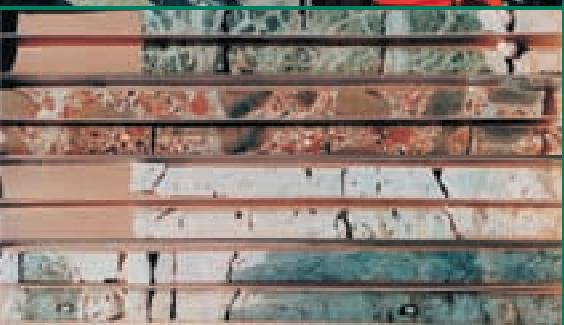
Report and working papers
Workshop – Brussels, 8-9 January 2001

Workshop on Alternate Drilling Platforms: Europe as the Third Leg of IODP


October 2001

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Report and working papers from

A Workshop on Alternate Drilling Platforms: Europe as the Third Leg of IODP

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Introduction

Introduction to the Report

Alister Skinner,
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The Brussels Workshop, *Alternate Drilling Platforms: Europe as the Third Leg of IODP*, which was held on 8-9 January 2001 demonstrated that there were methods available to expand scientific drilling. This would have to be done in conjunction and cooperation with industry and would allow sophisticated scientific coring in a variety of environmental and/or geographical locations at present poorly served or not served at all by the current Ocean Drilling Program (ODP).

There is an opportunity in the next phase of ocean drilling – the *Integrated Ocean Drilling Program (IODP)* – to broaden scientific horizons and encompass exciting new dimensions with an expanded scientific community. This report contains papers, edited discussions and company profiles which were presented in verbal form at the Brussels Workshop.

The IODP Science Plan entitled "Earth, Ocean and Life" provides a framework for drilling proposals for IODP. The Lisbon Conference, APLACON, (Alternate Platform CONference) to be held in May 2001 will determine quality proposals for drilling consideration within this framework which, when highly ranked for their science, can then be drilled by the use of alternate platforms under IODP. This report is a primer for APLACON and serves as an initial reference to the technologies available under the heading of "alternate platforms".

Specific coring scenarios from high, ice-covered latitudes to tropical coral reefs and deep to shallow water are illustrated in this document. Some can be addressed, at least in part, by the use of alternate drilling platforms with derricks for conventional drillstrings and platforms and handling equipment for seabed drills and long sediment corers specifically designed for niche geological requirements. Coupled together within IODP these provide a powerful additional dimension to the technology available for scientific coring. A case is also made for a new polar research icebreaker and a decade-long drilling project in the Arctic.

Industry played a very important role at the workshop and there are two clearly defined areas of cooperative interest:

- Mutual investigation and pursuit of scientific objectives. Collaboration to achieve best borehole locations, and in industry the provision of 3D seismic data for academic modelling.
- Provision of sophisticated coring and logging services.

A selection of information provided by the industry participants is contained in this document and should be supplemented by looking in detail on the web to really get a clearer idea of what these companies, and others, can do for the advancement of science.

Although similar meetings have been held in the past, the workshop was a serious step (of many to follow) in the direction and implementation of IODP and as such was supported by the EU, the integration of European nations under JEODI and endorsed by our Japanese and American partners. The dialogue with oil and gas companies is of vital importance and needs to be continued to allow mutual scientific projects and data sharing. JEODI and IODP should find avenues to accelerate the proposal process to ease and facilitate this collaboration. Companies providing coring and logging services are both able and willing to form a partnership for science. Whilst it is an over-simplification to agree with industry that "no technological challenges exist", science requires an inventory of technological solutions to scientific questions, and current industry techniques and facilities will form a good basis for this.

Acknowledgements

The Brussels Workshop was sponsored by the European Commission and the European Science Foundation (ESF) in partnership with the European Steering Committee on Ocean Drilling (ESCOD). This report is part of the Joint European Ocean Drilling Initiative JEODI. Their efforts on behalf of a European drilling initiative in IODP are gratefully acknowledged. Gilles Ollier, Irene Hirschmann, John Ludden, Jan Fraser, Patrica Maruejol and Andy Kingdon ably covered administrative details before and during the workshop. JoAnne Reuss of IPSC helped with note-taking at the meeting. All those efforts are also gratefully acknowledged. Industry participation was wide-ranging and interactive and contributed greatly to the success of the workshop. Jan Fraser and Alister Skinner compiled this report and the ESF arranged for the typesetting and sponsored the publication.

Opening Address – Alternate Drilling Platforms: Europe as the Third Leg of IODP

Christian Patermann,
European Commission,
Brussels

A collaborative approach in Europe within the IODP

This workshop gathers together almost 100 key representatives from the various organisations in Europe involved in the domain of scientific ocean drilling (universities and research centres, government agencies and an impressive delegation from industry). As announced in the title of the workshop: "Europe as the Third leg of IODP", Europe wants to participate in the future Integrated Ocean Drilling Program through a more unified/collaborative approach when compared to the present situation. Representatives of the ocean drilling community from outside Europe (Japan, USA, Canada, and Australia) are also participating in this meeting. Your participation will ensure a smooth transfer of information towards the groups already set up to prepare the IODP at international level. This preparatory work is already well advanced, notably with respect to the planning and construction of the Japanese drilling vessel, OD21, and with the COMPLEX (Conference on Multiple Platform Exploration of the Ocean) initiatives towards a non-riser drilling vessel funded by the USA. The present workshop is not part, in a sense, of the official planning approach for IODP, because it is a European initiative. It intends, however, to contribute to the preparation of the new international drilling programme. The specific situation in Europe, with many different countries, makes such a meeting unavoidable in order to define a potential European contribution to the new ocean drilling programme, by strengthening the collaboration between the European entities. The European Commission views this assembly as being very important. It comprises executives from all European national funding agencies, from the European Commission and from the ESF. You find many scientists involved in scientific drilling in Europe, and industrialists specialising in drilling. Therefore, I hope that the outcome of the discussions will be taken into account in the official IODP planning. Please take the participation of the European Commission also as a clear signal of its wish to contribute to the establishment of a European Research Area in a stricter sense.

ESCOD (The European Steering Committee on Ocean Drilling)

Much thought has been given in Europe over the past two to five years on how to participate in the future international ocean drilling programme. As an outcome of this reflection the ESCOD *ad hoc* group was created, endorsing the fact that an efficient European contribution within IODP would require more collaboration and integration between the national institutions involved. ESCOD has been created by the main funding agencies and as such is mandated to: refine the scientific contribution of Europe to IODP; to provide technological models for European contribution to IODP; to interact with the European Commission to set up coordination activities; and to give to the European/national funding agencies recommendations on how they should be involved in IODP.

The organisation of this conference by ESCOD is one of the first outcomes from this *ad hoc* group. The aim of the conference is to identify the technologies available in Europe and to operate internationally any alternate platforms as part of IODP. A series of scientific case studies will be presented and moderators will be asked for their inputs as to "how these targets should best be drilled", including the possibilities of joint scientific operators. In particular, the contribution of Europe to IODP through an Arctic research drilling vessel will be considered, as will the use of the geotechnical platforms available from industry (piggy-back with oil industry platforms). Other forms of contribution would be site support, site survey, post-cruise facilities etc., the role of robotics and of portable remote systems.

The role of the European Commission

The European Commission has for some time undertaken the fostering of a collaborative approach in Europe in the domain of scientific drilling. The Commission has a representative on the IWG (International Working Group) and is also closely associated with the work of ESCOD. There are also regular meetings with the main funding agencies directors STA in Japan and the NSF in the USA.

Concerning funding aspects, the Commission does not at present participate in the operation costs of ODP. The Commission cannot contribute to these costs under the current rules laid down for Community Research.

However, the Commission supports research projects that are relevant to scientific drilling. Some of these projects, most specifically in the technology domain, are closely linked to ODP. There will soon be tests conducted on the ODP vessel to validate a prototype of a corer for gas hydrates. This is the HYACE project (Hydrate Autoclave Coring Equipment System). Another project also relevant to ocean drilling is the GEOSTAR project (Geophysical and Oceanographic European Station for Abyssal Research) which is a long-term observatory prototype. It has now been deployed in the Thyrenian Sea for 6 months at 2 000 m water depth for its first deep-sea test mission. The Commission also supports a group of research projects on the European Margin, the OMARC cluster (Ocean Margin Deep-Water Research Consortium), which has identified a number of drilling sites for various topics (deep-water carbonate mounds, gas hydrates, slope stability, deep sub-seafloor biosphere). The Commission is therefore currently supporting ocean drilling science mainly through an in-kind contribution.

Apart from ocean drilling, the Commission also participates to a continental drilling project in the Gulf of Corinth (International Continental Drilling Program). This project is funded through the Support to Research Infrastructure activity of the Environment Program, and aims at developing a European seismic *in situ* monitoring lab. The Support for Research Infrastructure activity enables part of the drilling costs of the project to be covered by the Commission. This on-land *in situ* lab might be extended offshore in the Gulf of Corinth in the near future.

A thematic network project was recently funded by the Environment Program entitled JEODI (Joint European Ocean Drilling Initiative). This thematic network aims to bring a distinct European component to the IODP, which is due to commence in autumn 2003. The contribution to the consortium from the Commission is approximately of 1 million euros). The consortium is composed of the main research entities in Europe involved in Ocean Drilling. The project aims to provide a science and management structure and an outreach for Europe as part of the future international programme. This community contribution should enable Europe to prepare its entry into IODP in an efficient way.

Scientific and financial options

The expected starting date for IODP, autumn 2003, is in reality very close. It appears far away, but science planning is quite demanding and there will not be that much time for Europe should it choose to participate in an efficient manner within IODP. The other international participants within the IODP are looking forward to seeing how Europe will participate. It implies that the European participation is defined in a clear and unified way both scientifically and financially. The Commission expects that the present workshop will help this goal to be achieved. Concerning the science plan, we note with sympathy that Europe, through its representatives in the various IODP planning bodies, has endorsed the IODP Science Plan. There is a general agreement that the new ocean drilling programme should remain a programme with a global approach, and this is a view that is also largely shared in Europe. There are drilling sites that are already well identified all around Europe that could contribute to the global objectives of IODP (such as gas hydrates, seismic research, deep biodiversity), because they have been well investigated through various research programmes. These will be addressed at an ESCOD science meeting to be held in Portugal in May of this year.

The budgetary issues are of course very important. There are different types of costs that can be split roughly into operation costs and construction costs. Japan and the USA have committed themselves to support the *commissioning* costs for two drilling vessels to be used within the future IODP. The preliminary figures for the operation costs for these two vessels are anticipated to be in the order of 140-150 million euros per year. If Europe is to participate in IODP, then there will probably be a need for a contribution to these operation costs from the national funding agencies, as it was in the past through ODP, although on this occasion a different financial structure might be investigated though ESCOD and JEODI which has a more European approach (through one European consortium for example). As indicated previously, the European Commission cannot under its present rules participate in such operation costs. It is not excluded that this situation will change in the future, but this would require a strong case to be made for such infrastructure costs when discussing the preparation of the 6th Framework Programme. (It is currently more likely that the Commission will continue to contribute to coordination activities and to technology and research projects relevant to scientific drilling, as it is the case today.) Some other funding sources might be explored between now and 2003, these being the structural funds and the EIB (European Investment Bank) financing. The structural funds are regional funds set up through the European Commission for developing areas in Europe. They are usually used for economic infrastructure, but scientific infrastructures can be supported as well. This option has to be explored far in advance, but it could be envisaged for any drilling platform construction or improvement. The European Investment Bank also makes long-term loans for economic development and is now providing openings for scientific investment. The Commission is currently discussing this kind of financing with the EIB. Apparently the advantage of these loans is that they enable the expenses to be spread over long periods (i.e. 10-15 years) and they have reasonable interest rates. Therefore, the financial contribution to IODP from Europe might finally be, from several sources, for example national funding, community funding, structural funds, and EIB loans. This requires preparatory work to set up the structure of this financing, probably taking advantage of the ESCOD group and of the JEODI project. The present workshop should help in setting up the scientific and technical framework for this financing structure.

In conclusion, and most important to this meeting, Europe has a clear policy of encouraging close collaboration between industry and science for the benefit of the environment and to properly address societal issues. I therefore encourage you all to be proactive to ensure that this workshop identifies the way forward for the utilisation and development of technology for the advancement of science. In the area of Earth dynamics with clear spillovers into many other, even commercial, activities, I personally regard these planned activities as an exemplary case for a new discussion of global scientific and technological cooperation comparable to the activities of the International Space Station and the International Fusion activities.

Thank you for coming and successful working!

The Aims and Aspirations of Europe in IODP

Helmut Beiersdorf,
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Summary

In October 2003 IODP will start as the successor of ODP, the largest international programme of all time for investigating our dynamic Earth. It is also the most successful Earth science programme.

Background

Over the past decades scientific ocean drilling has led us to a comprehensive understanding of processes which govern the interaction of the solid Earth, oceans, atmosphere, ice sheets (cryosphere), orbital behaviour, and life. Such understanding would have never been achieved without ocean drilling. Ocean drilling has provided immeasurable contributions to the development of concepts for exploration and exploitation of mineral and energy resources as well as for mitigating geological hazards, or in more general terms, for the development of concepts for a better Earth management.

However, many important questions remained unanswered. This is mainly due to the lack of appropriate drilling and measurement technology in ODP and to the rapidly increased capability for modelling the Earth system, which in turn resulted in the discovery of a greater than anticipated complexity in this system as well as in the identification of new gaps in knowledge.

Those investigations which require further ocean drilling are documented in the IODP Initial Science Plan. The plan was developed by a significant part of the international Earth science community and is based on the mutual understanding that only through a wide international conference of scientists and funding agencies can the numerous problems identified in the plan be tackled and solved.

Like ODP, the IODP will be international for three simple reasons:

- it is forefront science
- it requires a huge human resource
- it requires financial resources which no single country can provide.

The key to the success of ODP was that the programme was entirely science-driven and borne by the good will of the scientists involved who cooperated closely in the planning and implementation of the programme. This will also be the case for IODP.

European scientific communities have been intensively involved in the planning of IODP from early on at all levels of the planning process. Not joining this effort would have prevented Europe from participating in setting the course for the most modern and cutting-edge Earth science.

The imminent problems related to providing mankind with mineral and energy resources, and the need to cope with changes in the global environment, make IODP more timely than ever.

Deeper drilling into the Earth's interior is needed, as well as the exploration of almost unexplored realms. The pressing need to answer many of the outstanding questions within a relatively short time also requires more drilling in less time than in ODP. In this context the IODP Initial Science Plan recommends a multiple-drilling platform approach. Two platforms, a riser drillship and a *JOIDES Resolution*-type riserless drillship will be provided by Japan and the USA. But drilling also has to be performed by fit-to-mission platforms, so-called "alternative platforms", in environments in which the other two platforms cannot operate technically or where their deployment would make no sense economically.

Europe should provide these fit-to-mission ocean drilling capabilities, thus forming the "Third Leg" of IODP. The benefits for Europe would be manifold.

By providing the "Third Leg" of IODP, Europe would become a strong partner in this programme of global importance, and gain more influence in its planning and implementation. This means that forefront science could be carried out in the best interests of Europe because many of the scientific goals of IODP can best be achieved by drilling within European waters or are based on globally important drilling proposals derived from excellent European research activities.

Greater European influence on IODP will enhance the scientific contributions to the programme by European scientists. It will also enhance international cooperation. This in turn will be instrumental for the programme's success, and thus will be of benefit to all IODP partners.

One of the key elements of ODP is education. Working together with eminent scientists during the drilling campaigns and scientific pre- and post-cruise activities has created a tremendous transfer of knowledge and ideas to the young scientists of all ODP member countries, including Europe. This will be enhanced by IODP, since more young scientists will join the programme than for the ODP. The requirement for more human resources in the new programme and its widened scope (see for example the deep biosphere research within IODP) will make it necessary to involve scientists from scientific communities which have not yet been involved in ocean drilling. This cooperation in turn will help science to cope with the increasing complexity associated with Earth-system research. Europe will benefit significantly from this development.

Europe's industry has the capability to make significant technological contributions to scientific ocean drilling, and it has done so in the past. It is difficult to quantify, but if European industry decides to work with the scientific community towards providing the technologies required for alternative platform drilling and other programme activities within IODP, it could gain very much in terms of enhancing its position on the world market. If European companies receive contracts for development and operations related to IODP, they are put into a position where they can demonstrate their ability to cope with the most demanding technological and operational problems. Such fields, among others, in which European industry could excel, would be shallow water drilling and drilling in the almost unexplored Arctic Ocean as well as other environments where drilling is very difficult.

If European industry becomes involved in IODP, it could also find easier access to first-hand information from a forefront science programme and would be enabled to transform this into new technologies or into concepts for the immediate exploration of mineral and energy resources. This in turn will give them an edge over competitors. It is obvious that this opportunity is greater in a global world-class programme such as IODP than in programmes of smaller scale and scope.

With all these benefits in mind, let us combine our forces, and make every effort to become the "Third Leg of IODP".

Joint European Ocean Drilling Initiative (JEODI)

John Ludden,
CNRS-CRPG,
Nancy, France

Introduction

The Joint European Ocean Drilling Initiative (JEODI) aims to bring a distinctive European component to a new era of scientific ocean drilling due to commence in autumn 2003 - The Integrated Ocean Drilling Program (IODP). This Thematic Network (TN) brings together all the major member states involved in scientific ocean drilling.

The USA and Japan have defined IODP in terms of a two-vessel programme involving a deep-drilling, riser-equipped vessel that the Japanese have started to construct, and a second vessel of similar capabilities to the *JOIDES Resolution* in the current ODP, which the USA will equip and operate. These two vessels are unable to achieve all of the objectives that have been laid down in the science plan for IODP. In particular, these vessels will not be able to core in ice-covered regions and in shallow-water environments; drilling in both of these environments will yield important information on climate change, global geochemical and biological cycles and natural resources. European geoscientists have experience and skill in using and operating alternative platform drilling technologies (now termed “mission-specific platforms” by IODP) that can work in these environments. The objective of the JEODI project is to harness these capabilities as part of the IODP by the provision of shore-based laboratories and other facilities to handle, process, curate and store core derived from these drilling activities. In addition, JEODI will create a management structure and an outreach programme for the new era of the Integrated Ocean Drilling Program in Europe.

Scientific objectives and approach

The objective of the JEODI Thematic Network (JEODI TN) is to promote scientific and technological cooperation internationally; to reinforce European Community capacities in the fields of science that require ocean drilling and to develop the technology required to make a significant increase in the quality of scientific drilling activities. JEODI aims to bring a distinctive European component (currently partners from 15 member states) to a new era of scientific drilling that is due to commence in autumn 2003.

The first role of the JEODI TN will be to work with European scientists to prepare a portfolio of conceptual advanced drilling targets (drill-hole prognoses), so that the industry can see and understand where European scientists would like to drill. This involves an evaluation of drilling conditions (temperature, pressure, stresses, fluids). In particular, JEODI will explore new ways of linking European technological capabilities and will define a science plan for ocean drilling through to 2010. This plan will draw on the successes and failures of ODP and will include all potential platforms for future scientific ocean drilling, and will underline key scientific objectives from a European perspective. Of particular importance is the development of a scientific rationale for drilling and definition of the technological requirements for scientific drilling in the Arctic. JEODI will also foster links with related international scientific programmes such as: the International Continental Drilling Program (ICDP); InterMargins; InterRidge; IMAGES, and with scientific programmes in individual European countries. In particular, research will be proposed for drilling related to the fields of climate change, risks, gas hydrates, deep-offshore resource development, and to ongoing EC projects : DeepBugs, Hydratec, Omarc, Costa, Geomound, DGLab Corinth.

Expected impacts

The primary result will be a portfolio of drilling targets and experiments for the Integrated Ocean Drilling Programme (IODP) using mission-specific platforms. This will involve a 10-year implementation plan for drilling using these platforms. In addition JEODI will develop a management structure for Europe as part of IODP, in which Europe as a consortium will aim to represent one-third of the membership in order to obtain maximum impact for Europe. Cores obtained from these drilling programmes will provide key information, in particular on climate change signals recorded in ocean sediments, on global geochemical budgets, on biogeochemistry and the evolution of the deep biosphere, on potential new energy resources in marine gas hydrates and in deep-water gas and petroleum deposits.

The JEODI project is divided into a suite of work-packages

- Coordination and management of JEODI
- Technology of mission-specific platforms in IODP
- A scientific programme for Europe as part of IODP
- Development of links between IODP and global programmes
- Scientific challenges of scientific ocean drilling in the Arctic
- Europe's role in downhole logging and instrumentation of drill-holes
- Shipboard and onshore laboratory facilities in Europe as part of IODP
- Public relations and communication in Europe for IODP
- A management structure for Europe as part of IODP

Science deliverables

- Provide the technical requirements for an alternative platform programme
- A portfolio of drilling targets and experiments for scientific ocean drilling
- Integrate the European science plan and the international science objectives for ocean drilling
- European report on integrating joint strategies with ICDP
- Present a prioritised portfolio of drilling targets in Arctic waters
- Present a technical strategy for deep coring in ice-covered regions
- Produce a portfolio of logging targets and experiments

Management – Outreach deliverables

- Definition of the political structure and funding geometry for a European consortium in ocean drilling
- Proposals and cost estimates for shore-based laboratories as part of an international programme
- Present a management structure for shore-based facilities in Europe
- Produce information brochures on the European role in scientific ocean drilling
- Develop an educational outreach programme for IODP in Europe

Timing of the project

By end of 2001

- Document defining integration with international and European programmes
- Present integrated science and technical plan to individual funding agencies
- Define management structure for Europe in IODP

By September 2002

- Implement management plan for Europe as part of IODP
- Prepare EC bid for participation in IODP

Late 2003 – early 2004

- Undertake drilling with mission-specific platforms as part of IODP

The JEODI Consortium

Centre National de la Recherche Scientifique – INSU	France
British Geological Survey (NERC)	UK
Federal Institute for Geosciences and Natural Resources	Germany
University of Stockholm	Sweden
Norwegian Geotechnical Institute	Norway
Thule Institute	Finland
Geological Survey of Denmark and Greenland	Denmark
Science Institute, University of Iceland	Iceland
Vrije Universiteit	Netherlands
Department of Public Enterprise	Ireland
Fonds National de la Recherche Scientifique	Belgium
Federal Institute of Technology, Zurich	Switzerland
Consejo Superior de Investigaciones Cientificas	Spain
Instituto de Cooperacao Cientifica e Tecnologica Internacional	Portugal
Consiglio Nazionale delle Ricerche	Italy

Earth, Oceans and Life: a preview of the "Life" part of the Initial Science Plan for IODP

Judith Mckenzie,
ETH-Zentrum Geological Institute, Zurich, Switzerland

What comprises Life within the Oceans? Everywhere in the world there are fluids, which transport nutrients, and there are communities of microbodies and living cells existing to great depths below the sea floor. Scientific initiatives such as deep biosphere research study their influence on climate change and interaction with other systems.

Biochemical and biological implications

- Survival mechanism
- Cellular metabolism
- Community structure and interreaction between species
- Occurrence over variable energy ranges

Biochemical implications. Organisms are sources of hydrocarbons, and they have an impact on sedimentary rocks and climate change links. Living cells exist at great depth under the sea floor. Permeability allows a direct link between surface and sub-seafloor.

Microbiology. Why study microbes? We need to expand on present studies, partly because microbes undergo cell division, which is of interest to petrochemists, and also because research is needed to expand on the link between hydrates, organic matter and climate. What are the limits? We need some method of reliably sampling biosphere material, therefore new technologies are just as important as a strong scientific input.

Biogeochemical implications

- Sources and sinks for hydrocarbons
- Impact on sedimentary records
- Feedback on climate
- Upside-down biosphere
- Limits of the deep sub-seafloor biosphere
- Biosphere/geosphere boundary
- Depth extent; global magnitude
- Influence on porosity permeability
- Evolution of isolates through time or adaptation to specific conditions
- Sedimentation rates
- Significance of deep biosphere and seafloor biosphere

If we do not understand what is going on and what processes are involved we cannot understand the record or predict the response. It is a "hidden world" reached only by drilling where we may find a completely new microbial biosphere.

New technologies to investigate these scenarios are just as important as multiple drilling platforms within the new IODP.

