An International Conference and Workshop
At Southampton Oceanography Centre
Southampton, United Kingdom
4-5 September 2003

New Ways Of Looking At Sediment Cores And Core Data

Programme and Abstracts

Conference sponsored by

Programme

Wednesday 3rd September

Exhibitor set up

4 pm – 7 pm	*Conference Registration*
7.30 pm	Conference Dinner and Ice-breaker aboard *SS Shieldhall* (Berth 48, Dock Gate 4, Southampton Docks)

Thursday, 4th September

Registration from 8.30 am

9.15	Coffee
9.45	Introduction and welcome
Session Chairman:	*Angus Best (SOC)*
10.00	Keynote: *Core logging, imaging, and analysis: Recent accomplishments and future challenges* Frank Rack (Joint Oceanographic Institutions Inc., Washington)
10.45	*New methods for the assessment of sediment and rock cores* Quentin Huggett (GEOTEK Ltd, Daventry)
11.10	Coffee
11.30	*The HYACINTH project* Tim Francis (GEOTEK Ltd, Daventry)
12.00	*Geophysical logging of pressure cores containing methane hydrate on ODP Leg 204* Peter Schultheiss (GEOTEK Ltd, Daventry) and M.E. Holland (Arizona State University, Tempe, Arizona)
12.30	*Geoacoustic analysis and imaging of gassy sediment cores from the Adriatic* Angus Best (Southampton Oceanography Centre)
13.00	Lunch

Session Chairman	*Ian Croudace (SOC)*
13.30	Keynote: *X-ray fluorescence (XRF) core scanning for unlocking fine-scale Cenozoic paleoceanography* Thomas Westerhold and Ursula Roehl (University of Bremen)
14.15	Keynote: *Yaxcopoil-1 core in the Chicxulub crater: XRF core scanning of the K/T boundary interval* Jan Smit (Free University of Amsterdam)
15.00	*Applications of X-ray fluorescence (XRF) corescanning to North Atlantic paleoceanography* Thomas O. Richter, Sjerry Van der Gaast, Tjeerd C.E. van Weering (Royal Netherlands Institute for Sea Research, Texel)
15.30	Coffee
15.50	*High-resolution oceanographic and atmospheric changes at the Plio-Pleistocene boundary in the equatorial Pacific Ocean inferred by XRF core scanning* Ana Moreno (Instituto Pirenaico de Ecologia, Zaragoza, Spain) and Isabel Cacho (Facultat de Geologia, Universitat de Barcelona, Spain)
16.15	*Cortex, state of the art of the AVAATECH XRF core scanner* Sjerry Van der Gaast (Netherlands Institute of Sea Research, Texel)
16.45	*Itrax corescanner - digital radiography and micro-XRF analysis of sediments - principles and applications* Anders Rindby (Chalmers Technological University, Gothenburg)
17.15	*Initial evaluation of the ITRAX micro-XRF sediment core scanner* Ian Croudace, (Southampton Oceanography Centre)
17.30	*High-resolution XRF scanning of sediment cores - a useful tool for lithostratigraphic analysis* Guy Rothwell (Southampton Oceanography Centre)
17.45	*A geochemical application of the ITRAX core scanner to a sediment core containing eastern Mediterranean sapropel units* John Thomson (Southampton Oceanography Centre)
18.00-19.00	Demonstration of ITRAX and CORTEX XRF corescanners in BOSCORF core laboratories (A1 Building, SOC)

<u>Friday, 5th September</u>

Registration from 8.30 am

9.00	Coffee
Session Chairman	Phil Weaver (SOC)
9.30	*Mechanics of coring: behaviour of gravity (square, round) and piston cores from a soil mechanics perspective with a view to assessing possible compression/stretching distortion of the records* Luke Skinner and Nick McCave (University of Cambridge)
10.00	*Colour Logging as a tool in high-resolution palaeoceanography* Mike Rogerson and Phil Weaver (Southampton Oceanography Centre)
10.30	Coffee
11.00	*Digital sediment colour analysis in laminated sediments and reconstruction of high frequency climate variability* Sandra Nederbragt (University College, London)
11.30	*A New mini-permeameter and laser surface profiler for sediment cores* Neem Aljabari (Heriot-Watt University, Edinburgh)
12.00	*Rapid porosity/lithology logging of soft sediment core using a novel non-contacting resistivity technique* Peter Jackson et al. (British Geological Survey, Keyworth)
12.30	Lunch and posters *Drinks provided courtesy of Challenger Oceanic*
Session Chairman	Guy Rothwell (SOC)
13.30	*Electrical resistivity of marine sediments - core measurements* Peter Jackson (British Geological Survey, Keyworth) and Mike Lovell (University of Leicester)
14.00	*Electrical imaging of fractured core using a novel electrode approach* Mike Lovell et al. (University of Leicester)
14.30	*Techniques used to detect storm and tsunami deposits in sediment cores from coastal lagoons* Pedro Costa (Brunel University, Uxbridge)

15.00	Keynote: *New computing methods for generating national coverages of seabed core and sample data* Chris Jenkins (INSTAAR, University of Colorado)
15.45	Coffee
16.10	OPEN FORUM: New sensor development: what do the scientists want and what can the technologists provide? Chair: Peter Schultheiss (Geotek Ltd.)
17.00	Concluding remarks
17.15	Close of meeting

Saturday, 6th September

Exhibitor dismantling

Abstracts

Oral Presentations

Abstracts are listed in alphabetic order according to first author surname.
Speakers are underlined where there are multiple authors.

A new non-contact permeability sensor

Naeem Al-Jabari

Institute of Petroleum Engineeing, Heriot-Watt University
Edinburgh, EH14 4AS, United Kingdom

Email: Naeem.Aljabari@pet.hw.ac.uk

Petroleum Engineering management decisions are based upon predictive flow models. Reliable flow models require an accurate knowledge of permeability distribution.

I shall describe a newly developed mini-permeameter in which:

- The probe does not contact the specimen, so maintenance costs are reduced and associated errors are avoided.
- The spatial sample interval, or resolution can be as little as 10 m.
- Data may be acquired over 10,000 times faster than any other permeameter.
- The repeatability of results is 20 times better than any other mini-permeameter.

The new mini-permeameter still uses the pressure decay principle; its enhanced features are due to its novel design. Because core slabs may now be scanned much more rapidly (in hours rather than days) and far more accurately; better quality, more extensive, and cheaper data can be provided for reservoir model building.

Laser-acoustic array in rock physics

Naeem Al-Jabari

Institute of Petroleum Engineeing, Heriot-Watt University
Edinburgh, EH14 4AS, United Kingdom

Email: Naeem.Aljabari@pet.hw.ac.uk

Most acoustic measurements made in Rock Physics laboratories are taken over the length of a cylindrical core specimen. Figure 1a,b shows how three traces are usually recorded:

- A single P-wave trace

- Two orthogonally polarized S-wave traces

Figure 1c,d shows that a ‘mini surface seismic spread’ may be deployed as an alternative. The advantages are:

- Peaks may be picked instead of first breaks. S-wave first-breaks are often obscured by P-wave trains (Figure 1b).

Each velocity is calculated by Least Squares Fit from fifteen or more traces. This provides accurate results together with a numerical measure of accuracy.

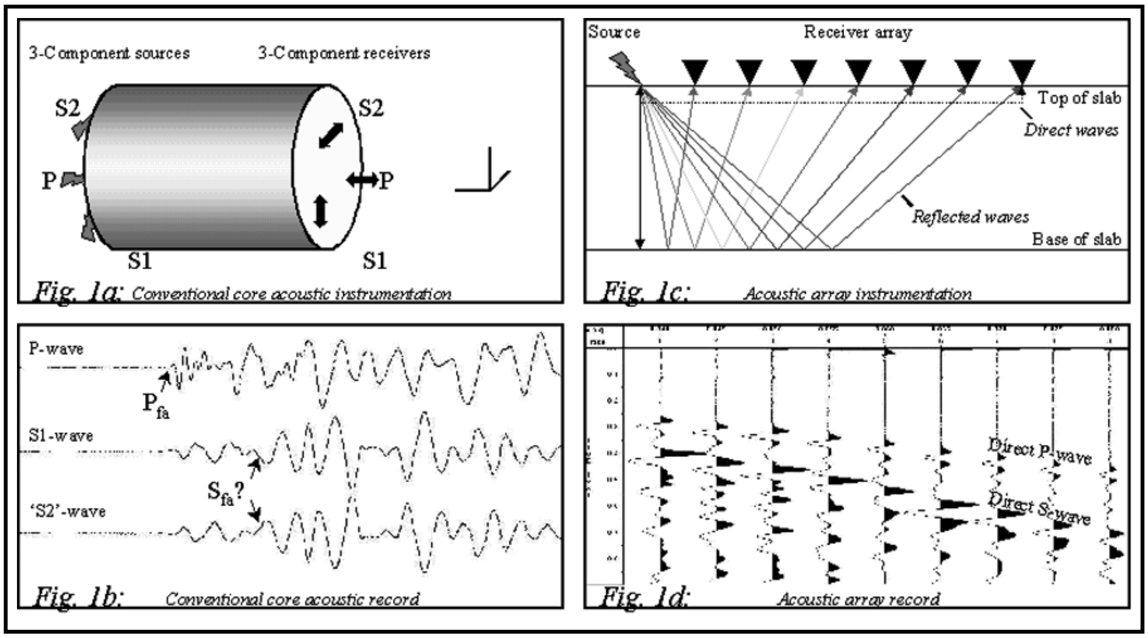

Figure 1:

a) normal core acoustic measurements,
b) P and S waveforms in Rock Physics,
c) An 'off-end' array of transducers,
d) Acoustic data from an 'off-end' array.

Furthermore, we may now apply the velocity filter to identify and separate wave-fields. Both frequency and polarization filters are well established in Rock Physics laboratory work. With the velocity filter, we may identify:

- Direct arrivals as in a surface seismic refraction shoot
- Ongoing and downgoing wave-fields with linear moveout, as in a VSP survey
- Cross-specimen reflected waves with hyperbolic moveout, or Normal Move Out (NMO)

Also, we have the intriguing possibility of measuring Amplitude Versus Offset (AVO) effects directly in the Rock Physics Laboratory.

