



September 18th, 2017

Burlington House, Geological Society of London

ABSTRACT BOOKLET



**Schedule for the Shackleton Conference:
Marine Geoscience, Past, Present, and Future**

Marine Studies Group

**September 18th, 2017
Burlington House, Geological Society of London**

9:15-9:40 – Arrival and Welcome, Coffee and Tea (Library of the Geological Society)

9:40 – Introduction to the day and conference (Member of the MSG Committee)

9:45 – Bill Austin, University of St Andrews

Craig Smeaton, Xingqian Cui, Thomas S. Bianchi, Alix G. Cage, John A. Howe

Climatic and human drivers of Holocene carbon burial along the North Atlantic margin

10:00 – Zvi Steiner, University of Cambridge

Boaz Lazar, Adi Torfstein, Jonathan Erez

Testing the utility of geochemical proxies for palaeoproductivity in oxic sedimentary marine settings of the Gulf of Aqaba, Red Sea

10:15 – **KEYNOTE: Carrie Lear, University of Cardiff.**

Ice sheet stability: A palaeoclimate perspective

10:45 – David Hodell, University of Cambridge

P. C. Tzedakis, L. C. Skinner, M. Vautravers, J. Rolfe, J. Nicolson

Persistent instability of glacial climate and overturning circulation in the North Atlantic for the past 1.5 million years

11:00 – **Coffee Break**

11:15 – **KEYNOTE: Rosalind Rickaby, University of Oxford**

The evolving role of phytoplankton in the carbon cycle

11:45 – Nick McCave, University of Cambridge

David Thornalley and Ian Hall

Relation of sortable silt grain-size to deep-sea current speeds: Calibration of the 'Mud Current Meter'

- 12:00 – Jenny Collier, Imperial College London
R. W. Allen, C. Berry, T. Henstock, F. J-Y. Dondin, J. L. Latchman, R. E. A. Robertson
Time-lapse bathymetric surveys of an active submarine volcano and implications for hazard in the southern Caribbean
- 12:15 – **KEYNOTE: Damon Teagle, University of Southampton**
The formation and evolution of new crust at ocean ridges: Tackling a fundamental Earth science challenge from multiple directions
- 12:45 – **Lunch and Discussion and Poster Session**
- 13:45 – **KEYNOTE: Rosalind Coggon, University of Southampton**
The South Atlantic drilling project, multi-disciplinary collaborations in marine science
- 14:15 – Rob Larter, British Antarctic Survey
Alastair G.C. Graham, Claus-Dieter Hillenbrand, Kelly A. Hogan, F. Javier Hernandez-Molina, James E.T. Channell, Chuang Xuan, David A. Hodell, Maria C. Williams, Simon J. Crowhurst, Karsten Gohl, Michele Rebesco, Gabriele Uenzelmann-Neben and RRS James Clark Ross cruise JR298 Scientific Party.
Development of a large sediment drift near the mouth of Marguerite Trough, Antarctic Peninsula as a record of past ice stream dynamics
- 14:30 – Daniela Vendettuoli – University of Southampton
Clare, M., Cartigny, M., Hage, S, Hughes Clarke, J., Talling, P., Vellinga, A., Waltham, D.
The stratigraphic incompleteness of submarine channel deposits
- 14:45 – **KEYNOTE - Bob Gatliff – British Geological Survey**
A BGS forward look at Marine Geoscience in the UK: Priorities in a time of change
- 15:15 – **Coffee Break**
- 15:30 – Mike Clare – National Oceanography Centre, Southampton
Vardy, M.E. , Cartigny, M.J.B. , Talling, P.J., Himsworth, M.D., Dix, J.K., Harris, J.M., Whitehouse, R.J.S., Belal, M.
How can we use emerging technology to directly measure powerful and damaging deep-sea geohazards?
- 15:45 – Ed Self – Gardline
Ken Games
3D seismic data Past (exploration), Present (exploration and geohazards) and Future (exploration, geohazards and decommissioning)
- 16:00 – **KEYNOTE: Russell Wynn - National Oceanography Centre, Southampton**

Marine robotics and their past, present and future applications for marine geoscience

16:30 – Neil Mitchell – University of Manchester

The rise of international collaborations in UK marine science from publication co-authorships

16:45 – Closing discussion and meeting wrap up

List of Posters

The versatility of petrophysical data to help ocean drilling research

Le Ber, E., Inwood, J., Morgan, S., Phillpot, L., Davies, S.

Geomorphometric characterisation of seabed features using a GIS-based semi-automated toolbox

Joana Gafeira, Diego Diaz-Doce, Laurence H. De Clippele, Robert Gatliff

How does marine sedimentary microbial sulfate reduction drive calcium carbonate polymorphism?

Chin Yik Lin, Alexandra V. Turchyn, Zvika Steiner, Pieter Bots, Giulio I. Lampronti, Nicholas J. Tosca

Challenger revisited: Illuminating anthropogenic climate change with 150 years of ocean science

Lyndsey Fox, Tom Hill, Stephen Stukins*

Changes in palaeo deep-water oxygen concentrations along the Iberian Margin across the Mid-Pleistocene Transition using a benthic $\Delta^{13}\text{C}$ proxy.

Nicola Thomas and David Hodell

Anatomy of the oldest known Heinrich events in MIS 16 at Site IODP1308

Abbie, P. B. Currington, Maryline J. Mleneck-Vautravers, David, A. Hodell

Marine operations: geology through technology

Joseph Hotherall, Will Lewis, Bob Gatliff

Abstracts for Oral Presentations

Climatic and human drivers of Holocene carbon burial along the North Atlantic margin.

Craig Smeaton¹, Xingqian Cui^{2,3}, Thomas S. Bianchi², Alix G. Cage⁴, John A. Howe⁵, William E.N. Austin^{1,5*}.

¹School of Geography & Sustainable Development, University of St Andrews, St Andrews, KY16 9AL, UK

²Department of Geological Sciences, University of Florida, Gainesville, FL 32611, USA

³Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA

⁴School of Geography, Geology and Environment, University of Keele, Staffordshire, ST5 5BG, UK

⁵Scottish Association for Marine Science, Scottish Marine Institute, Oban, PA37 1QA, UK

Fjords are connectors between the terrestrial and marine systems and are known as globally significant hotspots for the burial (Smith et al., 2014) and long-term storage (Smeaton et al., 2016) of carbon (C). The glacial geomorphology of fjords and their catchment results in the terrestrial and marine environments being strongly coupled more so than other estuary types. The clearest example of this is the terrestrial C subsidy to these sediment, it is estimated that globally 55-62% of C held in fjord sediments are terrestrially derived (Cui et al., 2016). Yet it is largely unknown how climatic and human forcing drives the transfer of terrestrial C to marine sediments.

