIET, J P. (2003). Seismic evidence of current-controlled sedimentation in the Belgica mound province, upper Porcupine slope, southwest of Ireland. Marine Geology, Vol. 195, 31-53.

WHEELER, A J, KOZACHENKO, M, BEYER, A, FOUBERT, A, HUVENNE, V A I, KLAGES, M, MASSON, D G, OLU-LE ROY, K, and THIEDE, J. (2005). Sedimentary processes and carbonate mounds in the Belgica mound province, Porcupine Seabight, NE Atlantic. 571-603 in Cold-water corals and ecosystems. FREIWALD, A, and ROBERTS, J M. (Editors). (Springer-Verlag: Heidelberg)

IODP Expedition 308: Gulf of Mexico Hydrogeology, Overpressure and fluid flow processes in the deepwater Gulf of Mexico: slope stability, seeps, and shallow-water flow

Valentina Zampetti (Vrije University, Amsterdam) and Expedition 308 Scientists

ntegrated Ocean Drilling Program (IODP) Expedition 308 is the first part of a two component program dedicated to the study of overpressure and fluid flow on the Gulf of Mexico continental slope examining how sedimentation, overpressure, fluid flow, and deformation are coupled in passive margin settings (Expedition 308 Scientists, 2005). This IODP expedition tested a multidimensional flow model by investigating how physical properties, pressure, temperature, and pore fluid chemistry vary within lowpermeability mudstones that overlie a permeable and overpressured aquifer. We drilled, logged, and made in situ measurements in a reference location where little overpressure was predicted: the Brazos-Trinity Basin#4 (Sites 1319, 1320 and 1321; Figures1 and 2). We contrasted these measurements with experiments performed in a region of very rapid Pleistocene sedimentation where overpressure was predicted: the Ursa region of the northern Gulf of Mexico (Sites 1322, 1323 and 1324 Figures1 and 3). Rapid sediment loading (>1 mm/y) drives overpressure (P*; pressure in excess of hydrostatic) in basins around the world (Fertl, 1976; Rubey and Hubbert, 1959). Sedimentation is so rapid that fluids cannot escape, the fluids bear some of the overlying sediment load, and pore pressures are greater than hydrostatic (Expedition 308 Scientists, 2005). Recent work has focused on how sedimentation and common stratigraphic architectures couple to produce two- and three-dimensional flow fields. For example, if permeable sand is rapidly loaded by a lowpermeability mud of varying thickness, fluids flow laterally to regions of low overburden before they are expelled into the overlying sediment. This will create characteristic distributions of rock properties, fluid pressure, effective stress, temperature, and fluid chemistry in the aquifers and bounding mudstones. This simple process can cause slope instability near the seafloor (Dugan and Flemings, 2000; Flemings et al., 2002); in the deeper subsurface, this process drives fluids through low-permeability strata to ultimately vent them at the seafloor (Boehm and Moore, 2002; Davies et al., 2002; Seldon and Flemings, 2005).

Expedition 308 science met many of the objectives proposed in the original IODP Proposal 589-Full3 and provided the



Figure 1. Bathymetric image of the continental slope of the Gulf of Mexico. Proposed drilling was in the Brazos-Trinity region and the Ursa region.

foundation to implement long-term in situ monitoring experiments in the aquifer and bounding mudstones in a future expedition designed to meet the full objectives of IODP Proposal 589-Full3. An important achievement of Expedition 308 is to have successfully recorded in situ formation pressure and temperature in an overpressured basin. This is the first time that we know of that such measurements have been obtained. The expedition achievements can be better summarized following the six original scientific objectives of the original proposal:

1. Document how pressure, stress, and geology couple to control fluid migration on passive margins.

Our goal was to establish the vertical and lateral variation in pressure and rock properties above the Blue Unit to test the flow-focusing model and image the flow system within the mudstone capping the Blue Unit. A fundamental achievement of the expedition is that we established the overpressure profile as a function of depth at two key locations in Ursa basin: Site U1322 and U1324. These measurements were difficult and we had a high failure rate; however, ultimately we acquired enough data to constrain the

overpressure field above the Blue Unit. To our knowledge, this is the first time in DSDP/ODP/IODP history that the spatial variation of the pressure field has been documented at this resolution. Previous deployments of the DVTPP generally yielded only single measurements in boreholes. We also acquired an extraordinary temperature data set that documented striking differences in temperature gradient between Sites U1322 and U1324. We also took an extensive amount of whole core for geotechnical analysis. Geotechnical experiments on these cores will further constrain the in situ pressure through analysis of the preconsolidation stresses. Modeling of the DVTPP and T2P pressure dissipation profiles will also further constrain the pressure field. Our initial observations suggest both lateral and vertical flows are present within the Blue Unit. A fundamental result is that the pressure gradients at the two sites (U1322 and U1324) are similar despite the large difference in sedimentation rate at these locations. We infer that the hydrodynamic flow field within the Blue Unit is more complicated than originally envisioned. Ultimately, to understand the flow field within and around the Blue Unit, it will be necessary to sample the pressures within the



Figure 2. Bathymetric chart of Brazos-Trinity Basin #4 showing locations of three drilled sites.



Figure 3. Bathymetric image of the Ursa region pointing out the location of Sites U1322, U1423, and U1324.

Blue Unit sands. We acquired whole core at Sites U1322 and U1324, LWD/MWD logs at Site U1322, U1323, and U1324, and wireline logs at Site U1324. These data will be used to accurately constrain the variation in rock properties across Ursa Basin. All objectives were met at Sites U1322 and U1324. Because we encountered shallow-water flow at Site U1323, we were unable to core at this location. LWD/MWD, wireline logging, and coring proceeded with extraordinary efficiency despite the fact we were drilling in zones of significant overpressure.

2. Establish reference properties at Brazos-Trinity Basin #4.

We wanted to establish reference logging and core properties at a location where overpressure is not present at a range of effective stresses in the Brazos-Trinity Basin. Coring and logging were successful at the Brazos-Trinity Basin #4 locations. However, only a limited number of pressures were measured due to early struggles with the DVTPP and T2P. An intriguing result is that the mudstones beneath Brazos-Trinity Basin #4 (Site U1319) may be overpressured. If Site U1319 is overpressured, then Sites U1319 and U1320 will provide important examples of a normally pressured location (Site U1319) and overpressured location (Site U1320) in the same location.

3. Illuminate the controls on slope stability. We wanted to determine pore pressure, rock properties, and overburden stress to predict the potential for slope failure and estimate the conditions that drove previous slope failures. We gained a beautiful suite of data (whole core for geotechnical analysis, in situ pressures, and logs) across the failure surfaces. A striking result is the high degree of consolidation that is present within the slumped units. A major component of the shore-based science will study the geometry, physical properties, timing, and pressures associated with these slumps.

4. Understand timing of sedimentation and slumping.

We wanted to establish the age of sediments in Brazos Trinity Basin #4 and Ursa Basin.

Our preliminary results suggest that the Brazos Trinity Basin #4 sediments span MIS VI to present, whereas the Ursa mudstones are <70 ka. At Brazos Trinity Basin #4, slumping, turbidite deposition, and sea level change were tightly linked. Dramatically high sedimentation rates were documented in Ursa Basin. Shore-based research will further constrain the chronostratigraphy of these systems.