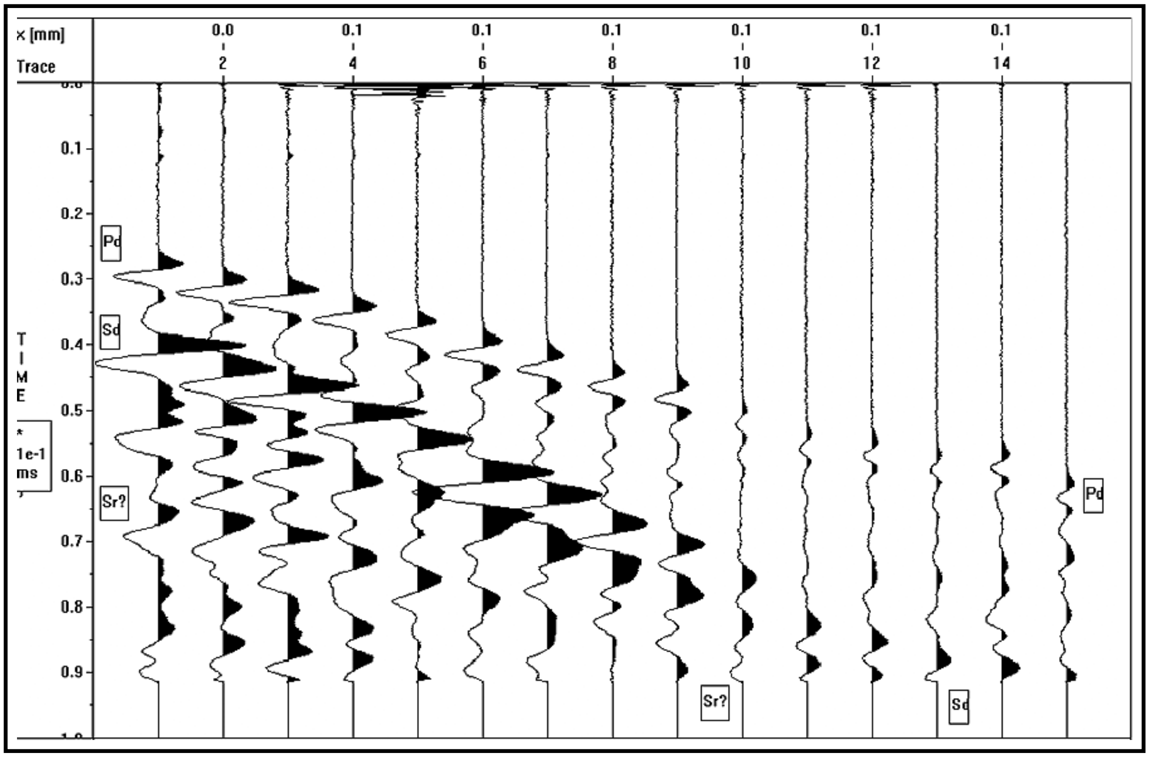

Figure 2: Wave-fields from an acoustic array on a sandstone slab:
Pd: direct P-wave with a velocity of 2,041 +/- 126 m/s,
Sd: direct S-wave with a velocity of 1,257 +/- 78 m/s,
Sr?: possible reflected S-wave with an NMO velocity of ~1,100 m/s.

Figures 3 and 4 examine the possibility of a cross-slab reflection event with hyperbolic moveout. In each figure, the semblance plot is on the left and the gather is on the right. With a longer record, the possible S-wave reflection, labelled 'Sr' would continue over more traces. The absence of near-offset traces makes the identification of hyperbolic moveout difficult to establish. However, Figure 4 shows that surface seismic velocity analysis and NMO correction could be applied to Rock Physics Laboratory data, if array measurements are made.

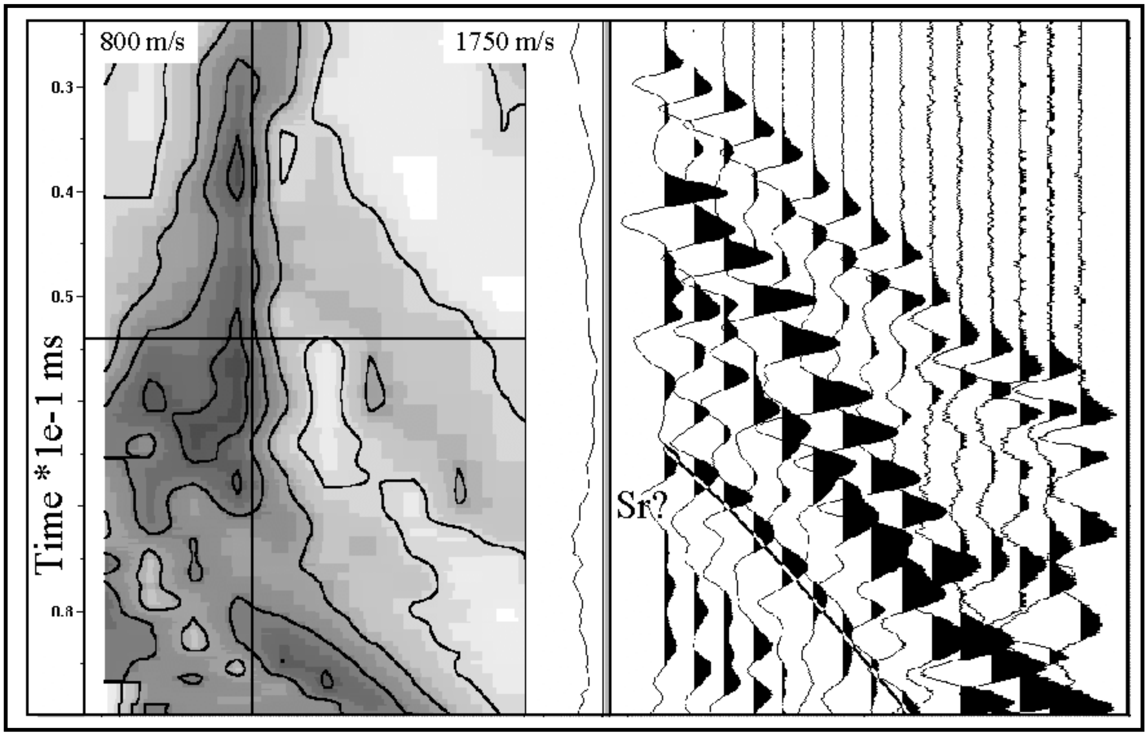

Figure 3: NMO velocity analysis of possible S-wave reflection.

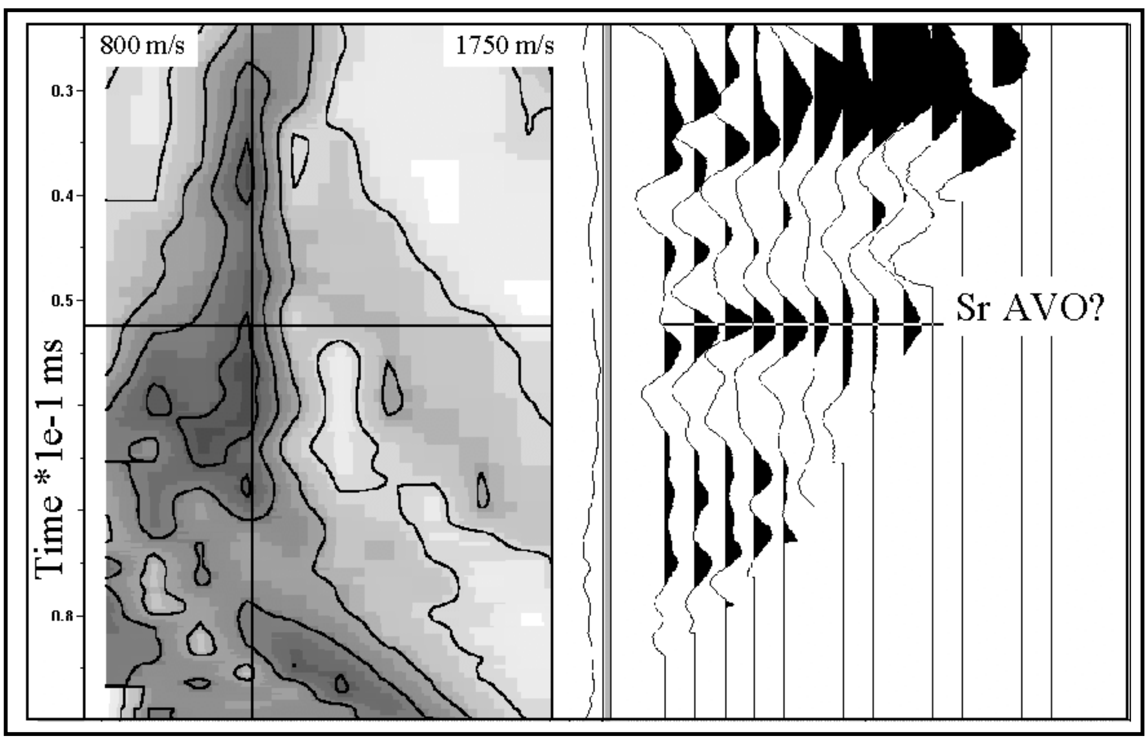

Figure 4: NMO velocity correction to show possible AVO.

We wish to acknowledge the use of the VISTA seismic data processing package from SIS, under an academic agreement in the preparation of Figures 2, 3 and 4. However, the opinions expressed are solely those of the authors.

Geoacoustic analysis and imaging of gassy sediment cores from the Adriatic

Angus Best[1], Magdalena Szuman[1], Jeremy Evans[1], Antonio Cattaneo[2] and Fabio Trincardi[2]

[1]Challenger Division for Seafloor Processes, Southampton Oceanography Centre, European Way Southampton, SO14 3ZH, United Kingdom
[2]Istituto di Scienze Marina - ISMAR (CNR), Sezione Geologia Marina (Bologna), via Gobetti 101 40129 Bologna, Italy

Email: aib@soc.soton.ac.uk

Our aim is to characterise the acoustical and geotechnical properties of gas-bearing sediments in the Adriatic, offshore Ortona, Italy, that may be linked to slope instability there. To this end, a 10 m long sediment core (COS01-20) and a special, gas-sealed, 3 m long gravity core (PAID1) were collected at sites where the gassy sediments form near the seabed. The 10 m core was logged whole and split for P-wave velocity, bulk density and magnetic susceptibility. Shear wave velocity was also measured on the split core after being imaged with a digital colour camera. Both cores were X-ray CT scanned in an effort to detect the nature of the gas bubbles in these muddy sediments. Numerous (up to about 1 cm long) cracks were seen in the core below about 1 m, taken as evidence for *in situ* gas (Fig. 1). Much larger, gas-filled fractures and voids were also seen in the core, becoming more predominant with depth. These voids were probably formed by gas expansion and escape during core recovery (we are awaiting X-ray results from the pressure core to confirm this). The P-wave signals become seriously degraded below about 5 m, corresponding to some threshold in the secondary gas expansion fractures. Although the degree of core disturbance makes it difficult to apply the measured acoustical properties to the *in situ* case, the X-ray images can give estimates of gas bubble size distribution, which in turn can be used as input to an acoustical model for gassy sediments. We plan to use these data to model the acoustic reflectivity of the gassy sediments, and hence to predict the physical properties of downslope “weak layer” sediments using chirp profiles.