With the permission of Professor Ted Moore we are able to include the Executive Summary of the IODP Science Plan final draft. Judith Mackenzie was one of the editorial team compiling the Science Plan. The full text of the IODP Science Plan Final Draft is now available on the Internet at *www.iodp.org*

Earth, Oceans and Life

Scientific Investigation of the Earth System Using Multiple Drilling Platforms and New Technologies

Integrated Ocean Drilling Program Initial Science Plan, 2003-2013

(May 2001)

IODP Initial Science Plan

A Letter from the IODP Planning Sub-Committee (IPSC)

The most ambitious programme of ocean drilling and exploration ever conceived is contained in this Initial Science Plan. An international community of Earth scientists gathered on several occasions over the past three years, sharing scientific goals, challenging one another's imaginations and generating ideas which IPSC used to develop this plan for the first decade of the Integrated Ocean Drilling Program (IODP). Even as mankind prepares for extraterrestrial exploration beyond the Moon to Mars and the outer planets of our solar system, Earth scientists will embark upon this exciting expedition to "inner space." Building upon thirty years of scientific achievements, this Initial Science Plan defines the goals of an international ocean drilling programme, synthesising the results of a comprehensive suite of conferences and workshops, including CON-CORD* and COMPLEX.** It highlights new process-oriented directions for addressing the Earth system, and it proposes a fundamentally new multiple drilling platform approach to the science of ocean drilling.

Ocean drilling achievements have set the stage for understanding the complex linkages among the different parts of the Earth system. The Deep Sea Drilling Project (DSDP, 1968-1983) validated the theory of plate tectonics, began to develop a high-resolution chronology associated with the study of ocean circulation changes, and carried out preliminary exploration of all of the major ocean basins except the high Arctic. The Ocean Drilling Program (ODP, 1985-2003), capitalising on DSDP's momentum, probed deeper into the oceanic crust to study its architecture, analysed convergent margin tectonics and associated fluid flow, and examined the genesis and evolution of oceanic plateaus and volcanic continental margins. ODP has also greatly extended our knowledge of long- and short-term climate change.

These ocean drilling achievements, and many others, have set the stage for understanding the complex linkages among different parts of the Earth system. This new, integrated Earth view is fundamental to IODP's vision, which is to better understand, among other things: (1) the nature of the earthquake-generating zone beneath convergent continental margin; (2) the nature of the complex microbial ecosystem that inhabits Earth's sub-seafloor; and (3) gas hydrates, the tremendous frozen carbon reservoir that lies beneath continental margins. Other primary IODP goals and initiatives include a more complete understanding of past climate extremes and rapid climate change as potential indicators of the sensitivity of Earth's climate system to anthropogenic inputs; examination of the role of continental break-up in sedimentary basin formation as one key to future resource exploration; the formation and evolution of volcanic margins and plateaus as an example of the Earth's non-steady-state behaviour through time; and the "21st Century Mohole", the drilling and monitoring of a complete section of oceanic crust. These goals will be realised through the use of multiple drilling platforms and the most advanced sampling and observation technologies available, and by forging new collaborations with other international Earth science initiatives and with industry.

As the world grows smaller, mankind's relationship with the Earth must improve. IODP will help to provide the information that can make that possible.

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*Conference on Cooperative Ocean Riser Drilling, Tokyo, 22-24 July 1997
**Conference on Multiple Platform Exploration of the Ocean, Vancouver, 23-27 May 1999

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The IODP Initial Science Plan: Executive Summary

A vision for scientific ocean drilling

Earth's surface veneer of seafloor sediment and extrusive volcanic rock represents the most recent snapshot of geologic time. Beneath that veneer, buried in sedimentary sections and the underlying crust, is a rich history of the waxing and waning of glaciers, the creation and ageing of oceanic lithosphere, the evolution and extinction of microorganisms and the building and erosion of continents. More than thirty years of scientific ocean drilling have been spent exploring this history in increasing detail, revealing the complexity of the processes that control crustal formation, earthquake generation, ocean circulation and chemistry, and global climate change. Drilling has also revealed that deep within marine sediments, rock pore spaces and rock fractures, is an active environment where ocean water circulates, microbes thrive and natural resources accumulate.

The Integrated Ocean Drilling Program, planned to begin 1 October 2003, envisions an ambitious expansion of exploration beneath the oceans, made possible by increasing drilling capability, from the single-ship operation currently in use, to the multiple drilling platform operation of the future. The centerpiece of IODP's deep-water efforts will be a brand new riser-equipped, dynamically positioned drillship, to be provided and operated by JAMSTEC (Japan Marine Science and Technology Center). This vessel will be partnered with a modern, non-riser, dynamically positioned drillship, a successor to the Ocean Drilling Program's *JOIDES Resolution*, to be supplied and operated by the US National Science Foundation. These drillships will be supplemented with additional drilling platforms as needed (for example drilling barges, jack-up rigs and seafloor drilling systems). European and circum-Pacific nations are establishing initiatives to provide some of these mission-specific drilling technologies. Enhanced downhole measurement devices and long-term seafloor observatories complete the suite of sophisticated, state-of-the art tools planned for the new programme. This new technology and multiple-platform approach will allow scientists to conduct experiments and collect samples in environments and at depths never before attempted.

The international community of ocean drilling scientists has devised a bold new strategy for investigating the Earth system that takes full advantage of these new drilling, sampling and observation capabilities. The IODP Initial Science Plan organises scientific study by major Earth processes, encouraging specialists to broaden their proposals to include cooperative work with colleagues in related disciplines. Using the new multiple-platform approach to scientific ocean drilling and a new process-oriented approach to research, IODP will focus on three broad scientific themes:

• *The deep biosphere and the sub-seafloor ocean*

New evidence suggests that vast microbial populations may live within a broad range of temperatures and pressures, where sediment and rock appear to provide life-sustaining resources. Microbes that characterise these extreme environments are now broadly considered to be a potential source of new biomaterials and are the basis of ideas for new biotechnical applications, such as water treatment and microbially enhanced oil recovery. Little is known about the architecture and dynamics of the vast sub-seafloor plumbing system, where flowing water alters rock, influences the chemical composition of the ocean, lubricates seismically active faults, concentrates economic mineral deposits and may teem with life. IODP will probe this environment globally, providing the first comprehensive characterisation of this ocean below the seafloor.

• Environmental change, processes and effects

Ocean sediments provide a unique record of Earth's climate fluctuations and permit detection of climate signals on four time scales: tectonic (longer than about 0.5 Myr.); orbital (20 kyr to 400 kyr); oceanic (hundreds to a few thousand years); and anthropogenic (seasonal to millennial). Studies of drill cores indicate that the pace of climate change has varied over time, from gradual to abrupt. What needs to be fully explored, however, is what initiates these changes, how they are propagated, what circumstances amplify or reduce the climatic effects of large and small events and what processes bring about change in the Earth's environment. IODP will recover cores from as yet poorly sampled environments, such as the Arctic Ocean basin, atolls, reefs, carbonate platforms, continental shelves beneath very shallow waters, and settings where sediments accumulate very rapidly (especially anoxic basins). Combined with drilling results from a global array of sites, these new sediment samples will allow a more sophisticated analysis of the causes, rates, sequencing and severity of change in the Earth's climate system over all time scales. They also permit a more thorough investigation of the relationship among climate extremes, climate change and major pulses in biological evolution.

• Solid Earth cycles and geodynamics

The vast amount of energy stored within the Earth is regularly brought to our attention by transient and often destructive events such as earthquakes, volcanic eruptions and tsunamis. These punctuating events are part of the solid Earth cycle, which involves the creation and ageing of oceanic crust, its recycling at subduction zones and the formation and evolution of continents. The rates of mass and energy transfer from the mantle to the crust and back again are not constant through time. The causes of these variations and their influences on the global environment are poorly understood. Using new IODP technologies, some pioneered by DSDP and ODP, researchers will sample and monitor regions of the sea floor that currently have the greatest mass and energy transfers, as well as regions where these transfers were largest millions of years ago. IODP will also drill deeper into the Earth's crust than ever before, providing new insight into – and perhaps answers to – longstanding questions about the processes related to oceanic crust formation and deformation, including the origin of marine magnetic anomalies and the role of fluids in earthquake generation. During its first phase, IODP will attempt to core, measure and monitor, for the first time ever, the deep seismogenic portion of a subducting plate boundary. This experiment will contribute significantly to our basic understanding of earthquake generation and to develop global policies on earthquake hazard mitigation.

These future scientific challenges, which include eight specific initial drilling initiatives, require IODP to deploy closely linked drilling platform types simultaneously. The drillship with riser capability will permit IODP to address deep objectives that require drilling for months to a year or more at a single location. Deep objectives include the "seismogenic zone" experiment, designed to determine the behaviour of earthquake-generating faults in subduction zones; the deep crustal and intra-sedimentary biosphere; the three-dimensional structure of oceanic and Large Igneous Province (LIP) crust; and the processes of continental breakup and sedimentary basin formation. The drillship without riser capability will enable

IODP to reach the ocean's greatest depths, while continuing to expand the global sampling coverage and disciplinary breadth characteristic of ODP and DSDP. Mission-specific platforms will permit unprecedented examination of the history of sea-level change in the critical region near the shoreline, the recovery of high-resolution climate records from atolls and reefs in shallow water areas and the exploration of climatically sensitive, ice-covered regions not yet sampled by drilling, such as the Arctic Ocean basin.

Of fundamental importance to successful drilling from these platforms will be the deployment of new or improved drilling, sampling and downhole petro-physical tools, which will allow scientists to recover drilled sections more completely, to obtain uncontaminated samples at ambient pressures, to isolate and record data on the physical properties of specific intervals within boreholes and to initiate drilling and recovery of exposed hard rocks. DSDP and ODP have laid a solid technological foundation in most of these areas. Some tools, such as the advanced piston corer (APC) developed for scientific ocean drilling by ODP, will require little engineering improvement. Significant improvement of tools, such as hard rock drilling systems, will require that IODP closely interact with scientific users, and call upon the advice and technical expertise of the drilling industries. As IODP drilling progresses into harsher environments, where the challenge of recovering biologically, chemically and physically intact samples continues to increase, improved tools will be critical for achieving the programme's scientific goals.

Post-drilling observations and experiments in boreholes, pioneered by ODP, will grow in importance in IODP. Sustained time-series recordings by instruments sealed within boreholes will be required to investigate active processes such as pore-water flow, thermal and chemical advection and crustal deformation. Boreholes will also be used for perturbation experiments to investigate *in situ* physical proper-ties of sediments and/or crust, and their associated microbial communities. A global network of geophysical observatories for imaging Earth's deep interior is also planned.

Another important element of our new vision for scientific drilling is the development of closer links between marine geoscientists and their continental drilling and industry colleagues. For example, many fundamental scientific questions to be addressed over the next decade "cross the shoreline". Attacking these problems will require an integrated approach combining continental studies (e.g., lake and continental crust drilling, field-based mapping, onshore-offshore geophysical transects) and drilling into the seafloor. Close interaction with international scientific programmes, such as InterRidge, InterMargins, the International Ocean Network (ION), International Geosphere-Biosphere Program of Past Global Changes (PAGES), International Marine Past Global Change Study (IMAGES), Nansen Arctic Drilling (NAD) and the International Continental Drilling Program (ICDP) will continue to contribute greatly to the quality of IODP science. Ongoing industry-academic dialogue is also defining broad overlap in fundamental research problems that are of interest to both communities. As hydrocarbon exploration rapidly expands into deeper water and the international scientific community's interest increases in using deep-water riser technology, opportunities for intellectual and technological collaboration should continue to grow.

To guide us in the opening phase of IODP, this Initial Science Plan also contains an implementation strategy, which is based on the scientific and technical needs of the new programme, the areas of emphasis spelled out in this document and the logistical constraints of platform availability. It is not meant to usurp the scientific planning process that has been and will continue to be the key to the successful execution of scientific ocean drilling programmes by the international community, but rather it outlines how IODP's scientific goals could be achieved as technology becomes available. As the goals become more clearly defined by specific drilling proposals, or as new discoveries and goals are established, this implementation plan can and will be modified.

A New Generation of Scientists for Ocean Drilling

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One of the great successes of international scientific ocean drilling (DSDP and ODP) has been the educational and collaborative aspects of the programmes. The ships operated by these programmes have informally been referred to as "sailing universities". Seagoing experience by young scientists was gained in a fruitful atmosphere of international cooperation during a drilling leg, and important and often life-long scientific networks were established ignoring national, discipline or age boundaries. This important function has also tremendously benefited the programmes, their success eventually being entirely based on the enthusiasm and personal involvement of the many and growing number of scientists attending the programme for whatever period of time.

The present ODP is therefore privileged by the involvement and support of many outstanding senior scientists who will secure a seamless transition as possible into the ODP successor. However, European participation in the new IODP should make the maximum benefit of the educational and collaborative aspects of scientific ocean drilling in the future, which will also help the IODP to continue to be successful and to constantly develop through the involvement of new generations of scientists.

It is therefore recommended that routines be established whereby young scientists and students will be invited to participate in cruises as observers and trainees. As part of a broader European IODP support programme, stipends for young researchers to work on IODP material should also be established.

The Report of the Brussels Workshop on Alternate Drilling Platforms: Europe as the Third Leg of IODP

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Summary

The Ocean Drilling Program (ODP) has successfully drilled scientific objectives around the globe with the *JOIDES Resolution* (*JR*) drillship since 1985. Scientists recognise that a substantially refitted *JR*, or a replacement vessel with similar capabilities, cannot achieve every scientific objective identified in the Initial Science Plan (ISP) for the Integrated Ocean Drilling Program (IODP), which succeeds ODP in 2003. Some of these objectives, such as drilling of the seismogenic zone, will be addressed by the Japanese OD21 deep-riser vessel currently under construction. However, geographical, topographical and mechanical limitations on IODP operations will persist with either proposed vessel.

It was to answer these technical challenges that the European Commission, the European Science foundation (ESF) and the European Steering Committee on Ocean Drilling (ESCOD) hosted a workshop on Alternative Platform Drilling technology in Brussels, Belgium on 8-9 January 2001. The meeting was co-chaired by Alister Skinner of the British Geological Survey and Jeroen Kenter of the Free University of Amsterdam and brought together an international group of marine Earth scientists and representatives of the hydrocarbon drilling and service industries, the geotechnical drilling industry, and platform operators.

Industry's key message to the academic community is that almost all of the problematic drilling environments can be cored provided that the correct vessels, technologies, and planning strategies are used. A clear understanding of scientific priorities, and dialogue between drillers and scientists are essential to successful drilling proposals. Improved results can be expected for shallow-water drilling and, possibly, deep drilling in hard rock formations at various water depths.

Technical challenges facing IODP

The meeting consisted of presentations of IODP science objectives by scientists followed by open forum sessions. Drilling-industry representatives suggested current and future technological and implementation approaches that would allow these objectives to be achieved. The importance of continuous coring, which is unusual in most oilfield operations but common in mining borehole operations, was a surprise to many in the oil industry, and helped focus the technical discussions.

The three restrictions on IODP operations not addressed by either a refitted *JR* (or replacement), or the Japanese OD21 deep-riser vessel, are:

- ***Geographical***

The ice strengthening of the *JR* is adequate for summer operations in some areas of broken ice, but is insufficient to allow drilling in ice-covered high latitude locations such as the Arctic. The highest ranked proposal currently within the ODP proposal system is the Lomonosov Ridge proposal in the Arctic Ocean.

- ***Topographical***

The *JR* is unsuitable for safe drilling operations in less than 200 m of water, which includes much of the continental shelves and coral reefs. These areas are vital targets for key Initial Science Plan objectives of passive margin and climate research.

- ***Mechanical***

The riserless design of the *JR* leads to problems with spudding boreholes into and maintaining borehole condition in hard seafloor substrates (e.g., basalts, hard rock breccias, or coral limestones), sand-rich horizons on margins, and glacial sediments. and maintaining borehole condition. Only minimal core recovery has been possible in boreholes that penetrate highly brecciated or unconsolidated material.

Industry's response

Industry representatives' responses to these limitations are summarised as follows:

• *The Arctic*

According to Arctic Drilling Planning Group representatives, the principal problem presented by the Lomonosov Ridge proposal is the need for a multi-ship programme that includes an ice-strengthened and dynamically positioned drilling vessel as well as two ice breakers. Another difficulty is the resupply and refuelling cycle for ice support vessels of 25 to 30 days. Industry and ODP Canada participants discussed existing platforms that could be used and offered suggestions for possible drilling strategies and resupply support vessels.

• *Shallow-water drilling: sandy substrates and coral reefs*

The need for scientific drilling through significant volumes of unconsolidated sands and coral reefs was widely discussed. ODP has repeatedly struggled to maintain stable boreholes where sand crops out at the seabed, and has had great difficulty achieving significant core recovery. The geotechnical community stressed that these problems, whilst not simple, were handled routinely in industry and could be overcome using appropriate technology and planning strategies. The major need, controlled weight-on-bit, requires ancillary tools that are not available on, or suitable for, the current *JR*, and would require alternative platforms.

• *Innovative drilling/logging technologies and approaches*

Innovative technologies of significant potential value to IODP include:

- Aluminium drillstrings that allow the use of much lighter-weight derricks and drilling platforms than conventional steel drillstrings;
- Containerised jack-up rigs that can be sent anywhere in the world, and assembled on the beach in two days by six people;
- Simple and robust technologies, such as sub-sea ice airbags to support the weight of the drill rig and plastic risers to minimise weight, used by the international Cape Roberts drilling programme in Antarctica;
- Piggy-back drilling, used in the Barents Sea, utilises two separate drillstrings from a single vessel, with one inside the other, as an alternative to conventional risers. The outer drillstring effectively acts as a riser for the inner one which performs the actual drilling;
- Advances in logging tool designs and geophysical log acquisition; NMR logging, LWD (Logging While Drilling), "wireline logging without wirelines", and new slimline logging tool technologies allow even smaller diameter geotechnical boreholes to be logged to industry-standard specifications.

Logistical planning, project management, industry data, and collaboration

Industry participants agreed that a multi-platform programme is needed, and advised that the complex logistics would require sophisticated project management. This is undertaken routinely in industry but may be less familiar to the academic sector. Amoco and Shell representatives offered IODP access to oil industry seismic data to depths of 1 second, including 3D data, for use in site surveys and planning. The need for joint industry-academic projects to drive the new programme was reiterated.

What next?

A report of the Brussels meeting plus an inventory of industry drilling equipment, techniques and suitable vessels is being compiled and will be made available as a planning resource for IODP and the scientific ocean drilling community. The inventory will probably be posted on a website.

Scientists will be encouraged to write proposals to address targets from the IODP Initial Science Plan using Alternate Platforms, at APLACON, the Alternate Platform Drilling Conference, in Lisbon, Portugal on 10-11 May 2001. This conference, following the CONCORD (deep-riser drilling) and COMPLEX (non-riser drilling) meetings will result in a portfolio of drilling pre-proposals to be submitted to IODP at the normal October proposal deadline.

The co-chairs were extremely pleased with the industry attendance and responses at the meeting but are very aware that there have been too many "talking shops" in the past and that something more positive must be done in the near future to continue the interest and interaction gained. IODP is the key to this.

Chapter 2

Polar Coring Requirements

The Development of ODP Proposal 533: Paleoceanographic and Tectonic History of the Central Arctic Ocean

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Summary

Seismic reflection profiles were acquired from the Lomonosov Ridge in the central Arctic Ocean during expeditions in 1991, 1996 and 1998. A scientific drilling proposal submitted to ODP in 1998 used these seismic profiles to identify drilling targets suitable for both paleoceanographic and tectonic objectives. The data collected in 1991 contain the two key seismic profiles. ODP proposal 533 was ranked No.1 by the JOIDES Science Committee (SCICOM) during its meeting in August 2000. Drilling this proposal requires the use of a drilling platform supported by two icebreakers, that is, the use of alternate platforms. The ODP Long Range Plan (1996) emphasises the importance of drilling Arctic Ocean deep-sea sediments, and the ODP will also consider expanding operations by using alternate platforms. An Arctic Detailed Planning Group (DPG) was formed by SCICOM in December 2000. Its goal is to develop a project management plan encompassing the logistical, technical, and budgetary requirements for scientific drilling on the Lomonosov Ridge. Results from its preliminary report indicate that Proposal 533 can be drilled towards the end of ODP in 2003, at the cost of a standard ODP leg. The highly successful programmes thus far carried out by ODP in the world's temperate oceans can now be applied to one of the Earth's last frontiers, the Arctic Ocean, using drilling and alternate platforms – as ODP's crowning achievement in 2003.

Background

The scientific exploration of the central Arctic Ocean made huge progress during the 1990s, as a result of several successful icebreaker expeditions: 1991 *(Oden* and *Polarstern*, the surface ships No. 4 and No. 5 to reach the geographic North Pole); 1994 *(Louis St. Laurent* and *Polar Star)*; 1996 *(Oden* and *Polarstern);* and 1998 *(Arktika* and *Polarstern)*. These expeditions had broad scientific mandates and covered sampling and data acquisition of all natural systems from the atmosphere to sea floor. Geological coring and seismic reflection programmes thus were key components of all these expeditions; the longest piston core that has been retrieved is 17 m long. Acquisition of geophysical data sets and sea-floor mapping were greatly enhanced through a series of yearly expeditions using US navy nuclear submarines, for example the 1999 *Hawkbill* cruise, collecting sidescan, swath bathymetry and chirp sonar data. All these efforts created a wealth of new data and provided a scientific basis for a much more accurate representation of Arctic processes in, for example, global climate models.

We have learned that the Arctic Ocean indeed plays a fundamental role in the global ocean/climate system: the dense cold bottom waters of most of the world's oceans partly originates in the Arctic Ocean; the permanent Arctic sea-ice cover has a tremendous influence on the Earth's albedo and the distribution of fresh water and its variation, both seasonally and over longer time periods. Thus, the ocean has a direct influence on global heat distribution and climate. Despite this, the logistical difficulties associated with the work in this remote and harsh region have prevented us from gathering the critical data needed to document the role of this key region in the development and maintenance of the global climate system.

Several hundred short cores of Pleistocene age have been retrieved from the Arctic Ocean, but little information is available about its pre-Pleistocene paleoenvironments. Four cores have been retrieved from a small sector of the Alpha Ridge (85°N-86°N/98°W-129°W) that are of Late Cretaceous (3) and Eocene (1) ages. None of these four cores exceed 4 m in length. Temperate marine conditions existed during the Late Cretaceous (Campanian-Maastrichtian) based on evidence provided by silicoflagellates and diatoms from the three short T-3 and CESAR cores (Clark et al., 1980; Bukry, 1981; Thiede et al., 1990). A recent finding of crocodile-like vertebrates from Ellesmere Island is also compatible with temperate conditions in the Arctic during the Late Cretaceous (Tarduno et al., 1998). One very short T-3 core containing an assemblage of cool temperate silicoflagellates of middle or late Eocene age provides the sole evidence for early Cenozoic marine conditions in the Arctic (Bukry, 1984). Thus, existing core material, at best, represents a few percent of the Cenozoic history of the Arctic Ocean.

In a series of visionary reports, paleoceanographers have emphasised the importance of sampling the Arctic's deep-sea sediment archive, without which it appears difficult to fully appreciate and model global environmental change (e.g., COSOD I and II, ODP Long Range Plan, FUMAGES, COMPLEX). Another paper focusing on the central Arctic Ocean is Thiede's (1992) "The Arctic Ocean Record: Key to Global Change (Initial Science Plan)", in which a series of potential Arctic deep-sea drilling sites were suggested, based on, in most cases, lower-quality seismic records collected before the late 1980s.

The Lomonosov Ridge breakthrough during the 1990s

The Lomonosov Ridge was discovered in 1948 by the Soviet "High Latitude Air Expeditions", but the presence of a deep bathymetric barrier across the Arctic Ocean was inferred from earlier tidal measurements in 1904 and 1936, and also from deep water temperature differences made in 1953. This transpolar feature rises over 3 km above the adjacent abyssal plains. Aeromagnetic surveys of the Eurasian Basin reveal a remarkably clear pattern of magnetic lineations which can be interpreted in terms of seafloor spreading along the Gakkel Ridge since Chron 24 (~55 Ma). If we compensate for that motion, the Lomonosov Ridge is brought into juxtaposition with the Barents/Kara Sea margin in the early Cenozoic.

Two seismic profiles were acquired across the Lomonosov Ridge in about 8/10 ice during the Arctic Ocean 1991 expedition (Jokat et al., 1992). At 88°N in 1 km of water, the ridge is 80 km wide with a 450-500 m thick section of acoustically stratified sediments that cap the ridge above an unconformity (Fig. 1).

Two seismic profiles were acquired across the Lomonosov Ridge in about 8/10 ice during the Arctic Ocean 1991 expedition (Jokat et al., 1992). At 88°N in 1 km of water, the ridge is 80 km wide with a 450-500 m thick section of acoustically stratified sediments that cap the ridge above an unconformity (Fig. 1).