Here, we examine the role of late Holocene climate and human activity on the transfer of C from the terrestrial to marine environment along the North Atlantic Margin. Loch Sunart a Scottish fjord sits at the land ocean interface of the North Atlantic. The catchment of the fjord has been shown to be sensitive to local and regional climatic change (Gillibrand et al., 2005) and the fjord sediments have been able to record these changes in climate (Cage and Austin, 2010). Using a long (22 m) sedimentary record we discuss our understanding of mid to late Holocene regional climate and its impact on terrestrial C transfer to the coastal ocean. Alongside this we examine the role of humans on the landscape and their impact on the transfer of terrestrial C to the coastal ocean. The results from this study will further our understanding of the long-term drivers of terrestrial C transfer to the coastal ocean. Potentially this research provides insights on future C transfers under a changing future climate allowing the importance of fjords as a climate regulation service to be reassessed.

Testing the utility of geochemical proxies for paleoproductivity in oxic sedimentary marine settings of the Gulf of Aqaba, Red Sea

Zvi Steiner^{1,2}, Boaz Lazar¹, Adi Torfstein^{1,3}, Jonathan Erez¹

¹The Fredy and Nadine Herrmann Institute of Earth Sciences, The Hebrew University, Jerusalem 91904, Israel

² Department of Earth Sciences, University of Cambridge, CB2 3EQ, Cambridge, UK

³The Interuniversity Institute for Marine Sciences, Eilat 88103, Israel

During the early stages of sediment diagenesis, most of the organic matter reoxidizes, leaving behind a small, potentially unrepresentative fraction of organic carbon. Paleo-productivity reconstructions therefore identify changes in the chemical composition of carbonate shells or, when pristine ones cannot be found, in the sedimentary content of inorganic elements associated with the original organic matter. To examine the applicability of bulk inorganic elements composition for this task, we compare recorded changes in known anthropogenic nutrient fluxes to the oligotrophic and oxygenated Gulf of Aqaba in the north Red Sea, with the sedimentary records of barium, cadmium, copper and nickel over the last decades. Among these elements, nickel and copper strongly correlate with recorded nutrient fluxes and primary productivity in the region. In the present case, nickel is a more reliable proxy since part of the copper is possibly contributed from air-borne pollution sources. The applicability of cadmium to serve as a tracer for nutrient additions could not be reliably tested because contribution of cadmium associated with phosphate ore loading in the adjacent ports may be significant. We do not observe any bulk sediment barium enrichments associated with increased nutrient fluxes. Overall, it appears from these correlations that nickel and probably also copper reliably record past changes in nutrient availability and organic matter fluxes while sedimentary barium and barite, which are commonly attributed to productivity, do not.

10:15 (30 minute Keynote)

Ice sheet stability: A palaeoclimate perspective

Caroline Lear,
Cardiff University

The impacts of the growth and decay of Earth's continental ice sheets reach far throughout the Earth System. Yet the local records of these changes are constantly rewritten through geological time, so their history must be determined using indirect evidence. The oxygen isotopic composition of foraminifera reflects both the changing salinity of the ocean as the ice sheets waxed and waned and also the changing temperature of that ocean. Independent proxies such as the Mg/Ca-paleothermometer can be used to separate these two climate signals. What do such geochemical proxy records tell us about ice sheet dynamics? First and foremost they demonstrate that the cryosphere does not respond linearly to external forcing of Earth's climate system. For example, the establishment of the Antarctic ice sheet at the Eocene-Oligocene Transition (~34Ma) was the rapid culmination of a long-term cooling trend that began several million years earlier, as a threshold in the climate system was passed. Defining the thresholds for ice sheet growth and decay is challenging because it integrates different aspects of the climate system, including radiative forcing and paleogeography. Nevertheless, most ice sheet models agree that the climate threshold for melting the Antarctic ice sheet is higher (warmer) than for its inception, due to the cold, elevated nature of its upper surface. The geochemical proxy records of the orbitally-paced ice sheet growth and decay at the Oligocene-Miocene Boundary (~24 Ma) therefore present something of a geological puzzle, because at first sight they seem to contain little evidence of this hysteresis effect.

One possible explanation is that the deglaciation of the Antarctic ice sheet at the Oligocene-Miocene Boundary was facilitated by an input of carbon to the ocean-atmosphere system. In addition, recent advances in ice sheet modelling provide a better fit to these proxy records. However, these models have worrying implications for future ice sheet stability. Further work is required to (1) evaluate these new ice sheet models, and (2) identify the positive feedback processes that caused these impressive deglaciation events in the geological record.

Persistent instability of glacial climate and overturning circulation in the North Atlantic for the past 1.5 million years

D. A. Hodell¹, P. C. Tzedakis², L. C. Skinner¹, M. Vautravers¹, J. Rolfe¹, J. Nicolson¹

¹Godwin Laboratory for Palaeoclimate Research, Department of Earth Sciences, University of Cambridge

²Department of Geography, University College London

Nick Shackleton's pioneering work on piston cores from the Iberian Margin demonstrated that the planktonic $\delta^{18}\text{O}$ signal resembles in great detail the temperature record of Greenland for the last glacial cycle. In the absence of an ice core older than the last interglacial (~124 ka) in Greenland, a long sediment sequence from the Iberian Margin could serve as a surrogate for millennial climate variability (i.e., Dansgaard-Oeschger events) in the North Atlantic during the Quaternary. To this end, we drilled IODP Site U1385 (the "Shackleton site") on the SW Iberian Margin and recovered a 166.5-m continuous section that extends back to ~1.5 million years BP. The age model is based on precession-tuning of the colour record and is independent of oxygen isotope stratigraphy (i.e., LR04). We measured stable isotopes of foraminifera continuously at 1- or 2-cm resolution corresponding to a temporal resolution of 100-200 years. The isotope record is used to evaluate how the magnitude, duration, and pacing of millennial variability changed as glacial boundary conditions evolved over the last 1.5 Ma, including the Middle Pleistocene Transition (MPT).