Broadband P-wave transmission data have also been collected on the pressure core PAID1. In a previous study, velocity and attenuation results showed large increases in the gassy parts of the core and gave usable frequency information in the range 300 – 700 kHz. Although not automated and repeatable coupling depends on careful positioning of the flat-faced transmit and receive transducers using a special collar, this technique is comparable to that developed at Bremen University in Germany in terms of the data collected. Moreover, the heavily damped transducers used here give a superior bandwidth with a smooth, “bell-shaped” amplitude spectrum that greatly improves the quality of the observed signals. Cross-correlation, spectral ratios and multiple-filtering techniques of reference and sediment signals allow accurate measurement of phase velocity and attenuation over the frequency band. The reference signal is obtained on the water-filled part of the core, or on an identical core liner filled with water, and allows the unknown liner velocity, attenuation and geometric spreading to cancel out using the above methods. There may be small geometric spreading differences in the water and sediment, but these are generally ignored and are not significant when comparing the large magnitude changes in velocity and attenuation between non-gassy and gassy parts of the core. It may be possible to use the frequency response to characterise bubble sizes below the resolution of X-ray CT scanning (c. 0.5 mm in above example) using the Anderson and Hampton theoretical model.

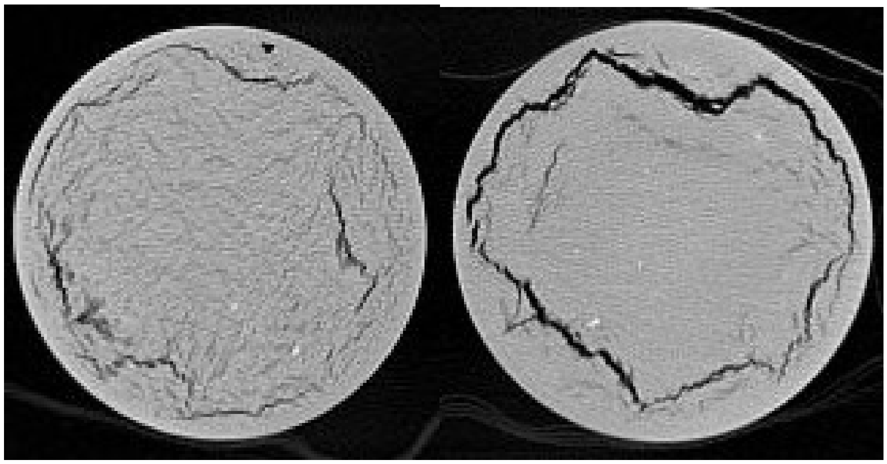

Figure 1. Examples of large gas-filled voids in core COS01-20 due to gas escape upon core recovery. Fine (< 1 cm long) cracks are just visible in the left hand image, probably flooded with water, but possibly representative of *in situ* gas cracks. Core diameter is 6 cm.

Techniques used to detect storm and tsunami deposits in sediment cores from coastal lagoons

Pedro Costa[1], Suzanne Leroy[1], Stephen Kershaw[1] and Jorge Dinis[2]

[*]Department of Geography and Earth Sciences, Brunel University
Uxbridge, UB8 3PH, Middlesex, United Kingdom
[+] Departamento de Ciências da Terra, Universidade de Coimbra
Largo Marquês de Pombal, Coimbra, 3000-272 Portugal

Email: Pedro.Costa@brunel.ac.uk

A series of lakes and coastal lagoons are being studied along the Portuguese and Mauritania coasts with the aim of:
- Discovering and studying the 1755 tsunami sediment layer
- Understanding the environmental effects of the 1755 tsunami
- Detecting storm deposits
- Detecting major environmental changes in that geographical area, since then.

Due to their specific conditions (erosion, deposition, biodiversity, salinity, etc.) coastal lakes can be useful when conducting palaeoseismological and/or palaeoenvironmental researches. Identifying storm and tsunami deposits is still a matter under intense debate. The hydrodynamics of this type of event contributes to complex deposition. To clearly distinguish storm and tsunami deposits from the under and overlying deposits a multi proxy analysis is required. We studied a group of palaeolimnological and palaeoseismological proxies in order to establish the full extent of the catastrophic event, but we also looked at other non-catastrophic changes in the study area.

The techniques used include magnetic susceptibility, x-ray imaging, sediment visual description, laser granulometry, geochemistry (Atomic Absorption Spectrometry), Pb^{210} and OSL dating, palaeontological studies and a range of sedimentological and palaeoecological proxies with the focus of obtaining well-dated tsunami/storm indicators such as salinity changes, grain size changes, erosive and compaction microstructures. We also used historical data to collect complementary information about the effects of the tsunami and to reinforce the age-depth model of the sedimentary sequences.

A geochemical application of the ITRAX core scanner to a sediment core containing eastern Mediterranean sapropel units

I.W. Croudace, R.G. Rothwell and J. Thomson

Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, United Kingdom

Email: jth@soc.soton.ac.uk

The new ITRAX core logger at the British Ocean Sediment Core Research Facility (BOSCORF) has been applied to a sediment geochemistry investigation. The core sections analysed contained examples of the organic-rich sedimentary units (sapropels) that form periodically in the eastern Mediterranean basin. Sapropels are visually obvious from their dark colouration, but the ITRAX X-radiograph also reveals physical property changes that result from the high pore water content of sapropel sediment. A consideration of discrete sample wavelength-dispersive XRF data from the most recent sapropel (S1) along with the set of elements reported by the ITRAX instrument's energy-dispersive XRF over core sections containing S1 allowed selection of a suite of eight inter-element ratios or element integrals through which to investigate characteristic features of sapropel development and geochemistry. While recognizing that the measured XRF element integrals do not have an exact constant relationship with element concentration through changing sediment types, this combination of elements provided evidence for (i) the presence of high Corg contents in the visual sapropel from Ba/Ti and Br/Cl ratios, (ii) post-depositional oxidation that had thinned the visual sapropel from Mn/Ti and Cu/Ti ratios, (iii) pyrite authigenesis in the visual sapropel from Fe/Ti and S/Cl ratios and the As integral, and (iv) aragonite formation in and around the visual sapropel from the Sr/Ca ratio. These same ratios were then used to interpret scans from a deeper section of the same core that contained the older sapropel S3, where the same characteristics including oxidative thinning of the original unit could be identified with only minor differences of detail. Directions of supply of Fe, As and Cu into the sapropels could be inferred from profile shapes.

Initial evaluation of the ITRAX micro-XRF sediment core scanner

Ian Croudace, John Thomson and Guy Rothwell

Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, United Kingdom

Email: iwc@soc.soton.ac.uk

Traditional determination of elemental profiles in sediment cores normally requires gram quantities for accurate chemical analysis, often from material that is available in very limited quantities. An instrument capable of providing high-resolution geochemical profiles non-destructively, prior to any further sampling (destructively), is valuable. The ITRAX™ Core Scanner allows sediment half cores up to 1.5 metre to be characterised at a resolution as fine as 100-micrometers. The intense X-ray beam, focused through a flat capillary waveguide, is used to irradiate samples to enable both micro X-radiography and the determination of a range of major and trace elements. The digital information is incrementally acquired by progressively pushing a half core, via a programmable stepper motor drive, through the flat beam. The usefulness and quality of the ITRAX data are evaluated and compared with accurate and precise results obtained using the traditional more laborious method of WD-XRF. Artifacts in the data arising from imperfections in cores are also considered.

The HYACINTH project

Tim Francis

Geotek Ltd., 3 Faraday Close, Drayton Fields
Daventry, Northants, NN11 5R, United Kingdom

Email: tim@geotek.co.uk

HYACINTH is the acronym for "Deployment of HYACE tools In New Tests on Hydrates". It is a European Framework Five project, which is being carried out by a consortium of six companies and academic institutions from Germany, The Netherlands and the United Kingdom. Its primary objective is to bring the pressure corers developed in the earlier HYACE project, together with new core handling technology developed within the HYACINTH project, to the operational stage. Our philosophy is that, if all one does with a pressure core is to bleed off the gas it contains, a major scientific opportunity has been missed. The current system enables pressure cores to be acquired, then transferred, without loss of pressure, into laboratory chambers so that they can be geophysically logged.

The suite of equipment making up the system - HYACE Rotary Corer (HRC), Fugro Pressure Corer (FPC), Shear Transfer Chamber (STC), Logging Chamber (LC), Storage Chamber (SC), and Vertical Multi-Sensor Core Logger (V-MSCL) - will be described. Other developments currently in progress to extend the capabilities of the system will be summarised: - to allow electrical resistivity logging of the pressure cores, to enable pressurised sub-samples to be taken from the cores, and to facilitate microbiological experiments to be made on pressurised sub-samples.

The first scientific results obtained with the HYACE/HYACINTH technology were achieved on ODP Leg 204 last summer and are the subject of the talk being given by Peter Schultheiss to this conference.

New methods for the assessment of sediment and rock cores

Quentin Huggett

Geotek Ltd., 3 Faraday Close, Drayton Fields
Daventry, Northants, NN11 5R, United Kingdom

Email: quentin@geotek.co.uk

Geotek has developed a new multi-sensor core logging (MSCL) system for the analysis of sediment and rock cores. This is a three axis system (XYZ) into which up to nine 1.5m long core sections can be loaded ready for analysis. The first system of this type was developed for the Ocean Drilling Program (ODP), when they had a requirement for the digital imaging of cores, and was installed on the *JOIDES Resolution* two years ago. The ODP system has just two axes of movement (XY) and space for four 1.5m core sections.

Geotek has developed this arrangement further and added a third axis onto which a variety of sensors can be installed. In the first half of 2003 a series of XYZ-MSCLs were constructed for the collection of digital core images, spectrophotometer data (using a Minolta device), and high-resolution magnetic susceptibility data (using a Bartington MS2E sensor). Three of these systems have been delivered to Japan for use on the OD21 drilling ship *Chikyu* and in its onshore support laboratory at Kochi University. The software that controls the XYZ-MSCL provides the user with flexible options so that a time efficient data acquisition process can be devised. Because up to nine core sections can be loaded onto the system at any one time, the system does not require constant monitoring while data are being collected.

The XYZ-MSCLs have been designed so that they can be adapted to carry a variety of different sensors (both contact and non contact) apart from those already fitted (spectrophotometers, magnetic susceptibility sensors and digital imaging systems). In particular spectral natural gamma measurements on whole or split cores (which can often be a very time consuming measurement) may be particularly suited to this arrangement. Other sensor systems may include electrical resistivity (contact or non contact) and contact probe permeametry.