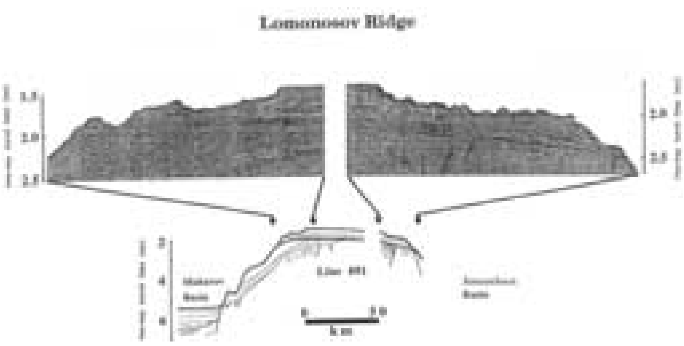

Fig.1: Seismic profile AWI-91091, transecting the Lomonosov Ridge at ca. 87°40'N. The key paleoceanographic sites (LORI-01, -09) will be located on the shallow, flat crest.

Below this unconformity, sediments are present in down-faulted asymmetric half-grabens. Seismic velocities from refraction experiments are typical for hemipelagic sediments above the unconformity (1.8-2.2 km/s) and are > 4 km/s below. Other regions of the Lomonosov Ridge have been explored, also containing potential drilling targets. For example, during the Arctic Ocean 1996 expedition, a third seismic profile was acquired across the ridge at 85°N, in shallower water, but with a thinner sediment cover (Kristoffersen, 1997). Subsequently, Jokat (1999) collected additional seismic reflection data from the crest of the Lomonosov Ridge between about 85°N and 80°N.

The Lomonosov Ridge is interpreted to be a continental sliver that separated from the Eurasian plate during the Paleocene and moved into its current position with seafloor spreading along the Gakkel Ridge, the Arctic extension of the mid-Atlantic ridge system (Wilson, 1963; Vogt et al., 1979; Kristoffersen, 1990). As the Lomonosov Ridge moved away from the Eurasian plate and subsided, sedimentation on top of this continental sliver began and continued to the present, providing what may be a continuous stratigraphic sequence. The elevation of the ridge above the surrounding abyssal plains indicates that sediments on top of the ridge have been isolated from turbidites and are probably of purely pelagic origin.

The upper 450-500 m section of stratified sediments on the Lomonosov Ridge is considered to represent a stratigraphic record spanning approximately the last 50 million years, yielding an average sedimentation rate of ~1 cm /1 000 years if assuming continuous deposition. One may thus conclude that the 450-500 m thick hemipelagic sediment sequence draping the crest of the Lomonosov Ridge between 87°N and 88°N, at about 1 km water-depth, contains a unique archive of climatic and paleoceanographic information, which is the key to unravelling the Cenozoic environmental history of the central Arctic Ocean.

JOIDES encouragement to develop a mature ODP drilling proposal for the Arctic

The obvious target for scientific drilling on the Lomonosov Ridge was recognised in 1991, from the moment the key reflection seismic profiles were collected. Seven years later, in 1998, a small group of scientists decided to submit a preliminary proposal to ODP. Encouraged by the wording in the ODP Long Range Plan about the importance of both Arctic Ocean drilling and alternate platform drilling, the proponents thus challenged the ODP community with the opportunity of capturing a beautiful climate record from the Lomonosov Ridge sequence. The preliminary proposal was well received, and the JOIDES ESSEP (Science Steering and Evaluation Panel – Earth's environment) review urged the proponents to submit a full proposal.

In order to add expertise, the proponent group was enlarged from five to eleven people, and the full proposal (533-Full) was submitted in March 1999. The proposal was revised later during 1999, and an addendum was written in early 2000. Proposal 533 was thereafter sent for external review. The reviews were entirely consistent in that they strongly supported the science presented, that the choice of drilling site locations was excellent for solving the proposed scientific problems, that the drilling strategy offered a good solution for fulfilling stated goals, and, finally, that the suggested platform strategy, involving two icebreakers and a drilling platform, was highly appropriate for this proposal.

No. 1 ranking by JOIDES SCICOM of Proposal 533 and establishment of the Arctic DPG

"The JOIDES Science Committee considered 33 drilling proposals at its August meeting in Halifax and assigned a global ranking to 30 of those proposals. This was the most competitive ranking and scheduling meeting ever, with nearly all of the proposals judged to have merits as drilling projects. Your proposal ranked 1st out of 30..." Letter from the SCICOM Chair, 23 August 2000.

At the August 2000 meeting, SCICOM also decided to establish an Arctic Detailed Planning Group (DPG) to discover the best way to put Proposal 533 into effect. The membership of the Arctic DPG was established in December 2000, and the kick-off meeting was held in January 2001. The preliminary DPG report presents three alternatives consisting of different drilling platform and support icebreaker configurations. The preferred platform scenario draws a cost of about 6.3 million (long) dollars, if Sweden's contribution, the icebreaker *Oden*, is taken into account. Scientific ocean drilling on the Lomonosov Ridge can thus be achieved at a cost which is virtually that of a standard ODP leg.

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Drilling in the Laptev Sea in 2000

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Summary

The Arctic comprises some of the most sensitive elements of the global environment, which are considered to respond rapidly to climate change. In this context the Laptev Sea and its Siberian hinterland are of particular interest. River discharge into the Laptev Sea constitutes a key source for the Arctic halocline's freshwater budget and the shallow Laptev Sea shelf is a major ice production area, linking the Siberian shelves to the Arctic Ocean and the Nordic seas.

Background

During the past years Russian and German scientists have systematically investigated the extreme environmental system of the Laptev Sea in the Siberian Arctic in order to decipher the mechanisms which controlled past climate variations as well as ongoing environmental changes. However, our knowledge of the processes which drove the system in the past is still very limited because only a few short sediment cores that penetrated Holocene sequences have been obtained so far.

The Transdrift VIII expedition (20 August-27September 2000), the first scientific drilling leg to visit the Siberian Shelf seas, was designed to recover sediment sections in the Cenozoic-age rift system of the eastern Laptev Sea to study Arctic climate changes on time scales beyond the Holocene. Because of the shallow water depth of the Laptev Sea shelf, one major objective of the expedition was to investigate whether past sealevel lowstands caused the development of the permafrost also on the shelf. For this purpose, the Transdrift VIII shipboard party cored five holes at three sites (vibra- and rotary coring) in the north-eastern Laptev Sea onboard the Russian drilling vessel *NIS Kimberlit*. During the leg, a total length of 40 m of sediments were recovered. The sediments show that submarine permafrost exists at two sites already at about 9 m below the sea floor. Preliminary shipboard results indicate the occurrence of different types of permafrost-affected sediments. In all instances, however, ice-bearing and ice-bonded sediments were discovered, verifying for the first time the existence of offshore submarine permafrost in the Arctic Ocean. Further investigations will therefore concentrate first on the age and the depositional setting of these frozen shelf deposits.

Polar Drilling: a vision of drilling in ice-covered high latitude deep sea basins

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Introduction

In the Arctic there are three ocean basins covered by ice, this ice is shrinking leading to potential openings for northern sea route traffic. Unfortunately the environmental history and tectonics of the area is not well known and in most instances research vessels are not available to drill in these extreme environments. Europe needs a purpose built research icebreaker capable of long, international and interdisciplinary expeditions during all seasons in the Arctic Ocean. This would be a major European research infrastructure facility and utilised in support of a wide variety of sciences including a major contribution to Global Change research. The Nansen Arctic Drilling Science Plan and APPG arctic science planning group reports of ODP define drilling objectives and highlight the great technical difficulties of Arctic drilling. The ice cover is constantly moving; therefore staying on station is very difficult and the application or extension of existing technology (existing icebreaker vessels are not suitable) and are not the most efficient way to drill in the Arctic. A unique solution to the complex problem of high-arctic research is proposed by the European Polar Board under the project name Aurora Borealis.

A proposal for a unique new dedicated European research Ice-breaker with a mission-specific deep drilling capability

Project Aurora Borealis

A dedicated European research icebreaker is proposed by The European Polar Board (Project name: *Aurora Borealis* – see specifications and Fig. 1). This would be a novel ship for dual use, able to visit the Arctic in all seasons. A removable drill rig would allow summer drilling operations. Container laboratories would maximise space/versatility. It would be a powerful ship similar in size and power to the Russian nuclear icebreakers approx 30,000 m tonnes and be able to keep station in the drifting ice pack. Riserless deep drilling in a principle moon pool is envisaged. It will also be able to deploy AUVs and ROVs through a smaller secondary moon-pool. The Novel propulsion system, power supply and icebreaking capability in drifting pack would make this vessel unique in the world.

A European Science and technical planning group has been established with representatives from 10 countries around Europe. The science plan is to support the concept of such a unique

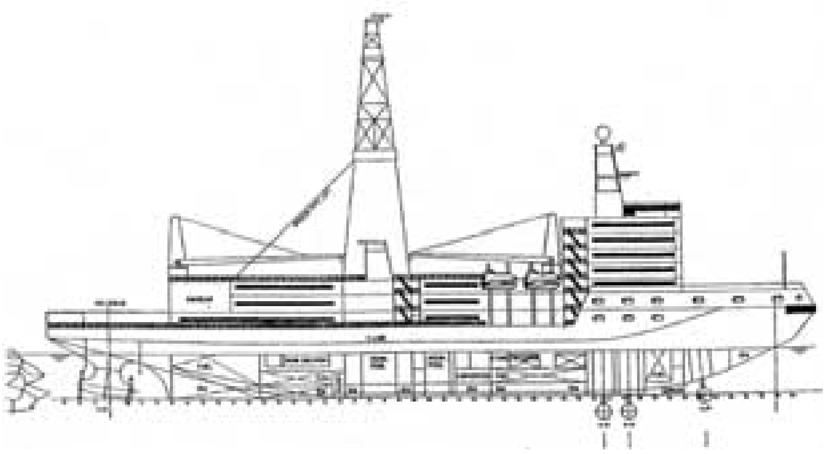


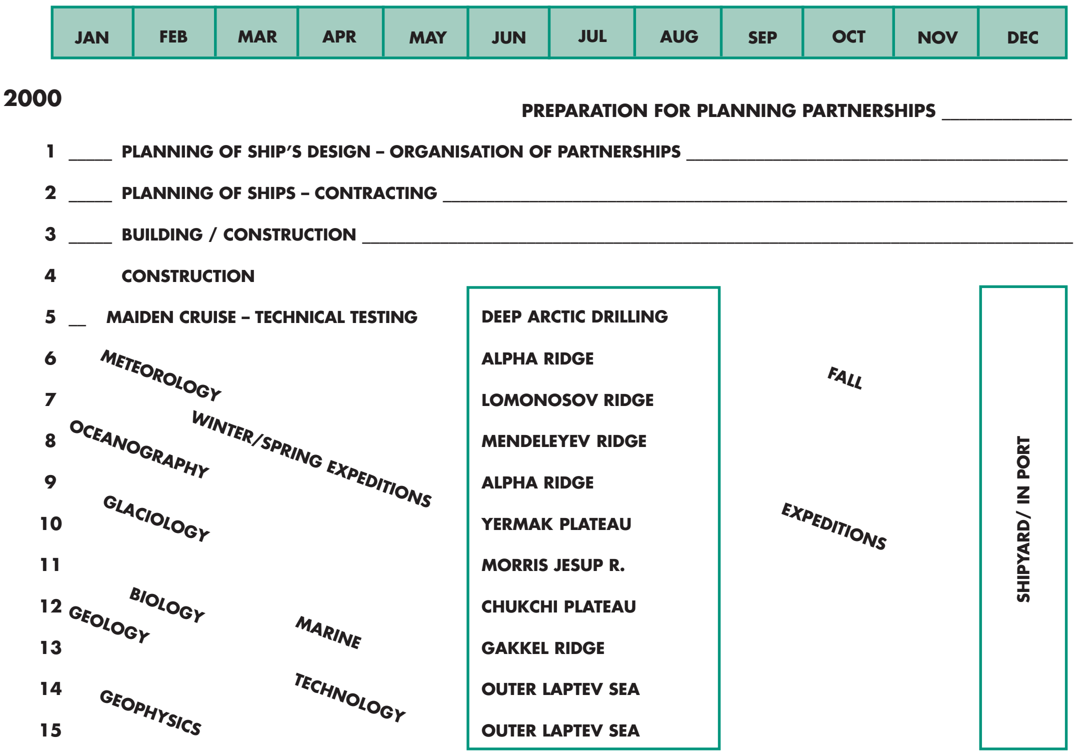
Fig. 1: Schematic layout of proposed Aurora Borealis. Design © HSVA-2001

Research Infrastructure and satisfy the science requirements of the Polar Programme Boards and Research Councils around Europe.

Requirements and specification

- Requires a long term commitment in the polar sciences from a core group of interested European countries
- European Arctic capability for two to three decades
- Long, international and interdisciplinary expeditions
- Operations during all seasons of the year
- Sophisticated unique research vessel with no world wide analogue
- Deep drilling capability based on ODP technology
- Station keeping and dynamic positioning capability in permanently Ice covered Oceans
- Polar research in participating countries will grow and gain in continuity
- Drilling capability could also be used in the Antarctic
- Drilling operations in the Arctic should be part of the IODP initiative
- The Ship should fulfil highest environmental standards
- Technology development and application should be open for industry partnerships in Europe and cooperation outside Europe.

Table 1: Proposed Timescale for Arctic Vessel and Operations



Cape Roberts Drilling

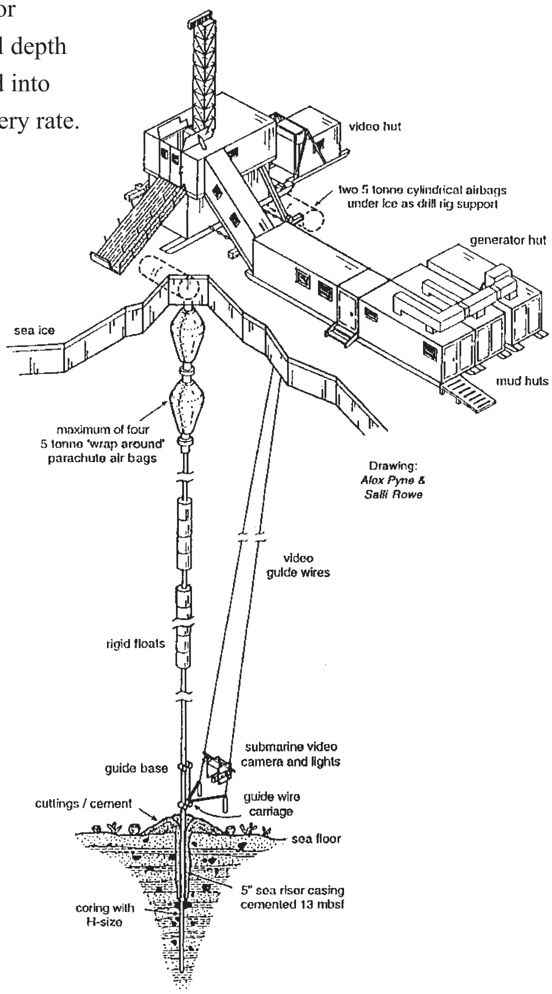
Mike Thomson,
British Antarctic Survey,
Cambridge, UK

The Antarctic ice sheet is important. Continental ice sheets are rare in geological records but they exert a major control over global sea levels, climate systems and ocean currents.

The Cape Roberts Project is in the New Zealand sector of Antarctica. Each year the sea freezes in winter along the coast and it is possible to drill up to 16 km offshore and in 200-300 m water depth. A portable, sled-mounted rig 20 m high and 50 tonnes in weight was used together with other sled-mounted containerised labs, workshops etc. The ice at the drill sites was 2 m thick. Seismic records show a series of dipping reflectors offshore. The plan was to drill three holes and pick up reflector sequences. To date a total depth of 939 m has been drilled into seabed with a 95% recovery rate.

The whole operation is so designed to allow shutdown and removal to safety within 24 hrs and this includes cutting off the riser at the sea bed. Airbags are used under the ice to support some of the weight of the rig and also on the riser to support some of the weight. GPS monitoring ensured that any ice movement was recorded and there was also a video camera at the sea floor. Downhole logging was also carried out.

The Figure below shows the layout of the operation at the drillsite.



Drill rig and sea riser, Cape Roberts Project, Antarctica. Dec 98

A Contribution from Canada for IODP and Arctic Drilling

Shiri Srivastava,
Canadian Associate Director, ODP, Dartmouth, N.S. Canada

Canada is a member of ODP and is interested in joining IODP. The Canadians have commenced their planning and, like the European science community, they see industry support and participation as an integral part.

The Canadian IODP proposal process is underway and a new international fund announced in Canada in October is fully supported by the Geosciences Council of Canada. The IODP proposal under preparation will include a request for full membership and support for scientists.

Canada has been an active operator and researcher in the Arctic for many years doing drilling and geotechnical work. Dynamic positioning mode is different in ice than it is in the open sea; there are technical issues and icebreaker ships to be considered.

The role of the drilling vessel is to stay on location and guide ice around the vessel in a lateral plane, not to guide ice down to the drill site. The dynamic positioning operation must be fully automated. It should not be handled manually.

The Canadian icebreaker *Terry Fox* could be used for ice management. It would require a definite commitment to the programme and would need refuelling after two weeks (average fuel consumption 100T/day). Cost would be approximately Canadian $25 000 per day at present-day prices.

From the Canadian Arctic experiences the following comments can also be made:

- Allow lots of ice-induced downtime
- Separate ice management from drilling part
- Fit-to-mission targets will require different approaches for:
  - Ice-infested (flowing or pack ice) water
  - Shallow water
  - Deep water
  - Ice-free shallow water.

Summarised by Alister Skinner

Jorn Thiede asked about the future of the Cape Roberts drill rig. **Mike Thomson** replied that as it was so successful they want to keep it operating. He said there were many remaining targets that could be attacked by mounting the rig on sea ice. It could also be used to drill into the ice shelf itself and this may be a potential project in the next few years. He thought that the drill rig could be used in the Arctic but that others would be better able than he to judge. The drill rig would require stable ice and the problem in the Arctic is ice movement but it might be possible to use the rig on a large ice floe over the target area if its movement were monitored. **Kate Moran** added that there is land-fast ice in the Canadian Arctic Ocean Basin extending to about 20 km offshore, which could be used for a drilling platform.

Greg Mountain remarked on the excellent recovery obtained at the Cape Roberts drilling site and asked how much of the 95% recovery could be attributed to the riser. **Mike Thomson** responded that probably most of it was due to the riser. It was very important; it allowed re-circulation of mud, which was environmentally important, allowed bit and core barrel changes and supported the slim-line drill rods when drilling. **Marcus Rampley, Mikhail Gelfgat, Gene Pollard** and **Karl Oscar Sandvik** all confirmed that an external pipe support or riser was essential when deploying a mining type drillstring in deep water.

Mikhail Gelfgat suggested that it might be possible to use an aluminium riser and that would further reduce weight. In Lake Baikal, an aluminium riser was used in 600 m water depth. **Mike Thomson** said that plastic risers were also being looked at. This was treated with some scepticism from the floor but **Karl Oscar Sandvik** and **Alister Skinner** were able to report that plastic risers were already in use but not yet in deep water.

Alister Skinner remarked that the Arctic was a good example where fit-to-mission needs multiple platforms and techniques and that was why industry expertise was essential. He reminded the meeting of Shiri Shrivastava's Canadian experiences. **Mike Thompson** asked for clarification on what was required for work in the Arctic – an icebreaker or multiple vessels to break ice and keep a drillship in the open? **Alister Skinner** suggested that when working in moving ice at least one icebreaker would be required as well as the drillship, but the drillship does no work other than drilling. **Jan Backman** considered that under relatively light ice conditions a single ship could manage to stay on station drilling and breaking ice – it depended so much on ice conditions. **Jorn Thiede** commented that when he was co-chief on ODP Leg 151 he had observed that ice management is extraordinarily complicated. He would prefer to have an independent vessel, but sometimes ice conditions make that impossible. He said that Chris Wiley from Canada had already assisted with ice management information and had arranged a talk by experts in the field at the last ODP Arctic PPG in Calgary, using the ice management for the Arctic oil drilling rigs offshore Beaufort Sea and Shakalin Island as a basis.

Bill Hay commented that he had been serving as liaison person between JOIDES and the Antostrat programme, working on the stratigraphy of continental margins in the Antarctic. ODP had advised them to work further offshore if they wanted to achieve successful drilling and their programme was modified to allow operations with the *JOIDES Resolution*. He believed that at the Lisbon APLACON meeting there would be a number of well thought-out proposals for similar work, which would involve going to places where an alternative platform would be the only logical method of drilling.

Claus Chur felt that there was a marketing issue here. He compared the science world's method of working with that of the oil industry.

Firstly, he said that he could not tell the meeting how to drill in ice-infested waters but that he could give the industry perspective on other aspects, using his experience in industry and his involvement in the German DeepScientific Borehole at KTB.

Secondly, he said that at present the general market situation was allowing a significant increase in capital spending in the oil industry. Unfortunately, this leads to significant shortages of management resources with respect to capable drilling engineers and leads to a situation where personnel and capital resources will be allocated only for projects that give a necessary return on revenue.

Thirdly, industry is interested in participating, but always assuming that they can make a return on revenue within a given time frame. To be successful in industry it is necessary to develop a clear project, which means one project, not just one scientific goal. Some different projects could be joined into one project. Funding is also crucial; if targets are spread over too many projects then it will be too hard to get the funding.

He had two clear messages:

- Try to combine most of the scientific targets into one big project.
- Use existing technology when possible; industry does not look favourably on new investment in capital resources when return is uncertain.

Alister Skinner felt that there *was* a single project – IODP. He said that if science works in conjunction with various aspects of industry technology then that is what is required, but IODP is a ten-year programme at least.

Herman Zuidberg remarked that if one wants drilling or coring, it all comes down to having a suitable vessel. Vessel capabilities are more or less fixed and it is not difficult to draft performance requirements for fit-to-mission platforms. Industry would frown on building a new vessel when vessels already exist. If each programme asked for its own budget that would also be too inefficient. He said that one reason why ODP had been able to accomplish so much was that the vessel determined what was possible and committees decided on scientific proposals centred around those possibilities.

Helmut Beiersdorf commented that this "European drilling initiative" was in an exploratory stage and was not aware of what was available, what possibilities existed, and how they could be used in IODP. He said that the purpose of this meeting was to find out what was available and to prepare for the Lisbon APLACON conference.

Shiri Srivastava stated that Canada wanted to proceed with science but the problem was finding the financing. He asked whether the funding for IODP was going to be per leg, and pointed out that in Arctic drilling one is talking about ten times the cost of a usual leg. An Arctic drilling programme in the next ten years would be phenomenally expensive, he said. **Jan Backman** disagreed with these costs but stated that the Arctic DPG had the task of coming up with hard figures. He felt it could probably be done in some situations for less than double a present ODP leg. For example, for the Lomonosov Ridge a preliminary estimate for a 35-day ice operation breaks down as ice management estimates of US$.3 million plus a drilling platform, rig, etc. Therefore, he said, one could get a drilling leg in the Arctic for US$ 6-8 million.

Chapter 3

Shallow Water, Margins and Reef Drilling

Shallow-Water Fluid Flow, Diagenesis, Paleoclimate, and Sea-level Objectives in the Great Australian Bight

David Feary,
National Research Council, Washington DC, USA

An opportunity exists on the vast continental shelf off southern Australia to address important diagenesis, fluid flow, paleoclimate, and sea-level scientific objectives. Achieving these objectives will require deployment of a shallow-water drilling platform, as Leg 182 *JOIDES Resolution* drilling confirmed the absolute necessity of decoupling the drill bit from the pervasive heave in order to obtain adequate recovery. The drilling of Leg 182 provided exciting results in some areas, but in others offered only tantalising insights into processes controlling deposition and post-depositional alteration of a dominantly cool-water carbonate platform. The shallow-water parts of this depositional system, underlying the present continental shelf, remain as the critical unexplored component needed to link shelf-edge and deeper sequences with the onshore record.

The Great Australian Bight, south of central Australia, encompasses a vast, tectonically-stable shelf that extends for some 300 km offshore, reaching a depth of 200 m at the shelf edge. Because of water depth constraints, the Leg 182 drilling transect (Fig. 1) extended from the upper continental rise to the shelf edge. This proposal advocates the drilling of a complementary transect from the shelf-edge to the innermost shelf, in water depths of 35-188 m.