Millennial-scale variability has been a strong, persistent feature of surface climate on the Iberian Margin during all glacial periods of the last 1.5 Ma. All millennial increases in planktic $\delta^{18}\text{O}$ are mirrored by decreases in benthic $\delta^{13}\text{C}$, suggesting surface water cooling during stadials was accompanied by changes in Atlantic overturning circulation. We observe a diverse array of millennial variability with differing magnitude, duration and pacing throughout the late Pleistocene. During the "41-kyr world" from 1.5 to 1.25 Ma, millennial variability was frequent and persisted throughout each glacial period when obliquity dropped below the near present-day value of 23.5° . We suggest the link between increased millennial variability and low obliquity may be related to the response of sea ice extent to integrated summer insolation, which shifts the source areas of deep-water formation in the North Atlantic. After the start of the MPT at 1.25 Ma, very strong millennial variability occurred at each of the glacial inceptions associated with declining obliquity, and at each of the glacial terminations associated with rising insolation. Millennial variability appears strongest when the earth's climate system is transitioning into and out of a glacial state, reflecting an unstable AMOC. Although much of our concept of millennial variability is based on the Greenland ice core record during MIS 3, this type of millennial variability in the middle of a glacial cycle is relatively uncommon.

11:15

(after coffee, 30 minute Keynote)

Rosalind Rickaby, University of Oxford

The evolving role of phytoplankton in the carbon cycle

Relation of sortable silt grain-size to deep-sea current speeds: Calibration of the 'Mud Current Meter'

Nick McCave¹, David Thornalley² and Ian Hall³

¹ Godwin Laboratory for Palaeoclimate Research, Department of Earth Sciences, Downing Street, Cambridge CB2 3EQ;

² Dept of Geography, University College London, Gower Street, London, WC1E 6BT;

³ School of Earth and Ocean Sciences, Cardiff University, Cardiff, CF10 3AT.

Fine grain-size parameters have been used for inference of palaeoflow speeds of near-bottom currents in the deep-sea. The basic idea stems from observations of varying sediment size parameters on a continental margin with a gradient from slower flow speeds at shallower depths to faster at deeper. In the deep-sea, size-sorting occurs during deposition after benthic storm resuspension events. At flow speeds below 10-15 cm s⁻¹ mean grain-size in the terrigenous non-cohesive 'sortable silt' range (denoted by \overline{SS} , mean of 10-63 μm) is controlled by selective deposition, whereas above that range removal of finer material by winnowing is also argued to play a role.

A calibration of the \overline{SS} grain-size flow speed proxy based on sediment samples taken adjacent to sites of long-term current meters set within ~100 m of the sea bed for more than a year is presented here. Grain-size has been measured by either Sedigraph or Coulter Counter, in some cases both, between which there is an excellent correlation for \overline{SS} ($r = 0.96$). Size-speed data indicate calibration relationships with an overall sensitivity of $1.36 \pm 0.19 \text{ cm s}^{-1}/\mu\text{m}$ for Sedigraph (1.26 ± 0.18 Coulter counter). A calibration line comprising 12 points including 9 from the Iceland overflow region is well defined, but at least two other smaller groups (Weddell/Scotia Sea and NW Atlantic continental rise/Rockall Trough) are fitted by sub-parallel lines with a smaller constant. This suggests a possible influence of the calibre of material supplied to the site of deposition (not the initial source supply) which, if depleted in very coarse silt (31-63 μm), would limit \overline{SS} to smaller values for a given speed than with a broader size-spectrum supply. Local calibrations, or a core-top grain-size and local flow speed, are thus necessary to infer absolute speeds from grain-size.

The trend of the calibrations diverges markedly from the slope of experimental critical erosion and deposition flow speeds versus grain-size, making it unlikely that the \overline{SS} (or any deposit size for that matter) is simply predicted by the deposition threshold. A more probable control is the rate of deposition of the different size fractions under changing flows over several tens of years (the typical averaging period of a centimetre of deposited sediment). This suggestion is supported by a simple depositional model for which the deposited \overline{SS} is calculated from measured currents with a size-varying depositional threshold. More surficial sediment samples taken near long-term current meter sites are needed to make calibrations more robust and explore regional differences. See doi: 10.1016/j.dsr.2017.07.003

Time-lapse bathymetric surveys of an active submarine volcano and implications for hazard in the southern Caribbean

J. S. Collier¹, R. W. Allen¹, C. Berry¹, T. Henstock², F. J-Y. Dondin³, J. L. Latchman³, R. E. A. Robertson³

1. Department of Earth Sciences and Engineering, Imperial College London, SW7 2AZ
2. Ocean and Earth Science, National Oceanography Centre Southampton, SO14 3ZH
3. The UWI Seismic Research Centre, St Augustine, Trinidad and Tobago

Since the first recorded eruption in 1939, the Kick-'em-Jenny volcano, 8km off of the north coast of Grenada, has been the source of 13 notable episodes of T-phase recordings. These distinctive seismic signals, often coincident with heightened local seismicity, have been interpreted as indicative of extrusive eruptions with a mean recurrence interval of 5-6 years. However, direct confirmation of volcanism during these episodes is rare. By conducting bathymetric surveys from the *RRS James Cook* in 2016 and 2017 (EM120 and EM710) and reprocessing 4 further legacy data sets spanning more than 30 years and several incidences of T-phase recordings we are able to present a clearer picture of the development of the volcano through time. The final bathymetric grids produced have a cell size of just 5m and, for the more modern surveys, a vertical accuracy on the order of 1-4m. These grids show that T-phase episodes correlate with morphological changes at the volcano's edifice. In the time-period of observation we document a clear construction deficit with 5 times more material lost through landslides and volcanic dome collapse than added through volcanic construction. The apparent limited recent magma production means that the volcano may be susceptible to larger eruptions with longer repeat times than those covered in our study. These larger eruptions would clearly pose a more significant local hazard than the small scale volcanic events observed in recent decades. This behavior is more similar to some of the sub-aerial volcanoes in the arc than previously thought. Our results clearly demonstrate the capability of repeat swath bathymetry surveys as a means of assessing submarine volcanic hazard.

12:15 (30 minute Keynote)

The formation and evolution of new crust at ocean ridges: Tackling a fundamental Earth science challenge from multiple directions.

Damon A.H. Teagle*, Peter B. Kelemen, Juerg Matter, Eiichi Takazawa, Katsuyoshi Michibayashi, Judith Coggon, Michelle Harris, Juan Carlos de Obeso, and the Oman Drilling Project Phase 1 Science Party

* Ocean & Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14-3ZH, UK.
Damon.Teagle@southampton.ac.uk

The formation of new ocean crust at the mid-ocean ridges is the foundation of the plate tectonic cycle and the principal mechanism for the transfer of heat and mass from the Earth's interior to the surface. Since the inception of scientific ocean drilling, understanding mid-ocean ridge processes has been the primary objective of the 'Solid Earth', exemplified by numerous of the Grand Challenges in the current IODP science plan (2013-2023). Although we have conceptual models of the processes occurring during the formation of the ocean ridges, there remains only poor knowledge of the mechanisms and interplays between magmatic accretion, tectonics, hydrothermal circulation. Basic concepts such as the size and location of magma chambers or the depth and intensity of hydrothermal exchange continue to be debated. This lack of knowledge is principally due to a lack of appropriate samples or direct observations. This greatly hinders our ability to quantify the impacts of changes in the mid-ocean ridges, such as spreading rates or relative lengths of fast versus slow ridges, on the biochemical budgets of major constituents of seawater and many of the key tracers we use to decipher the operation of our planet (e.g., C, H₂O, Mg, ⁸⁷Sr, ¹⁸O).