5. Establish geotechnical and petrophysical

properties of shallow sediments.

We wanted to break new ground in understanding geotechnical and petrophysical properties of shallow sediments (0-1000 mbsf). To support and complement core observations and laboratory measurements, we derived a complete logging suite, in situ measurements of pressure, and whole-core geotechnical samples. We will use these data to understand the compaction process near the seafloor and the evolution of overpressure during sedimentation. The ultimate scientific impact of acquiring these data will unfold in the years ahead. However, the Expedition 308 data set represents a linked data set that has the potential to provide unparalleled insight into mudstone permeability and rheology.

6. Provide an extraordinary data set to observe ponded and channelized turbidite systems. Expedition 308 sampled the ponded turbidite system at Brazos Trinity Basin #4 and the channelized systems present in Ursa Basin. These data are of great interest to both academic and industry researchers and will be deeply studied in postcruise research.

Furthermore, Expedition 308 was the first time where downhole pressure and lithology were monitored in real time (MWD) and it was the first time that weighted mud has been used as a tool to drill through overpressured regimes. Real time monitoring allowed us to observe shallow-water flow and to respond to this incident by raising the mud weight in order to hold back flow into the borehole. At both Sites U1323 and U1324 we showed that weighted mud and real-time monitoring can be used to safely drill and complete operations. Future expeditions in a variety of settings might benefit from the planned use of weighted mud to stabilize the borehole. We expect research on the cores and data generated during Expedition 308 to break new ground, especially in the field of geotechnical and hydrogeological analysis of continental slope sediment successions, be it at passive or active continental margins. Despite initial setbacks, we have shown that programs of in situ measurement of pore pressure in finegrained sediments can be done with overall success. We have demonstrated that drilling into overpressured formations with riserless technology can be managed using heavy mud, fluid flow into the borehole can be controlled, and operations can be safely concluded without risk to the seafloor environment.

A more complete account of the full results from Expedition 308 can be found by reading the Expedition 308 Preliminary Report (Expedition Scientists, 2005).

References

BOEHM, A, and MOORE, J C, 2002. Fluidized sandstone intrusions as an indicator of paleostress orientation, Santa Cruz, California. Geofluids, Vol. 2, 147–161. DAVIES, R, BELL, B R, CARTWRIGHT, J A, and SHOULDERS, S. 2002. Threedimensional seismic imaging of Paleogene dikefed submarine volcanoes from the northeast Atlantic margin. Geology, Vol. 30, 223–226.

DUGAN, B, and FLEMINGS, P B. 2000. Overpressure and fluid flow in the New Jersey Continental Slope: implications for slope failure and cold seeps. Science, Vol. 289, 288–291.

EXPEDITION 308 SCIENTISTS. 2005. Overpressure and fluid flow processes in the deepwater Gulf of Mexico: slope stability, seeps, and shallow-water flow. IODP Preliminary Report, 308. doi:10:2204/iodp.pr.308.2005

FLEMINGS, P B, STUMP, B B, FINKBEINER, T, and ZOBACK, M. 2002. Flow focusing in overpressured sandstones: theory, observations, and applications. American Journal of Science, Vol. 302, 827–855.

RUBEY, W W, and HUBBERT, M K. 1959. Role of fluid pressure in mechanics of overthrust

faulting, Part 2. Overthrust belt in geosynclinal area of western Wyoming in light of

fluid-pressure hypothesis. Geological Society of America Bulletin, Vol. 70, 167–205.

SELDON, B, and FLEMINGS, P B. 2005. Reservoir pressure and seafloor venting: Predicting trap

integrity in a deepwater turbidite reservoir. AAPG Bulletin, Vol. 89, 193-209.

IODP Expedition 309: Superfast Spread Crust II: Towards an in situ section of the upper oceanic crust

Christopher Smith-Duque (National Oceanography Centre, Southampton) and Expedition 309 Shipboard Scientific Party (csd2@noc.soton.ac.uk)

n the evening of 12th July 2005, MRV JOIDES Resolution set sail from Puerto Cristobal, transited the Panama Canal back into the Pacific Ocean, and embarked on the 3-day journey back to Site 1256. IODP Expedition 309 was the second cruise in a major drilling campaign to recover, for the first time, a complete in situ section of the upper oceanic crust from the extrusive lavas, through the sheeted dikes and down into the upper gabbros (see Teagle *et al.*, 2004).

Ocean crust formed at fast spreading ridges makes up ~50% of all oceanic crust and hence ~30% of the Earth's surface. Recovery of a complete section of ocean crust formed at fast spreading rates will provide critical, hitherto unavailable, information about the

formation and evolution of oceanic crust. Because processes at fast spreading rate ridges should be more uniform than those at slower spreading rates, a continuous section at Site 1256 has the potential to characterise the magmatic, hydrothermal and tectonic processes for one end member in the continuum of ocean spreading rates. Penetration of the gabbros will allow us to determine the nature of the upper magma chambers and increase our knowledge of hydrothermal processes at depth. Although tectonic windows on slow spreading midocean ridges and ophiolites such as the Troodos (Cyprus) or Semail (Oman) Massifs provide easier access to oceanfloor gabbros, these sections formed in either complex tectonic or supra-subduction zone settings that are not representative of most ocean crust from the major ocean basins.

Site 1256 is located in the Guatemalan Basin at 6°44.2'N, 91°56.1'W, on crust that formed ~15 m.y.-ago during a period (~20 to 11 Ma) of sustained superfast rate spreading (200-220 mm/yr) along the southern end of the Pacific/Cocos plate boundary (Figure 1, Wilson, 1996). Multi-channel seismic reflection experiments across mid-ocean ridges have revealed an inverse relationship between spreading rate and the depth of the axial lowvelocity zones, interpreted to be the axial magma chambers that freeze to form the uppermost gabbros (Purdy et al., 1992). Following this inverse relationship, and reasonable estimates of the thickness of lavas that flowed off-axis, it is predicted that at Site



Figure 1. Location of Site 1256 with isochrons calculated from seafloor magnetic anomalies (Wilson, 1996). DSDP and ODP sites that reach basement are shown. Wide isochron spacing around Site 1256 reflect the superfast (200-220mm/yr) spreading rate (following Wilson et al., 2003).



1256, gabbros should occur 1100m to 1300m sub-basement (msb). This is relatively shallow depth compared to in situ ocean crust formed at slower spreading rates. Drilling deep holes into the upper ocean crust remains technically challenging. Hence the occurrence of gabbros at relatively shallow depths should increase the likelihood of reaching this hitherto unattained target in a minimum number of drilling days (Wilson *et al.*, 2003).