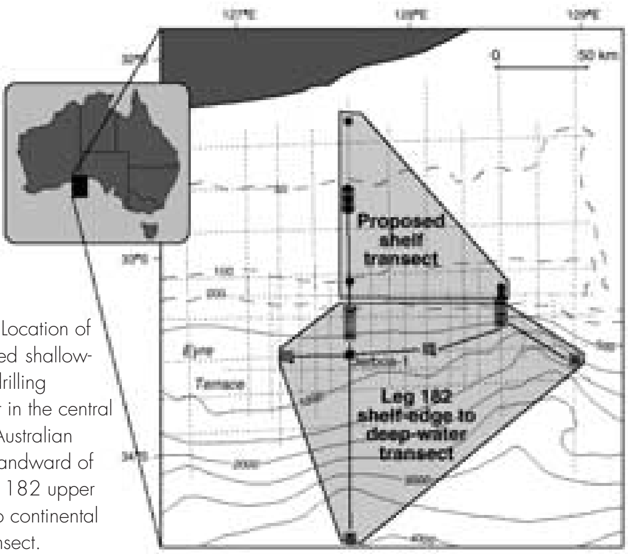


Fig. 1: Location of proposed shallow-water drilling transect in the central Great Australian Bight, landward of the Leg 182 upper slope to continental rise transect.

Fluid flow and diagenesis objectives

One of the most unexpected results of Leg 182 drilling was the discovery of a high salinity brine in pore waters at seven sites. The salinity reached values as high as 106, and it appears that there is a common depth of the salinity maxima below sea-level at all sites (Fig. 2). Pore fluids in the Pleistocene portion of some of the sites also possessed a Na+/Cl- ratio in excess of seawater, suggesting that the fluids in these sediments had been involved in the dissolution of NaCl.

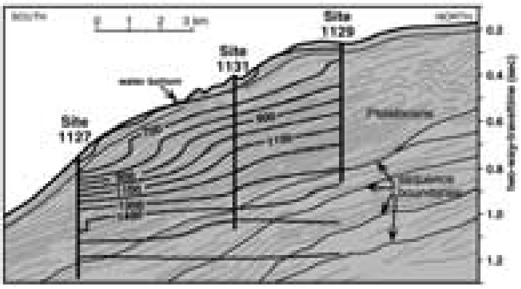


Fig. 2: Contour plot of chloride concentration (mM) at Leg 182 sites 1127, 1131, and 1129, showing approximately constant depth of brine body below the sea surface.

The most likely source for such high salinity fluids is from evaporative systems episodically fed by seawater, and we speculate that during successive low sea-level periods the vast Eucla Shelf may have contained shallow saline lakes that produced multiple episodes of brine infiltration into the substrate underlying the present-day continental shelf. The modern shelf surface consists of broad areas of older Cenozoic limestone with interspersed coarse-grained bioclastic ridges, oriented approximately normal to the prevailing energy direction. These ridges may have constituted semi-permeable barriers between open ocean salinity waters and evaporative, high-salinity lakes, with sufficient permeability to allow episodic recharge of the shallow lakes.

We suggest that a combination of fluids derived from the continental landmass, with greater hydrostatic head, together with these intra-shelf infiltrated brines, produced a "tongue" of high salinity fluid that now extends out to the upper slope within the uppermost few hundred metres of sediment. It is likely that hydrostatic variability resulting from both sea-level fluctuations and ocean swell contributed to brine circulation by hydrostatic "pumping" (Fig. 3). Confirmation of the source and geochemistry of these brines, together with an analysis of fluid circulation controls, requires pore-water analysis along a transect of drill sites across the modern shelf. The compilation of geochemical data trends from these sites offers an opportunity to make a major contribution towards an understanding of the relationship between hydrogeological driving forces and sea-level oscillations –an important component of the sites – to determine fluid composition and circulation rates. The shallow water depths of the proposed sites should minimise the technical difficulties associated with revisiting and servicing CORK(s).

Leg 182 drilling showed the importance of the interaction between the abundant organic material derived from biogenic activity on the shelf with the high salinity brines. Under normal conditions, the organic material would be oxidised first by oxygen and then by sulfate utilising bacteria, thereby creating alkalinity and hydrogen sulfide. The high salinity brines underlying and within the Pleistocene succession provide up to three times the normal sulfate concentrations and therefore, with sufficient organic material, significantly higher amounts of hydrogen sulfide can be formed. This significantly accelerated the normal diagenetic alteration of metastable aragonite and high-Mg calcite to the more stable low-Mg calcite and dolomite. The high alkalinity environment created a thermodynamic regime favourable to the formation of dolomite. These effects were least apparent towards the distal margin of the high salinity brines at deeper sites on the slope, and increased to reach a maximum of ~20% dolomite at the shallowest site drilled at the shelf edge. A full understanding of the components and interactions within this complex system requires analysis of the more landward sequences underlying the modern shelf.

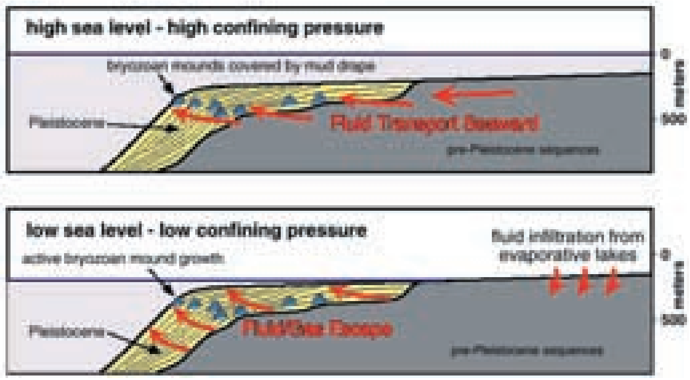


Fig. 3: Schematic diagram showing speculative fluid transport paths under different sea-level conditions, contributing to hydrostatic pumping action.

Paleoclimate objectives

Seismic imagery shows that Cenozoic sequences on the Eucla Shelf preserve a spectacular record of climate change, with sequence geometry indicating that the cool-water depositional conditions prevalent throughout the Cenozoic were interrupted by an episode of warm subtropical or cool tropical reef growth to form a rimmed "Little Barrier Reef" (Fig. 4) platform edge underlying the central Eucla Shelf. A series of sites across this feature offers the opportunity to obtain a detailed record of climatic oscillations during the early stages of Southern Ocean development.

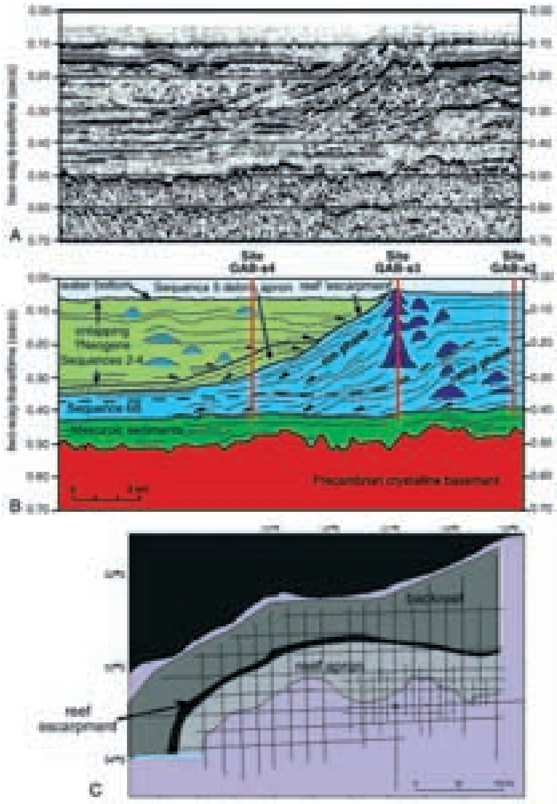


Fig. 4: The “Little Barrier Reef” is spectacularly visible on seismic data (A,B), occurring in the middle of the broad Eucla Shelf (C). The top of the reef escarpment occurs in 50 m water depth.

These sites would permit:

- evaluation of paleotemperature control on carbonate facies that form a rimmed carbonate platform edge, deposited under presumed warm subtropical or tropical conditions, compared with ramp platform morphology deposited under warm temperate or cool subtropical conditions elsewhere on the margin;
- a comparison of the faunal composition and community structure of the reefs forming the rimmed margin with the characteristics of the bryozoan mounds representing cooler water deposition.

Sea-level objectives

An understanding of the effects of sea-level on sediment deposition and post-depositional processes are common to the fluid circulation, diagenesis, and paleoclimate objectives. In addition, the direct effect of sea-level fluctuations on sediment facies can also be targeted by the proposed drilling programme. Leg 182 recovered excellent, high resolution Pleistocene shelf-edge and upper slope successions (>450 m of Pleistocene sediment at two sites). However, the absence of a record from the shallow, uppermost parts of the clinoforms imposes critical restrictions on the extent to which we can describe facies variations within cool-water carbonate depositional systems resulting from sea-level movements. The combination of excellent high resolution seismic reflection data and full down-hole logging enables high resolution site-to-site correlation that will permit a detailed understanding of the role of the relative contributions of shelf-edge bryozoan build-ups and off-shelf sediment transport to form the clinoforms. We propose that drilling shallow-water sites to sample the upper “limbs” of the clinoforms underlying the outer shelf (Fig. 5) will enable the full architecture and process/response reaction of this system to sea-level fluctuations to be determined.

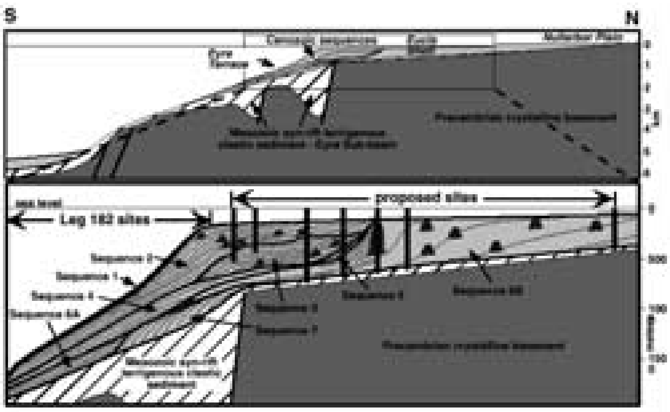


Fig. 5: Schematic diagram showing the distribution of seismic sequence across the Eucla margin. The transect of proposed sites (heavy bars) occur in water depths from 35-188 m.

Much of the above is derived from “Effects of Climate, Sea-level, and Fluid Flow on development of the Eucla Cool-water Carbonate Platform: An ODP Proposal for the Great Australian Bight shelf”, by D.A.Feary, N.P. James, A.C. Hine, P.K. Swart, M.J. Malone, and A.R. Isern.

Christian Dullo,
GEOMAR,
Germany

Introduction

ODP has drilled on reefs and there is a highly ranked proposal currently in the review system which could be drilled using an alternate platform.

The scientific goals to date have been to determine the Holocene history of reef revolution and drilling has stopped at the Holocene/Pleistocene boundary.

Bard (1996) showed that the reef history extended for longer than the Holocene. It also showed that there were two melting pulses recorded in the reef. (See Fig. 1)

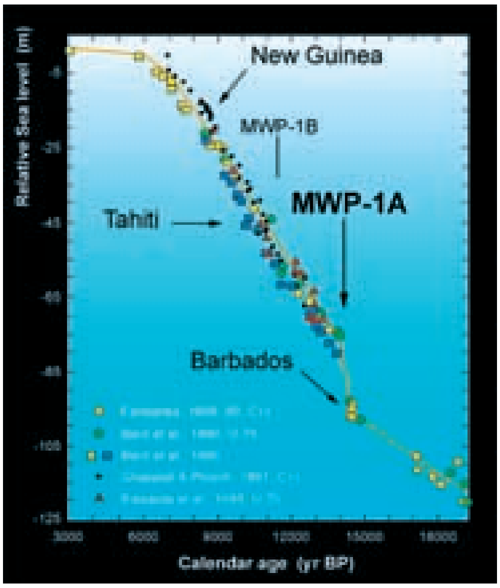


Fig. 1: Sea Level Curve derived from Reed Measurements (after Bard et al 1996)

Submersibles have been used in the Western Indian Ocean to collect data and determined that the lowest sea level which occurred was between 125 and 150 m.

The Barbados and New Guinea Reef sites are in tectonically active areas. Tahiti at present is stable. Figures 2-5 summarise data collected from Tahiti.

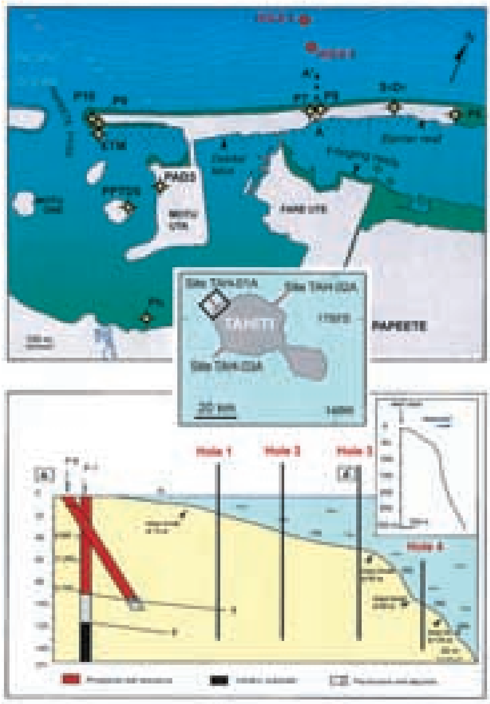


Fig. 2: Location of Tahiti drill sites

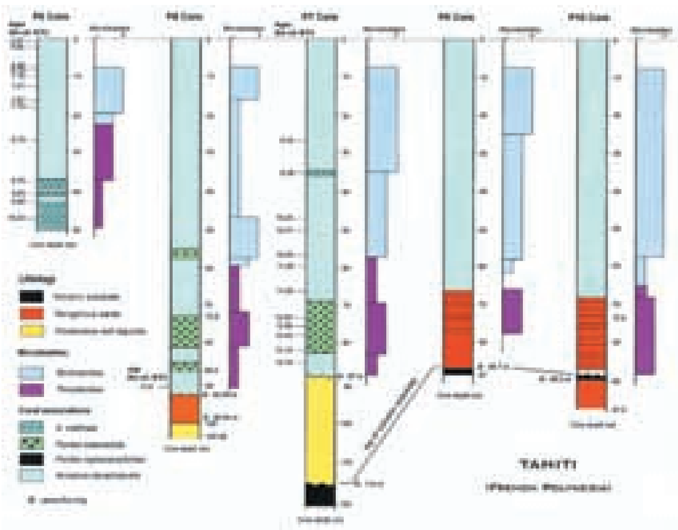


Fig. 3: Geological correlation of Tahiti sites

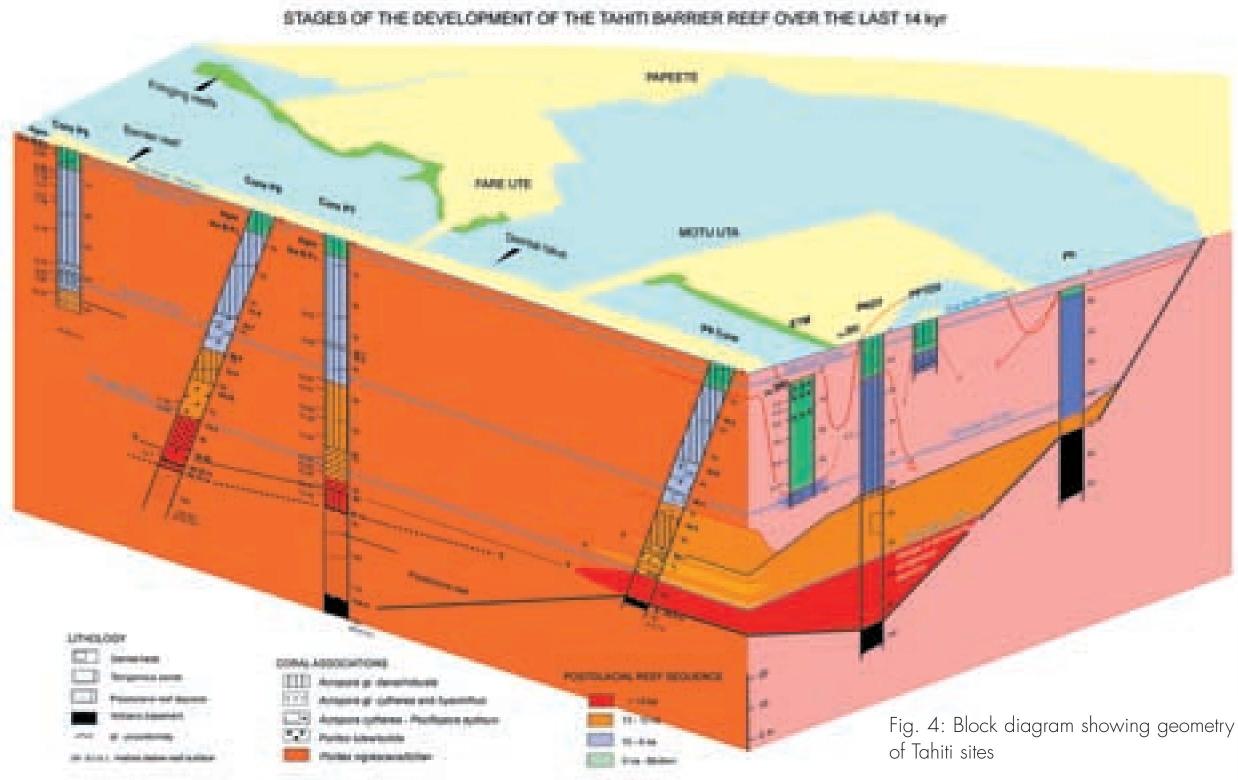


Fig. 4: Block diagram showing geometry of Tahiti sites

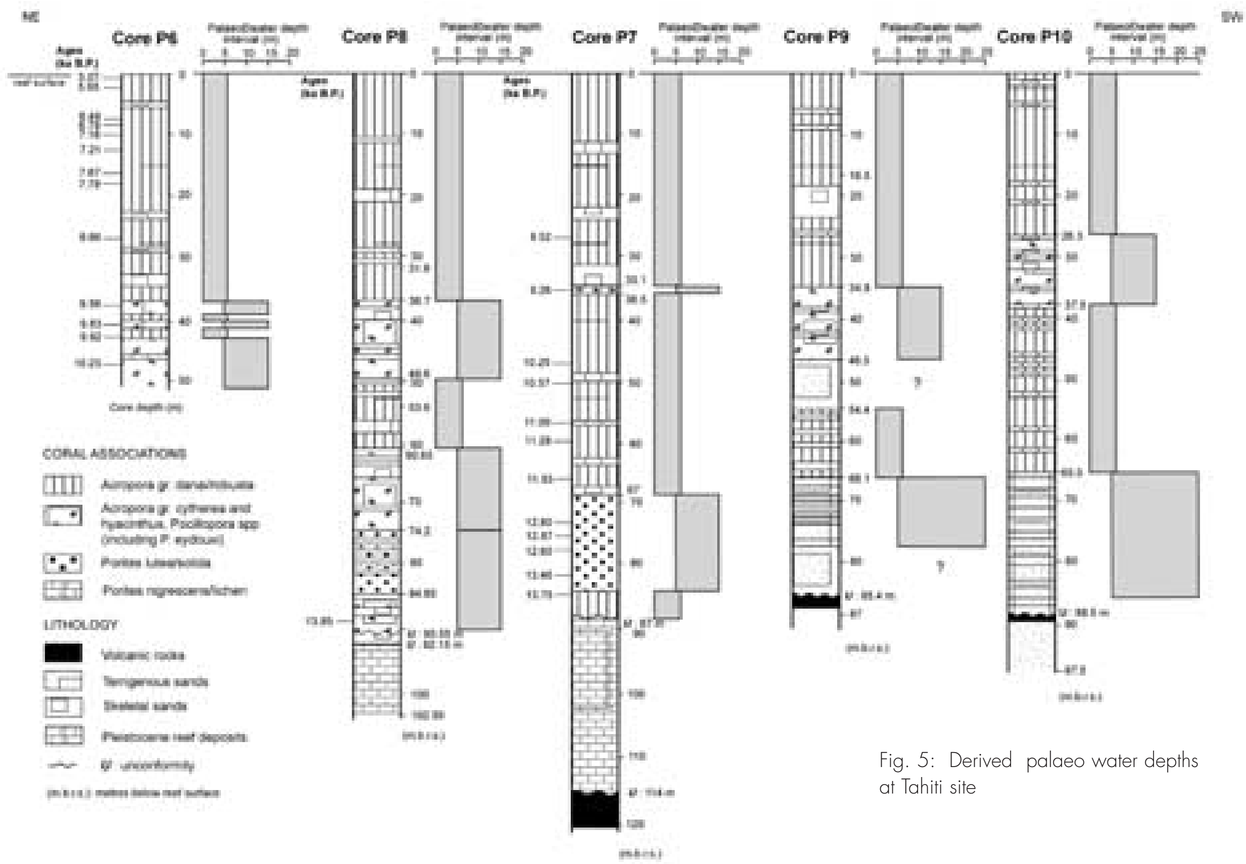


Fig. 5: Derived palaeo water depths at Tahiti site

Technology requirement

There is a need for drilling platforms to operate in various water depths to fill in the history of reef development. Data to extrapolate sea surface temperatures (seasonal variability) during the reef building period would also be of interest.

Research into the geometry of reefs requires a capability to drill obliquely, and existing data suggest a series of overlapping reefs. Therefore we need a drilling device that can operate in water depth of 100 m and which can be moved around.

The core diameter is also important as one needs sufficient diameter to get colonies of 5-10 years growth. A sufficient core diameter for this would be 150 mm.

References

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New Jersey Margin Drilling

Greg Mountain, Lamont-Doherty Earth Observatory, Palisades, NY. USA

Why drill on the New Jersey Margin?

There is high Neogene siliclastic sedimentation rate, low-mid latitude location, simple tectonics, lots of background data and it is a very accessible location for drilling.

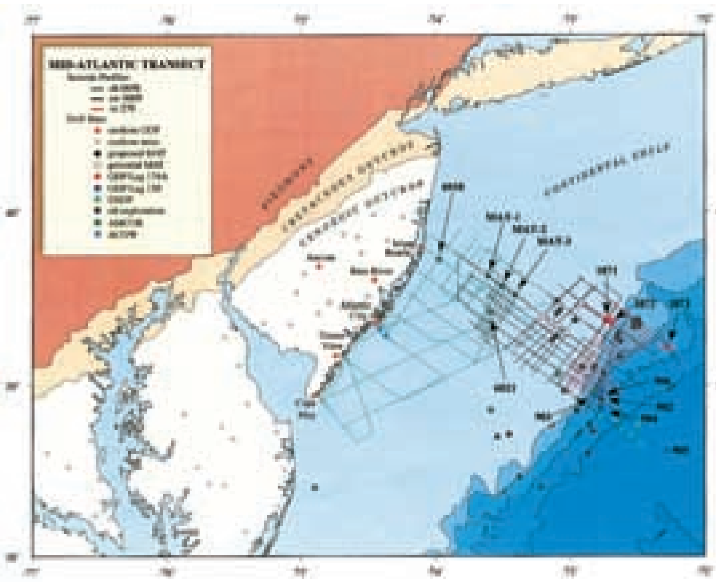

Fig. 1: Location map, New Jersey Margin

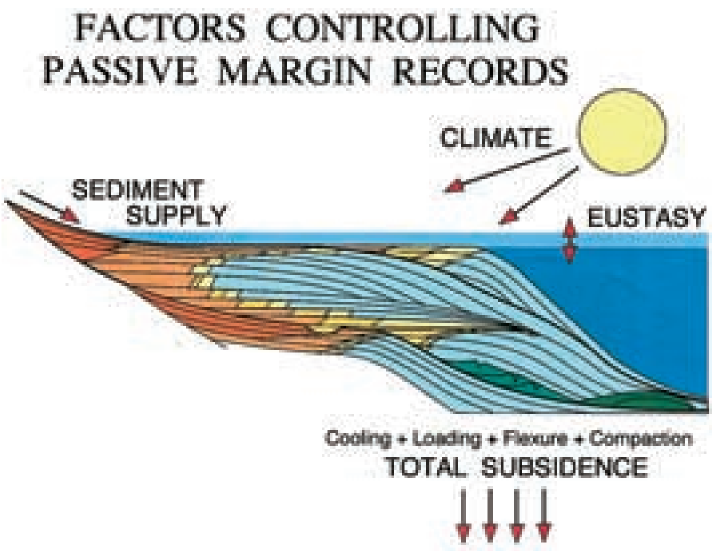

Fig. 2: The build-up of the stratigraphic record

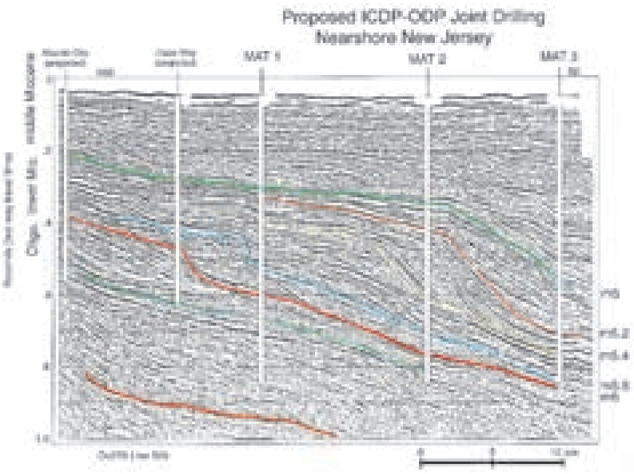

Fig. 3: Seismic section with stratigraphic annotation and location of the MAT boreholes shown in Fig. 1

Goals

- To date margin-wide unconformities.
- To compare with glacio-eustatic changes inferred from delta O18 records. There are undisturbed corals.
- To evaluate amplitudes, rates and mechanisms of sea-level changes. Factors controlling passive margin records are climate, sediment and total subsidence.
- To assess depositional models
- To evaluate sea level change in a purportedly ice-free world (Cretaceous-Eocene)

Outstanding tasks

- The drilling conducted in 1997 left unresolved the reason for an overlap pattern in the siliceous sequences but sequences are identifiable.
- There are a number of preferred drilling locations, which will also require drilling on cliniform structures.
- The targets of interest are the strata surfaces identified on seismic records.