The remoteness of the ocean ridges, submerged beneath thousands of meters of seawater, and their vast extent, requires multiple approaches to graft key observations, from oceanographic surveys, through marine geology, geophysics and modelling, to deep ocean drilling, to recovery of intact samples in sterile conditions for study of subsurface microbial ecosystems. The ocean ridges have been inspirational driving forces for technological development and new scientific approaches (e.g., ROVs and AUVs, CSEM). Although remote observations and numerical methods provide important insights, in situ samples are required to test concepts of magmatic accretion, crustal cooling, or hydrothermal exchange. This requires scientific ocean drilling through the exploitation of tectonic windows or through the drilling of deep holes into intact ocean crust. This has proved extremely challenging, especially for deep holes, with poor rates of core recovery, engineering difficulties, and career-duration experiments.

Studies of ridge processes at sea have always been complemented by onshore investigation of ophiolites. Although it is apparent that ophiolites are not identical to Pacific Ocean crust, studies of obducted blocks of crust and upper mantle formed at spreading ridges have formed a vital touchstone used for interpreting geophysical data and sparse samples from dredging and drilling in the context of idealized crustal sections and hypotheses about along-strike variation. In a recent, ambitious example of this dialectical relationship, a significant proportion of the ocean ridge community is currently focused on the Samail ophiolite in Oman, the largest and best exposed slice of ocean crust and its underlying mantle preserved on-land.

Phase 1 of the ICDP Oman Drilling Project has just ended, with 1500 m of diamond drill hole recovered from the lower crust and mantle of the Samail ophiolite, with scientific ocean drilling quality core characterisation having just been completed aboard the D/V Chikyū. The combination of excellent 3-dimensional exposures, decades of meticulous field geology, wireline geophysical logs, and 100%

rates of core recovery provides exceptional new opportunities to understand and quantify the processes operating in ophiolites and the ocean ridges. New facilities such as continuous X-ray tomography, core scanning XRF, and near visible infrared scanning available aboard Chikyu have been used at scale for the first time and enable objective quantification of features to complement traditional visual core description, sampling and analysis. The huge amount of data generated by these new techniques necessitates new machine learning approaches of data analysis and verification. The Oman Drilling Project observations provide a unique opportunity to quantitatively integrate drill cores, wireline logs, and outcrop observations, and master techniques for future deployment in scientific ocean drilling.

13:45

(after lunch, 30 minute Keynote)

The South Atlantic Transect drilling project, multi-disciplinary collaborations in marine science.

Rosalind M. Coggon, Robert S. Reece, Gail L. Christeson, Mark Leckie, Brandi Kiel Reese, Damon A.H. Teagle, William P. Gilhooly III, Jason Sylvan, Nicholas W. Hayman, James Zachos, Brandon R. Briggs, Clifford Heil, Matthew Huber, Julia S. Reece, Svenja Rausch, John Kirkpatrick, Michelle Harris, Debbie Thomas, Miriam Katz, Christopher Lowery

Deep Sea Drilling Project Leg 3 drilled a transect of sediment holes across the western flank of the southern Mid-Atlantic Ridge to demonstrate that the basal sediment age increased with distance from the ridge, proving the theories of seafloor spreading and plate tectonics. During Leg 3 the sediments were only spot-cored, but revealed moderate to excellent preservation of the CaCO₃ microfossils required to generate high-fidelity proxy data for paleoceanographic reconstructions. Given dramatic advances in drilling technology and analytical capabilities since Leg 3, many high priority scientific objectives could be addressed by revisiting the Leg 3 transect. We therefore proposed a multidisciplinary IODP transect through the Leg 3 area at ~31 °S, to recover complete sediment sections and the upper 150-250 m of 7, 15, 31, 48 and 63 Ma ocean crust. The proposal (IODP 853Full-2) received excellent reviews and has been recommended for scheduling, with the drill ship expected to operate in the Atlantic in 2020.

The proposed transect follows a crustal flow-line from the slow/intermediate-spreading Mid-Atlantic Ridge and will fill critical gaps in our sampling of intact in-situ ocean crust with regards crustal age, spreading rate, and sediment thickness, required to investigate the low-temperature hydrothermal aging of ocean crust. The transect also traverses the hitherto unexplored sediment- and basalt-hosted deep biosphere beneath the South Atlantic gyre, and is located near World Ocean Circulation Experiment (WOCE) line A10, providing access to records of carbonate chemistry and deep-water mass properties (e.g., temperature and composition) across the western South Atlantic through key Cenozoic intervals of elevated atmospheric CO₂ and rapid climate change. The proposed transect therefore provides a wealth of opportunities for multi-disciplinary collaborations in marine science.

Development of a large sediment drift near the mouth of Marguerite Trough, Antarctic Peninsula as a record of past ice stream dynamics

Robert D. Larter¹, Alastair G.C. Graham², Claus-Dieter Hillenbrand¹, Kelly A. Hogan¹, F. Javier Hernandez-Molina³, James E.T. Channell⁴, Chuang Xuan⁵, David A. Hodell⁶, Maria C. Williams¹, Simon J. Crowhurst⁶, Karsten Gohl⁷, Michele Rebesco⁸, Gabriele Uenzelmann-Neben⁷ and RRS James Clark Ross cruise JR298 Scientific Party.

¹British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK (email: rdla@bas.ac.uk);

²College of Life and Environmental Sciences, University of Exeter, Exeter EX4 4RJ, UK;

³Department of Earth Sciences, Royal Holloway University London, Egham, Surrey TW20 0EX, UK;

⁴Department of Geological Sciences, University of Florida, Gainesville, Florida 32611, USA;

⁵School of Ocean and Earth Science, University of Southampton, Southampton SO14 3ZH, UK;

⁶Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK;

⁷Alfred Wegener Institute, Helmholtz-Centre for Polar and Marine Research, Bremerhaven, Germany;

⁸Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Sgonico (TS) Italy.