Electrical resistivity of marine sediments - core measurements

Peter Jackson[1] and Mike Lovell[2]

[1]British Geological Survey, Keyworth, Nottingham, NG12 5GG, United Kingdom

[2]Department of Geology, University of Leicester, Leicester, LE1 7RH, United Kingdom

Although the potential of electrical resistivity measurements to characterise sediment properties both on the seafloor and in the laboratory is demonstrated in the literature, the resistivity method is poorly utilised in marine investigations. While a drawback of laboratory resistivity measurements is direct contact with the sample and its consequent disturbance and potential for contamination, their resolution is limited only by the physical size of their electrodes and the signal to noise ratio. Theoretically, electrodes are often considered infinitesimally small points. For example, we have demonstrated resistivity imaging of split core at resolutions of 5 mm during Leg 133 of the Ocean Drilling Program.

While the work of Archie, relating resistivity to pore fluid resistivity, porosity, cementation and oil saturation is becoming well known outside the hydrocarbon industry, the control of grain shape is less well known but of primary significance when considering fully-saturated, un-cemented marine sediments. Results of extensive laboratory testing are presented illustrating ‘grain-shape’ control and its independence of particle size, each sample following Archie’s equation with a characteristic value of his ‘m’ parameter. Thus at the ‘site’ scale subtle changes in porosity and lithology may be detected. On the ‘regional’ scale, laboratory measurements taken from a bay in the Irish Sea demonstrate a strong trend of resistivity decreasing as particle size decreases, being consistent with the sphericity of the grains decreasing and porosity increasing as mean grain size becomes smaller. Consequently, resistivity may be considered as a lithology indicator.

Resistivity imaging of core is presented, illustrating the high-resolution possible when the electric field resulting from a uniform flow of electric current through the sample is taken as the measurement dataset. While sub-horizontal features extending across the core are imaged with fidelity, a correction for heterogeneity contained within the core is demonstrated. Examples of resistivity imaging taken during Leg 133 of the Ocean Drilling Program show fine scale structure within sedimentary features including turbidites and debris flows, plus responses seen in the electrical image of an expanded section which were invisible to the naked eye.

Examples are also presented of resistivity images of very shallow two-dimensional cores inserted into soft sediments by divers and the control of pore shape in a carbonate environment.

Rapid porosity / lithology logging of soft sediment core using a novel non-contacting resistivity technique

Peter Jackson[1], Mike Lovell[2], John Roberts[3], Peter Schultheiss[3], Dave Gunn[1]
Robert Flint[1,4], and Adrian Wood[5]

[1]British Geological Survey, Keyworth, Nottingham, NG12 5GG, United Kingdom

[2]Department of Geology, University of Leicester, Leicester, LE1 7RH, United Kingdom

[3]Geotek Limited, 3 Faraday Close, Daventry, Northants, NN11 5RD, United Kingdom

[4]Now at Department of Aeronautical and Automotive Engineering, Loughborough University Leicestershire, LE11 3TU, United Kingdom

[5]Adrian Wood Associates, Danehill, Brookhill Rd, Copthorne, Crawley, RH10 3PS, United Kingdom

Email: peter.jackson@bgs.ac.uk

Electrical resistivity is used by the hydrocarbon industry as a primary method for reservoir characterisation, being related to porosity, porosity style and the fluids in the pore space (e.g. oil, water, or gas). Where sediment is fully saturated the resistivity changes will reflect changes in porosity and fabric, whereas changes in pore fluids (e.g. associated with hydrate dissociation) may be dominant over these. Consequently, electrical resistivity has significant potential for characterising marine sediments. Traditionally, methods of measuring the electrical resistivity of cores make direct electric contact with the sample material. These galvanic methods can be successfully applied with care, but may be inappropriate where avoidance of sample contamination is an issue.

We use laboratory experimentation to demonstrate a non-contacting approach to whole-core and split-core resistivity measurements at a resolution of the order of 10 mm. The method operates at low induction numbers, needing highly sensitive coil pairs to provide resistivity measurements at the desired resolution. A four-coil arrangement, of two pairs of transmitter and receiver coils is used to stabilise the measurement. One ‘coil pair’ acts as a control, enabling the effects of local environmental variations, which can be considerable, to be removed from the measurement at source. Comparing the new non-contact approach and independent traditional 'galvanic' resistivity measurements using fluids of differing concentrations of sodium chloride, indicates the non-contact measurements are directly proportional to the reciprocal of the resistivity (i.e. conductivity) of the sample. The depth of investigation is discussed in terms of both theory and practical measurements. The response of the technique to a variety of synthetic 'structures' is presented. A whole core image of a dipping layer is used to demonstrate imaging with azimuthal discrimination at a resolution of the order of 10 mm is possible, thus demonstrating the technique could be used to investigates to different depths within the core, in agreement with theoretical predictions. In addition, the non-contact approach to electrical resistivity characterisation can be carried out relatively rapidly on cores in a non-destructive mode, thus enabling large quantities of core to be rapidly characterised and providing core resistivity logs prior to core-splitting as a basis for high resolution sub-sampling.

New computing methods for generating national coverages of seabed core and sample data

Chris Jenkins

Institute of Arctic & Alpine Research (INSTAAR)
University of Colorado, 1560 30th Street
Campus Box 450, Boulder CO, 80309-0450, USA

Email: chris.jenkins@colorado.edu

The dbSEABED compilation now holds over a million attributed sites worldwide. It is a research structure, a federation of agencies and universities, and open to others to use and contribute to. A major goal is to produce mappings of marine substrates for research on large scales, such as for chemical cycles and climate change, and for fisheries and habitat. Under the system, local- national- and global-scale integrations are made of seafloor data which has been collected by multitudes of expeditions over the years, based on cores, grabs and dredges, divers, cameras and electronic probes. Because these data were collected for diverse research, environmental, defence, engineering and survey goals, the total information is extremely rich. Because the compilation is point (sites) based, the overall spatial and attribute resolution constantly improves with new additions and new expeditions. The worldwide data holdings may be explored via the web at “iSEABED”.

Integration is achieved through “information processing”. Algorithms work on data documents to produce outputs, including GIS-ready data and a relational database. This gives huge efficiencies in data import and later editing, refinement and extension of the system, and production of table and visual outputs. dbSEABED will be demonstrated at the meeting. A feature is its processing of word-based descriptions, the outputs of which are conformable with those of numeric analytical data.

Core and subbottom data is held and treated in dbSEABED. Data is located by coordinate, water depth, subbottom depths, and phase (e.g., for an analysis of a special clast). Analytical data such as MultiSensor Core Logger results and word-based descriptive core-logs are integrated and output to formats that are readily useable by almost any vendor’s GIS or CoreLog software application. Automated generation of graphic core-logs has been developed recently for US offshore aggregates and defence projects, and will proceed ultimately to the interactive inter/intranet serving of 3D data for the seabed for agencies, corporations and the public.

Electrical imaging of fractured core using a novel electrode approach

Mike Lovell[1], Peter Jackson[2], Robert Flint[2,3], Peter Harvey[1], and John Roberts[4]

[1]Department of Geology, University of Leicester, Leicester, LE1 7RH, United Kingdom

[2]British Geological Survey, Keyworth, Nottingham, NG12 5GG, United Kingdom

[3]Now at Department of Aeronautical and Automotive Engineering, Loughborough University Leicestershire, LE11 3TU, United Kingdom

[4]Geotek Limited, 3 Faraday Close, Daventry, Northants. NN11 5RD United Kingdom

Email: mtl@leicester.ac.uk

Downhole electrical images are used to assess the nature, variability and distribution of subsurface formations. The images can be used to describe and delineate sedimentary features, to provide input into depositional models, to describe and quantify fracture occurrence and orientation, to identify and distinguish breakouts and hydraulic (induced) fractures, and to provide indications of local variability and heterogeneity in terms of porosity and permeability variations (with calibration to core). In parallel to these downhole images, detailed laboratory studies have provided improved understanding of the variability of petrophysical properties at the pore scale. These variations are often related to the fine scale sedimentary (depositional and/or diagenetic) and structural (gross geometry and stress related) fabric, although stratigraphic descriptions based on visual (optical) observations do not always agree with petrophysical parameters (averaged over core plug?).

We have previously demonstrated the ability to image sedimentary fabric in the laboratory and to relate the electrical core images to properties such as porosity and permeability as well as to grain size and cementation. More recently we have adapted our approach to enable electrical imaging of fractures in core using similar principles to those employed in downhole electrical imaging. Successful imaging of fractures has required the development of a novel electrode approach, effectively incorporating a 4-electrode measurement at the core surface and with passive focussing to effectively force current flow through the saturated fracture (by limiting surface flow). The results demonstrate the ability of the technique to image conductive fractures in fully saturated water-bearing core; because of the nature of the measurement we can be confident that these fractures are electrically connected from the flat measurement surface through to the outer surface of the core.

Published results for numerical modelling of downhole electrical imaging tools show the electrical response to be related to fracture depth and fracture aperture. Initial experimental results on fractured core in the laboratory appear to support these numerical observations with increased current flowing into the fracture as the aperture increases. The finite size of the electrode, however, (e.g. the downhole button) means that this technique cannot theoretically distinguish between a single fracture and smaller groups of fractures adjacent to the electrode.

In cores where the fractures may be filled with clays we recognise that it is impossible to determine solely from the static electrical images whether the fractures are open or closed to fluid flow. Although not demonstrated here, however, our work on sedimentary fabric, has demonstrated that passing a tracer fluid of different resistivity to the saturating fluid can identify fluid pathways from clay-filled pathways in core.

Application of XRF core scanning to infer rapid oceanographic and atmospheric changes at the Plio-Pleistocene boundary in the Equatorial Pacific Ocean

A. Moreno[1] and I. Cacho [2]

[1]Pyrenean Institute of Ecology, Spanish Research Scientific Council, Apdo 202
Zaragoza, E-50080, Spain
[2]CRG Marine Geosciences, Faculty of Geology, University of Barcelona, Campus de Pedralbes
08028 Barcelona, Spain

Email: amoreno@ipe.csic.es, isabel@geo.ub.es

ODP Site 1240 (drilled in the Panama Basin during ODP Leg 202) has been studied to explore marine-atmosphere interactions in the eastern equatorial Pacific. This site is located beneath an area of high biological productivity supplied by the divergence-driven upwelling associated with the regional trade-wind system. Terrigenous components at this site are the result of the eolian transport of dust originating from the Atacama Desert. Preliminary onboard results documented the occurrence of severe changes in the mode of operation of the upwelling cell over the late Pliocene-early Pleistocene. In view of the relatively high sedimentation rates for that interval (~15 cm/kyr), this sediment sequence represents an excellent opportunity to explore the reorganisation of the marine-atmospheric system at millennial-centennial time scales.