- Trying to achieve correlation between shore and near shore.
- None of the sites where there is recovery is where there was maximum climate change.
- Recoveries on the shelf were much lower (50%) than on the slope (90%)

Scientific needs

- High core recovery is required in these areas
- The ability to drill any location; flexibility is a requirement for this strategy
- There is a need to log holes; a slimline drillstring cannot be used as that will restrict the number of tools
- There is a need to integrate holes into a three dimensional grid

Technical requirements

- Weight-on-bit
  - Well designed heave compensation
  - Bottom landing
  - Seabed frame
  - Jack-up platform

- Closed circulation
  - Achieve environmental impact goals; fluids have to be recovered
  - Safety concern of BOP and diverter needed for anything that goes beyond 10 m sub-bottom
  - Hole casing needed

- Station keeping
  - Dynamic positioning system or better

Shallow-Water Coring

Terry Quinn,
College of Marine Science, University of South Florida, USA.

Introduction

A report on the shallow-water workshop has been compiled by Quinn and Tudhope and entitled "Submerged Coral Drilling". It will be available on the web in due course but at present exists only in draft form. Countries represented in this project were France, Germany, Japan, New Zealand, Norway, UK and the USA.

The workshop looked into various aspects of coral science (climate, history, radiocarbon calibration, fluids) requiring drilling and logging. Industry (imaging and geotechnical) representatives were present and contributed to the meeting.

The workshop demonstrated that the issues are based on today's needs and that drilling and imaging technology does exist and it can be used in shallow water (0-200 m).

What do we want to do?

We need to fit our goals into the academic structure and have shallow-water drilling at "academic prices". We need to promote an integrated approach for site survey work in remote areas and therefore innovative approaches to drilling will be necessary. We need to establish a website and it is especially important that we always keep the weight on the bit!

Some conclusions from the workshop relevant to this meeting

A lot of "paraprofessional" drilling has been done but there is a need for "professional" drilling.

Corals can be drilled without a lot of pre-site surveying; coral reef geomorphology guides drilling without geo-acoustical surveys.

Potential platforms for submerged coral drilling exist, such as:

- Barge (GLAD800 – mining technology hooked onto sea containers)
- Seabed frames (e.g. BGS/BMS, PROD)
- Jack-up rigs
- Vessels (Seaprobe 1, CDS, etc.)
- Drillships (*Mariner, Bucentaur, JOIDES Resolution* etc.)

Tables 1-5 below summarise some of the equipment options.

Recommendations

- Strong support for Europe as the Third Leg of IODP
- Release time for an ODP engineer for consulting on drilling
- Development of an international tropical science initiative
- Establishment of official liaison relations with other working groups
- Promotion of the use of alternate platforms

Website

http://www.marine.usf.edu/coraldrilling/index.html

Reference

Quinn, T.M. and Tudhope, A.W., "A Report from International Workshop on Submerged Coral Drilling", in press.

Table 1: Comparison of Samplers Available for Various Pipe Sizes

Item	Description	Sampling Method	Steel API Pipe w/Upset Tool Joints			Al. Pipe	Geobor
			3.5"	4.5"	5"	5"	5.5"
1	**Dimensions of Pipe**						
1a	OD tube body, inches	n/a	3.5	4.5	5	5.125	5.5
1b	ID tube body, inches	n/a	2.764	3.826	4.276	4.125	4.94
1c	OD tool joint, inches	n/a	4.75	6.25	6.625	7	5.5
1d	ID tool joint, inches	n/a	2.75	3.5	4.0625	4.0625	4.94
1e	submerged weight/ft(note 2)	n/a	12.5	16.3	21.2	8.3	13.6
1f	normal bit size, inches	n/a	5.5-6.5	7.5-8.5	8.5-10	8.5-10	6-7
2	**Soil Samplers**						
2a	2 1/4" thin walled shelby tube	push	yes	yes	yes	yes	yes
2b	2" split spoon	percussion	yes	yes	yes	yes	yes
2c	2 1/4" liner sampler	push	yes	yes	yes	yes	yes
2d	2 14" thick wall taper tube	percussion	yes	yes	yes	yes	yes
2e	3" thin wall shelby tube	push	no	yes	yes	yes	yes
2f	3" piston sampler	hydraulic	no	yes	yes	yes	yes
2g	3" thick wall taper tube	percussion	no	yes	yes	yes	yes
2h	3" piston liner sampler	hydraulic	no	yes	yes	yes	yes
2i	2.2" rapid piston sampler	hydraulic	no	yes(4)	yes(4)	yes(4)	yes(4)
2j	2.05" pilot rotary corer	rotary	no	yes(4)	yes(4)	yes(4)	yes(4)
2k	1.5" split tube sampler	percussion	yes	yes	yes	yes	yes
2l	1.625" swelling soil barrel	push	yes	yes	yes	yes	yes
2m	165 lb wireline percussion hammer	percussion	yes	yes	yes	yes	yes
2n	300 lb wireline percussion hammer	percussion	no	yes	yes	yes	yes
2o	Geobor S shelby tube	push	no	no	no	no	yes
3	***In Situ* Testing/Speciality Tools**						
3a	umbilical type CPT/PCPT	hydraulic push(1)	no	no	yes(4)	yes(4)	yes(4)
3b	Dolphin Remote vane	push	no	no	yes(4)	yes(4)	yes(4)
3c	Dolphin CPT/PCPT	hydraulic push(1)	no	no	yes(4)	yes(4)	yes(4)
3d	2.2" hydraulic hammer sampler	hydraulic hammer	no	no	yes(4)	yes(4)	yes(4)
4	**Boart Longyear Geo-Barrel**						
4a	2" push	push	no	no	yes	yes	yes
4b	3" push	push	no	no	yes	yes	yes
4c	2.155" pilot corer	rotary/wireline	no	no	yes	yes	yes
4d	2.937" pilot corer	rotary/wireline	no	no	no	no	yes
4e	3.345" hard rock core	rotary/wireline	no	no	no	no	yes
4f	2.5 « hard rock core	rotary/wireline	no	no	yes	yes	yes
5	**Hard Rock Coring Systems**						
5a	BQ - diamond coring	rotary/wireline	yes(3)	yes(3)	yes(3)	yes(3)	yes(3)
5b	NQ - diamond coring	rotary/wireline	no	yes(3)	yes(3)	yes(3)	yes(3)
5c	HQ - diamond coring	rotary/wireline	no	no	yes(3)	yes(3)	yes(3)
5d	BW44- diamond coring	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5e	BV double - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5f	BV - triple - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5g	NV -double - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5h	NV- triple - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5i	3.0" Christensen Marine Barrel	rotary/wireline	no	no	yes	yes	n/a
5j	3.11" rotary corer	rotary/wireline	no	no	yes	yes	n/a
5k	Geobor S corer/pilot corer	rotary/wireline	no	no	no	no	yes

Notes: 1. Seafloor reaction frame is required for operation. 2. Submerged unit weights are based on the ID of the tool joint being bored to accept geotechnical tools. 3. If proper stabilisation is provided inside of outer string. 4. May not be compatible with other systems.

Table 2: Comparison of Samplers Available for Various Mining Flush Joint Casing Sizes

Item	Description	Sampling Method	Steel Mining Style Flush Joint Casing (2)				
			BW	NW	HWT	CHD 101	CHD 134
1	**Dimensions of Flush Joint Casing**						
1a	OD tube body, inches	n/a	2.875	3.5	4.5	3.701	5
1b	ID tube body, inches	n/a	2.375	3	4	3.268	4.5
1c	OD tool joint, inches	n/a	2.875	3.5	4.5	3.701	5
1d	ID tool joint, inches	n/a	2.375	3	4	3.091	4.125
1e	submerged weight/ft(note 2)	n/a	6.09	7.5	10.1	7.65	12.2
1f	normal bit size, inches	n/a	2.98	3.782	4.827	4.5	5.5
1g	typical core size	n/a	N	H	P	H	P
2	**Soil Samplers**						
2a	2 1/4" thin walled shelby tube	push	no	yes	yes	yes	yes
2b	2" split spoon	percussion	no	yes	yes	yes	yes
2c	2 1/4" liner sampler	push	no	yes	yes	yes	yes
2d	2 14" thick wall taper tube	percussion	no	yes	yes	yes	yes
2e	3" thin wall shelby tube	push	no	no	yes	no	yes
2f	3" piston sampler	hydraulic	no	no	yes	no	yes
2g	3" thick wall taper tube	percussion	no	no	yes	no	yes
2h	3" piston liner sampler	hydraulic	no	no	yes	no	yes
2i	2.2" rapid piston sampler	hydraulic	no	no	no	no	yes
2j	2.05" pilot rotary corer	rotary	no	no	no	no	yes
2k	1.5" split tube sampler	percussion	yes	yes	yes	yes	yes
2l	1.625" swelling soil barrel	push	yes	yes	yes	yes	yes
2m	165 lb wireline percussion hammer	percussion	no	yes	yes	yes	yes
2n	300 lb wireline percussion hammer	percussion	no	no	yes	no	yes
2o	Geobor S shelby tube	push	no	no	no	no	no
3	***In Situ* Testing/Speciality Tools**						
3a	umbilical type CPT/PCPT	hydraulic push(1)	n/a	n/a	yes	n/a	yes
3b	Dolphin Remote vane	push	n/a	n/a	yes	n/a	yes
3c	Dolphin CPT/PCPT	hydraulic push(1)	n/a	n/a	Poss.(3)	n/a	poss.(3)
3d	2.2" hydraulic hammer sampler	hydraulic hammer	n/a	n/a	possible	n/a	possible
4	**Boart Longyear Geo-Barrel**						
4a	2" push	push	n/a	yes	yes	yes	yes
4b	3" push	push	n/a	no	yes	no	yes
4c	2.155" pilot corer	rotary/wireline	n/a	yes	yes	yes	yes
4d	2.937" pilot corer	rotary/wireline	n/a	yes	yes	no	yes
4e	3.345" hard rock core	rotary/wireline	n/a	yes	yes	no	yes
4f	2.5 « hard rock core	rotary/wireline	n/a	yes	yes	yes	yes
5	**Hard Rock Coring Systems**						
5a	BQ - diamond coring	rotary/wireline	yes(4)	yes(4)	yes(4)	yes(4)	yes(4)
5b	NQ - diamond coring	rotary/wireline	yes(4)	yes(4)	yes(4)	yes(4)	yes(4)
5c	HQ - diamond coring	rotary/wireline	no	yes(4)	yes(4)	yes(4)	yes(4)
5d	BW44- diamond coring	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5e	BV double - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5f	BV - triple - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5g	NV -double - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5h	NV- triple - diamond core barrel	rotary/conventional	n/a	n/a	n/a	n/a	n/a
5i	3.0" Christensen Marine Barrel	rotary/wireline	n/a	n/a	n/a	no	yes
5j	3.11" rotary corer	rotary/wireline	n/a	n/a	n/a	no	yes
5k	Geobor S corer/pilot corer	rotary/wireline	no	no	no	no	no

Notes: 1. Seafloor reaction frame is required for operation.

2. Drill rods have the following dimensions:

Item	Description	Conventional Drill Rods			Wireline Drill Rods		
1	**Mining Rod Dimensions**	**BW**	**NW**	**HW**	**BQ**	**NQ**	**HQ**
1a	OD tube body,in.	2.125	2.625	3.5	2.19	2.75	3.5
1b	ID tube body.in.	1.75	2.25	3.06	1.81	2.375	3.06
1c	OD tool joint,in.	2.125	2.625	3.5	n/a	n/a	n/a
1d	ID tool joint,in.	0.75	1.375	2.375	n/a	n/a	n/a
1e	submerged weight/ft	3.65	4.7	7.4	3.48	4.52	6.7
1f	core size,in.	1.32-1.601	1.875-1.99	2.406-2.5	1.32-1.601	1.875-1.99	2.406-2.5

3. Depending upon burst pressure of tubular used. 4. If proper ID stabilisation is provided inside the outer string.
5. Range of core sizes represents whether a triple tube is used or thin kerf diamond bit.

Table 3: Typical Hole and Core Sizes for Existing Diamond Coring Systems

Operator/Type	SYSTEM Designation	Core Size, in.	Hole Size, in.	Ratio Hole/Core	Bit Kerf	Notes
Mining	AQ	1.062	1.89	1.780	0.414	
Mining	AQTK	1.202	1.89	1.572	0.344	
Mining	BQ	1.433	2.36	1.647	0.4635	
Mining	BQTK	1.601	2.36	1.474	0.3795	
Mining	NQ	1.875	2.98	1.589	0.5525	
Mining	HQ	2.5	3.782	1.513	0.641	
Mining	PQ	3.345	4.827	1.443	0.741	
Mining	BQ3	1.32	2.36	1.788	0.52	
Mining	NQ3	1.775	2.98	1.679	0.6025	
Mining	HQ3	2.406	3.782	1.572	0.688	
Mining	PQ3	3.27	4.827	1.476	0.7785	
Mining	CHD76	1.712	2.98	1.741	0.634	
Mining	CHD101	2.5	3.99	1.596	0.745	
Mining	CHD134	3.345	5.276	1.577	0.9655	
DOSECC		2.312	5.5	2.379	1.594	
ODP	RCB	2.312	9.875	4.271	3.7815	
ODP	DCB	2.312	7.25	3.136	2.469	
ODP	ADCB/PQ	3.345	7.25	2.167	1.9525	1
ODP	ADCB/PQ3	3.27	7.25	2.217	1.99	1
BGS/Fugro/ Seacore	Christensen Marine Barrel	2	8.3875	4.194	3.19375	

Notes: 1. Sea trials schedules f/ Nov. 2000.

Table 4: Potential Platforms for Conducting Geotechnical Sampling/Coring Operations

Vessel/ Platform Type	Water Depth (m)	Typical Rig Orient-ation	Total Depth (m) or Capacity (mbsf)	Rig/Corer Type	Pipe/ Rods	Anchoring/ Positioning	Riser Req'd	Heave Comp.	Comments	Exp.
Portable flexi-float	3-30	M/C	<300	mining rig or portable	API/mining	4-point	possible	possibly req'd	weather sensitive	n/a
Work barges	5-100	C/C	300-600	mining rig or portable	API/mining	4-point	possible	possibly req'd	weather sensitive	n/a
Special design drilling barges	5-200	M	< 800	mining rig or portable	API/mining	4-point/DP	possible	possibly req'd	weather sensitive	GLAD 800
Small seabead frame (diver assist)	0-20	n/a	10-30 mbsf	mining rig sitting	mining	Seabead sitting	none	not required	limited wd /penetration	n/a
Small seabead frame	< 2000	n/a	6 mbsf	mining rig	mining	Seabead sitting	none	not required	limited pen./ A-frame req'd	BGS/BMS
Seabead frame	10-2000	n/a	5-100 mbsf	mining rig	mining	Seabead sitting	none	not required	A-frame req'd	PROD
Very small lift barge	0-20	C	30-100	small mining rig	mining	lift legs	possible	not required	limited, weather sensitive	n/a
Small self elevating barge	10-60+	CL	<1000	portable/ mining rig	API/mining	lift legs	probable	not required	limited water depth	n/a
Oil field jack up	20-100+	C/C	<1000	fixed portable /mining	API/mining	lift legs	probable	not required	limited wd/ high day rate	n/a
Small work vessel < 30m	<100	CL	<300	small portable /mining rig	mining	4-point	probable	required	weather sensitive	n/a
Research/survey/ work vessel < 60m	225-365	M/C/C	<350/ 1000	mining/ portable rig	API/mining	4-point	API as riser	required	seafloor reaction mast	Seaprobe I
Research/survey/ work vessel < 60m	20-1500	M/C/C	< 650/ 1500	mining/ portable rig	API/mining	DP	API as riser	required	seafloor reaction mast	CDS
Geotechnical drillship	< 330	M	< 600	fixed derrick	API	4-point	no	required	seafloor reaction mast	Mariner
Geotechnical drillship	<1500 (note 4)	M	1650	fixed derrick	API	DP	no	required	seafloor reaction mast	Bucentuar
Geotechnical drill-ship w/ piggy back	<1500	M	1000 (note 5)	fixed w/ mining rig	API/mining	DP	API as riser	required	seafloor reaction mast	Bucentuar
Science drillships	50-7000	M	<7000	fixed derrick	API	DP	no	required	poorer recovery	JR
Oil Field Semi submersiables	50-3000	M	< 3000	fixed or portable rig	API	DP	API as riser	required	seafloor reaction mast	Uncle John

Notes:
1. M refers to moon pool.
2. CW refers to centrewell.
3. CL refers to cantilevered unless noted.
4. Without using aluminium pipe.
5. Depth limitations of HQ piggy-back coring system.
6. A portable rig is designated as a rig which uses API style drillpipe.
7. Mining/mineral rig is designated as a rig which used mining style drillrods.

Table 5: Comparison of Typical Drilling Options Available for Shallow-Water Coral Drilling Operations

Item	ODP	Typical North Sea Geotechnical Vessel	Small Mining/ Mineral Type Rig
Total depth capability, m for HQ size core	<7000 n/a	<1650 <1000	<1500 <800
Drilling type heave compensation	yes	available on some ships	yes
Accuracy	dependent upon water depth & string stiffness ('+/- 7.5k)	hard tie system simulates land drilling <1k	very sensitive/accurate <1k
Coring system available	RCB ADCB	Christensen Marine Barrel HQ and possible BQ available	HQ/NQ/BQ
Typical % recovery	15- 30%+ for RCB High recovery expected for ADCB but dependent upon AHC	30-60% for Christensen Marine Barrel 60-90%+ for piggy back HQ	80%+
Riser	no	yes	yes
Mud returns	no	no	depends on system & water depth
Pipe size	API w/ upset tool joints	API w/ upset tool joints mining string w/ flush joints	mining string w/ flush joints
Vessel duration	<60 days	<30 days	<30 days
Accommodation	<120	<46	<40
Onboard science laboratory	extensive	very limited	very limited
Seafloor template	no	yes	depends on system & water depth
RPM	<120	<120 for API <1000 f/ mining string w/ riser	<1200 w/ riser
Casing size available	20/16/13 3/8/10 3/4	API drill pipe	PQ/HQ/NQ size rods
Interchangeable tools for diamond coring system	not at this time	no, but may be added	yes, but not developed by contractors
Logistics	very good logistical established	must be set up f/ specific job awarded	must be set up f/ specific job awarded
Time to establish start-up programme	must follow existing science protocol <2 yrs	<6 months could be performed much quicker once placed on schedule	<6 months could be performed much quicker once placed on schedule
Costs	turn key operation once proposal placed on schedule	medium to high, depends on ability to perform back to back projects, location, water depth, etc.	low to medium, depends on ability to perform back to back projects, location, water depth, etc.

Discussion

Summarised by Alister Skinner

Marcus Rampley opened the discussion by stating that the technology does exist to successfully core in this type of environment. His company (Seacore Ltd.) drills between 30 000-50 000 m per year for core samples and are paid on a recovery basis. No recovery, no pay, therefore the technology has to be there to do the job properly. Equipment is containerised to be flexible and freightable. Drilling is possible from 0-5 000 m string length. Jack-up platforms can have a beach assembly and are capable of coral drilling in, for example, the Red Sea in Egypt and also in permafrost. He said that his company discusses technology and design with other companies to ensure the best solution, and if science has problems with this type of drilling then industry should have a solution. In fact he was keen to point out that the nature of the drilling industry made each operator quite insular and thus he would welcome academic cooperation that broadens industry's horizons.

Kate Moran remarked that at the time when Greg Mountain did his *JOIDES Resolution* drilling in loose sand she was working on a project with Mobil Oil on Sable Bank, offshore Canada. She said that geotechnical drilling conditions had been difficult with a lot of sand. They used a Seacore rig, which was able to achieve, with standard geotechnical drilling techniques and a seabed frame, 85% recovery in this material.

Trond By confirmed that the technology does exist and that a drill rig and heave compensator can be put on many types of ship, including icebreakers. His company (Nemo Engineering/ DSND) is most interested in joining up with a new programme and sees the issue as one of identifying and funding projects. He also wondered if it was simply an issue of pricing or whether there were other issues which required addressing for alternate platforms. (This relates to the "academic pricing" mentioned by Terry Quinn (see Shallow-Water Coring) but which was never defined by the scientists, and was commented on by a few of the industry participants).

Alister Skinner reminded the participants that many scientists, working outside the present ODP already use such alternative technologies and would continue to refine them and keep informing the science community of such activities.

Greg Mountain asked what kind of technology could drill the New Jersey shelf where the following conditions exist:

- 110 m water depth
- Loose sands in upper 10 m
- Targets 800-1200 m sub-bottom
- Occasionally in Gulf Stream sea currents
- Want 80% core recovery

He wanted to know whether a jack-up, with riser; would have to be used and stay on site for four months. He asked how much had earlier attempts really cost.

In his opinion these drilling operations need not be prohibitively expensive, for example he thought that a cost of US$ 2 million for drilling holes over a 75-day period with logging etc. would be in line with the average costs of a 56-day ODP leg.

Herman Zuidberg pointed out that it was very common in industry for clients to go and explain scientific/technical objectives to a potential supplier and be able to get a rough costing based on this.

Claus Chur commented that in his experience on KTB drilling, things changed as the project developed. In the beginning there was always a need for continuous coring which is time consuming and costly. Very often, spot coring became more acceptable when funds were less available. He said the technology existed to deliver good quantitative chemical values and even cutting analysis with only spot cores. However, it was pointed out that in offshore coring there is not always a riser system, which is essential to obtain cuttings for analysis.

Michael Gelfat stated that he was delighted to be invited to attend this meeting and outlined coring systems that are available at present for scientific drilling:

- ODP Drilling Program (ODP) Coring System
- Complete Coring System (CCS)
- Geotechnical Marine Drilling and Coring Systems
- NEDRA Baikal Coring System

ODP – A unique offshore drilling system capable of operating from *JOIDES Resolution* in water depths to 7 000 m changes BHA system for different operations.

CCS – Aluminium drillstring large diameter 164-168 mm OD; 146 mm ID providing one BHA system for several coring systems – piston, rotary and downhole motor. Also retrievable core barrel drill bits with different heads – diamond, drag and cone

Geotechnical systems – A number exist, including portable units, which can fit on vessels or fixed platforms. All can be supplemented with aluminium drillpipe to reduce weight.

Baikal system – Similar to the CCS system but used from a frozen-in (fixed) platform with smaller core barrels for more restricted working. This is a similar situation to Cape Roberts drilling.

All can be used as examples of technology that can be merged and used in shallow waters. With regard to scientific needs the weight-on-bit is the most significant because of the high recovery required. We must be able to drill in almost any location therefore flexibility is always a key factor, he said. (See Annex A under Aquatics Company Marine Surveys and Drilling Operations).