Large sediment drifts on the continental rise west of the Antarctic Peninsula have developed since the middle Miocene and contain continuous, high-resolution records of ice sheet and oceanographic change. New high-resolution multichannel seismic data, multibeam echo sounding data and acoustic sub-bottom profiles were collected around proposed drill sites on several different drifts during RRS *James Clark Ross* cruise JR298 in January–February 2015. Seven piston cores were also collected, all but one of which were from locations close to the proposed drill sites. In this presentation we will focus on results from Drift 5, which is located close to the mouth of Marguerite Trough and thus ideally located to record dynamic changes in the major ice stream that flowed along the trough during Quaternary glacial maxima. The proposed drill site on the crest of Drift 5 is 30 km from the shelf edge at the mouth of the trough. In the Pliocene the mouth of Marguerite Trough was located further south along the margin, and migration of the trough to its present position influenced development and morphology of the drift.

Nine new multichannel seismic lines covering 580 line-km were collected over Drift 5 and the surrounding area, providing an unprecedented opportunity to examine its internal structure and development. The data confirm a very simple ‘layer cake’ stratigraphy beneath the crest of the drift, showing continuous, parallel reflectors with a very gentle seaward dip that extend to within 25 km of the continental shelf edge. Connections to sparse older seismic lines allow age control to be established by correlation to ODP Leg 178 sites and DSDP Site 325. The new multibeam echo sounding data combined with previous data now provide complete coverage of the drift and reveal evidence of extensive mass wasting on its flanks. Acoustic sub-bottom profiler data collected along the seismic lines show evidence of localised fluid escape structures that are likely pathways for expulsion of fluids released by silica diagenesis at depth. A 9.4 m-long piston core recovered at 2647 m water depth near a proposed drill site on the crest of the drift did not penetrate into Marine Isotope Stage 5. In a 12.9 m-long piston core recovered at 3000 m water depth on the crest of the drift further away from the continental slope, Marine Isotope Stage 5.5 is identified near the base of the core below 11 mbsf, indicating an average sedimentation rate of >9 cm/kyr through the last glacial cycle. We conclude that a drill site on the crest of Drift 5 has the potential to provide an expanded, continuous record of past dynamics of the Marguerite Trough palaeo-ice stream.

The stratigraphic incompleteness of submarine channels deposits

Vendettuoli, D^{1*}, Clare, M.², Cartigny, M.³, Hage, S³, Hughes Clarke⁴, J., Talling, P.³, Vellinga¹, A., Waltham, D.⁵

¹ University of Southampton, School of Ocean and Earth Science, UK

² National Oceanography Centre, Marine Geoscience, UK

³ Durham University, Department of Geography, UK

⁴ Center for Coastal and Ocean Mapping, University of New Hampshire, USA

⁵ Royal Holloway University of London, UK

Turbidity currents transport prodigious quantities of sediment across the world's oceans through submarine channels, deposit major oil and gas reservoirs within submarine fans and damage strategically important seafloor infrastructure. We therefore need to understand these flows, but their very powerful nature makes direct monitoring challenging. Most studies to date focus on the deposits that turbidity currents leave behind in the sedimentological record. However, deposits of individual flow are likely to be reworked, particularly in the proximal part of submarine channels where supercritical flows dominate. This leaves us with the questions: How complete is the stratigraphy of these deposits? Are some events better preserved than others? Quantifying stratigraphic completeness, and how it varies over different temporal and spatial scales, is crucial to understand how well deposits can be used in quantifying turbidite frequency, identifying the best locations for reconstructing palaeoenvironments, and to unravel past sediment budgets.

We address these questions by re-analysing the most detailed time-lapse mapping yet of a submarine turbidity current system. This field dataset comes from the fjord-head Squamish Delta in British Columbia, Canada where Hughes Clarke (2016) collected 93 near-daily repeat surveys in 2011. These surveys revealed the seafloor response to more than 100 turbidity currents. Three channels are identified (northern, central and southern) that initiate from a delta-lip and extend to depositional lobes at approximately 150 m water depth. Thus, a highly active system can be studied from source to lobe in a compact area.

Here we use temporal changes in seabed elevation to understand patterns of deposition and erosion (and thus deposit stratigraphy) at each point during these 100 successive flows. We calculate the total thickness of sediment deposited at each location, and the percentage of this sediment that is preserved (the stratigraphic completeness). Erosion by subsequent flows may substantially reduce stratigraphic completeness, and the majority of initial deposits are reworked by later flows. The average stratigraphic completeness near to the three channels is <1%, but this is highly spatially variable, as some levees record up to 40% completeness. This low value is largely due to upstream migrating bedforms that constantly rework previously emplaced sediments. Three different patterns are found in the three channels. The northern channel shows a disproportionate preservation (up to 60%) of limited run-out, but large delta-lip failures in its upper course (due to their plugging effect, which drive minor avulsions). The central channel is mainly erosional in its proximal part, and has little preservation of deposits in the lower channel. The southern channel is dominated by erosion, with net-erosion due to meander bend incision, and at the channel lobe transition zone. Perhaps surprisingly, even at the terminal lobes, stratigraphic completeness is typically <5%; especially close to the channel mouths. These results provide new insights into the evolution of submarine channels and why their deposits produce a highly incomplete record of submarine flows.

14:45 (30 minute Keynote)

A BGS forward look at Marine Geoscience in the UK: Priorities in a time of change

Robert Gatliff, Director Marine Geoscience, British Geological Survey,
The Lyell Centre, Research Avenue South, Edinburgh, EH14 4AP

The Marine Geological Survey in the UK began in 1966 in response to the new offshore oil and gas industry. The Government funded a major national mapping programme (including high-resolution shallow seismic, magnetic and gravity data, a series of boreholes, gravity cores etc.). By 1992, the shelf areas were all mapped at 1:250,000 scale (seabed sediments, Quaternary and bedrock). The final offshore regional report (Rockall) was published in 2013 following an extensive collaborative research programme with industry covering the Atlantic Margin. Established skill sets and extensive experience in marine operations and engineering has since enabled BGS to lead the European Consortium for Ocean Research Drilling operations.

Increasing demand for more detailed evidence to meet the requirements of the offshore renewables industry, aggregates extraction, decommissioning, fishing, aquaculture and meeting EU environmental Directives and the development of a network of marine protected areas has led to the gradual development of more detailed maps and models based on new seismic and in particular, multibeam data. Excellent collaboration between different parts of Government has led to freely available multibeam data to underpin a new generation of geological, geomorphological and habitat interpretations. Although the UK still only has around 30% coverage of multibeam data, the coverage grows annually, primarily through the Civil Hydrography Programme, but supported by many other sources, including data collected by the BGS small survey vessel, the *White Ribbon*. Many countries now have national mapping programmes based on multibeam data (e.g. INFOMAR in Ireland and Mareano in Norway) and the UK's understanding of its own territorial waters is now lagging behind many in Europe.