We present here high resolution geochemical records (every 2 cm) estimated by means of the XRF Core Scanner from the University of Bremen along 100 meters of marine sediments covering the time interval ~1.4-2.2 Ma. These geochemical measurements include semi-quantitative records of K, Ca, Ti, Mn, Fe, Cu and Sr. Additionally, in order to calibrate the intensity data provided by the Scanner and also to obtain a broader set of elements, 31 samples were analysed by the ICP-OES. Comparison between the Scanner and ICP results yield correlation coefficients of over 0.8 for most of the elements and of over 0.9 for some element, such as Ca.

The obtained results show coherent oscillations with those observed in the physical properties records previously measured on board (magnetic susceptibility, lightness and colour reflectance). These results indicate the occurrence of prominent and persistent changes in the eolian transport pattern that preceded the two major changes in the composition of the biogenic components. Nevertheless, the most important change in the behaviour of the eolian transport seems to have occurred, broadly, at the time of the Pliocene-Pleistocene boundary when no relevant changes in the biogenic components appear to have occurred. Detailed palaeoclimatic interpretations await an accurate chronostratigraphy for the studied interval. However, these early results indicate the exciting nature of this material.

Digital sediment colour analysis in laminated sediments and reconstruction of high-frequency climate variability

Alexandra Nederbragt and Juergen Thurow

Department of Earth Sciences, University College London
Gower Street, London WC1E 6BT, United Kingdom

Email: a.nederbragt@ucl.ac.uk

Digital images of sediment surfaces allow the possibility to analyse millimetre scale variations in sediment composition, which are too small to handle with conventional geological and geochemical techniques. Since the colour of a sediment reflects its chemical composition, colour records provide a proxy for changes in sediment composition. The resolution that can be obtained with a typical digital camera is around 100 measurements per centimetre of sediment. With the computing power of modern personal computers, it is relatively easy to collect and process large data sets. Digital sediment colour analysis is therefore ideally suited to collect annual resolution climate proxy records from laminated sediments. However, various corrections need to be made to the raw colour values registered in the digital images, to allow extraction of calibrated colour values that accurately describe stratigraphic variation.

To illustrate application of the method to palaeoclimate records, we present results obtained from Holocene laminated sediments at ODP Site 1098 in the Palmer Deep, off the Western Antarctic Peninsula. The sequence consists of light clay rich background sediments alternating with dark laminae of variable thickness. The dark laminae have low L* values (Lightness) and are enriched in biogenic silica and organic carbon. They represent a seasonal signal of high productivity and/or diatom blooms during the short spring/summer growing season. Spectral analysis of annual average colour values in the mid Holocene portion of the sequence shows that variability is concentrated in the high frequencies (2 to 5 year, Antarctic Circumpolar Wave, driven by ENSO) and in the low frequencies (> ~30 year), with little in between. The implication is that gradual changes in the Antarctic observed during the past years (e.g. ice shelves) are part of relatively low frequency cycles and therefore unlikely to reverse in the near future.

Core logging, imaging, and analysis:
Recent accomplishments and future challenges

Frank R. Rack

Joint Oceanographic Institutions Inc., 1755 Massachusetts Avenue, NW, Suite 700
Washington, DC 20036; USA (Tel: 1-202-939-1624; Fax: 1-202-462-8754)

Email: frack@joiscience.org

Field activities of the Ocean Drilling Program (ODP) will concluded on September 30, 2003, ending eighteen years of the current phase of international scientific ocean drilling. At the start of the ODP, there were few core-logging sensors and the existing core imaging systems relied on film-based methods. This situation has changed dramatically over the intervening years and increasingly technical innovations are being introduced at an accelerated rate. Today, prototype sensors and imaging arrays are being integrated into track-based, cabinet mounted, or stand-alone systems incorporating advanced hardware and software, which sometimes provide options for real-time digital data visualization and interactive data exploration and analysis. The future looks bright, as computing power continues to increase, components shrink in size, systems achieve higher resolution and precision, and the demands of the scientific community continue to grow. In parallel, the desire for database integration, and an increasing focus on metadata (i.e., information about data) to determine the existence and quality of cores and digital assets, will likely lead to a greater need for international coordination and the integration of efforts among curators, database managers, and independent projects or programs.

This presentation will review some of the highlights of core logging, imaging, and analysis activities since 1999, when Ortiz and Rack published a review of non-invasive measurement systems. Over the past five years there has been a significant expansion in the number and types of available systems. The use of digital imaging systems, as part of sediment and hard rock core description and analysis efforts, has advanced considerably; experience has been gained in the use of ultra-violet through mid-infrared diffuse spectral reflectance techniques for remote sediment classification; split-core XRF scanning techniques have increasingly been used for rapid, non-invasive mineral identification; thermal infrared imaging of cores has been used to identify the presence and distribution of methane hydrate in cores; and X-ray and nuclear magnetic resonance (NMR, MRI) imaging techniques have improved and become more accessible to marine geoscientists for use in routine core imaging and analysis efforts. Accompanying these significant technological advancements have been the growing challenges presented by the need to describe, visualize, manage, and archive these data while preserving their related metadata in an organized, open, and accessible manner. Future discussions should address the potential for collaborative efforts among national and international projects and programs, to coordinate use of core repositories, databases, and other assets, to address fundamental science objectives and goals in a cooperative and holistic manner.

Reference: Ortiz, J.D., and Rack, F.R. 1999. Non-Invasive Sediment Monitoring Methods: Current and Future Tools for High-Resolution Climate Studies. *In*: Abrantes, F. and Mix, A. (Eds.), Reconstructing Ocean History: A Window into the Future (Kluwer Academic/ Plenum Publishers) New York, p. 343-380.

Applications of X-ray fluorescence (XRF) corescanning to North Atlantic paleoceanography

Thomas O. Richter, Sjerry Van der Gaast, Tjeerd C.E. van Weering

Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790 AB Den Hoorn, Texel, The Netherlands

Email: thomasr@nioz.nl

The AVAATECH X-ray fluorescence (XRF) corescanner provides rapid high-resolution (down to 1mm) semi-quantitative records of chemical composition on split sediment cores. The measurements are non-destructive and require very limited sample preparation. The XRF scanner is placed in a seagoing container, hence logging records can be produced onboard the research vessel within a few hours after core retrieval. The recently installed, now operational second-generation XRF scanner can determine major and minor elements (atomic mass range Al to Fe, operating voltage 10kV) as well as trace elements (e.g. Sr, Rb, Y, Zr [operating voltage 30kV, detection limit 5ppm], Ba [operating voltage 50kV, detection limit 40ppm]).

Results from key areas in the NE Atlantic Ocean will be presented to illustrate a wide range of paleoceanographic applications. Examples include glacial-interglacial cycles of Ca and Fe, Holocene centennial- to millennial-scale variability, terrigenous input patterns in the Faeroe-Shetland Channel (records of K and Ti), diagenetic processes in mud volcano sediments at the Faeroe-Shetland Margin (records of Fe, Mn and S), and aragonite and calcite distribution in cold-water carbonate mound sediments at the Irish margin (based on Sr/Ca-ratios).

ITRAX corescanner - digital radiography and micro-XRF analysis of sediments - principles and applications

Anders Rindby

Chalmers University of Technology, Gothenburg, Sweden
Cox Analytical Systems, Teatergatan 36, SE-41135 Gothenburg, Sweden

Email: anders@coxsys.se

Recent developments in x-ray technology makes fast and precise digital radiographic imaging of sediment cores possible. By using flat-beam optics, high-power x-ray tubes and digital recording devices sediment samples up to 1.8 meters can be scanned within an hour and structures can be resolved down to the microscopic level, and minute density changes can be revealed. The scanning principle is well suited for layered structures and offers high image quality. The system is completely non-destructive.

Micro-XRF (X-Ray Fluorescence) technique can also be applied to simultaneous multi-element scanning along split sediment cores. A wide range of elements, including most metals from Aluminum and heavier can be analyzed.

The basic principles and functionality of this new instrument will be presented together with examples demonstrating the new possibilities to quickly and precisely obtain large amounts of detailed information from sediment samples.

Colour logging as a tool in high-resolution palaeoceanography

Mike Rogerson and Phil Weaver

Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, United Kingdom

Email: mr9@soc.soton.ac.uk

Colour and diffuse reflectance records have been proposed as a means of developing astronomically tuned age models for long sediment cores. Here, we present high resolution (1mm) colour records from a sediment core (D13892) spanning the last deglaciation that are shown to correlate with stable isotope (^{18}O) and Sea Surface Temperature proxy data. An age model developed from AMS radiocarbon dating is also presented. Comparison between the colour record of D13892 and the GISP2 oxygen isotope series is close (R2 = 0.81) and confirms that sediment colour reflects the state of the climate. Use of colour to develop initial age models for sediment cores records by astronomical tuning or correlation to a well-constrained climatic record is therefore considered valid.

The causes of the colour variability in D13892 are also considered, and related to changes in the local particle flux. The colour of sediment has also been shown to be diagnostic of its mineralogical / chemical composition. The colour records in D13892 indicate that the last glaciation and Younger Dryas were characterised by increased supply of terrigenous detritus to the western Gulf of Cadiz (southwest Spain) and this is supported by evidence from XRF-logging. This terrigenous detritus is probably supplied by the Mediterranean Outflow, and the source of the detritus seems to be southwestern Iberia.

High-resolution XRF scanning of sediment cores - a useful tool for lithostratigraphic analysis

R.G. Rothwell, J. Thomson and I.W. Croudace

Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, United Kingdom

Email: rgr@soc.soton.ac.uk

Determination of genetic units within cored sediment sequences is a fundamental pre-requisite for lithostratigraphic analysis, particularly in determining depositional processes and basin architecture. In deep-sea marine sediments, the two main sediment types are pelagites, largely formed from material that has settled through the water column to blanket the bottom topography, and turbidites, consisting of biogenic and/or terrigenous material that has been transported laterally downslope by turbidity currents. Traditionally, such deposits are distinguished through a range of sedimentological and textural criteria, which involves recording of visual descriptions and specialised laboratory analyses, such as grain size determinations. In certain instances, it can, in practice, be difficult to determine visually whether particular intervals are pelagic or turbiditic in origin, particularly when the pelagites and turbidites are similar in colour and sediment bioturbation is of low intensity. At times it can therefore be difficult to establish the true thicknesses of turbidites and hence the proportion that turbidite muds contribute to particular sediment columns. In any case, traditional lithostratigraphic analysis of a cored sequence can be time-consuming and sometimes uncertain. Split-core X-ray scanners can provide a rapid means of distinguishing genetic units within a core. Pelagites and turbidites may show clear differences in minor and major element geochemistry and grading in elemental profiles commonly mirror textural and sedimentological parameters. Major element XRF profiles through an interbedded pelagite/turbidite sequence from the Balearic Abyssal Plain (western Mediterranean Sea) obtained using the ITRAX XRF split corescanner will be presented and discussed. Turbidite and pelagic intervals may be distinguished unequivocally on Fe and Ca content and graded intervals and depths of bioturbation within turbidites are clear. Besides providing a wealth of geochemical data (which may be important in correlation and provenance studies) XRF scanning of split sediment cores provides a rapid and low-effort means of obtaining accurate lithostratigraphic logs, promising significant time-saving in routine lithostratigraphic analysis.