Alister Skinner commented that there is a need for logging of alternate boreholes and that a wide range of slim hole logging tools was available.

Peter Elkington was intrigued to know what “academic rates” were but he could explain where the costs in logging came from.

He said that the cost of conventional open hole logging was controlled by the capital cost of the hardware; equipment is large and heavy (57 tonnes) and requires two engineers and three to four operators. The weight is what one is paying for most of the time. His company (Reeves Wireline Services) does not build this sort of equipment any longer and is using smaller diameter equipment, designed for conventional hole sizes. It is also lighter and in some instances can be operated without a wireline which means that a winch is not necessary and this further reduces the weight.

Logging-recording equipment is now the size of a laptop computer and a small box. Probes can be conveyed at the end of a drill pipe, can be pumped down a 57mm ID annulus, pumped through modified drill bits and thus drill core and log without tripping. Alternatively, with Shell, his company has designed a piece of equipment that allows the hole to be cased whilst logging. His conclusion was that even while he still did not know what the academic costs were, this was one way of keeping costs down. (More information is contained in Annex A under Reeves Wireline).

John Ludden said that he was surprised to hear that the technology is as advanced as it is. He felt that scientists would be using more of it if

ODP were not locked into existing contracts. His question was whether IODP should be locked into fixed platforms or a fleet of platforms on lease from several companies. **Gilles Ollier** commented that he thought the point was well made and hence it is necessary to review the existing technology.

Paul Dauphin added that what has been done over the last four or five years is in response to the scientific challenge. The new science plan for IODP recognises that probably the riser and non-riser vessels can do 90% of the science requirement proposed for IODP. The USA has decided to fund the non-riser vessel and the Japanese the riser vessel. The USA certainly welcomes and encourages what is being discussed here for the remaining portion of the science plan.

Jeroen Kenter concluded by stating that clearly there is a need for an inventory of fit-to-mission technology and that any one with information to contribute to it should please inform Alister Skinner.

Chapter 4

High Resolution Sediment/ Stratigraphic Coring Requirements

Prograding Wedges on Glaciated Margins: a developing ODP drilling proposal from the EC 5th Framework STRATAGEM project

Dan Evans
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and members of the STRATAGEM Group

Haflidi Haflidason (UiB-Norway), Jan Sverre Laberg (UiT-Norway), Tove Nielsen (GEUS-Denmark), Laura De Santis (OGS- Italy), Hans Petter Sejrup (UiB-Norway), Pat Shannon (UCD - Ireland), Martyn Stoker (BGS - UK), Tjeerd van Weering (NIOZ-Netherlands), Tore O Vorren (UiT-Norway)

The STRATAGEM project

The STRATAGEM project is a EU-funded 5th Framework project that is investigating the late Cenozoic development of the glaciated European margin; it forms part of the OMARC (Ocean Margin Research Consortium) cluster. The project also has substantial support from the oil industry in the form of co-operation agreements with four Joint Industry Projects active in the area: the Seabed Project in Norway, GEM in the Faroes, WFA in the UK, and PIPCo RSG in Ireland. Together, these represent 27 oil companies who have in particular provided a vast amount of data in addition to that already held by the partners or collected by them during the project itself.

STRATAGEM is a three-year project that started in March 2000, and aims firstly to generate a stratigraphic framework for the late Cenozoic of the European glaciated margin from the Lofoten Islands of Norway to the northern Porcupine Basin off Ireland. A second major product will be a model for the evolution of the area during the same time period. This form of project will enable the STRATAGEM partners to be in an excellent position to identify the optimum drilling sites for any investigation involving the Upper Cenozoic section, and for advising more-specialist projects on the regional geological context of their work.

As STRATAGEM remains at an early stage, there is as yet no detailed proposal of specific sites for drilling using an ODP vessel of whatever type. Nevertheless it remains a goal of the project to be in a position to prepare a suitable proposal as the project matures.

Prograding wedges and trough mouth fans

As implied by the STRATAGEM logo, a particularly important feature of the glaciated European margin is the common occurrence of prograding wedges or of trough mouth fans. The seismic interpretation work of the project, allied to the incorporation of existing sample data, will allow STRATAGEM to map these features and discuss their nature and development. However, detailed understanding of the wedges and their causes will not be possible until drilled sections can be obtained in order to carry out a wide range of analyses. It has to be stressed that although a number of commercial wells have been drilled into the wedges, the recovery from these is generally poor and is inadequate for detailed studies. The wedges to be found along the margin are good examples of a world-wide phenomenon (eg Larter and Barker, 1991; Clausen, 1998; Vorren et al., 1998; Kristofferson et al., 2000).

Vøring margin

The largest wedge development in the STRATAGEM study area is to be found on the Vøring margin (Fig. 1), where up to 100 km of shelfbreak advancement has occurred since late Pliocene times (Hendriksen and Vorren, 1996). The volume of the wedge north of the Storegga Slide has been calculated as 80 000 km^3, and it has a maximum thickness of approximately 1500 m (Evans et al., 2000). It is suggested that the major development of the wedge began in late Pliocene times (Eidvin et al., 2000). A stratigraphic subdivision of the outer part of the wedge has been established by McNeill et al. (1998), and it is an aim of STRATAGEM to refine this stratigraphy.

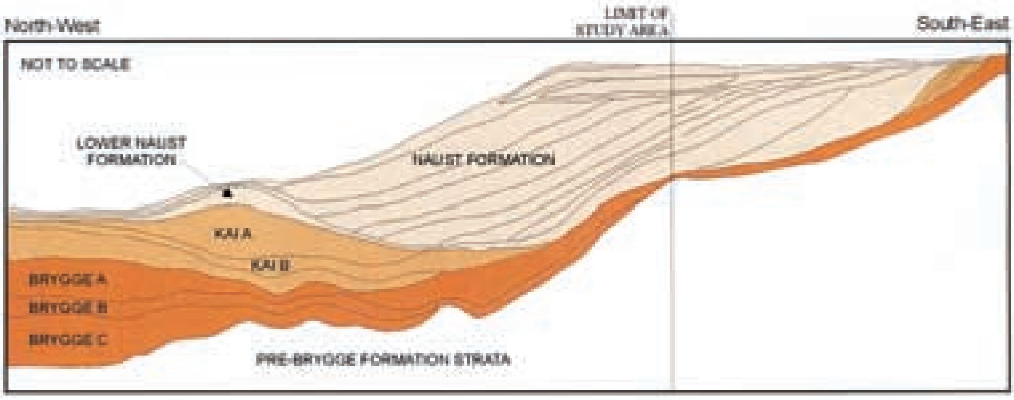

Fig. 1

The development of the wedge represents a major change in the style of sedimentation in the region. Previous deposition had been in the Vøring Basin, where the Eocene to Miocene Brygge and Kai formations had slowly accumulated. In late Pliocene times there was uplift of the adjacent land (Riis, 1996), providing a rapid supply of detritus to the subsiding shelf. Later, probably mainly in mid- to late Pleistocene times, there was major glaciation of the shelf, leading to the development of the URU (Upper Regional Unconformity) and other glacial unconformities. There is also evidence of major slides and palaeoslides on this part of the margin, especially in the "glacial" section (Evans et al., in press).

North Sea Fan

The North Sea Fan is a major trough mouth fan depocentre located at the distal end of the Norwegian Channel (Sejrup et al., 1996). A stratigraphy for the upper part of the fan has been established by King et al. (1996), and this has been adapted and extended downwards by McNeill et al. (1998). The Plio-Pleistocene Naust Formation deposits on the fan are over 1 600 m thick, and include a number of paleoslides as well as the vast Holocene Storegga Slide that dominates the seabed on the northern flank of the fan (Bugge et al., 1987; Evans et al., in press). Investigation of the sediments of the North Sea Fan is particularly important because this is the depocentre for sediments derived from a large area of southern Fennoscandia that were transported by ice through the Norwegian Channel.

Faroe-Shetland Channel margins

Prograding wedges have also built out into the channel from both the Sheltand and Faroese archipelagos (Fig. 2). The smaller west

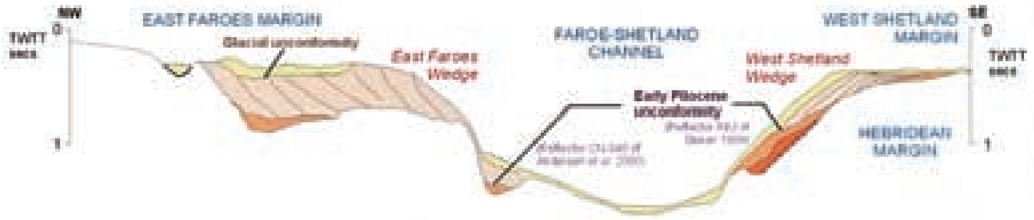

Fig. 2

Shetland wedge is the better documented and appears to be of late Pliocene origin. It locally represents a shelfbreak advancement of up to 50 km, is over 300 m thick, and limited sampling of the older portion of the wedge has recovered sandy sediments indicative of a deltaic environment (Stoker et al., 1993). A well-defined glacial unconformity marks mid-Pleistocene and later advancement of glaciers across the shelf, and together with the base of the wedge, this surface forms a major stratigraphic boundary in the region (Stoker, 1999).

On the Faroese side of the channel (Anderson et al., 2000) there is a much larger wedge up to 700 m thick, again with a well-defined glacial unconformity. Most work on this margin has been of a commercial nature, and largely confined to seismic interpretation; there is no direct evidence for the age of the wedge or of the nature of the sediments forming it. However, this wedge is a particularly useful model for study as it must contain sediments derived only from the Faroe block (other than iceberg- related debris), and can therefore be used to study the un-roofing history of the islands.

Rockall Trough

The Rockall Trough includes a number of prograding wedges or trough mouth fans (Stoker, in press), although with the exception of the Barra/Donegal Fan (Holmes, 1998), these are significantly smaller than those farther north. This may reflect the more-southerly latitude and perhaps less-intense history of glaciation; it is certainly an important aspect of this region that it includes the southern limit of ice advancement to the shelfbreak, although this point has yet to be defined. Although the wedges derived from the UK and Ireland have been known for some time, only recently has a wedge been identified prograding eastwards from the Rockall Plateau (Stoker, in press). Another aspect is that current work tentatively suggests that wedge development may have begun earlier, during the early Pliocene, in this southern area.

Drilling objectives

A number of transects across selected wedges would be proposed, with each hole penetrating the base of the wedge. This would entail drilling in water depths ranging from 150 to 1800 m, with targets at a sub-seabed depth from 100 m to over 1800m. Additionally, deeper-water sites could be proposed in the ocean basins to recover the products of slides or palaeoslides and the intervening oceanic record of sedimentation. It is envisaged that the primary studies to be carried out on the recovered cores would include the following:

- Identification of the lithological makeup of the wedges and of changes with time; relate to source areas and their history, and to climatic changes.
- Detailed sedimentological studies of the cores.
- Dating of the sediments by all possible means in order to accurately define the history of sedimentation and relate this to source area erosion, un-roofing and uplift history.
- Identification of gas hydrates or diagenetic fronts within the successions.
- Geotechnical studies related to instability, including the detailed analysis of possible weak layers.

From these studies and ongoing work on STRATAGEM and other projects, it will be possible to more-accurately answer a series of very significant scientific questions that are additionally of considerable importance to the oil industry and others who require knowledge of the ocean margin. The following ideas will be refined by discussion with interested groups such as the UK CRUST project that is investigating Neogene uplift, other OMARC projects, and STRATAGEM's industry supporters:

- The reasons for a change in the pattern of margin sedimentation in the late Neogene, and when precisely did it happen? Were there latitudinal variations in timing? How do these relate to other prograding wedges worldwide?
- Was this pattern related to uplift (e.g. Japsen and Chalmers, 2000), and if so can we contribute to an understanding of the cause of the uplift that appears to be a feature of North Atlantic significance?
- The detailed history of glaciation on the margins, the timing of the first shelf-wide glaciations and the frequency and intensity of subsequent events and the latitudinal variations. Relate these to studies of the source areas.
- The historical pattern of major instability on the margin; can this be related to climatic, tectonic or oceanographic events in an attempt to better predict future slides?
- Contribute to detailed studies of the sedimentology and internal architecture of clastic prograding wedges.
- Gain an improved knowledge of the geotechnical characteristics of the margin sediments in order to improve future operational safety.
- Assess the extent of gas hydrates in sediments in relation to theoretical models.
- From the sedimentological studies allied to seismic interpretation, examine the temporal and spatial relationships between alongslope, downslope and vertical flux in the development of a margin.

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Gas Hydrates and Slope Stability

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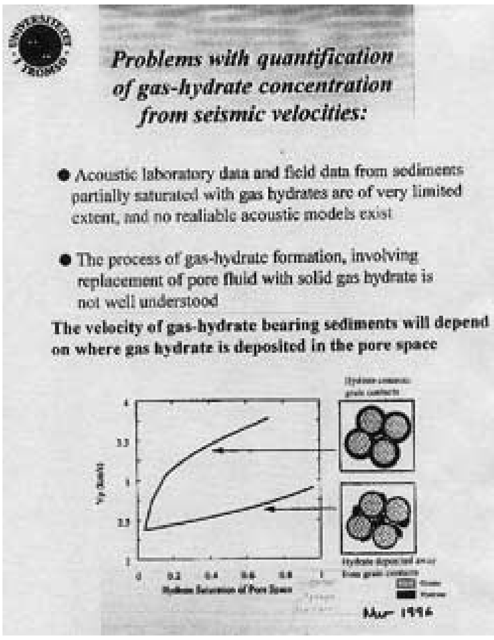
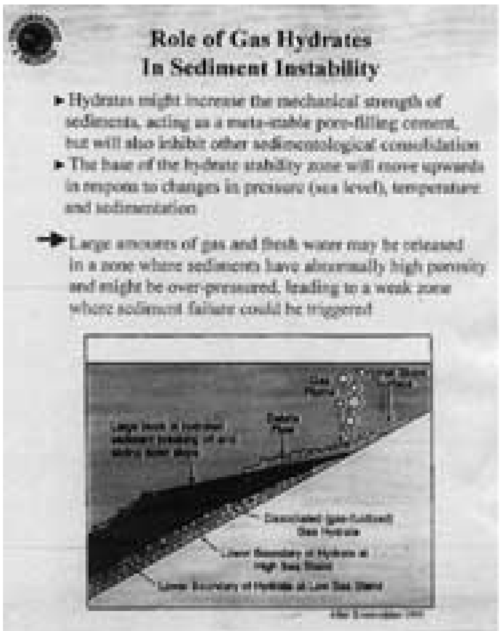
Another industry-academia joint project within the EU OMARC cluster is an elegant and novel project dealing with the acoustic response and mechanical signature of gas hydrates and their effects on slope stability along the Norwegian Shelf edge. Modelling has also been carried out. The project is called COSTA (Continental Slope Stability Project) and involves twenty-seven oil companies in Europe working with academia.

When we talk about ice we automatically think about the Arctic and Greenland ice cover. However gas hydrates are ice-like crystals; they cement the sea floor sediments and increase the stability of slopes, but if they melt, then large amounts of gas are released, and instability of marginal slope sediments is increased.





Figures depicting the properties of gas hydrate with regard to acoustics and stability of sediments

Problems requiring solutions

- There are no reliable models relating velocity profile to hydrate content of sediments partially saturated with hydrate.
- Experimental data are needed to build reliable models.
- Ocean bottom cables record P and S waves. S waves look through the strata for hydrates.
- Drilling is needed to quantify velocity profiles.
- Borehole imaging and logging while drilling is needed to ensure that hydrates are detected.
- A slight mass movement from the margin to the deep sea can create a tsunami.
- Tsunami triggered by Storegga event (-8000 BP) has been confirmed by onshore geological investigations in Northern Europe.

Alternative platforms will provide a solution to some of these problems.

Mounds I can See but not yet Core

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A number of EU-supported science activities, ranging from ENAM II, via CORSAIRES to OMARC have identified scientific targets for drilling. Four gas hydrate-linked themes were better understood following the CORSAIRES programme but to date there has been no drilling calibration although this was proposed in a pilot project.

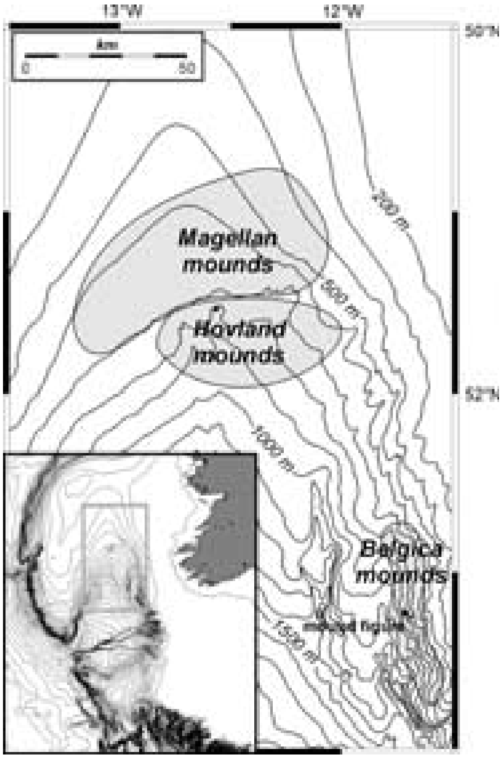

Fig.1: An overview map of Porcupine Basin with schematic outline of the Magellan, Hovland and Belgica Mound Provinces. The location of Figure 2 is also shown.

Identified targets from the themes are:

- Ireland's Great Barrier Reef: cold water corals and carbonates (CORSAIRES) proposed pilot study area.
- Mounds as a planetary phenomenon.
- Mounds as natural seabed observatories: training through research (CORSAIRES/ IFREMER Workshop Report).
- Mound physiology: Porcupine Bank, Celtic Sea English Channel, Methane steps.

Figures 1 and 2 illustrate the geographical location and geophysical signature of some of these mounds.

With regard to carbonate mounds, coral reefs etc. there are similar events in the geological record and carbonate build-up in Earth history are well documented on land. Stromatolites provided the Earth with all of its oxygen at one stage.

Industry has supplied additional data and the information is being integrated to provide excellent science.

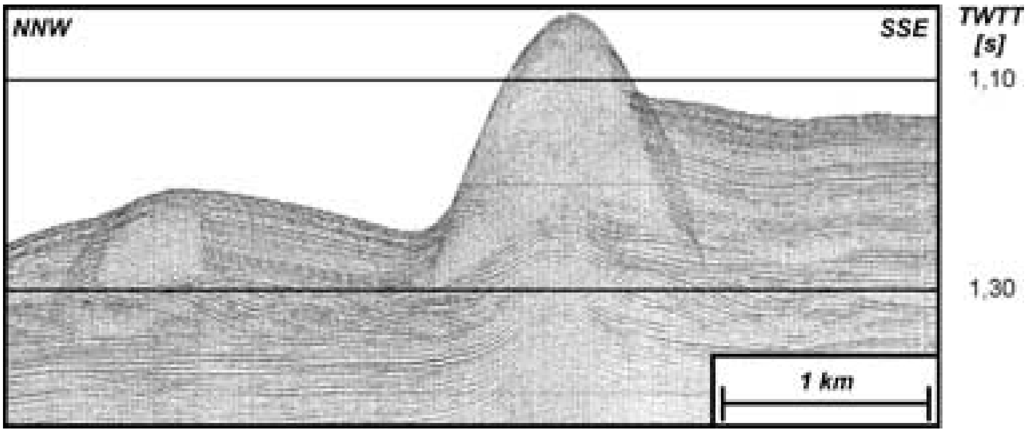

Fig.2: Very high resolution profile through the "Challenger mound" in the Belgica mound province shown in Figure 1.

IMAGES and IODP Beyond 2003

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Summary

Concern over the social and economic problems which may arise from global warming and the increase in greenhouse gases is growing across most countries. One potential output of global warming that is of major significance is global rapid/abrupt climatic changes (cooling, warming, succession of major droughts or floods) analogous to those experienced on Earth during the last few hundred thousand years. The international programme IMAGES (International Marine Global Change Study), a key action of the IGBP-PAGES-SCOR, offers a strategy to improve our knowledge regarding the causes and consequences of rapid climatic change on the basis of detailed analyses of high resolution paleoclimatic records obtained from ocean sediments.

The instrumental record (the last fifty to hundred years) is much too short to take in account the natural variability of the climatic system (which changes over decades to millenia, if we include the dynamics of the ocean and ice sheets). In the more distant past (the last few hundred thousand years), the study of the different connections between climatic forcing factors and responses (insolation, greenhouse gases, continental albedo and ice coverage, ocean and atmosphere dynamics) will help to better understand the interactions between the main components of the Earth's climate. Those studies are essential to develop and validate accurate climate models. The large amount of proxies that may be measured in ocean sediments forms a unique source of information about past climates if measured at sufficient spatial and temporal resolution.

Background

The IMAGES programme has realised over the last five years a major effort to retrieve 30-60 m long cores, with more than 400 cores already collected from the major ocean basins. Among those, about a third presents sufficiently high sedimentation rates (20 cm/kyr or more) to allow paleoclimatic studies with a temporal resolution of 100 years, decades, or better. Such a target constitutes a minimum requirement for understanding the role of the ocean in the chain of events driving climatic changes. Decadal to annual resolution records are also necessary to link paleoclimatic records to the more recent instrumental period, directly affected by the increase in greenhouse gases.

Following its initial success, the IMAGES scientific effort now must be consolidated and strongly expanded. The new effort should involve both the multiplication of cruises for collecting giant cores and drilling shallow holes (100-300 m) and the targeting of sites with particularly high sedimentation rates (in the order of 1 m/kyr). At present, the French research vessel *Marion Dufresne* is the only oceanographic ship fully operational for cruises capable of multiple giant coring operations producing continuous, large-diameter (11.5 cm) sediment sections (typically 1-2 per day, 50-150 per cruise; mean length 35-45 m). With small technical developments, maximum core length could be expanded from about 60 m to 100 m, with a mean length around 50 m. The other main drilling facility, represented by the ODP with its experience with the *JOIDES Resolution*, has proved perfectly adapted to mount and initiate paleoceanographic programmes based on short drillings.

The IMAGES scientific committee strongly supports the IODP concept of a multiple-platform drilling programme that would include the capability to take long, large diameter cores in a cost effective manner, using platforms such as *RV Marion Dufresne*. We offer the assistance and expertise of the IMAGES community in helping to define the specific scientific objectives as well as the strategies and tools needed to meet these objectives. We hope that the Integrated Ocean Drilling Program will evolve beyond 2003 to become a true multiplatform programme that can efficiently address the scientific objectives of the IMAGES community.

For the transition period 2003-2006, we therefore propose that a special effort be conducted at the European level to charter giant coring cruises on the *Marion Dufresne* (2-3 months/year, cost about 3-5 million euros a year) as a contribution of the European community to the IODP. We ask ESCOD to recognise the unique opportunity offered by IMAGES for identifying a specific EU contribution within the new global framework of the IODP.

Drilling and Coring Mediterranean Deltaic Margins: the needs of the Eurostrataform Programme

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Introduction

The Adriatic and the Gulf of Lion have been selected for a joint Europe-North American research on strata formation on continental margins. These areas represent deltaic margins where recent (<400 ka) sedimentary processes are particularly well preserved. "Nested" seismic investigations (from ultra-high resolution to conventional multi-channel operations) demonstrate that in both areas glacio-eustatic cycles (probably corresponding to 100 ka cycles) have distinct expression, and that important facies changes (of unknown origin) occur within each single sequence. Along the shelf edge (in the Gulf of Lion) and on modern prodeltas (in the Adriatic) recent slope failures are important processes that also require long coring and *in situ* measurements. On the shelf, prograding sandy clinoforms represent a particularly challenging target, both in terms of understanding sedimentary processes at their origin and for the capability of recovering good cores from such material, as demonstrated by problems encountered during ODP leg 174A on the New Jersey margin (Mountain, this meeting). Similarly, deep-water massive sand sheets are poorly understood and sampled. Deglacial sediments represent another important component of the stratigraphic record, with prodeltaic systems responding to rapid changes in sediment and water fluxes by shifts of depocenters. The three-dimensional aspect of stratigraphic modeling can better be addressed in such deltaic systems, and long cores would lead to the understanding of which processes in the drainage basin are at their origin.

In both the Gulf of Lion and the Adriatic, very few (if any) operations have been dedicated to the recovery of long sections of sediments and *in situ* measurement of their physical properties. This information is critical for ground-truthing of acoustic facies, chrono-stratigraphic framework for interpretation of depositional sequences and canyon incisions, determination of zones prone to failure and high-resolution analysis of climatic changes.