Today there are new challenges to answer:

Can we really manage our seas effectively with almost 70% of the UK seabed not mapped using modern methods?

What is happening at our coasts? Do we need more detailed onshore-offshore models across the coast to answer questions about rates of erosion, amounts and changes in sediment budgets, and what we can do to mitigate the impacts of sea level rise? The history of sea level rise since the last glaciation recorded in seabed geomorphology demonstrates the complex nature of erosion rates during the last 10,000 years and guides our models for future changes at the coast.

Can we maximise the effective development of marine renewable energy? The results of the last glacial advance and retreat are fundamental to the offshore renewables industry and a better understanding of related processes and engineering properties of the shallow offshore geology are critical to the installation and maintenance of our offshore renewable energy capacity.

Did the Storegga slide generate the last large tsunami to hit the UK? What is the potential for locally derived tsunamis (from cliff falls; nearshore landslides etc.), or far-field tsunami damage around the UK coasts?

How will our marine ecosystems evolve with climate and respond to development pressures?

Can we develop the deep-sea mining industry? Nodules, crusts and massive sulphides are major targets for new mining. Ores are high grade. Is the UK being left behind? Autonomous and robotic technologies for environmental monitoring, exploration and production could put the UK in the lead across a newly developing supply chain.

15:30 (after coffee break)

How can we use emerging technology to directly measure powerful and damaging deep-sea geohazards?

Clare, M.A.*¹, Vardy, M.E.¹, Cartigny, M.J.B.², Talling, P.J.², Himsworth, M.D.³, Dix, J.K.⁴, Harris, J.M.⁵, Whitehouse, R.J.S.⁵, Belal, M.³

1) National Oceanography Centre, University of Southampton Waterfront Campus, European Way, Southampton, SO14 3ZH, UK;

2) Departments of Earth Science and Geography, University of Durham, Durham, DH1 3LE, UK;

3) School of Physics and Astronomy, University of Southampton, Highfield, Southampton, SO17 1BJ, UK;

4) School of Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton SO14 3ZH, UK;

5) HR Wallingford, Howbery Park, Wallingford, Oxfordshire, OX10 8BA, UK.

Seafloor networks of cables, pipelines and other infrastructure underpin our daily lives, providing communication links, information and energy supplies. Despite their global importance, these networks are vulnerable to damage by a number of natural seafloor hazards, including landslides, turbidity currents, fluid flow and scour. Conventional geophysical techniques, such as high-resolution reflection seismic and side scan sonar are commonly employed in geohazard assessments. These conventional tools provide essential information for route planning and design, however such surveys provide only indirect evidence of past processes and do not observe or measure the geohazard itself. As such, many numerical-based impact models lack field-scale calibration and much uncertainty exists about the triggers, nature and frequency of deep-water geohazards. Recent advances in technology now enable a step-change in their understanding through direct monitoring. We outline some emerging monitoring tools and how they can quantify key parameters for deep-water geohazard assessment. Repeat seafloor surveys in dynamic areas show that solely relying on evidence from past deposits can lead to an under-representation of geohazard events. Acoustic Doppler current profiling provides new insights into the structure of turbidity currents; while instrumented mobile sensors record the nature of movement at the base of those flows for the first time. Existing and bespoke cabled networks enable high bandwidth, low power and distributed measurements of parameters such as strain across large areas of seafloor. These techniques provide valuable new measurements which will improve geohazard assessments, and should be deployed in a complementary manner alongside conventional geophysical tools.

3D Seismic Data: Past (Exploration), Present (Exploration and Geohazards) and Future (Exploration, Geohazards and Decommissioning)

E. Self and K.P Games

Gardline Geosurvey Ltd

In the early years of the Offshore Oil and Gas Industry, the exploration data were all 2D, acquired by towing one streamer and one source along every sail line. Data were acquired with closely spaced lines but even the densest of these were of the order of hundreds of metres apart. With such line spacing, many geological features are spatially aliased. Then the ability to shoot and process 3D was developed, with the first 3D commercial dataset being acquired in the North Sea in 1975. The 3D technique reduces the onset of aliasing by at least an order of magnitude. The industry rapidly improved the acquisition of such 3D data by the use of closely spaced (typically 25m) multi-streamer systems (12 streamers up to 10km in length soon became the norm), and this enabled large areas to be covered in relatively short time. Ever increasing improvements in both acquisition and processing have led to greatly enhanced datasets, and these data are gridded into 'bins' during the processing stage, with typical bin sizes of 12.5m x 12.5m. However, the use of these datasets in the evaluation of geohazards has always been very limited, mainly due to the lack of vertical resolution of such data. This is essentially due to the frequency content of the data and the acquisition geometry, and while these can be enhanced to improve the resolution, in many cases they will always mean that these datasets cannot be used to provide the required geohazard assessment. This geohazard analysis was normally carried out using High Resolution Seismic (HRS) 2D data. However, recent developments have led to the introduction of HRS 3D data acquisition, with typical bin sizes of 6.25m x 6.25m or smaller, and this is now being used as the optimum technique for complex areas of geohazard problems. With the Oil and Gas Industry now entering a new phase where decommissioning of major fields is starting to happen, this new HRS 3D technique has great potential for resolving some of the issues coming to the fore in the decommissioning phase.

16:00 (30 minute Keynote)

Marine robotics and their past, present and future applications for marine geoscience

Prof Russell B Wynn

Chief Scientist, MARS (Marine Autonomous and Robotic Systems)

National Oceanography Centre, European Way, Southampton, SO14 3ZH

Marine robotic vehicles have been used in marine geoscience research for over two decades, but the number of deployments and range of applications have both rapidly increased in recent years. Marine geoscience applications are primarily focussed on seabed mapping and imaging, using high-power, short-range, propeller-driven autonomous underwater vehicles (AUVs) or physically tethered remotely operated vehicles (ROVs). However, new unmanned surface vehicles, capable of carrying multibeam sonars, and low-power, long-range AUVs are opening up new possibilities for scientists. This presentation will provide a series of case studies illustrating past and present applications of marine robotics for marine geoscience, based upon the UK National Marine Facilities – Marine Autonomous and Robotic Systems fleet (see photo below), and will conclude with a look at potential future applications based upon new technological innovations.