Geophysical logging of pressure cores containing methane hydrate on ODP Leg 204

Peter J. Schultheiss[1] & M. E. Holland[2]

[1]Geotek Ltd., 3 Faraday Close, Drayton Fields, Daventry, Northants, NN11 5R, United Kingdom
[2] Department of Geological Sciences, Arizona State University, Tempe, AZ, USA

Email: peter@geotek.co.uk

Fully-pressurised cores containing methane hydrate were recovered on ODP Leg 204 at Hydrate Ridge, offshore Oregon, with both the HYACE Rotary Corer (HRC) and the Fugro Pressure Corer (FPC). The cores were then transferred without loss of pressure into laboratory pressure chambers and geophysically logged. This is the first time that laboratory measurements have been made on of the physical properties of natural hydrates at sub-seafloor pressures without ever releasing this pressure. The pressure corers were developed as part of the EC-funded HYACE project and the laboratory chamber system was developed during the current HYACINTH project.

Two hydrate-bearing pressure cores were dissociated over a period of many hours. During this time, multiple gamma density profiles were acquired and the evolved gas was measured and analysed. Core 204-1249F-2E, 80 cm long, released over 100 L of gas (methane, 1000 ppm ethane, 5 ppm propane) and contained several centimetre-thick layers of massive hydrate. Based on an analysis of total gas and core volume, the hydrate content of this core was calculated to be 40% of the total core volume. In comparison, Core 204-1244E-8Y, 75 cm long, released only 3.8 L of gas (methane, 10 ppm ethane, 5 ppm propane) and had only 2 individual layers of gas hydrate. The depressurised core was X-rayed and sampled for pore water chlorinity analysis which confirmed the existence of hydrate layers. The hydrate content of this core was calculated at 1% of the total volume, with all the hydrate contained within the 2 identified layers. There was no evidence for any disseminated hydrate distributed throughout the clay sediment structure. Core 204-1249G-2E, which was frozen and then preserved in liquid nitrogen, had multiple layers of massive gas hydrate, similar to Core 204-1249F-2E. Core 204-1249H-2Y also showed significant low density intervals interpreted as thick hydrate layers and was kept under pressure for further analysis, including CT scanning. This core also contained centimetre-scale low-density intervals consistent with massive hydrate. Spikes of extremely low density within these layers are conclusive evidence for the existence of free gas within the massive hydrate structure.

Analysis and modelling of gravity and piston coring based on soil mechanics

L.C. Skinner[1] and I.N. McCave[2]

[1]Godwin Laboratory, Dept. of Earth Sciences, University of Cambridge, Pembroke St. New Museums Site, Cambridge CB2 2SA, United Kingdom
[2]Department of Earth Sciences, University of Cambridge, Downing Street Cambridge CB2 3EQ, United Kingdom

Email: luke00@esc.cam.ac.uk

The effects of gravity- and piston-corers on the dimensional accuracy of marine sediment cores is analysed using principles of soil mechanics. A model for the coring process is built around the feedback that arises and develops between the core-barrel and the sampled sediment. This model for sediment response is applied to different hypothetical coring scenarios, which are then compared to real examples, providing insights into the specific effects of each sampling method and the development of these effects down-core. Four cores from a single location on the Iberian Margin are found to contain stratigraphically intact successions that differ in length by a factor of up to 2.7, due solely to the different effects of each coring method. These dimensional discrepancies are attributed to the combined effects of 'over-sampling' in the upper portions of the piston cores (due to cable rebound causing upward piston acceleration), and 'under-sampling' dominant in the basal portions of the open-barrel gravity-type cores. It is suggested that heavier piston corers, deployed on longer, lighter cables, are prone to greater over-sampling ratios over longer stratigraphic intervals, due to the increased likelihood and extent of cable rebound. Cable rebound may also give rise to double penetration of gravity corers, resulting in repeated stratigraphic intervals. Knowledge of the dimensional accuracy of marine sediment cores is essential to an evaluation of past sedimentation rates, and hence interpretations of past depositional processes. It is therefore essential that we recognise the sampling effects of each coring method, and their variability down-core, lest coring artefacts be interpreted as sedimentary signals. Different core types may be more suited to different palaeoceanographic investigations. Hence, failing the development a practical cable-deployed recoilless piston corer, a combination of a variety of core types will permit the best acquisition of the *in situ* stratigraphic truth. Our results suggest that a large diameter (D_c~20-30cm) square barrel gravity corer for the top 10-12m combined with a cylindrical piston corer below ~10m may provide the least deformed material.

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Yaxcopoil-1 core in the Chicxulub crater: XRF core scanning of the K/T boundary interval

J. Smit

Department of Sedimentology, Vrije Universiteit Amsterdam, de Boelelaan 1085
1081HV Amsterdam, The Netherlands

Email: smit@geo.vu.nl

The 180km Chicxulub crater, Yucatan, Mexico is approximately the same age as the mass-extinctions at the Cretaceous-Tertiary (K/T) boundary. Hole Yaxcopoil-1 was drilled in 2002 in the crater as part of the Chicxulub Scientific Drilling Program (CSDP). Yax-1 recovered an 1107 m continuous cored sequence from a depth of 404 to 1511 metres. The recovery of the transition from the impact ejecta to the post impact crater infill was one of the more important goals of the project, because that interval supposedly holds the critical information about the relation between the Chicxulub impact and the mass-extinctions at the Cretaceous Tertiary boundary. The 75cm long interval (794.50-793.85m) analysed contains the transition from ejecta to post impact deep-water crater infill. The transition is marked by a thin clay layer at 794.11m, which might have contained anomalous amounts of iridium, Ni, Co, Cr, and As, as these elements are commonly enriched at the K/T clay layer. This 75cm interval can be divided into a lower interval (794.6-794.19m) of impact ejecta, now visible as smectite clay blebs, mixed with sand-sized dolomite rhombs, cross-bedded in small climbing ripple sets. The overlying interval from 794.19-794.11 represents a hardground, including open burrows filled with clay, and grading into a clayey interval showing dissolution features (horse-tail lamina), and bioclast fragments. A thin dark clay layer occurs from 794.11-794.10m. It is rich in pyrite and contains the highest fragments of altered impact glass. The upper interval 794.10-793.85m consist of foraminifer-bearing hemipelagic marls, lithologically identical to the overlying post-impact infill of the deep (>1400m) crater.

The relative amounts of Al, Si, K, Ti, Ca, Sr, Mn Fe, Co, Cr, Ni, S, Cl, and Br were measured in the 75cm interval with the second version of CORTEX XRF core scanner (Jansen et al. 1998). Measurements were done with a step size of 1mm. The irradiated sample length was set at 1mm in combination with a width of 10 mm. Counting time was set at 70 sec/step. The spectra were processed with software from Canberra (Winaxil 4.2.1).

The layers rich in altered impact glass, now smectite, show peaks in Al, Si, Ti, K, Fe, as expected. Sr displays erratic peaks in the reworked ejecta intervals, probably related to coelestine, detected by electron microprobe in these intervals. The reworked ejecta are generally characterized by higher amounts of Ca and Mn, the initial crater fill are relatively rich in Sr, Ti, Fe and particularly Cr. The clay layer at 794.11m, which might be enriched in siderophile elements if it would behave similar to other K/T boundary clay layers, is not significantly enriched in siderophile elements, except Co. Ni and Cr are even depleted, whilst Cr is one of the elements that is invariably enriched in K/T boundary clay together with Ir. The XRF data support the conclusion based on the lack of Ir, the presence of a hardground and the strong sedimentological dissolution features, that the clay at the base of the Paleocene is not enriched in elements from the Chicxulub bolide, but forms a residual clay on top of the ejecta, representing a probable hiatus.

Reference: Jansen J.H.F., Van der Gaast S.J., Koster B., and Vaars A.J. (1998). CORTEX, a shipboard XRF-scanner for elemental analyses. *Marine Geology*, **151**(1-4):143-153.

Cortex, state of the art of the AVAATECH XRF core scanner

Sjerry Van der Gaast

Netherlands Institute of Sea Research, P.O.Box 59
1790AB Den Burg, Texel, The Netherlands

Email: gaast@nioz.nl

The first XRF core scanner (CORTEX) was developed by the NIOZ at Texel in 1988. At this stage the scanner was equipped with a Kevex X-ray tube with a Mo target and a Si-Li detector from Kevex. The X-ray path was flushed with He applying a cell with windows covered with thin Mylar foil. The collected patterns were processed with software from KEVEX. The (wet) sediment of core sections was covered with the Mylar foil. The elements that could be measured ranged from K to Sr.

Since 2002 a new XRF core scanner was developed that is equipped an X-ray tube from Oxford with a Rh target and a PIN-detector from Amptek. The He flushed cell was slightly modified. Windows of the cell were covered with highly transparent 4-micron thick ultralene foil. The sediment is now also covered with this foil. This increases strongly the detection limits of light elements such as Al. The elements that can be measured now range from Al to Ba.

The specifications of the present state and future developments are discussed in relation to sediment parameters.

X-ray fluorescence (XRF) core scanning for unlocking fine-scale cenozoic paleoceanography

Westerhold, T., Röhl U., Kuhlmann, H., Bickert, T., and Wefer G.

Geosciences Department, University of Bremen, 28334 Bremen, Germany

Email: tho@uni-bremen.de

To infer paleoceanographic information from physical and chemical element characteristics of sediment it is necessary to obtain the most continuous and accurate measurements possible. Standard analytical methods for discrete samples are non-continuous, time consuming, and expensive.

Relatively fast and non-destructive core-logging methods can now be employed to obtain continuous data at much finer scales (down to millimeter range) than are practical for individual sampling methods. These advantages are enormous for relatively long time series and especially important for high-resolution analyses on critical boundaries/intervals, which are major objectives of several scientific projects, e.g., within the Ocean Drilling Program (ODP) and IMAGES. Quantitative documentation of regular variations in marine sediments has utilised physical properties, e.g., colour reflectance or magnetic susceptibility, which are indirect indicators of the combined influences of iron content, iron oxidation stage, and carbonate abundance.