These projects are conducted within the OMARC cluster of projects, in cooperation with the Strataform Program funded by the US Office of Naval Research. Some targets are also relevant for very high resolution paleoceanographic and paleoclimatic investigations, in collaboration with the IMAGES community (sedimentation rates exceed 1m/ka in some of the proposed sites).

Requirements

Both areas require acquisition of long (50-300 m) cores of undisturbed sediments at water depths ranging from 50 to 2 500 m, in order to have access to:

- continous sections with fine-grained sediments allowing very high resolution chronostratigraphic and paleoceanographic reconstructions for "time-windows" including particular intervals (such as the last deglacial) or the entire last 400 ka,
- *in situ* measurements of physical properties especially in the perspective of understanding mechanisms of slope failure,
- cores within sandy material allowing facies characterisation, interpretation of primary sedimentary structures and modelling of acoustic wave propagation.

Considering the variety of measurements carried out on retrieved materials, another critical aspect is the dimension of coring devices. Ten cm must be considered as a minimum, 15 cm being a much more appropriate size for core diameters. Plastic liners are necessary in order to measure physical properties such as magnetic susceptibility. Together with cores, downhole logging (within unconsolidated material) would permit access to *in situ* physical properties and acoustic velocities necessary for prediction of slope failure, propagation of seismic waves, inverse seismic modelling, and lithologic characterisation of non-recovered intervals.

Obviously, one single drilling/coring platform is not sufficient for completing, with the best efficiency/cost ratio, these different objectives in contrasted environments (in terms of water depths and targeted depths). The integrated (from source to sink) understanding of sedimentary systems requires, in addition to onshore drilling in the deltaic/fluvial plains, the use of several platforms.

PROMESS (Profiles across Mediterranean Sedimentary Systems) is a package of projects for recovering continuous expanded sedimentary sections, together with *in situ* measurements of their physical properties. It includes three different platforms, each best suited for specific penetrations, type of sediments and water depths (ranging from 50 to 2500 m) (Fig. 1).

Giant piston coring (Calypso) with the *Marion Dufresne* is considered as best adapted to objectives within unconsolidated sediments where requested penetration is less than about 50 m. Shallow water unconsolidated muds of deglacial prodeltaic systems are typical objectives, as well as mixed sand/mud turbiditic channel-levee systems. On the continental shelf/ upper slope, consolidated Pleistocene muds or very sandy sediments are poorly recovered by piston coring, and vibrocorers have limited penetration of 5-10 m. The use of a geotechnical vessel is necessary for our targets where expected penetration ranges from 50 to 300 m (Fig. 2).

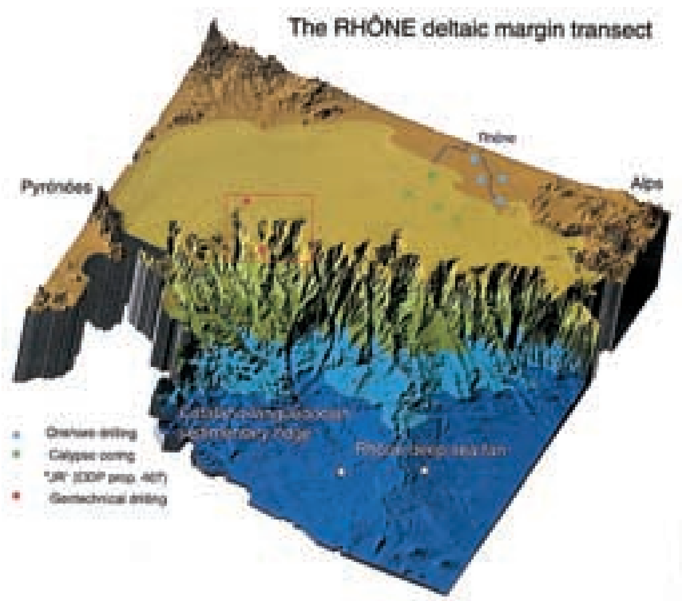

Fig. 1: Location of different coring/ drilling operations envisaged by the Eurostrataform programme for the study of the Rhone deltaic margin (NW Mediterranean). Similar targets are selected in Central Adriatic. onshore drilling has to be carried out within a different programme.

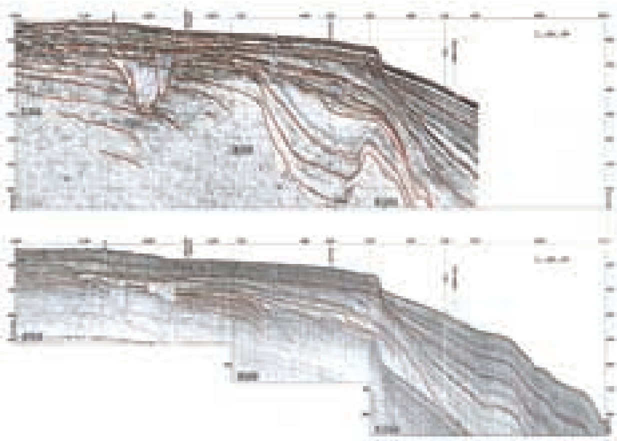

Fig. 2: Seismic profiles across the shelf edge in the Gulf of Lion. Each steep-clinoform unit corresponds to a sandy lowstand shoreface formed during glacial periods. Targets for drilling/coring with a geotechnical vessel are represented, as well as penetration obtained with the Calypso coring. In sandy clinoforms, penetration with vibrocorer or Calypso corer never exceeded 2.5 m.

On the continental rise, at depths about 2 000 m, long and continuous sections of hemipelagic/ turbiditic sediments (including mixed sand and silt) could be recovered with HPC/APC system of the *JOIDES Resolution* (or her replacement). However, massive sand sheets such as the debris flow covering the abyssal plain offshore of the Pyrenees requires another technology.

Finally, another challenge is our ability to organise such a relatively complex operation, which might be considered as a test in the perspective of the future IODP.

Summarised by Alister Skinner

Alister Skinner opened the discussion by emphasising the links in Europe between industry and academia as evidenced by the previous presentations. He believed they certainly showed what can be done to advance science with facilities which can access 3D seismic data.

Mikhail Gelfgat then discussed a number of coring options with which to meet the requirements presented in the preceding talks and some details of his company services are contained in Annex A (Aquatics Company Marine Surveys and Drilling Operations). He said that core barrels modified by BGS and by other companies are used to make up a marine drilling and coring system. These systems are similar to ODP's but adjusted for other platforms. ODP is certainly well known with its unique offshore sampling and drilling system for *JOIDES Resolution*. If this system were put on another platform it could fail because of the specific configuration of the system. The CCS system was prepared originally for a large Russian scientific ship but then it was modified to work in commercial situations and from geotechnical vessels. The idea behind this Complete Coring System is interchangeability without having to pull up the drillstring. A large diameter aluminium drillstring is also used to allow more flexibility in tool (and core) sizes. Also the aluminium pipe is lighter and one can therefore obtain a longer drillstring length from the same derrick compared to using steel.

The CCS system was designed for interchangeability of all downhole coring tools within the one outer core barrel assembly. This allows operation in formations from soft sediment to hard rock coring with variations in between. This avoids having to pullup the drillstring when changing from one type of coring to another as has to be done in some ODP operations.

Additionally, downhole motor systems can be used for extended coring in hard rocks and in assisting bare rock spud-in. Again the same outer core barrel system is used. Another important feature for coring is not only weight-on-bit but also the type of core head. Under some circumstances the drill and core bits can be interchanged downhole using the CCS system.

On a project-to-project basis with this interchangeability there is a far better opportunity to obtain good core in any formations encountered.

Alister Skinner emphasised that there is always a number of options and that Mikhail Gelfgat had given an example of one integrated system. But there are others available and as a client one can pick and choose between the systems; specifying what your requirements are. He also said that ODP is not unaware of the problem in unconsolidated materials; they are currently considering, with Fugro Houston, different tools that could be used within the existing ODP and their findings will be taken forward for IODP. Ongoing discussions and the May meeting of the next technical committee (TEDCOM) of ODP will be held at Fugro, Houston. **Gene Pollard** added that a lot had been made of coring in sands etc. and the lack of that capability on the *JOIDES Resolution*. He said that most coring operations were specific to a location or geology and therefore used purpose-built equipment. The *JOIDES Resolution* has deep ocean capacity and fast transit work but it is a compromise. For coring in unconsolidated material there are tools available as one cannot push into unconsolidated material with a piston corer or use a rotary where the action plus flushing will wash away the sand. For sand, slow rotation, good control of feed rate and water flush is important as well as weight-on-bit.

A base plate is required for a riser, usually casing and drilling mud which all add weight to a derrick system. The piggy-back systems essentially do this with drillpipe (shouldered connections) providing a strong, flexible riser, and a thin "mining rod" can be used inside this for the more delicate coring. This protection and centralisation is essential. The formation is also important. He explained that in the case of the New Jersey site there was fresh water from inland that was flowing under the ocean and flowing sands were present at depth in the borehole due to this.

Alister Skinner reminded the meeting about the HYACE tool development to collect *in situ* pressure cores that will aid the study of gas hydrates and the deep biosphere. He said it would assist Jurgen Mienert to obtain cores of the type he requires. This HYACE tool had recently undergone prototype trials on *JOIDES Resolution*.

Herman Zuidberg added that this development project for equipment is the first time that Fugro has been closely involved in a cooperative effort between science and industry. There is a need for a pressurised tool that can obtain samples at *in situ* pressures, bring them to surface and study them under the collected conditions prior to opening. The project was triggered by the lack of this facility on the Blake Ridge site on *JOIDES Resolution*. The system had to be designed to fit a coring system that would fit any ODP bottom assemblies. The sediment to be recovered is variable – gas hydrates can be found in hard core, which requires rotary coring, but are also disseminated in more sandy/gravelly materials where a percussive form of coring is more appropriate. Requests for sampling systems in sand and gravels are, he strongly believed, best addressed by considering a pressure-type tool which can be hammered at the bottom of the hole without moving the drillstring, in other words there is no flushing movement of drillstring. This is a more straightforward way and can be used to power a variety of core collectors.

Claus Chur confirmed that systems are available both from drilling suppliers and manufacturers, they offer various systems but simply having or buying the equipment is not sufficient. He emphasised that one needed the backup, resources and philosophy of the operator. A dynamic approach is to use not just one tool, but to use as many as you can in the same category. It is relatively cheap equipment, such as bottom hole core barrels, drill bits etc. compared with vessel costs which, if operated correctly, was going to make or break a project. He stressed that one should ensure that the equipment is operated correctly and logistically, but in drilling terms make sure one has as many arrows in your quiver as possible.

Greg Mountain stressed that we need to have a reality check; we must not "throw out the baby with the bath water". The *JOIDES Resolution* is, at times, the fit-to-mission platform for our purposes. A non-riser ship by definition has a lot of flexibility and the *JOIDES Resolution* has advantages that cannot be duplicated on other platforms.

Philipe Pezard made a comment relating to the difficulties in sampling sand and clay and the direct relationship between the (increasing content of) clay and the capacity to sample the sequence. He suggested that with the advances in scientific understanding of mechanical and thermal properties in relation to overpressure studies that perhaps industry could tap into these developments and we could utilise the knowledge to gain an understanding of what is happening when the coring is taking place.

He also asked whether there was a small diameter version of aluminium pipe, which could be used as a conductor guide for running a logging tool. The aim would be to have a method of re-logging boreholes by re-entering them with a logging string long after the drillship has left, and perhaps on a routine basis. This may have to be in water depths of 4 km. **Mikhail Gelfgat** responded that there were aluminium drillstrings available in a variety of sizes and strengths. **Herman Zuidberg** said that they would not be best for drilling but if it was understood this would be purely for allowing monitoring in an already drilled borehole then in principle the answer is "yes".

Chapter 5

Requirements for High Resolution, Hard Rock and Sub-sampling Coring

Alternate Platforms for Seafloor Hydrothermal Systems and Massive Sulfide Deposits

Thomas Kuhn and Peter M. Herzig,
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More than 200 sites of polymetallic massive sulfides have been found on the modern seafloor in diverse volcanic and tectonic settings at water depths from about 3 700 m to less than 1 000 m. These deposits are located at fast, intermediate, and slow spreading mid-ocean ridges, on axial and off-axis volcanoes and seamounts, in sedimented rifts adjacent to continental margins and in subduction-related arc and back-arc environments (Fig.1).

Fig. 1: Distribution of the seafloor hydrothermal systems in the world oceans. Sites which have been drilled by ODP are indicated.

High-temperature hydrothermal activity and large accumulations of polymetallic sulfides, however, are restricted to about 35 different locations to date. Out of the larger sites, only four have been drilled by ODP so far (Fig. 1): Middle Valley (sediment-covered; Juan de Fuca Ridge, Legs 139 and 169, including Escanaba Trough), TAG (sediment-free; Mid-Atlantic Ridge, Leg 158), and Pacmanus (sediment-free; Manus Back-Arc, Leg 193). The results of those legs had major impacts on the understanding of the third dimension of seafloor hydrothermal systems. For instance, the TAG mound was found to consist to a major extent of anhydrite (Fig. 2; Petersen et al., 2000), a mineral which does not occur in terrestrial volcanic-hosted

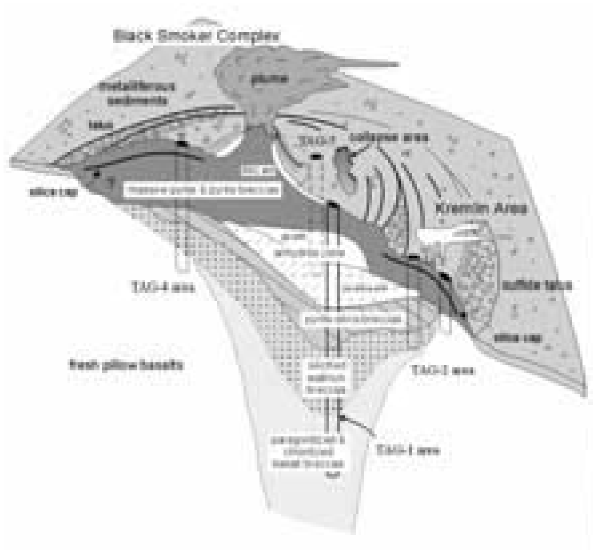

Fig. 2: Simplified cross section through the TAG mound showing the location of different lithological zones as inferred from ODP Leg 158 (from Petersen et al., 2000). One important drilling result was that the TAG mound consists to a major extent of anhydrite, a mineral that does not occur in ancient volcanic-hosted massive sulfides on land.

massive sulfide deposits that represent the ancient analogs to the modern seafloor deposits (Herzig and Hannington, 1995). The retrograde solubility of anhydrite causes dissolution if the temperature drops below 150°C which in turn leads to the instability of sulfide structures. This results in the formation of collapsed breccias which, in some cases, have been misinterpreted as tectonic breccias in some ancient massive sulfide deposits.

An important outcome of drilling at Bent Hill, Middle Valley (Juan de Fuca Ridge) was the unexpected detection of a zone of massive copper mineralization below the sulfide stockwork (Fig. 3; Zierenberg et al., 1998). The occurence of such a “deep copper zone” has important implications for land-based exploration programmes since drilling is normally not conducted beyond the stockwork zone.

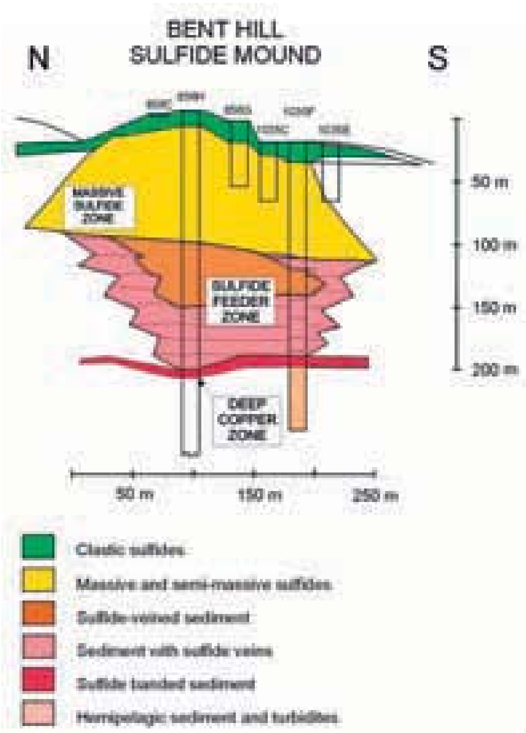

Fig. 3: Simplified cross section through the Bent Hill Sulfide Mound at Middle Valley (Juan de Fuca Ridge) as inferred from ODP Legs 139 and 169 (from Zierenberg et al., 1998). One unexpected drilling result was the discovery of the "deep copper zone".

A third result of drilling at seafloor hydrothermal systems is the evaluation of their size, composition, and possible economic significance which has been done reasonably only at four sites so far (e.g., Herzig and Hannington, 1995 and references therein):

- Middle Valley (Juan de Fuca Ridge): 8-10 mt (ODP Leg 169)
- TAG (Mid-Atlantic Ridge): 4 mt (ODP Leg 158)
- 13°N Seamount (East Pacific Rise): 5-10 mt (visual estimation)
- Atlantis II Deep (Red Sea): 94 mt based on sediment coring by Preussag AG

The results from the three ODP legs mentioned have already indicated how significant research on seafloor hydrothermal systems can benefit from drilling. Since there is a large number of seafloor hydrothermal systems in the world's ocean which have been studied only in terms of a 2D approach, major scientific progress can be achieved only with 3D information obtained by both shallow and deep drilling. The main scientific objectives to be addressed with regard to seafloor hydrothermal systems are:

- to study their size, structure, and chemical/ mineralogical composition (e.g., alteration haloes, mineralised zones, stockwork zone)
- to assess their resource potential
- to establish the tectonic versus compositional control of textures and structures
- to determine the depth and dimension of the reaction zone
- to estimate the magmatic input into the seawater circulation system
- to search for a deep biosphere
- to estimate the vertical and lateral chemical fluxes

Recently, a new type of seafloor hydrothermal systems with a style of alteration and mineralisation that indicates a similarity to subduction-related subaerial epithermal systems and gold deposits rather than to conventional black smoker-type seawater circulation systems has been discovered (Herzig et al., 1999). Conical Seamount located in the New Ireland Fore-Arc of Papua New Guinea is an example of this type which to date totally lacks 3D data.

To reach the above-mentioned scientific objectives, several technical options exist. One is certainly the use of a *JOIDES RESOLUTION*-type successor drill ship. To sample and investigate the reaction zones of hydrothermal systems, deep drill holes of about 1-2 km (maybe more) in deep water are necessary. This will only be possible with a riser-equipped vessel. However, some of the scientific goals can also be addressed by smaller technical systems. For instance, containerised drilling systems (CDS) as provided by Seacore Ltd. or Geo Drilling Ltd. may be an alternative. Such systems are able to drill holes of some hundred metres into hard rocks using diamond core barrel drilling and riser technology. Containerised systems provide better control on the weight-on-bit and a more sophisticated diamond core barrel drilling system that would result in a much better recovery rate than ODP technology has achieved during drilling hydrothermal systems. Therefore, it is important that the providers of such alternate platforms prove their success in drilling heavily fractured hard rocks as they are found in hydrothermal systems. A further advantage of CDS is their mobility and their deployment from ships-of-opportunity making them more flexible and more speedily available for the scientific community than a *JOIDES Resolution*-type successor vessel.

Another option is the use of lander-type robotic drills such as the BGS Rockdrill and the Japanese BMS. Even with a drilling/coring capability of only 20 m into hard rocks at the seafloor, these drills have the advantage that they (i) have been tested successfully; (ii) can be rented on a day to day basis; (iii) can be used even from medium-sized research vessels; (iv) are very cost effective; and (v) are readily available. Since there are currently only two such systems available (BGS and BMS), the US marine scientific community concerned with petrological, geochemical, and biological objectives is planning to build such lander-type robotic drills. In November 2000, a conference was held at the ODP headquarters in College Station, Texas. At this meeting, it was generally agreed to obtain four new robotic drills on the basis of already existing technology The results of this conference will be published on the ODP homepage.

Results of the Workshop on Requirements for Robotic Underwater Drills in US Marine Geological Research (3-4 November 2000, College Station, Texas)

The idea that there is a strong need for robotic underwater drills for marine geological research was met with general approval from the partici-pants.

ROV- Drill:

- mounted on a ROV
- drilling horizontal (non-oriented) cores up to 1 m in length
- development on the basis of the existing MBARI drills

Mini Drill Lander:

- drilling of 1 m oriented cores (up to three cores at one site) in water depths of up to 8 000 m
- equipped with a slow-scan video
- development on the basis of BGS Oriented Drill

Compact Drill Lander:

- drilling of 3-5 m oriented cores in water depth up to 6 500 m
- equipped with high quality video
- easily shipped
- can be deployed from medium-large vessels
- development on the basis of BGS Rockdrill

Robotic Ocean BOttom Drill (ROBO Drill):

- penetration greater than 30 m
- water depth greater than 4 500 m
- transportable in a standard shipping container
- development on the basis of BMS and PROD

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The Science Need for Long Igneous Sections

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There is a need for a simple but effective sampling of fresh basalt. This research is an essential part of the InterRidge Program.

In order to research the nature of the seafloor surface (fault, deformation, style) and the petrography of exposed rocks (architecture of the lower crust) a systematic dense and oriented sampling regime is required.

But the seafloor surfaces are very smooth and do not offer steep slopes that can be dredged. The seafloor surfaces are sediment-covered and also any dredging does not provide oriented samples.

Further difficulties arise from the temporal variations at mid-ocean ridges; in slow spreading ridges the variation of segmentation pattern with time reflects variations in magma production and/or delivery. Also the hotspot influence on ridges is not steady state but varies with time.

Requirement

- systematic dense sampling
- systematic oriented sampling
- off-axis sampling of well-positioned fresh basalt/glasses

Why drill ?

Existing (non-drilling) methods are difficult or unreliable. Off-axis dredging requires steep slopes, and seabed surface rocks are weathered and the seafloor is frequently sedimented and often indurated with magnesium.

Ideally, 50-100 m long cores are required, oriented and representing good recovery. A simple method of operation is desirable even for deep water.

Potential technical problems

- The Upper Crust is commonly highly fractured and vugs are abundant.
- Mantle peridotites are serpentinised
- There is unconsolidated sediment cover

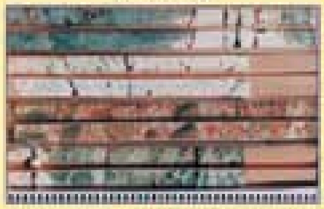
The BGS Seabed Drills are shown on the next two pages to illustrate the seabed drill concept.

Seabed Rockdrill and Vibrocorer

Seabed sampling off King George Island ANTARCTICA

The combined 5m ROCKDRILL & VIBROCORER, developed in the early 1980's, and upgraded in 1994 and 2000 is designed to obtain up to 5m of rock cores with a diameter of 50mm, in water depths ranging to 2000m. The drill utilises an electro-hydraulic power pack to convert 3 phase electrical energy, transmitted from the surface, into hydraulic energy. This hydraulic energy is used to drive the drill kelly, which rotates the corebarrel and the retraction winch which controls bit weight and pulls the drill barrel out of the seabed. Two electric water pumps are incorporated to flush the drill bit. A subsea computer controls the hydraulic and electrical functions whilst monitoring a variety of sensors. Data from these sensors and control functions are sent to the surface and displayed on a monitor at the operator's console. Provision is also made for Seabed Camera operations.

ROCKDRILL CORE
Rock core collected in the Indian Ocean



Sensor data includes:

Oil Pressure
Oil Flow
Oil Temperature
Inclination in two planes
3-Phase Voltage supply
Water Flow
Speed of rotation
Height of Rig above seabed
Penetration into Seabed

ROCKDRILL Base Configuration

ROCKDRILL Specifications

Weight overall - 4.00 tonnes
Drilling speed - variable up to 500 rpm
Core barrel - Hex outer, non-rotating inner
Core Length - Up to 5m
Core diameter - 50mm
Core Bits - Surface set diamond - various styles
Impregnated diamond - various styles
Tungsten Carbide
Retraction - Base-mounted winch with 12 Tonne withdrawal force
Power requirements - 30 kVA, 415 VAC, 3phase, 50 Hz

Shipboard console - Microprocessor linked to drill
Coring control via keyboard
Monitoring of functions, monitoring and recording of sensor data
Winch - 2500m Hoist/power/signal umbilical, single drum Winch
power pack - 3 tonnes; requires 415 VAC, 3 phase 120A power supply
Working water depth - designed for use to 2000m

Umbilical Termination at head of Rig

The incorporation of a vibrating unit in the system allows the ROCKDRILL to be configured as a VIBROCORER by replacing the rotary core barrel with a vibrocorer barrel. The VIBROCORER configuration is used when the seabed is composed of soft sediments, and uses the vibrating unit to penetrate into the seabed. This penetration can also be monitored and recorded.