Operations at Site 1256 were initiated on ODP Leg 206 (Nov, 2002 to Jan, 2003), which completed the groundwork for selecting the exact location and preparing Hole 1256D for deep drilling. Thick sediment cover (~250 m) allowed for the installation of a large reentry cone supported by 95m of 20-inch casing and 270m of 16-inch casing cemented 20m into basement. Drilling into the basement then continued to a total depth of 752m below seafloor (mbsf), with the uppermost crust being a thick (>75m) flow of massive, fine grained basalt that appears to have ponded in a fault bound depression some 5-10km off-axis. The lava pond overlies massive, sheet and pillowed flows (350-534 mbsf) with rare inflation structures that indicate eruption onto a sub-horizontal surface. From 534 to 752 mbsf a sequence of cryptocrystalline to microcrystalline basalt sheet flows (<3 m thick) with subordinate massive lavas were encountered. All lavas have normal mid-ocean ridge basalt (N-MORB) chemistries and display moderate fractionation up-section (Wilson et al., 2003).

Expedition 309 Operations

Following preliminary wire line logging to determine the condition of Hole 1256D, drilling commenced on Expedition 309 and continued to a depth of 1255.1 mbsf. Hole 1256D is now the second deepest penetration of in situ ocean crust after Hole 504B. Core recovery averaged 36% on Expedition 309, however, at depths below 1200 mbsf core recovery was over 70%. Drilling rates were slow due to the very hard nature of the basalts, a pipe-trip time approaching 24 hours, and the endurance of the nine CC-9 rotary coring bits used on Expedition 309 being only just over 50 hours before a bit change was required (Figure 2). Twice the vigilance of the drill crew averted major loss of equipment in Hole 1256D by interpreting drops in pump pressure as possible drill string failure and making the tough call to pull pipe back to the rig floor for inspection. On the first occasion,

Figure 2. Expedition 309 drilling progress in Hole 1256D. Solid black line shows the actual drilling process versus time. Bit changes and withdrawal caused by damage are indicated. In addition the minimum and maximum predicted depth for gabbros is shown (Shipboard Scientific Party, 2005).



Figure 3. Catastrophic failure of the bit sub along a horizontal torsional tear caused by jamming of the rotating drill string by debris in the hole. Only a few centimetres of steel remained connected to the underlying drill bit. The rig floor team detected this fracture, which occurred almost 5km from the ship, through a drop in pump pressures. Prompt action recovered the drill string without losing the bit in Hole 1256D and saved Expedition 309 (and 312!) from a difficult and time-consuming fishing or milling operation.

recovery of the bottom hole assembly revealed a near-circumferential crack in the bit sub (which connects the bit to the drill collars, Figure 3) and in the second incident ~10 days later, an unrelated but similar torsional failure of the 5-inch pipe directly above the drilling collars. Although drill string failures a relatively common during hard rock coring, the successful recovery of such damaged equipment had not occurred in the shipboard memory of scientific drilling. Prompt action by the rig floor team certainly saved Expedition 309 from lengthy and difficult fishing and milling operations.

The sheet flows encountered during Leg 206 are also present in the cores recovered on Expedition 309 down to a depth of 1004 mbsf where a lithologic transition zone begins (Figure 2). The sheet flows become increasingly massive and more fine grained (i.e., coarser) down hole. At 1004 mbsf the beginning of a transition zone is marked by the presence of a cataclastic unit composed of sub-vertically orientated cryptocrystalline basalt clasts hosted by intensely altered, incipiently brecciated fine grained basalt cross cut by thin veinlets and cataclastic stringers. Although sub-vertical fractures possibly indicative of diking are common from a depth of 900 mbsf, the first unambiguous subvertical intrusive contact occurs at 1018 mbsf. The transition zone is characterized by a number of breccias including a spectacular mineralized volcanic breccia at ~1028 mbsf. This breccia is composed of hyaloclastite and

basaltic clasts cemented by sulphides and subgreenschist facies minerals (Figure 3). Below 1061 mbsf there is an absence of evidence of submarine eruption and the rocks are massive, aphyric, non-vesicular basalts with numerous sub-vertical intrusive dike contacts. These chilled margins are commonly brecciated and mineralized by sulfides and greenschist facies hydrothermal minerals. Whether the host massive basalts are dikes or sub-volcanic sills remains unconfirmed although the former interpretation is preferred. Although, there is no direct evidence to suggest the presence of sills, because of only moderate core recovery this possibility cannot be completely dismissed until there has been detailed analysis of the continuous wireline logs.

Expedition 309 sampled, for only the second time, the transition from rocks altered by seawater to low temperature assemblages, to those partially recrystallized to (sub-) greenschist facies minerals by interaction with hydrothermal fluids. Alteration in Hole 1256D is manifest by veins, vesicles, and breccias filled and altered by secondary minerals as well as vein halos and isolated alteration patches where primary igneous phases are replaced by secondary minerals. The most common alteration in Hole 1256D is pervasive, slight to moderate dark grey background alteration resulting from the replacement of mesostasis by smectite or chlorite.

The low temperature alteration observed in Leg 206 continues in the Expedition 309 cores. Slight to moderate alteration characterized by black, brown and mixed saponite, celadonite and iron-oxyhydroxide halos are observed down to 964 mbsf. From ~964 to 1028 mbsf a transition to high temperature assemblages is signalled by the presence of pyrite-rich halos associated with mixed-layered chlorite/smectite and anhydrite veins, mineralized volcanic breccias altered to sub-greenschist facies secondary minerals, and an absence of iron oxyhydroxides and celadonite from this interval. Hydrothermal breccia was recovered from the transition zone but a mineralized stockwork as present in Hole 504B was not encountered.

Below 1028 mbsf chlorite is commonly present in the basalts and rocks are partially altered to greenschist facies assemblages with actinolite, prehnite, titanite and epidote, and anhydrite veins are increasingly common. Green and grey patches with 10-100% replacement/fill of plagioclase, clinopyroxene and interstitial areas by greenschist facies secondary minerals are common.

The extent of alteration in Hole 1256D is low when compared with the basement drilling in Holes 504B, 896A and at Sites 417/418. The slight to moderate alteration in Hole 1256D is similar to that observed in Hole 801C, which also formed at a fast spreading rate albeit 165 m.y.-ago (Wilson *et al.*, 2003). The intensity of alteration must reflect the basement hydrological environment. This will be influenced by basement topography, sedimentation, lava flow morphology and other factors. The relatively smooth basement topography surrounding Hole 1256D, the initial high sedimentation rate (>36 m/m.y.), and the capping of the

Figure 4. a) Mineralized volcanic breccia with altered basaltic clasts and hyaloclastite in a sulphide matrix. (309-1256D-122R-1, 29-51 cm). b) Dike-margin breccia with impregnated sulfide (309-1256D-140R-1, 42-58 cm; Shipboard Scientific Party, 2005).



basement off-axis by the thick (>75m) ponded flow has probably restricted seawater ingress and fluid movement in the Site 1256 crust.

Conclusions

Expedition 309 accomplished its principal objective of deepening Hole 1256D, which currently has a maximum depth of 1255.1 mbsf (1003 msb). Drilling penetrated for only the second time in scientific ocean drilling, the extrusive-intrusive boundary and recovered the transition from seafloor-dominated alteration to high temperature hydrothermal alteration. The cores from Hole 1256D can be divided into a preliminary igneous stratigraphy that

comprises (from top to bottom), a ponded flow (to 350 mbsf), sheet, massive and pillowed flows with inflation structures (to 534 mbsf), sheet and massive flows (to 1004 mbsf), a lithologic transition zone from extrusive to intrusive rocks (to 1061 mbsf), and a zone of sheeted massive basalts, most probably dikes, to the bottom of the hole (Shipboard Scientific Party, 2005).