The X-ray fluorescence (XRF) core scanners of Bremen University are non-destructive analysis systems for relatively fast (35 to 70 seconds per measurement) and closely spaced (as small as 1mm) analyses of major and minor elements by scanning the surface of split sediment cores. The scanners were developed and built at the Netherlands Institute for Sea Research (NIOZ, Texel, The Netherlands) and Avaatech Analytical X-ray Technology, respectively. XRF measurements of the entire suite of elements between aluminium (Al) and barium (Ba) can be recorded. The resulting element intensities in total counts or counts per second (cps) are calibrated for sediment cores by measuring a suite of lithological standards.

We analyzed element intensities (e.g., K, Fe, Ti, and Ca) and element ratios obtained by the XRF Core Scanner as a proxy for calcium carbonate content and supply of terrestrial material. Iron (Fe) was selected as a geochemical proxy for climatic-paleoceanographic cycles. This major element mirrors changes in carbonate/clay ratios, and is in significant abundance throughout the sediments. Fe is located in the center of the measurable element range, and therefore provides a stronger signal than the heavy or light ends of the XRF range.

One great advantage of the XRF data is that the concentration of iron, for example, is less affected by post-burial diagenetic alteration than is the oxidation state of Fe and associated magnetic susceptibility. Additionally, the XRF data match very well with other proxy data (e.g., magnetic susceptibility, colour reflectance), but they show a significantly higher signal-to-noise ratio and a more consistent hole-to-hole agreement. The data obtained hence allow the construction of a more accurate high-resolution composite depth scale.

Our detailed interpretations of XRF scans have substantially improved the knowledge in the areas of high-resolution time series definition, global correlations, important paleoceanographic events and the detailed reconstruction of the sedimentary and climatic history for various time intervals from the Holocene to the Cretaceous. Representative examples will be shown. A high-resolution chronology for the Paleocene/Eocene Thermal Maximum (PETM) boundary was established, providing new insights regarding dramatic environmental changes (Röhl et al. 2000; Norris and Röhl 1999). XRF data have been successfully used to construct new composite depth records, to extend the astronomically calibrated geological time scale into the Late Eocene and to provide revised estimates for the ages and durations of magnetochrons (Pälike et al. 2001). They have also been essential in deciphering the Middle to Late Miocene “Carbonate Crash” events, improving Neogene time scales at high-resolution, and investigating global climate changes during the Messinian events (Vidal et al., 2002). Rapid changes in the hydrological cycle of the tropical Atlantic during the last Glacial were decoded by high-resolution Ti and Fe data (Peterson et al. 2000), as were variations in the hydrological cycle over northern South America during the past 14,000 years with subdecadal resolution (Haug et al., 2001). Holocene rainfall variability in southern Chile could be reconstructed on multi-centennial to millennial time-scales (Lamy et al., 2001).

References

Arz, H.W., Gerhardt, S., Pätzold, J., Röhl, U., 2001. Millennial-scale changes of surface- and deep-water flow in the western tropical Atlantic linked to Northern Hemisphere high-latitude climate during the Holocene. *Geology*, **29** (3): 239-242.

Arz, H.W., Pätzold, J., Wefer, G., 1998. Correlated millenial-scale changes in surface hydrography and terrigenous sediment yield inferred from last-glacial marine deposits off Brazil. *Quaternary Research*, **50** (2): 157-166.

Arz, H.W., Pätzold, J., Wefer, G., 1999. Climatic changes during the last deglaciation recorded in sediment cores from the northeastern Brazilian continental margin. *Geo-Marine Letters*, **19** (3): 209-218.

Behling, H., Arz, H.W., Pätzold, J., Wefer, G., 2000. Late Quaternary vegetational and climate dynamics in northeastern Brazil inferences from marine core GEOB 3104-1. *Quaternary Science Reviews*, **19** (10): 981-994.

Haug, G.H., Hughen, K.A., Sigman, D.M., Peterson, L.C., Röhl, U., 2001. Southward Migration of the Intertropical Convergence Zone Through the Holocene. *Science* (Aug 17 2001): 1304-1308.

Haug, G.H., Günther, D., Peterson, L.C., Sigman, D.M., Hughen, K.A., Aeschlimann, B., 2003. Climate and the Collapse of Maya Civilization. *Science* (March 14 2003); **299**: 1731-1735

Jahn, B., Donner, B., Müller, P.J., Röhl, U., Schneider, R., Wefer, G., 2003. Pleistocene variations in dust input and marine productivity in the northern Benguela Current: evidence of evolution of global glacial-interglacial cycles. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **193**, 515-533.

Lamy, F., Hebbeln, D., Röhl, U., Wefer, G., 2001. Holocene rainfall variability in southern Chile: a marine record of latitudinal shifts of the Southern Westerlies. *Earth and Planetary Science Letters*, **185** (3-4): 369-382.

MacLeod, K.G., Huber, B.T., Pletsch, T., Röhl, U., Kucera, M., 2001. Maastrichtian foraminiferal and paleoceanographic changes on Milankovitch time scales**.** *Paleoceanography*, **16** (2): 133-154.

Norris, R.D. and Röhl, U., 1999. Carbon cycling and chronology of climate warming during the Palaeocene/Eocene transition. *Nature*, **401** (6755): 775-778.

Pälike, H., Shackleton, N.J., Röhl, U., 2001. Astronomical forcing on late Eocene marine sediments. *Earth and Planetary Science Letters*, **193**, 589-602.

Peterson, L.C., Haug, G.H., Hughen, K.A., Röhl, U., 2000. Rapid changes in the hydrologic cycle of the tropical Atlantic during the last glacial. *Science*, **290** (5498): 1947-1951.

Richter, C., Blum, P., Röhl, U., 2001. Magnetic properties and XRF-scanner data of site 1075 (Lower Congo Basin). *Proceedings of the Ocean Drilling Program, Scientific Results*, **175**: 1-31.

Röhl, U. and Abrams, L.J., 2000. High-resolution, downhole and non-destructive core measurements from Sites 999 and 1001 in the Caribbean Sea: application to the Late Paleocene Thermal Maximum. *Proceedings of the Ocean Drilling Program, Scientific Results*, **165**: 191-203.

Röhl, U., Bralower, T.J., Norris, R.D., Wefer, G., 2000. New chronology for the late Paleocene thermal maximum and its environmental implications. *Geology*, **28** (10): 927-930.

Röhl, U., Ogg, J.G., Geib, T.L. and Wefer, G., 2001. Astronomical calibration of the Danian time scale. In: R.D. Norris, D. Kroon and A. Klaus (eds), Western North Atlantic Paleogene and Cretaceous Paleoceanography. *Geological Society Special Publication*, London, pp. 163-183.

Röhl, U., Norris, R. D. Ogg, J. G. (2003): Cyclostratigraphy of upper Paleocene and late Eocene sediments at Blake Nose Site 1051 (western North Atlantic). *In*: Gingerich, P. Schmitz, B., Thomas, E. and S. Wing (eds): Causes and Consequences of Globally Warm Climates in the Early Paleogene, *Geol. Soc. of America (GSA) Spec. Paper Series, v.* **369**, 567 to 588.

Röhl, U., Brinkhuis, H., Fuller, M. (in revision): On the search for the Paleocene/Eocene boundary in the Southern Ocean: exploring ODP Leg 189 Holes 1171D and 1172D. *AGU, Geophysical Monograph Series*.

Röhl, U., Brinkhuis, H., Fuller, M., Schellenberg, S. A., Stickley, C. E., Williams, G. L. (in press): Sea level and astronomically induced environmental changes in Middle and Late Eocene sediments from the East Tasman Plateau (Site 1172). *AGU, Geophysical Monograph Series*.

Vidal, L., Bickert, T., Wefer, G., Röhl, U. (2002): Late Miocene stable isotope stratigraphy of SE Atlantic ODP Site 1085: relation to Messinian events. *Marine Geology*, **180**, 71-85.

Abstracts

Poster Presentations

A high-resolution geochemical study of sapropels and turbidites in eastern Mediterranean sediments by XRF core scanner

T. Courp[1], R.Gieles[2], S.J. Van der Gaast[2], E. Gonthier[3] and A. Murat[4]

[1]LEGEM, Université de Perpignan, 52 Avenue P. Alduy, 66860 Perpignan Cedex France
[2]Royal Netherlands Institute for Sea Research, PO BOX 59, 1790 AB, Den Burg, Texel, The Netherlands
[3]Université de Bordeaux 1, DGO, UMR5805 - EPOC, Avenue des Facultés, 33405 Talence Cedex France
[4]CNAM - Intechmer, BP 324, 50103 Cherbourg Cedex France

Three eastern Mediterranean sediment cores from FANIL and NOE cruises have been analysed for major and minor elements (Al to Ba) by X-ray fluorescence analysis with the AVAATECH CORTEX core scanner applying a resolution of 1 mm to 1 cm with a total number of 1500 analysed positions. This is the first attempt to investigate longer sedimentary sequences which contain several sapropels and turbidite layers from the eastern Mediterranean by very high resolution major- and minor-element geochemistry. The basic idea behind such an approach is that any change in paleoenvironmental or climatic condition should be reflected in a change in major- and minor-element abundance. Several studies have demonstrated that one of the main difficulties is to make a distinction between a) sapropels (TOC >2%), b) sapropelic layers (TOC between 0.5% and 2%, that are generally recovered in pelagic sediments but with a lower carbonate content than the classical one), and c) fine grained turbidites.

Cyclic variations in the chemical composition of the cores document the alternation of periods of enhanced Nile discharge and sapropel formation with arid periods associated to high aeolian input. With these data we are able to give rapidly a complete scenario of sapropel formation and evidence of millimetre sized turbidite layers along the cores.

High resolution analyses of terrigenous sediment components in the Southern Ocean: a record of glaciations and ocean currents

Gerhard Kuhn

Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany

Email: gkuhn@awi-bremerhaven.de

Sediment distribution in the Southern Ocean and its spatial and temporal changes in composition is a result of biogenic production, terrigenous input from different source regions and redistribution by currents. The Antarctic Circumpolar Current (ACC) and changes in this circulation

system play an important role in these processes. Late Quaternary glaciological changes in Patagonia and the Antarctic Peninsula cause variations in terrigenous sediment supply that are documented in sediment records.