Reference

Wynn, R.B., Huvenne, V.A.I., Le Bas, T.P., Murton, B.J., Connelly, D.P., Bett, B.J., Ruhl, H.A., Morris, K.J., Peakall, J., Parsons, D.R., Sumner, E.J., Darby, S.E., Dorrell, R.M. and Hunt, J.E. (2014) Autonomous Underwater Vehicles (AUVs): their past, present and future contributions to the advancement of marine geoscience. *Marine Geology*, 352, 451-468 (50th Anniversary Special Issue).

The rise of international collaborations in UK marine science from publication co-authorships

Neil C. Mitchell

School of Earth and Environmental Sciences
University of Manchester
Manchester, M13 9PL
U.K.

The numbers of co-authored research articles provide a record of the history of international collaborations. In this study, articles in marine science with co-authors based in the UK and in one other country (the USA, Germany, France, Italy or Spain) were extracted from the Web of ScienceTM. To overcome problems with keyword searches, the study used journal names to indicate marine science subject matter. Although the search may not fully reveal absolute numbers of marine science articles, interesting trends are found.

Whereas the number of UK publications in marine science increased steadily from the early 1970s with a doubling time of 16 years, those with co-authors based in the USA increased with a doubling time of only 8 years on average until 1997. They then abruptly more than doubled in only one year and subsequently continued to rise, though with a slower acceleration (doubling time 11 years). This pattern of early rapidly accelerating rise, abrupt increase and subsequent more modest acceleration is seen in articles co-authored with researchers from France, Germany, Spain and Italy, though with delays in the abrupt increase stage by up to a few years compared with the USA co-authored articles. European funding has likely been important for promoting collaborations and the numbers of European co-authored papers are greater than those with USA-based co-authors by an amount that is indeed higher than would be expected from the sizes of the country populations.

Abstracts for Poster Presentations

The versatility of petrophysical data to help ocean drilling research

Le Ber, E., Inwood, J., Morgan, S., Phillipot, L., Davies, S.
University of Leicester, UK.

Since the late 1980s, petrophysicists from the University of Leicester have been involved in offshore scientific coring projects, mostly sailing with the International Ocean Discovery Program (IODP) and its predecessors. Each IODP expedition aims to address different scientific objectives, covering themes including climate and sea level change, geohazards, deep biosphere and earth dynamics. Research undertaken by Leicester petrophysicists uses *in situ* data collected downhole and physical properties measurements from subseafloor core samples. Commonly this work is done in collaboration with other international researchers involved in the expeditions.

Petrophysical data are a crucial source of information: they provide insight to a wide range of geoscientific fields. They have been used to contribute making the link between geology and geophysics (IODP Expeditions 325, 340, 352), an important step in offshore environments where seismic data cover wide areas. Standard measurements in holes and on recovered cores also facilitate correlations between multiple holes at one site, or between sites across a region. Downhole logging has also proven to be extremely useful as a source of *in situ* information, notably images to evaluate the quality of the formation and borehole (IODP Expeditions 310, 343). Petrophysics generates a lot of data, and the group at Leicester frequently uses cluster analysis as a tool to help with the interpretation of lithologies and in intervals with low core recovery (IODP Expeditions 310, 313, 325). Ongoing and future research also uses cluster analyses on images (high-resolution digital linescans), and core and downhole petrophysical data to identify changes in sediment/rock facies/textures (IODP Expeditions 364, 381). A workflow is being created to perform similar studies with datasets from other expeditions*.

**IODP expeditions are international scientific collaborations that use research platforms to explore rocks and sediments from the subseafloor.*

Expeditions:

310 - Tahiti Sea Level

313 - New Jersey Shallow Shelf

325 - Great Barrier Reef Environmental Changes

340 - Lesser Antilles Volcanism and Landslides

343 - Japan Trench Fast Drilling Project (JFAST)

352 - Izu-Bonin-Mariana Fore Arc

364 - Chicxulub K-Pg Impact Crater

381 - Corinth Active Rift Development

Geomorphometric Characterisation of Seabed Features Using a GIS-based Semi-automated Toolbox

Joana Gafeira¹, Diego Diaz-Doce¹, Laurence H. De Clippele², Robert Gatliff¹

1 - British Geological Survey, Lyell Centre, Edinburgh, EH14 4AP

2 - Centre of Marine Biodiversity and Biotechnology, School of Life Sciences, Heriot-Watt University, Edinburgh, EH14 7AY

Marine geological mapping methods have evolved substantially over recent decades, along with the diversification of the uses for this mapping. However, manual mapping of seabed features can still be an enormously time-consuming and subjective component of the effort to map and understand the seabed geology. To address that the British Geological Survey developed a semi-automated mapping toolbox. This ArcGIS-based “*BGS Seabed Mapping Toolbox*” recognises, spatially delineates and morphometrically describes seabed features including pockmarks, coral mounds and other confined features.

Since it was first developed, several thousand pockmarks have already been mapped and characterised around the UK continental shelf, especially, within the central North Sea (Gafeira *et al.*, 2012). It has also recently been applied to other geographic areas (Barents Sea, Norway and Malin Deep, Ireland) with varied pockmark and seabed morphology, and in different geological settings. This systematic and consistent characterization of such vast numbers of pockmarks, with multiple morphological characteristics, allows an unprecedented statistical analysis of their morphology. Combining this with the geological and oceanographical knowledge of individual areas provides insights into the processes responsible for their development and the influence of local seabed conditions.

This toolbox was also used to semi-automatically delineate over 500 *Lophelia* reef ‘mini-mounds’ in the Mingulay Reef. The morphological characterization extracted was combined with data from the ROV-based microbathymetry. This allowed the creation of prediction maps of the likelihood of the presence of live cold-water coral colonies in individual coral mounds (De Clippele *et al.*, 2017) and improved the understanding of the factors that control the distribution of these ecosystems.

These are just some examples of potential of the use of objective semi-automated methods of seabed mapping and quantitative characterization of the seabed features.

How does marine sedimentary microbial sulfate reduction drive calcium carbonate polymorphism?

Chin Vik Lin^{1*}, Alexandra V. Turchyn¹, Zvika Steiner¹, Pieter Bots², Giulio I. Lampronti¹, Nicholas J. Tosca³

¹Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, United Kingdom.

²Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow G11XJ, United Kingdom.

³Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, United Kingdom.