On 28th August 2005 Expedition 309 completed borehole operations and started the transit back to Panama leaving Hole 1256D in excellent condition ready for Expedition 312 that returns to Site 1256 in November 2005. Hole 1256D is now extremely close to the



Figure 5. Minerals vs depth plot for Hole 1256D showing full transition from low temperature seawater alteration to high temperature hydrothermal alteration indicated by the presence of chlorite, actinolite, titanite and prehnite. The alteration transition zone is defined by the presence of mixed layered chlorite/smectite (Shipboard Scientific Party, 2005). depths at which gabbros are predicted to occur (Fig. 2, ~1300-1500 mbsf) and this target is now well within range of a single expedition assuming that drilling operations continue smoothly.

References

PURDY, G M, KONG, L S L, CHRISTESON, G L, and SOLOMON, S C. 1992. Relationship between spreading rate and the seismic structure of mid-ocean ridges. Nature, Vol. 355, 815-872

SHIPBOARD SCIENCE PARTY. 2005. IODP Expedition 309 Preliminary Report "Superfast Spreading Rate Crust II: A complete in situ section of upper oceanic crust formed at a superfast spreading rate". http://iodp.tamu.edu/scienceops/Expeditions/Expe dition309.html

TEAGLE, D A H, WILSON, D S, ACTON, G D, and ODP LEG 206 SHIPBOARD PARTY. 2004. The "Road to the MoHole" Four Decades On: Deep Drilling at Site 1256. Eos, Trans. Am. Geophys. Union, Vol. 85(49).

WILSON, D S. 1996. Fastest known spreading on the Miocene Cocos-Pacific plate boundary. Geophysical Research Letters, Vol. 23, 3003-3006.

WILSON, D S, TEAGLE, D A H, ACTON, G D, et al. 2003. Proceedings ODP Initial Reports, 206. Superfast Seafloor Spreading I, TAMU-IODP, College Station, TX.

News

Activities within the UK

n June 2005 the UK-IODP hosted its first major conference, Palaeoclimate Change: High Latitudes and Ocean Circulation, at the Geological Society of London. Over 150 participants registered for the event which was organised by Ian Hall, Paul Wilson, Mike Bickle and Juergen Thurow. The conference hosted 18 lectures on a number of subjects, ranging from models of the impact of ice sheets and sea ice on climate change (Didier Paillard, Paul Valdes and Rob DeConto), to a long awaited glimpse of the results from the successful ACEX expedition in presentations by Jan Backman, Heiko Pälike and Henk Brinkhuis. Marine sedimentary records of high latitude climate change were discussed in a number of talks including those by Jerry McManus and Harry Elderfield; meanwhile David Beerling gave an intriguing presentation on the evolutionary significance of the occurrence of deciduous forests at high latitudes. Participants ranged from distinguished professors to undergraduate and graduate students who all enjoyed the spectrum of lectures.

An ESF Magellan Series Workshop hosted by Oxford University followed up this successful event. The Workshop was attended by 12 participants from the UK, France, Germany, Spain and the USA and focused on the Environmental Change, Processes and Effects theme of the IODP Initial Science Plan with particular emphasis on high latitude exploration. The Magellan IODP proposal writing workshop successfully produced two new IODP proposals, and revisited two existing IODP proposals. The focus of all four proposals was in the Southern Ocean/Weddell Sea and have been submitted to the IODP proposal system.

For more details on the workshop go to: www.essac.ecord.org/reports/Arctic_new.pdf where the report by Heiko P Pälike can be read in full.

The new IODP Site Survey Data Bank

By Roger Searle, Durham University (Chair, IODP Site Survey Panel)

New initiative

A new site survey data bank has recently been set up by IODP, and become active on August 15th this year (www.iodp.org/newsreleases/ssdb/). Following competitive tender, the contract was awarded to Scripps Institution of Oceanography, where it is directed by Stephen Miller, head of the SIO Geological Data Center (Figure 1). The new data bank builds on the experience of the previous ODP Data Bank at Lamont Doherty Earth Observatory, and the resources of the University of California San Diego, including the SIO Geological Data Center, and the San Diego Supercomputer Center (SDSC).

The data bank is fundamental to much of the work of IODP. The data is normally first used by the Site Survey Panel to assess the quality and completeness of the "site characterisation data package", which in practice largely means answering the question "has the drilling target been adequately imaged?" For example, if the target is a particular sedimentary layer, can it be reliably identified and its depth determined from available seismic reflection data? Next to use the data may be the Environmental Protection and Pollution Prevention Panel, who might, for example, use it to look for evidence of potentially threatening petroleum traps. Although they have not done so in the past when the data were held as unwieldy paper copies, now with the development of web-



Figure 1. The "launch" of the IODP Site Survey Data Bank at SIO, September 2005. Left to right: Dale Sawyer, SSP Vice-chair; Manik Talwani, IODP President; John Orcutt, SIO Deputy Director; Hans-Christian Larsen, IODP Vice-president; Stephen Miller, Data Bank Director; Roger Searle, SSP Chair.

based access the Science Steering and Evaluation Panel may come to make use of the data to help evaluate the science of drilling proposals. Finally, the resources of the data bank are drawn on to provide data packages to take to sea in support of drilling expeditions and to contribute to the broader understanding of drilling results post-cruise.

Before tenders were invited, IODP drew up a detailed specification of requirements, including the fundamental principle that all new data submissions should be in digital form. SIO's implementation of the data bank makes extensive use of Digital Library concepts together with SIO's existing webbased cruise data browser SIOExplorer, and provides a flexible, secure, and easily webaccessible facility. John Helly of the SDSC is the principal information architect of these systems. It is hosted by a server that is part of SDSC, ensuring more than adequate capacity and response speed. Backups are housed offsite, and a mirror development version is housed on the main SIO campus away from SDSC. In fact, current technology now permits the data bank software to run on a normal laptop, and the whole data holding to be placed on a portable (briefcase-sized) hard disc, allowing easy transport, if required, for example to the drill-ship or to venues of IODP panel meetings.

Extracting data

The data bank is accessed at http://ssdb.iodp.org/ Users need to have Java Runtime Environment installed on their PC (free download from http://java.sun.com), and to be registered (typically as either a proponent, reviewer or IODP staff), which is done by completing the simple form shown on the first visit to the site. Once logged in they have access to two options: SSDBviewer and SSDBquery.

SSDBviewer is based on SIOExplorer, and presents a map of the world (with a choice of topography or crustal age) and the ability to search on proposal numbers or various keywords such as data type (Figure 2). Objects (data files) matching the search criteria are then displayed as icons in their geographic positions on the map, and all the files are listed in the window above the map.

The user can pan and zoom over the map for more detailed searches. Clicking on a map object or file name allows it to be opened on screen or downloaded.

Alternatively, choosing SSDBquery provides a detailed text-based search based on stored metadata: proposal number, data type, date, geographic position, etc. (Figure 3).

Currently under development are various

Figure 3. Screen view of SSDBquery.