Sources and transport paths of terrigenous sediment were traced in modern and Late Quaternary marine sediments from the Scotia Sea by geochemical and mineralogical compositions. Downcore variations of compositional data correlate with fluctuations in magnetic susceptibility. Sediments were derived from very different sources at both localities the northern and southern Scotia Sea, as revealed by contrasting clay-mineral assemblages. However, a common feature is the input of more basic and undifferentiated crustal material with the potential of high magnetic susceptibility during glacial periods. High IRD input was recorded during cold to warm climate transitions, when grounded ice masses refloat and disintegrate (calving events)

More to the eastern South Atlantic high-resolution sediment sequences were recovered across the frontal system of the ACC. We address variations in terrigenous sediment supply for the last 500 kyr and responses of regional ocean circulation to both glacial-interglacial climate oscillations on orbital time scale and to climate variability on sub-orbital millennial time scale. The data comprises mineralogical tracers of water-mass configurations and grain-size characteristics of the mud fraction as indicators of relative bottom-current strengths. Current sorting and coarsening of terrigenous mud, independently from its source signals, takes place during interglacial periods. It is linked to a stronger formation of Antarctic Bottom Water and the invigoration of deep contour currents in response to long-term changes (100-kyr cyclicity) in Antarctic ice-sheet extension and high-amplitude fluctuations in global sea level. No significant short-term changes in bottom-water circulation are evident for the MIS 3 interval. Volcanic ash makes up a high portion of lithogenic sand and is nicely displayed by the magnetic susceptibility signal, which has a clear on/off pattern with maxima during glacial periods, reflecting IRD supply by extended sea-ice. Fine-grained lithic components are distributed by ACC water masses. The natural gamma radiation signal clearly reflects this saw-toothed pattern that is anticorrelated to the biogenic opal content. Although nicely resembling the Vostok ice core dust signals it does not reflect eolian input, but fine-grained lithogenic content at this Southern Ocean site.

Ice-mass extensions in southern Patagonia, on the Antarctic Peninsula and Continent likely control the supply of glaciogenic detritus to the open ocean during times of glacial expansion, diluting the sediment input of interbasinal origin. Expansion of ice sheets into the fjords and onto the shelves off western Patagonia and onto the shelves off the Antarctic Peninsula produced a high glaciogenic sediment discharge. Current transport is mainly responsible for sediment dispersal to the pelagic environments and may amplify the glaciological source signals, because of increased current speeds and particle fluxes in the ACC.

BOSCORF - The British Ocean Sediment Core Research Facility

Guy Rothwell

Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, United Kingdom

Email: rgr@soc.soton.ac.uk

BOSCORF, located at Southampton Oceanography Centre, is the UK's national deep-sea core research facility and provides a unique and strategic service to the UK scientific community. It provides an advanced state-of-the-art non-destructive core logging and analysis capability that is unique in the UK. BOSCORF also provides specialised long-term core storage facilities, so that sediment cores collected by NERC ships, and NERC-funded researchers, can be kept under optimum conditions to ensure long-term preservation and availability to the scientific community. BOSCORF promotes secondary multiple usage of the core material in its care ensuring cost-effective exploitation of an important national scientific resource. It is also responsible for long-term curation of core-based data relating to its holdings and from core-based national marine programmes in compliance with NERC data management policy.

Sediment cores and samples are the fundamental data source for information on seabed character and global environmental change and are very expensive to collect. Therefore, the cores held by BOSCORF represent a considerable investment of many millions of pounds already spent by the UK in Earth Science research. Unless cores are stored under optimum conditions they can dry out and fracture within months, limiting their value for further research. Further, as new measurement techniques become available and new concepts evolve, existing cores can be re-sampled to add to the knowledge base. Major developments in our understanding of recent environmental change (e.g. the North Atlantic Heinrich Layers, indicating repeated collapse of the North American ice-sheet during the late Quaternary glaciations) have come from material stored effectively in long-term core repositories. Therefore specialised core storage and analysis facilities are essential if the UK is to be a significant player in marine research.

The BOSCORF suite of core logging equipment includes an innovative ITRAX split-core high-resolution XRF scanner and a GEOTEK multi-sensor core logger which can be interfaced with a Minolta spectrophotometer for high-resolution colour measurements. The BOSCORF core collection currently consists of 920 sediment cores, although data are held on 1428 sample stations. BOSCORF's core holdings cover all the major world oceans and are recognised internationally as being of global importance. Currently the facility holds 5 km of core in total.

BOSCORF welcomes applications from *bona fide* researchers who wish to use its facilities or sample core material in its care. Further information on the facility can be found on www.boscorf.org.

EU-SEASED - An online data catalogue of European-held marine sediment cores and seafloor sediment samples

Guy Rothwell

Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, United Kingdom

Email: rgr@soc.soton.ac.uk

Marine sediment cores and other samples are a raw data resource of immense scientific value and hundreds of thousands of bottom samples have been collected by European research institutes, Geological Surveys, universities and exploration and survey companies. Such data is vital to a large number of end-users in governments, industry and academia. Research into global climate change, slope stability, pollution control and assessment, hydrocarbon exploration, surveying for laying telecommunication cables and offshore pipelines, siting of offshore structures and coastal development all rely on data provided by marine sediment samples. After they have been analysed for the purpose for which they were taken, cores and bottom samples are normally stored under controlled conditions for further use. Consequently, seafloor samples are stored at a large number of locations throughout Europe and provide a legacy of continuing scientific usefulness and importance. However, until recently, secondary usage of this important data resource has been seriously impeded by lack of knowledge of what cores are available and where they are stored.

In the late 1990's there was increasing recognition within Europe that measures needed to be taken to increase access to European-held collections of seafloor samples. The advent of the Internet provided the mechanism to do this. In 1998, the European Union funded, within the MAST programme, two separate, but linked, consortia - EUROCORE (a consortium of European deep-sea core repositories) and EUMARSIN (a consortium of European Geological Surveys) to populate a searchable online database called EU-SEASED, accessible to all through the Internet (at http://www.eu-seased.net). This database has been populated with metadata on cores and marine sediment samples collected by European universities, research institutes, marine stations and Geological Surveys. Metadata is held on marine sample stations located anywhere in the world ocean, providing the samples were collected by, and are held at a European institution. This database now contains metadata on over 300,000 seafloor samples. Searches can be made using a graphic interface (map-based search) or by text-filled fields which allows searching on a wide range of parameters. Search results only list metadata, access to samples and any related accessory datasets is for negotiation between the user and the institution where the sample is stored (contact information is provided). A total of 65 European sample-holding institutions now submit metadata to the database. In its first three years of operation (map-based searching became available in July 2000), the EU-SEASED website has consistently received over 600,000 'hits' per year (about half of which result in database searches) from as many as 25,000 clients. It has thus proved itself to be the world's premier site for searching for seafloor data.

An EU Framework Programme 5 funded project, EUROSEISMIC, has now added metadata on more than 2.5 million seismic lines (mainly from the European continental shelf) to the EU-SEASED database and consortia are active in Europe seeking funding to add metadata on non-sample seafloor data to EU-SEASED. The EU-SEASED database thus promises to evolve into a unique portal for accessing information on European marine data holdings.

Replicability of the millennial-scale climatic variability in marine records: Marine Isotope Stage 3 and the last interglacial off Portugal

Shackleton[1] N.J., Vautravers[1], M., Cheshire[3] H., de Abreu[1,2] L., Martrat[4] B., Skinner[1] L., Thouveny[5] N., Grimalt[4] J.

[1]Godwin Institute for Quaternary Research, Cambridge University, Pembroke St.
New Museums Site, Cambridge CB2 2SA, United Kingdom
[2]Instituto Geologico e Mineiro de Portugal, Departamento de Geologia Marinha, Lisbon, Portugal
[3]Department of Earth Sciences, University College London, Gower Street
London WC1E 6BT, United Kingdom
[4]Institut d'Investigations Quimiques y Ambiental, Barcelona, Spain
[5]CEREGE, Europole de l'Arbois, Aix en Provence, France

Email: mv217@cus.cam.ac.uk

One of the objectives of the 2001 Coring Campaign off Portugal abroad *Marion Dufresne* (funded by the EC through the POP project) was to obtain records that would document the replicability of records such as that published by Shackleton et al., 2000 (*Palaeoceanography*) from core MD95–2042. Here we demonstrate some of the results of these tests noting first that the cores are readily correlated using magnetic susceptibility data collected on board *Marion Dufresne*.

Particularly important features that we have replicated include:

1) The relationship between temperature (UK_{37} method) and the benthic isotope record in Marine Stage 3.
2) The relationship between benthic and planktonic isotope records in Marine Isotope Stage 3.
3) The detail of the early part of Marine Isotopic Stage 3, including planktonic foraminifera census counts and planktonic stable isotopes in relation to the Greenland atmospheric $d^{18}O$ record (Johnsen et al., 2001).
4) The relationship between vegetation (through pollen) and marine climate (through isotope data) records of the last interglacial.

Corporate collections project - The offshore archive

Graham Tulloch

British Geological Survey, Murchison House, West Mains Road
Edinburgh EH9 3LA, United Kingdom

Email: gjt@bgs.ac.uk

The BGS has an extensive collection of seabed and sub-seabed samples collected from the UK Continental Shelf. The Offshore Sample Archive comprises seabed samples, gravity and vibrocore samples and shallow boreholes.

The programme to collect information from the North Sea commenced in 1966 funded by the, then, Department of Energy until 1986 and has continued to the present day through a combination of consortia funding, commercial projects and recently a return of Science Budget funding. Complimentary seismic and potential field surveys have also been conducted and the data from these surveys are also held in the archive.

Development of seabed robotic rockdrills and sediment corers

Graham Tulloch

British Geological Survey, Murchison House, West Mains Road
Edinburgh EH9 3LA, United Kingdom

Email: gjt@bgs.ac.uk

In order to calibrate seismic reflection data and hence produce geological maps to gain an understanding of the UK Continental Shelf, BGS had, until the early 1980's used divers, one shot sediment corers and expensive ship based drill rigs. A cheaper and more flexible alternative was sought.

Powered corers, remotely operated from ships of opportunity are 4 times cheaper to operate than a drillship, thereby reducing the cost of data collection or allowing a greater spread of boreholes to be accomplished. These tools also allow science to be carried out that otherwise would be impossible as a) the tool does not exist, b) due to the location, e.g Arctic and Antarctic regions or c) funding for a drillship would not be available.

There is a depth below seabed where existing technology still limits the use of seabed corers. Where deeper penetration below seabed is required BGS contract drill ships and use their own suite of specialist wireline coring tools.

The development of wireline coring methods for drillships

Graham Tulloch

British Geological Survey, Murchison House, West Mains Road
Edinburgh EH9 3LA, United Kingdom

Email: gjt@bgs.ac.uk

The popular concept of the 'go-anywhere, do-anything, driller' facing the rigours of the offshore environment is only part of the requirement. Without the ability to collect core at such locations the scientists will not be impressed! - Oilfield drilling technology cannot be used directly for scientific coring.

BGS have developed wireline coring tools using mining and geotechnical coring technology for quality core recovery melded with the robustness of oilfield drilling technology to withstand the rigours of offshore operations. Ship and shipboard developments to allow coring from a variety of multi-purpose vessel types is also undertaken.