(*correspondence: cyl48@cam.ac.uk; chinyik85@gmail.com)

Microbial sulfate reduction, coupled either to organic matter oxidation or anaerobic methane oxidation, may be one of the key drivers of sedimentary authigenic carbonate formation in marine sediments, intertidal marshes and hypersaline lakes. While much work has been done exploring the precipitation of different carbonate polymorphs in abiotic conditions, less is known about the different carbonate polymorphs produced during microbial biomineralization driven by microbial sulfate reduction. In this study, we grow sulfate reducing bacteria (*D. bizertensis*) in media with varying Mg/Ca and seeding materials (calcite and kaolinite). Our results suggest that sulfate reducing bacteria induce carbonate precipitation and serve as a nucleation for the growing carbonate; the majority of our carbonate was found grew on cell material rather than the mineral seeds. We also find the Mg/Ca ratio and phosphate in the media plays a key role in controlling how quickly carbonate is produced and which polymorph grows. In media where the Mg/Ca is greater than 2, a crystalline monohydrocalcite is the primary carbonate mineral produced. We converted monohydrocalcite to either calcite or aragonite abiotically at the end of the incubation. Although phosphate concentrations have a lesser effect on which polymorph initially precipitates, the presence stabilizes monohydrocalcite crystals and prevents their transformation to more stable polymorphs. This study suggests that calcium carbonate cements precipitated through microbial sulfate reduction is determined by the solution chemistry at the time when nucleation started.

Challenger Revisited: Illuminating Anthropogenic Climate Change With 150 Years Of Ocean Science

Lyndsey Fox*, Tom Hill, Stephen Stukins

Department of Earth Sciences, The Natural History Museum, London, SW7 5BD, UK

[*Lyndsey.Fox@nhm.ac.uk](mailto:Lyndsey.Fox@nhm.ac.uk)

Widely regarded as an imminent threat to our oceans, Ocean Acidification (OA) has been documented in all oceanic basins. Both measured and projected changes in seawater chemistry have potentially catastrophic biotic effects as OA hinders biogenic carbonate production, leading to substantial changes in marine ecosystems. Current attempts to address this issue via laboratory based studies have serious limitations, which can only be overcome by exploiting newly discovered plankton tows from the historic HMS Challenger expedition (1872-1876) and ground-breaking TARA expeditions (2009-2016). This project will investigate the biological effects and reveal the impact and magnitude of OA across the globe.

Changes in palaeo deep-water oxygen concentrations along the Iberian Margin across the Mid-Pleistocene Transition using a benthic $\delta^{13}\text{C}$ proxy.

Nicola Thomas and David A. Hodell

Godwin Laboratory for Palaeoclimate Research, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ

Deconvolution of the benthic $\delta^{18}\text{O}$ signal at Site 1123 into its temperature and seawater components suggests an abrupt increase in glacial ice volume occurred at 900 ka (MIS 24-22) during the MPT. At the same time, neodymium and carbon isotopic evidence suggests a major change occurred in deep-water circulation. Benthic $\delta^{13}\text{C}$ values are among the lowest at many sites during MIS 22-24, suggesting increased carbon storage in the deep sea. This should have affected atmospheric CO_2 and indeed lower values of glacial CO_2 have been observed after 900 ka.

To study the changes in nutrient regeneration and apparent oxygen utilization across the MPT we used a recently calibrated stoichiometric proxy for palaeoxygen based on the carbon isotope gradient between epifaunal *Cibicides wuellerstorfi* and infaunal *Globobulimina affinis* on the Iberian Margin (Hooggakker et al., 2015). We have thus far measured $\delta^{13}\text{C}$ of these two species at Site U1385 ("Shackleton site") from MIS 30 to 22. Sharp decreases in the $\delta^{13}\text{C}$ gradient are observed at terminations 26/25, 24/23 and throughout much of MIS 22 suggesting oxygen concentrations as low as $135 \mu\text{mol kg}^{-1}$, similar to values obtained for values observed during some Heinrich events (Hooggakker et al., 2015). Further work is needed to assess whether there was a step change in glacial deep-sea oxygen concentrations at 900 ka.

Anatomy of the oldest known Heinrich events in MIS 16 at Site IODP1308

Abbie P.B. Currington, Maryline J. Mleneck-Vautravers, David, A. Hodell

Godwin Laboratory for Palaeoclimate Research, Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ

Marine Isotope Stage (MIS) 16 represents one of the largest glaciations of the Quaternary, consisting of the Donian glaciation in Europe. It also marks the start of dynamic behaviour of the Laurentide Ice Sheet through Hudson Strait expressed in North Atlantic sediments as Heinrich layers. We studied IODP Site U1308 (re-occupation of Site 609) in the central North Atlantic to document the first two recorded Heinrich events that occurred near the end of MIS 16. Similar to Heinrich events of the last glacial period, H16.1 and 16.2 are marked by razor-sharp bases, abundant detrital carbonate grains, and low abundance of planktonic foraminifers. However, planktonic foraminiferal assemblages were noticeably warmer during H16.1 and 16.2 than those of their last glacial counterparts and contain rare, but well-preserved, temperate foraminifera (*G. bulloides* & *G. inflata*).

Between H16.2 and 16.1, two distinctive silicate-rich peaks of IRD are recorded consisting of well-rounded grains of diverse lithology in the coarsest sediment fraction (>1 mm), perhaps reflecting ice incorporation in coastal region. Quartz dominates in the finer sediment fractions. Although the source of these IRD events awaits completion of Sr and Nd isotope analysis, they may be derived from multiple ice sheets and contain substantial contributions from Eurasia. The older event postdates H16.2 and the younger predates H16.1 with a period of high carbonate content and low IRD between the silicate-rich IRD peaks.

The silicate-rich events appear to be closely related to H16.1 and 16.2 although the older event postdates H16.2 whereas the younger event predates H16.1. They are not as simple as the precursor events proposed for last glacial Heinrich events, whereby instability of European ice sheets were suggested as a trigger for Heinrich events. Increased roundness of coarser grains in the silica-rich events, and potential better sorting, suggest not only that these events originated from a different source than the Heinrich events, but that sea-ice may have played a role in the transport of IRD, in addition to ice-bergs.

Marine operations: geology through technology

*Joseph Hotherall, Will Lewis, Bob Gatliff
British Geological Survey*

The BGS Marine Operations department, designs, builds and operates a suite of remote subsea sampling systems. These have seen use on a wide range of research projects ranging from deep sea drilling into hydrothermal systems to the mapping of the last British and Irish Ice sheet. They range from the RD2 seabed rock drill capable of drilling, coring, logging and sealing boreholes in water depths up to 4000m to the shallow water White Ribbon survey vessel.

Please note there will also be several industry poster presentations from Geotek and GESAMP and we are awaiting several more poster abstracts as of this printing.