Figure 2. Screen view of SSDBviewer.

visualisation tools, e.g. to display SEG-Y seismic data or to support 3-D viewing and integration of data files.

Data uploading

For many users, the most important aspect of the data bank will be the ability to upload their data. Again, this can be done over the web (Figure 4), and instructions can be found at www.iodp.org/drilling-proposals/. Proprietary data can be flagged, and will only be available to the proponent and relevant IODP staff and panel members in confidence.

As mentioned above, an important principle is that all new data should be in digital form, either as an image (e.g., jpg, pdf) or a discrete digital file (e.g. bathymetry grid, SEG-Y file). To assist in the reviewing process,

Figure 4. After selecting the appropriate proposal number, the user is presented with this window from which to choose the data type to upload. After selecting the type and clicking "Next Step", she is prompted to select various metadata.

+ IODI	Site Survey Data Bank	
Home About St	UB F&O Glossagy Help Contact	
Reviewer Menu	Hatta Lean SSGGrawy	
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Quest Links Tools	Search ->	
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	Data Type: All	-
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	Description.	
	Location:	ude East

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SSP asks that wherever possible all data files should be provided at least as an image of sufficient resolution to allow review (e.g., a pdf of a seismic section or of a bathymetry map), which optionally can be accompanied by detailed digital grids, etc. Figure 5 shows examples of some currently acceptable data types, although these are being reviewed at present, and some details may change.

A serious problem for SSP in the past has been that many data packages have been poorly organised, so it is hard for panel members to locate relevant data files. To overcome this, SSP now asks for a summary one-page pdf or similar image for each drill site showing the following: a simple map (with bathymetry or other information if desired) of the proposed site location and positions of relevant essential data (normally at least two crossing seismic lines) annotated with file names, shot-point or CDP locations, etc.; a list of the relevant file names; and low-resolution, annotated images of the seismic lines or other relevant data.

Once logged on to the data bank, the user will be prompted to enter a proposal number, and then guided through the process of uploading data. Each file will need to have

Figure 5. An indication of the range of data types that are acceptable for uploading to the data bank.

Data Type	Format		
Seismic Data High-Resolution Deep Penetration	SEG-Y file (Data must be submitted as stacks or migrations along with supporting metadata), or Image file (scanned images must be lossless TIFF, 300 dpi)		
Seismic Velocities • Time-Depth Curve • Check shots • Velocity Model • Stacking Velocity	Image file for velocity model ASCII Files (clearly annotated) Table of values		
Sub-bottom Profiler – chirp, parasound, etc, -3.5 kHz	Image file SEG-Y file		
Maps Multi-beam Swath Bathymetry Side-looking Sonar Contour Map Other	Image file Document file		
Gridded Data Magnetics Gravity Bathymetry Electromagnetic data	Grid data file ASCII XYZ file GMT-GRD file ARC GRD file Image file		
Digital Images • Seabed conditions	Image file Document file		
Heat Flow • Tables of values • Plots/graphs of values	ASCII Table Image file		
Document Files • Core descriptions • Ice conditions • Current/tide data • Sample descriptions	Document file		
Log Data	LAS format files LIS files		
OBS • Microseismicity	ASCII File (clearly annotated) Image file		
Navigation	UKOOA MGD77 ASCII File (clearly annotated) SEG-PI		
Video (e.g., seafloor images of target area)	Video file Immediate drilling area		

descriptive information (metadata) attached. The metadata are what allow searching, and will include geographic position for each file, along with other relevant information depending on data type. There are also guidelines on the web for the annotation required for each data image (e.g. locations, scales, etc.).

Guidance on data types

SSP, together with EPSP and the data bank staff, has put considerable effort into developing an on-line guide for the sorts of data that will likely be needed for different types of drilling proposal. (Developing this online guidance started as the SSP MATRIX

project, which has been announced at IODP town hall meetings during AGU meetings.) The guidance is intended as an early aid to proponents in planning site-survey cruises and proposals. This guide, which is currently being implemented, will explain the nature and relevance of the various required data types and give examples of them, to assist proponents from disciplines that may not be familiar with the predominantly geophysical data types that are often required.

Conclusion

IODP is making significant investments of funds, staff, and effort from SAS panellists, to improve the quality, functionality and ease of use of the new data bank. This is an ongoing process, which has only just begun, and we anticipate continuing improvements as time goes on. We welcome constructive comments and suggestions from anyone with an interest in the data bank. But most of all, we encourage everyone to try its new features and use it!

IODP Expedition 310 - Tahiti Sea Level

By David McInroy

limate change and its effect on global sea level is currently a hot topic for scientists, politicians and the general public. To better understand possible future events and climate change, and how much human activities may drive them, we must have a clear understanding of the natural variability of climate and sea-level over the last few thousand years.

This was the objective of a recent Integrated Ocean Drilling Program (IODP) Expedition conducted offshore Tahiti, involving staff from the ECORD Science Operator (ESO). The Expedition successfully recovered over 600 m of core from 37 boreholes drilled into the submerged parts of the barrier reef that surrounds the island of Tahiti. Coral reefs are extremely sensitive to environmental changes, and as they grow through time they accurately record past sealevels, temperatures, and salinities. By studying their morphology, and their physical and chemical properties at high-resolution, it is possible to extract climatic records from coral skeletons, often at sub-monthly time scales.

The BGS played a key role in planning and executing the operation, as part of the European Science Operator (ESO), the European 'wing' of IODP. From 6th October, 2005, a ship contracted by the BGS for the operation, the DP Hunter, spent 40 days within a few hundred metres of Tahiti's barrier reef recovering ancient coral reef material. A specially designed drill rig was installed and run on the ship's aft deck by the contracted drillers (Seacore, Cornwall). Great care was taken to limit environmental damage to the reefs, and before drilling, an underwater camera was used to survey the sea bed for the presence of live corals.

The cores were studied in February at the Expedition Science Party in Bremen, Germany. It is hoped that the cores will yield climatic records for the last 23,000 years, and will help chart natural sea level rise in detail since the Last Glacial Maximum.

The expedition preliminary report will be posted online at www.ecord.org and www.iodp.org/publications.

R/V Roger Revelle cruise "AMAT03" March-April 2006

by Neil Mitchell, University of Cardiff and the AMAT03 Expedition Party

cientific cruises of Scripps research vessels are traditionally given expedition names, in our case the name comes from Don Manual de Amat, the Viceroy of Peru, who launched a series of expeditions in 1772, 1774 and 1775 to Polynesia with the frigate Aquila. According to a quotation in a book by ES Dodge, the expeditions of Amat were "impressive for their careful planning, the generally competent way they were carried out, and the kindness and good sense with which the natives were treated." The "natives' in our case are marine mammals, which are being carefully watched by qualified observers to ensure that our operations do not affect their safety. This "AMAT03" geologygeophysics cruise was conceived to address the large-scale stratigraphy of the equatorial Pacific sediment bulge, E-W gradients in sediment properties and to provide site evaluations for a forthcoming IODP leg (IODP-626FULL2). At the time of writing, we have completed the main easterly part of our survey and IODP sites and are heading generally westwards towards Hawai'i through a series of olderseafloor planned drilling sites.

Seismic reflection equipment is being deployed between drill sites at a 10-knot transit speed in order to map out the carbonate stratigraphy across a major part of the equatorial sediment bulge, connecting previous work at 110°W to earlier studies around DSDP Site 574 at 135°W and beyond, a region more than 3000 km across. This part of our work exploits the finding of Mayer (1986) that global oceanographic events causing widespread dissolution of surface carbonates left abrupt changes in sediment density, which in turn create very distinctive reflectors in seismic images. These reflectors allow us to map out the age structure of the sediments across large areas and therefore to quantify aspects of the carbonate system.

Our previous work with two westerly R/V Ewing seismic lines north of the equator revealed correlations between the spatial patchiness of deposition in seismic stratigraphy and occurrences of hiatuses, hinting at an origin from bottom water corrosiveness. We also found a surprising lack of the classical pattern of simply declining carbonate accumulation rates with increasing water depth.

The seismic data have revealed some remarkable localised karst-like terrain of erosional pits. They mostly overlie basement hills, where dissolution is somehow promoted or initiated by deformation caused by differences in sediment compaction across the underlying hills (Mayer, 1981). Carbonate dissolution in the pits may release less soluble components and help to explain incidence of reworked radiolarian species (older than host carbonate sediment) that are being identified by Ted Moore in cores. These localised areas of erosion suggest potentially more complex and interesting controls on dissolution more generally than were originally considered during the earlier days of examining individual DSDP site and other surface cores. The combined geology-geophysics dataset should now provide an excellent basis for working out how carbonate dissolution varies and for addressing possible causes.

We have taken two equatorial cores, which initiate the effort to work out how the more siliceous sedimentary input in the eastern Pacific at 110°W (ODP Leg 138) changes towards the more exclusively carbonate input at 135°W (DSDP Leg 85). From preliminary work on board, the near-equatorial cores show classical Pleistocene cycles reaching back several 100 ka. Those cores and the others taken at drill sites, along with others in the region, also provide a latitudinal transect, which should address aspects of equatorial productivity, sediment transport and dissolution. Work on terrigenous dust content is being undertaken by Steve Hovan and further microfossil identification by Jan Backman. All cores are being geophysically logged with a Geotek multisensor track system. Other underway geophysical equipment being operated includes multibeam echo-sounder, "chirp" sub-bottom profiler, acoustic Doppler current profiler, gravity meter and dual magnetometer for field gradients as well as magnitude.

Overall the cruise has been blessed by warm weather (not too warm thanks to equatorial upwelling of deep ocean waters) and excellent food. The cruise incorporates all



levels of scholars, from undergraduate to senior scientist. Although teaching schedules in UK universities can make this difficult, including undergraduates should be a model for passing on the marine geoscience "experience" to younger generations. The quality of data and morale on board are in good part a credit to the quality of technical support and crew.

Funding for the cruise, which is gratefully acknowledged, is being provided equally by the NERC and NSF. The AMAT03 scientific party were: (Cardiff University) Tom Parry, Marcus Badger and Neil Mitchell, (Southampton University) Heiko Palike, Kirsty Edgar and David Spofforth, (Bristol University) Maite Hernandez Sanchez, (Boise State University) Mitchell Lyle (Chief Scientist), Brandi Murphy and Chris Paul, (Stockholm University) Jan Backman, (UC Santa Cruz) Heather McCarren and Cecily Chun, (Universidad EAFIT, Columbia) Mauricio Pulido Taborda, (Indiana University of Pennsylvania) Tom Bondra, Brittany Fetter, Ashley Hague, Steven Hovan and Rebecca Reese, (University of Michigan) Ted Moore and (Indiana University-Purdue University at Indianopolis) Sarah Sutor. Technical support was provided by: (Oregon State University) Dale Hubbard, Chris Moser and Paul

V

Wolczak, (Scripps) Ben Drake, Lee Ellet, John Meyer, Gene Pillard and Woody Sutherland, and marine mammal observers Howard Goldstein, Julie Kondor and Laura Moores.

References

MAYER, L. A., 1981, Erosional troughs in deepsea carbonates and their relationship to basement structure: Mar. Geol., v. 39, p. 59-80.

MAYER, L. A., SHIPLEY, T. H., and WINTERER, E. L., 1986, Equatorial Pacific seismic reflectors as indicators of global oceanographic events: Science, v. 233, p. 761-764.

Reports on recent meetings

Biogeochemical Controls on Palaeoceanographic Proxies 3-4 October 2005, Geological Society, London

By Rachael James, Open University

alaeontologists, geochemists and palaeoceanographers from all over Europe, the US and even Taiwan gathered in London in October, to contribute to a two-day meeting aimed at better constraining biogenic proxies that are used for palaeoclimate reconstruction. More than 150 delegates registered for the meeting which was organised by Bill Austin (St Andrews), Leon Clarke (Bangor), Rachael James (Open University) and Ros Rickaby (Oxford). Funds from the UKIODP helped support three Keynote speakers, Ann Russell (University of California), Joan Bernhard (Woods Hole Oceanographic Institution) and Richard Zeebe (University of Hawaii).

All in all there were 28 oral as well as 40 poster presentations; four prizes were awarded to the best student posters. The first session focussed on palaeontological studies; in order to interpret palaeorecords, we need a proper understanding of the functioning of modern organisms. To this end, Joan Bernhard gave us an overview of her benthic foraminifera culturing facility at the University of South Carolina, including the results of recent experiments. Andy Gooday (NOC Southampton) followed up by bringing to our attention the existence of substantial reservoirs of benthic foraminiferal biomass that are not preserved in the fossil record and therefore may have important implications for the interpretation of fossil assemblages and the reconstruction of palaeoproductivity. Kate Darling (Edinburgh) presented the results of DNA sequence analysis of planktonic foraminifera which suggests that shell morphology may not be a true measure of species diversity, and Jeremy Young (Natural History Museum) bought the session to a close with a lively discussion of the utility of coccolithophores as palaeoceanographic proxies.

In the afternoon the focus was on biomineralisation, with the aim to develop a mechanistic understanding of the "vital effects" imposed upon trace metal and isotopic proxies captured in biogenic carbonates. Bob Williams (Oxford) pointed out that there is strict biological control on the precipitation of formaniferal calcite which means that the chemical composition of fossilised tests is likely to be species dependent, warning that foraminiferal proxies therefore need to be applied with great care. Calcification mechanisms in coccolithophores were covered in talks by Colin Brownlee (MBA, Plymouth), Nic Gussone (Bremen) and Ros Rickaby; Jean-Pierre Cuif (IDES, Paris) presented some fabulous NanoSIMS maps of magnesium in corals that can be used to interpret the growth mode of the coral skeleton. Finally, Albert Galy (Cambridge) discussed how studies of magnesium isotopes in foraminifera can be used to determine equilibrium versus kinetic controls on the biomineralisation process.

The second day focussed on experimental and theoretical studies of those factors that can influence elemental and isotopic proxies, such as temperature and carbonate ion concentration as well as post-depositional dissolution. Richard Zeebe kicked off with a discussion of the thermodynamic basis of trace element uptake in biogenic calcite. Next followed a series of talks that focussed on proxy validation. Amongst others, Harry Elderfield (Cambridge) and Carrie Lear (Cardiff) emphasized the importance of seawater carbonate ion concentration on foraminiferal Mg/Ca at low temperatures; organic proxies were discussed by Rich Pancost (Bristol) and Christina de la Rocha (AWI Bremerhaven) gave an overview of $\delta^{\scriptscriptstyle 18}O,\,\delta^{\scriptscriptstyle 30}Si$ and $\delta^{15}N$ in sedimentary opal. Paul Pearson's presentation on the effects of recrystallization on primary proxy signals provoked a lively discussion and the session concluded with a study by Ed Hathorne (Open University) that aimed to quantify this effect.

The vast majority of the presentations at this meeting were based on studies of DSDP, ODP and even IODP material, emphasizing the importance of these programmes to the palaeoceanographic community. The proceedings will be published in 2006 in a Special Publication of the Geological Society edited by Bill Austin, Rachael James and Leon Clarke; if you wish to prepare a manuscript for this publication then please contact Bill Austin (bill.austin@st-andrews.ac.uk).



Getting involved in IODP

pplication 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 missionspecific 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) and Rachael James (R.H.James@open.ac.uk). 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 (Heather Stewart, ukiodp@bgs.ac.uk).

EXPEDITIONS

Currently scheduled expeditions beyond 2006

Expedition	Date		
USIO			
Equatorial Pacific Transect	August 1—October 1, 2007		
NanTroSEIZE (Stage 1)	October 1—December 1, 2007		
NanTroSEIZE (Stage 1)	December 1, 2007—January 31, 2008		
TBN	January 31, 2008—TBD		
Juan de Fuca Hydrogeology	TBD		
TBN	TBD		
Canterbury	TBD		
Wilkes Land TBD			
CDEX			
NanTroSEIZE (Stage 1)	September 1, 2007—TBD		
NanTroSEIZE (Stage 1)	TBD		
NanTroSEIZE (Stage 1)	TBD—31 Dec 07		
Maintenance	January 1—April 31, 2008		
NanTroSEIZE (Stage 2)	May 1, 2008—TBD (~ 215 days)		
ESO			
New Jersey Shallow Shelf	TBD		
For more information please visit www	v.iodp-mi-sapporo.org/scheduled.html		

PARTICIPATION

UK Scientists who have participated in Legs since January 2005:

Angela Halfpenny	Liverpool	Leg 305	Oceanic Core Complex 2
lan Bailey	UCL	Leg 306	North Atlantic Climate 2
Patrizia Ferretti	Cambridge	Leg 306	North Atlantic Climate 2
Barry Cragg	Cardiff	Leg 307	Porcupine Basin Carbonate Mounds
Veerle Huvenne	NOCS	Leg 307	Porcupine Basin Carbonate Mounds
Damon Teagle (co-chief)	NOCS	Leg 309	Superfast Spreading Rate Crust 2
Christopher Smith-Duque	NOCS	Leg 309	Superfast Spreading Rate Crust 2
Ed Hathorne	Open University	Leg 310	Tahiti Sea Level
(sampling party)			
Alex Thomas	Oxford	Leg 310	Tahiti Sea Level
(sampling party)			
Michelle Ellis	NOCS	Leg 311	Cascadia Margin Gas Hydrates
Peter Jackson	BGS	Leg 311	Cascadia Margin Gas Hydrates
Damon Teagle	NOCS	Leg 312	Superfast Spreading Rate Crust 3
Sally Morgan	Leeds	Leg 312	Superfast Spreading Rate Crust 3
John MacLennan	Edinburgh	Leg 312	Superfast Spreading Rate Crust 3

Forthcoming events

Mission Moho: Understanding the Formation and Evolution of the Oceanic Lithosphere September 6-9, 2006, Portland, Oregon, USA

The goal of drilling a complete section through the oceanic crust and into the upper mantle has been reiterated throughout the history of scientific ocean drilling. It is highlighted in the IODP Initial Science Plan as the "21st Century Mohole" Initiative, one of eight high-priority scientific objectives.

Inherent in this goal is the need for scientific and technical growth, for a clearly defined scientific strategy, and for parallel development of essential technology and operational experience.

This workshop will develop the scientific and operational framework for Mission Moho, providing guidance for IODP's 21st Century Mohole Initiative for a decade or more. The workshop will focus on and define the "Road to Moho" by identifying the scientific and engineering objectives that can begin immediately with available technology while leading us toward the ultimate "Mohole," a complete, in situ section through ocean crust.

Please see the website for more information: www.iodp.org/ocean-lithosphere

SealAIX'06 – Sea Level Changes: Records, Processes and Modelling 25-29 September 2006, Aix-en-Provence and Giens, France

Major scientific themes considered for this symposium will include records, sedimentary processes, and modelling of sea level changes (amplitude-timing) on carbonate margins, siliciclastic, and mixed margins, deep sea settings etc.

The symposium will be structured around four themes corresponding to distinctive modes of the Phanerozoic Earth System:

- 1. Quaternary sea level changes
- 2. Icehouse Earth sea level changes (last 33 Ma)
- 3. Paleozoic sea level changes
- 4. Greenhouse Earth sea level changes (250-33 Ma).

A conference opened to the general public on Recent Sea Level Changes Recorded by Satellites by Annie Cazenave (CNES, France) will be organized in Aix-en-Provence on Saturday September, 23.

Contact: Gilbert Camoin (gcamoin@cerege.fr)



UK IODP Grants

pplicants should refer to the current conditions and eligibility requirements, which can be found on the NERC website at www.nerc.ac.uk/funding/forms 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, Heather Stewart (ukiodp@bgs.ac.uk) or the Programme Administrator, Helen Bell (hebe@nerc.ac.uk).

NERC IODP Research Grants

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

UK IODP will have one further funding round, with a closing date of 1st May 2007 up to 2008. IODP has a maximum of around £225,000 to spend in this funding round, to fund 80% of the Full Economic Cost (FEC) of proposals. Applications are now invited for Small Research Grants only.

Small grants provide funding for small discrete projects, proof-of-concept studies, pump-priming exercises etc. This scheme is not intended to extend the period of employment of a research assistant once a standard grant has ended.

The maximum funding that may be sought is £25,000 for the total Directly Incurred costs (i.e. the limit applies to 100% of costs under this heading). In addition, NERC will have to pay the standard proportion (i.e. 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. Please see the NERC IODP website for more information.

UK IODP Rapid Response Grants

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

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

Rapid Response proposals will be reviewed by members of the UK IODP Committee and awards will be limited by the funds available for this scheme. Although there is no closing date, applications should be submitted by email to the Science Coordinator Heather Stewart (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.

Small and Standard Awards

Dr P Wilson	NOCS	Testing the stability of Eocene warmth and carbon cycling: new
Prof H Elderfield	Cambridge	Using benthic foraminiferal Mg/Ca at ODP site 982 to assess the climatic response to orbital greenhouse gas forcing during the
Dr R Pancost	Bristol	The use of bacterial and higher plant biomarkers to track changes in wetland extent since the last Glacial period.
Dr M Kaminski	UCL	Biostratigraphy and paleoceanographic significance of benthic foraminifera from the Lomonosov Ridge.
Prof P Clift	Aberdeen	Stratigraphic Evolution of the Red River Delta and Fan Complex, South China Sea.
Dr A McCaig	Leeds	Mechanisms of fluid penetration into gabbroic crust, IODP Site 1309. mid-Atlantic Ridge.
Dr G Henderson	Oxford	Precisely dated records of sea level and environmental change from Tahiti.
Dr C Lear	Cardiff	An integrated study of the Middle Miocene climate transition.
Site-Survey /	Awards	
Prof R Searle	Durham	Origin, structure and deformation of low-magmatic oceanic lithosphere in the vicinity of ODP Leg 209, Mid-Atlantic Ridge 14N-16N.
Dr C MacLeod	Cardiff	Accretion of the lower oceanic crust at fast-spreading ridges: a rock drill and near-bottom seafloor survey in support of IODP drilling in Hess Deen
Dr N Mitchell	Cardiff	The equatorial Pacific record of Earth's climate and paleoceanography: site-survey support for IODP-626Full2.
PDRA Award	s	
Dr L de Abreu	Cambridge	A multi-geochemical approach to determine millennial scale
Dr S Leigh	St Andrews	The North-Atlantic Ice-Climate System: reconstructing the provenance and phasing of ice rafting events using
Dr R Coggon	NOCS	Geochemical evolution of Juan de Fuca Ridge flank hydrothermal fluids: evidence from veins and porefluids, IODP
Dr P Ferretti	Cambridge	Millennial-scale variability in North Atlantic superficial and deep
Dr I Bailey	NOCS	Pliocene intensification of Northern Hemisphere Glaciation: new constraints from North Atlantic IODP sediments.
PGRA Award	s	
Miss A Halfpenny	Liverpool	Deformation mechanisms, kinematics and conditions in an oceanic core complex: quantitative microstructural analysis of samples from IODP Expedition 305
Miss S Morgan	Leeds	High temperature fluid-rock interaction in the oceanic crust: a fluid inclusion study, IODP expeditions 309 and 312.
Opportunity /	Awards	
Dr D Teagle	NOCS	Contingency funds for the rental of the DMT 360 degree core
Prof J Parkes	Cardiff	Urgent use of new HYACINTH high-pressure microbiological equipment on IODP Leg 311.

IODP UK contacts

UK IODP 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

ECORD Council Chair

Chris Franklin Science and Innovation Manager Science and Innovation Programmes NERC Polaris House North Star Avenue Swindon, SN2 1EU Email: cfr@nerc.ac.uk

ESSAC Chair Chris MacLeod and Julian Pearce (acting chair)

School of Earth, Ocean and Planetary Sciences Cardiff University Main Building Park Place Cardiff, CF10 3YE Email: macleod@cf.ac.uk and pearceja@Cardiff.ac.uk

ESSAC Science Coordinator

Federica Lenci School of Earth, Ocean and Planetary Sciences Cardiff University Main Building Park Place Cardiff, CF10 3YE Email: essac@cardiff.ac.uk

UK ESSAC Representative

Rachael James Department of Earth Sciences Open University Walton Hall Milton Keynes, MK7 6AA Email: R.H.James@open.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

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

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

Science Steering and Evaluation Panel-Interior

Damon Teagle, School of Ocean and Earth Science, National Oceanography Centre Southampton

Science Steering and Evaluation Panel-Environment

Jürgen Thurow, Department of Earth Sciences, University College London

Engineering Development Panel Peter Schultheiss, Managing Director, Geotek Ltd., Daventry

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

Site Survey Panel Roger Searle (chair), Department of Earth Sciences, University of Durham

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

Useful websites

Integrated Ocean Drilling Programme (UK) - www.ukiodp.bgs.ac.uk and www.nerc.ac.uk/funding/earthsci/iodp.shtml

ECORD Sites

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

IODP Central Sites

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

IODP Implementing Organisations

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

IODP National Offices

Canada - http://web.uvic.ca/ceor/iodp/contact.html Finland - http://iodpfinland.oulu.fi/index.htm France - www.iodp-france.org Germany (Deutsch) - www.bgr.de/iodp/home.htm Italy (Italia) - www.bgr.de/iodp/home.htm Norway (Norge) - www.geo.uib.no/IODP Switzerland - www.swissiodp.ethz.ch

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

IODP Related Sites

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

ODP Legacy Sites

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

Margins Links

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

UK Academic Institutions

British Antarctic Survey - www.antarctica.ac.uk/ British Geological Survey - www.bgs.ac.uk/ Bullard Labs, Cambridge - www.esc.cam.ac.uk/geophysics/geophys.html Cardiff Earth Sciences - www.cardiff.ac.uk/earth Durham Geology - www.dur.ac.uk/geolsci.www Edinburgh Geology & Geophysics - www.glg.ed.ac.uk Godwin Institute of Quaternary Research, University of Cambridge www.quaternary.group.cam.ac.uk Leicester Borehole Research Group www.le.ac.uk/gl/re/resprofs/borehole.html National Oceanography Centre, Southampton - www.noc.soton.ac.uk Oxford MG&G Group - www.earth.ox.ac.uk/~tony SAMS Scottish Association for Marine Sciences - www.sams.ac.uk University College London Earth Sciences - www.es.ucl.ac.uk University of Leeds School of Earth and the Environment: Earth Sciences - http://earth.leeds.ac.uk University of Liverpool Earth and Ocean Science - www.liv.ac.uk/earth University of Plymouth School of Earth, Ocean and Environmental Sciences - www.plymouth.ac.uk/pages/view.asp?page=6195 University of St Andrews School of Geography and Geosciences www.st-andrews.ac.uk/gg

Societies And Organisations

American Geophysical Union - www.agu.org Challenger Society for Marine Science www.soc.soton.ac.uk/OTHERS/CSMS/index.html European Geophysical Society - www.copernicus.org/EGS/ European Union of Geosciences - http://eost.u-strasbg.fr/EUG Geological Society of America - www.geosociety.org/ Geological Society of London - www.geolsoc.org.uk/ Hydrographic Society - www.hydrographicsociety.org/ International Hydrographic Bureau - www.iho.shom.fr/ Intergovernmental Oceanographic Commission - http://ioc.unesco.org/ The Royal Society - www.royalsoc.ac.uk/ Scientific Committee on Oceanic Research (SCOR) www.jhu.edu/-scor/ Society for Underwater Technology - www.sut.org.uk/

Mid-Ocean Ridge Links

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

NERC Marine Programmes

Autosub Under Ice (AUI) Programme www.nerc.ac.uk/funding/thematics/autosub COAPEC (Coupled Ocean-Atmosphere Processes and European Climate) - www.soc.soton.ac.uk/coapec Ocean Margins LINK Programme www.nerc.ac.uk/funding/thematics/oceanmargins Rapid Climate Change (RAPID)- www.soc.soton.ac.uk/rapid Surface-Ocean/Lower-Atmosphere Study (SOLAS) www.nerc.ac.uk/funding/thematics/solas

Back cover: View looking forward from the pipe racker during Expedition 309 (image courtesy of IODP/TAMU).



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