VIBROCORER Specifications

Overall weights, power requirements and control/display parameters of the combined version are as for the rockdrill. Other frame configurations, different control and operating system are also available with core barrel lengths from 1.5m to 6m.

Umbilical and deployment Winch

Vibration force - 50 Hz 3 phase twin Vibrator motor housed in a pressure Vessel
Core barrel - 6m length, 102mm O.D.
Retraction system - base-mounted winch with 12 tonnes pull-out capacity
Deployment range - 0 to 2000 m water depth with separate umbilicals available for shallow water.

British Geological Survey

Deep Ocean Oriented Hard Rock Drill

This Deep Ocean drill was developed for use on the British Mid-Ocean Ridge Experiment, funded by the NERC BRIDGE Programme. Rock cores to a length of just over 1 metre have been obtained from water depths of 800 metres. Orientation is achieved by scribing the core along its length with a single reference line and then using the two drill mounted compasses to assign a heading to this reference mark. This marking can subsequently be related to a world reference, thereby allowing detailed paleomagnetic analysis to be carried out.

Whilst in use the drill is monitored by a subsea computer which sends data from the suite of sensors on the drill to a computer on the surface for display. The same subsea computer receives commands from the surface computer enabling sampling to be monitored and controlled in real time. There is a monochrome stills camera on the drill which is used to transmit seabed pictures to the surface. This allows the site to be selected or rejected prior to drilling and provides a visual record of the site for archiving purposes.

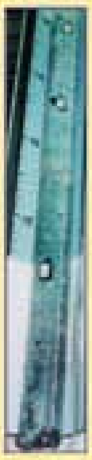
The drill has no dedicated cable, it is designed to be deployed using the 'standard' 17.5mm diameter coaxial CTD cable which may be found on many of the world's research vessels. It will also operate from other cable types.

Limitations imposed by the use of a coaxial cable, dictate the use of limited single phase power, onto which all data communications have to be transmitted. Through the use of modern compact motor controllers, the drives for rotation, retraction and water flushing are driven directly from 3-phase AC motors, providing a high degree of control and efficiency.

The onboard and subsea computers control all the functions and monitor sensors.

These include:

Rotation (Rpm)
Penetration into the seabed
Rig Orientation - two compasses at different heights
Water Depth
Drill Flush - Water Flow
Sea Water Temperature
Subsea Computer Temperature
Motor Controllers Temperature
Subsea AC Voltage
Subsea AC Motor Currents
Two Axis Inclination (Tilt/Roll)



Specification:

Core Length -	0.8m (max) rock cores
Core Diameter -	35mm
Weight in air -	1 tonne
Height -	2.40m
Umbilical -	Armoured coaxial power and hoist
Drilling speed -	Up to 600rpm
Power -	3kVA. Typically 240VAC, 13A, 50Hz
Orientation -	Orientate core to a world reference
Shipboard control -	Desktop Personal Computer Giving status and control of all subsea functions
Depth capability -	Designed for depths to 4500m
Seabed Camera -	Stores High Resolution photos. Transmits a degraded photo to surface for site decisions

British Geological Survey

Sverrir Thorhallsen, National Energy Authority, Iceland

The Reykjanes Ridge in Iceland is an onshore analogue to the offshore mid-Atlantic Spreading Ridge. At the invitation of the Chair, Sverrir Thorhallsen gave a short presentation on hard rock drilling in Iceland. In particular the geothermal area of the Reykjanes Ridge, with reference to a proposed Iceland Deep Drilling Project. A proposed deep borehole in basalt will enter a supercritical steam phase while drilling. This will in turn involve drilling into different physical properties in the rocks and will help in research on heat transfer from magmatic heat sources, transitions from brittle to ductile behaviour and deep permeable convection. The set of overhead slides presented are printed here.

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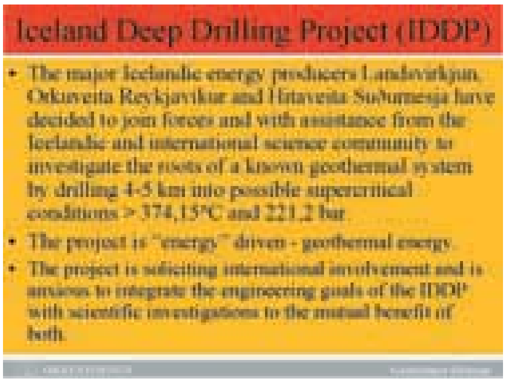

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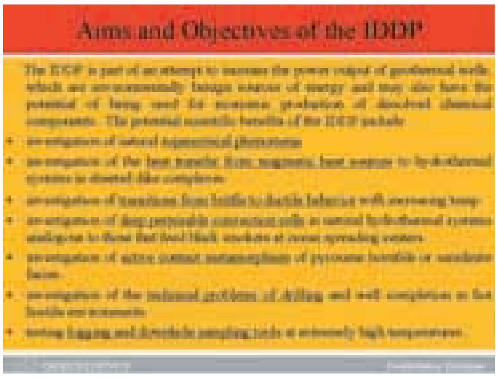

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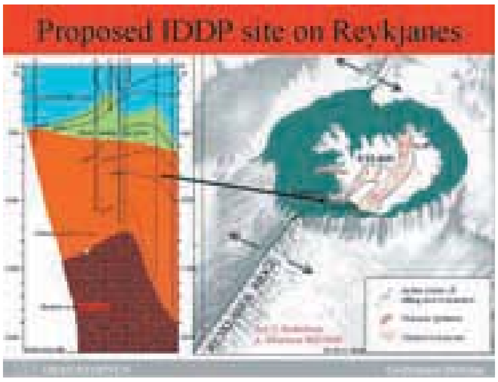

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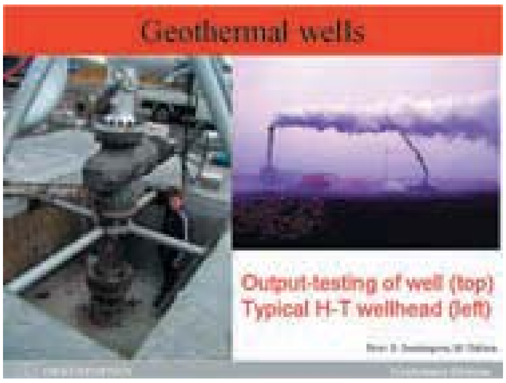

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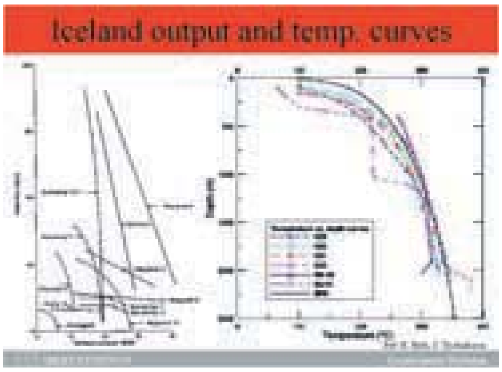

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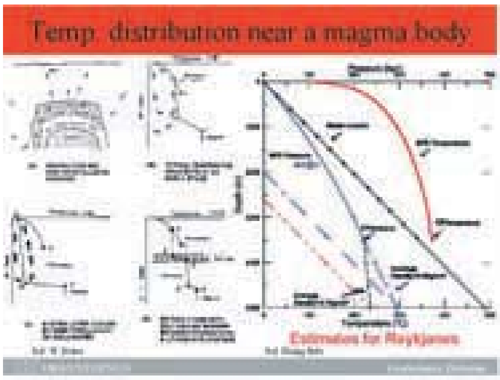

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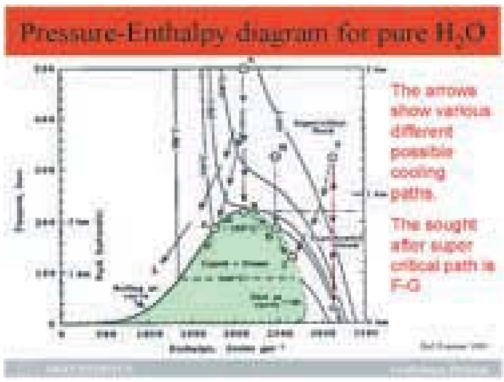

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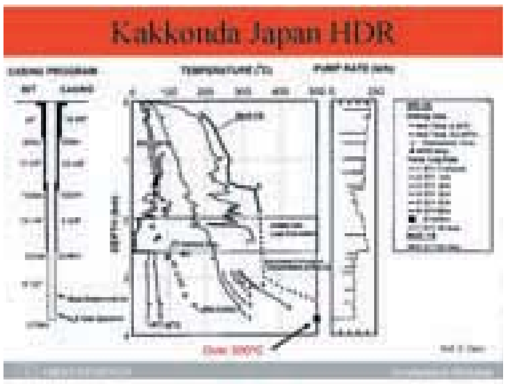

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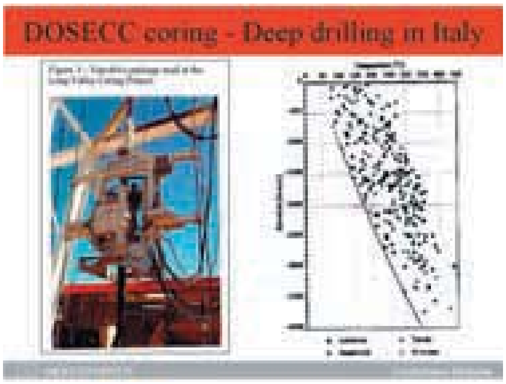

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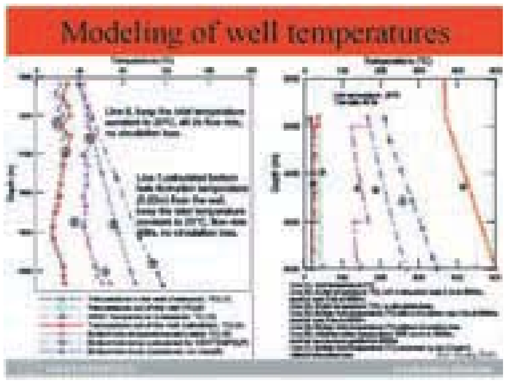

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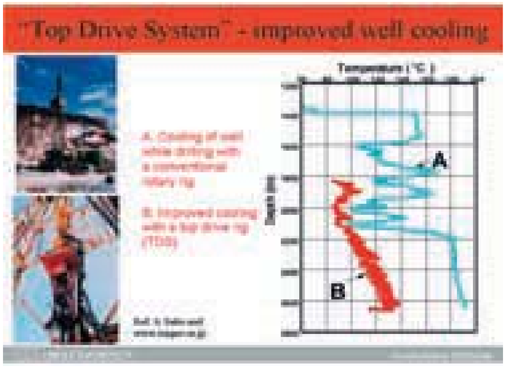

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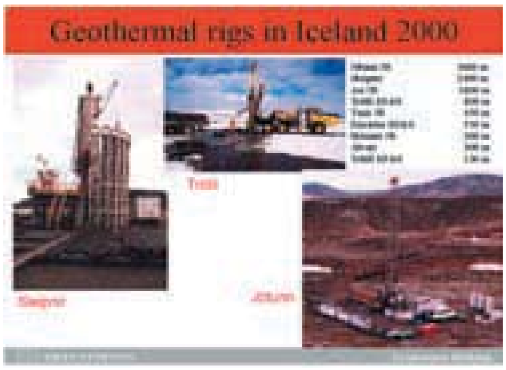


Slide 16

Discussion

Summarised by Alister Skinner

Herman Zuidberg questioned the strategy of seabed drill developments. He felt that the presentations by Catherine Mevel and Peter Hertzig promoted the idea of using remotely operated drill rigs sitting on the seabed for deep penetration of the strata. A lot of money had been pumped into the production of underwater drilling rigs and he felt that they had not yet achieved their goal. He said it was necessary to analyse the problem and find a possible solution as a vessel with a lot of support facilities would be necessary to operate this type of remote drill. He said there was no financial case yet available to support the building of such a seabed drilling rig. The only way to justify having this rig built and tested is if one can demonstrate an operating availability of 100 days use per year for the next 10-20 years. The cost per programme would be higher than renting the *JOIDES Resolution*. He believed that just because the rigs were small it did not necessary mean that they were cheaper.

Alister Skinner agreed with the statement on usage and said that the BGS remote drill experience shows it to be limited to operations from dynamically positioned ships and in less than 2 000 m water depth. He said that if a system such as PROD is going to be used – projected for 100 m below seabed – then all the station-keeping capabilities of the drill ship are required. There are also serious cable technology and handling problems to be overcome for remote drill use in very deep water. But the shallow-reach drills do work within limits in certain circumstances and they are much quicker and cheaper than mobilising a drill ship. However, he agreed with Herman Zuidberg, in that one has to use even these shallow reach drills before any further development is viable. He said that the possibility of building four types of drills would not reduce the cost of development but it would further reduce the usage of any of them.

Catherine Mevel reiterated that there is a need for deep cored holes of the type drilled from the *JOIDES Resolution* which can be instrumented, logged etc. but that there is also a requirement for shallow holes in order to get samples and a 3D/areal extent.

Herman Kudrass said that with remote drilling it is not possible to log the holes or carry out downhole experiments but **Alister Skinner** replied that under certain circumstances it was possible to log remote boreholes and conduct limited downhole experiments, although the applications were limited.

Peter Hertzig reminded the participants of another important point, i.e. the easier site access offered by these remote drills. To get a drill ship the size of the *JOIDES Resolution* to a certain site takes a very long time. It took ten years to drill three hydrothermal sites under the existing ODP system. With the BGS drill which is operational and which can be used, for example, on the German ship *Sonne*, a programme can be quickly developed and, if approved, a lot of information can be gained rapidly from the top 5 m of selected sites. He said that he agreed with Catherine Mevel that the necessary combination was deep holes and also shallow holes, and the advantage of the seafloor drills was availability and cheaper day rates. He thought that several types of investigations including drilling from the same vessel would be possible.

Mikhail Gelfgat said that comparison should be made with science in the ocean and science being considered for other planets, because space scientists are also considering using remotely operated drills. He explained that there was a serious project to have a robotic drilling system to drill on Mars within five or six years but it was very complicated and expensive. Realistically, shallow robotic drilling on the seafloor means 5-6 m penetration. Russia has an example of a 20 m drill prepared for the Moon but then switched to the seafloor. There is also a model for a 10 m drill but it is a multi-rod system. He had no information on drills for 50 m or more. An alternate platform such as a ship of *JOIDES Resolution* size is not an alternative platform but a leg of IODP. He felt that we could do more than 50% of the Herzig hydrothermal sites with a geotechnical ship. **Peter Herzig** responded that it might be so but it was cheaper to use a remote seabed system and drill shallower but at much lower cost. He advocated the use of a portable seafloor drill, for example the Japanese BMS drill, which is in existence and has drilled to10 m from a research vessel. In some cases he would like to go deeper than 10 m, maybe to 50 m, but in many areas he has information only on 2%. Many petrological questions can be answered by drilling 10 m with a system that can go on a ship-of-opportunity.

Catherine Mevel re-emphasised the need for scientific samples from these hard rock areas and asked what other way they could be obtained if not by drilling. Dredging gives questionable samples from the seafloor only, and samples taken with a submersible are limited and the submersible should be on a seafloor with no sediment cover. So, whatever the length these drills can provide would be welcome; a depth of 5-10 m is good, 50 m would be better. **Alister Skinner** advised that ODP are trying to address the hard rock spud-in problem and there are a number of developments to do that. He said that in many cases ODP will be able to get good rock core, with the advanced diamond core barrel. While he did not like selling the BGS product at meetings such as this he said that there were lots of problems with using mobile seabed rock drills and the BGS drill is successful because it does not go beyond 2 000 m and thus avoids some of the cable technology problems. He admitted that the maintenance cost was high and the drill cannot do everything but it did achieve results. **Gene Pollard** advised participants that the Mars drilling project had also been discussed with ODP engineers. He said that remote drills posed a huge technical problem and there was a time delay with regard to Mars before one could intervene. Unless there were unlimited resources it should not be attempted and it is not practical to go very deep. The *JOIDES Resolution* takes a long time to recover hard rock core from the seabed situation, especially one with a bare rock spud-in. If the surface is rubble or is fractured then it becomes even more difficult and fragments frequently wedge in the core barrel. Developments within ODP with regard to fluid hammers and the advanced diamond core barrel may help improve this situation. To get good samples from hard rock you have to use a diamond bit and a narrow kerf width. This allows better hole stability. The smaller the hole drilled in hard rock the more stable it is. Diamond coring is used for all these reasons, but it is slow. **Dominique Weiss** wished to point out that there are large igneous provinces at less than 2 000 m water depth where localised drilling techniques would be very useful.

Alister Skinner mentioned that BGS were looking into battery technology at the moment but explained that their rock drill required 30 amps current and could be drilling for two to three hours on one site and one cannot get a battery to do that yet. Control and sensor information is also needed. He thought that to transfer this from cable to acoustic technology would be expensive.

All of this is complicated financially by the fact that science funding to support the upgrading or fine-tuning of technology is very difficult to obtain. While there is development money for innovative technology there is little or none available to actually make something work.

Terry Quinn said that he would like to follow up on that point. He thought that if the choice was between the present technology of drilling on a ship such as the *JOIDES Resolution* and obtaining 10% recovery in certain formations or using a shallow drilling system in the same formation and obtaining 80% recovery then the selection, and support for it, should be obvious.

John Ludden reminded participants that a lot of people in the petrological community had concentrated on researching submarine hard rock ridges and that if the science community has some technology that could assist them then clearly it has to be considered.

He also drew attention to the fact that the meeting had not discussed Judith McKenzie's contribution and her list of technological challenges as yet without solutions. He thought this may be because the current meeting had lots of coring specialists but possibly not enough expertise in taking samples for biogeochemical and microbiological research. This should be kept in mind, he said; if the experts are not here today we must ensure that we have them at the meeting in Lisbon.

Chapter 6

Research Cooperation Between Industry and Science

Cooperative Research and Required Timescales

Harry Doust,
Shell
International
Exploration &
Production,
Rijswijk,
Netherlands.

Introduction

This is a perspective from the viewpoint of large international oil companies; the items we are interested in on the scientific and technology front and what kind of research would be of interest to the hydrocarbon industry. These ideas have been built up over the last year; some scientists have already been in discussion with our industry partners but this is largely my own perspective built together with my research colleagues in Shell and addressing the kind of questions they would like answered.

How can we help each other?

ODP results have been of great benefit to the oil and gas industry over the last three decades. Industry is ready to work with ODP and IODP to define programmes of mutual interest for the future. With regard to deep-water exploration I believe that there are a number of questions that could be answered by ODP-type drilling but there are also shallow-water analogues. Also industry has great expertise, technologies and project management skills, which they would be prepared to share with science to allow achievement of mutual goals.

With reference to the European Initiative JEODI and its goals, industry can play a part and some cooperative science is suggested. The main scientific objectives of JEODI coincide with many of those in industry. Industry is very interested in developing models for hydrocarbon charge and reservoir characterisation in deep water in the North Atlantic, the Western Approaches and the Mediterranean. They are also interested in hydrates as energy resources, general geohazards with respect to hydrates and other factors (shelf collapse etc.).

These priorities for industry – models for hydrocarbon charge and distribution in deep water situations – relate to investigations in passive margins. Specific targets would be turbidite facies and architecture and also sequence stratigraphical models over pressure mechanisms, and carbon cycle. Is source material being deposited in deep water? If so, how and where? These are technical questions with a strong scientific aspect of their own.

A proposal

What we would like to propose therefore is that European industry collaborates with JEODI in the definition of a research project to study the controls and evolution of turbidite channel deposits in slope settings. This is a high priority target in industry. At present large hydrocarbon discoveries are being made in various parts of the world in channel settings on the slope and in fans in the deeper parts of the slope or on the ocean floor.

How do we characterise the architecture of these channels on the slope? What is their lithofacies? And how can we predict what we are going to find when we drill into these? What is the seismic character of these features? Also we would like some feeling for the hydraulic behaviour of these sand bodies in deep water. Because exploring in deep water is expensive, it is crucial to have good permeability. Therefore we would like to get a much better feeling for this in a variety of settings. There is as much variety in deep-water sand facies environments as there is in shallow-water facies and environments. Only now is the industry beginning to understand the different environments and facies of deep water sand distribution and there is a major research interest here not only for scientific interest but also for technological methods.

A method and rationale to research

Such cooperation would mean dedicating one IODP leg to near seafloor meandering turbidite channel complex issues to obtain some data on shallow analogue situations. Detailed information already exists, including a large amount of 3D data sets close to the seabed. Although industry has all of this high frequency detailed seismic information it does not have detailed well information to tell us what the composition of these bodies are?

Industry would therefore be interested in shallow coring, relatively cheap shallow coring, in order to obtain this high detail of lithological information. It needs more information to construct models. Sand deposited in mini basins may become crucial objectives but there is not much analogue information at present and the areal extent of a reservoir has a major economic impact on the commercial viabilty of the field in various situations.

At the base of the slope there are narrow channels some of which are clay filled. Going into the abyssal plain, out from the base of the slope, fat channel fan complexes and a potential for stratigraphic traps exist. What we miss is a large amount of detailed well data, so shallow core data which can be built up into 3D models would be of great help. There are analogues of turbidite reservoirs and seismic geometries with potential for stratigraphic trapping in submarine fans (e.g. Indus Fan) which industry would like to investigate further in water depths of 1 500-2 000 m.

Further topics

Other aspects of research where there are mutual research objectives include:

- Hazard identification: slope stability and time frame of slumping events
- Feasibility of gas hydrates as an energy resource
- A need to develop technologies to sample adequately
- Follow developments in Japan
- Complement other initiatives (largely geophysical, reservoir engineering)
- Hydrology of sea floor processes
- Carbon cycle/source rocks
- Models for distribution of potential oil/gas source rocks in deep water
- Better understanding of
  - Sediment distribution, quality, type, thickness
  - Arctic and high latitude zones
  - Maturation in source rocks

The hydrocarbon industry is also interested in understanding the transition from continental to ocean crust and its impact on hydrocarbons. As we drill into deeper water, there will come a time when people will ask the question: When does the prospectivity stop? In what water depths?

The types of riser drillships we use are capable of drilling in water depths of about 3 km, beyond that we are looking at well control on a non-riser system. How does the source material get into such deep waters? We know very little about this.

On the technology side there is the riser versus riser-less (well head on the seabed) ongoing research. Logging and well drilling is important to the hydrocarbon industry and shallow analogues will provide models. The hydrocarbon industry needs access to a platform that can drill a number of (cheap) small diameter boreholes (with minimum logging requirement) to investigate shallow analogue objectives in deep water. There is also a question of how to guarantee sample quality in riserless systems in depths of up to 2 000 m of water.

Instrumenting the Subsurface from Logging to Monitoring

Jean Pierre Delhomme,
Schlumberger Riboud Product Centre, Clamart, France

Some industry technology has been made available to the scientific community through cooperative endeavour. Other cooperative efforts have been made between science and industry to meet challenges of mutual interest and it is this model in which we are interested.

In ODP this started with traditional wireline logging as a complement to coring, and discussion between my company (Schlumberger) and ODP has provided an opportunity to use the slim hole tool and develop it.

ODP is interested in logging and monitoring, on a continuum – this deals with *in situ* measurements.

Logging measurements (traditional wireline logging measurements) and acquiring physical parameters downhole has always been perceived as a complement to coring. My view is that in some circumstances economic reality could lead to the cancellation of coring, and one could base decisions on logging alone. It is possible to do this for some scientific goals as well.

With the advent of borehole imaging a new dimension was added. Something in addition to a set of "wiggling curves" (logging data) could be seen. Development of the imaging tool involved discussion between Schlumberger and other scientific bodies and this led to a successful development of the imaging tool, based on mutual industry and scientific needs.

Sometimes spending a lot of energy on coring may not be the best approach. Other industry developments can be used, for example Logging While Drilling (LWD). Logging While Drilling technology was developed to reduce rig time. It is also useful for science, especially in areas or situations of borehole instability.

Another common area of interest is in monitoring.

Industry requires reservoir monitoring in addition to the borehole knowledge. Emplaced observation tools monitor the parameters of the entire reservoir and they can be left in place for months or years.

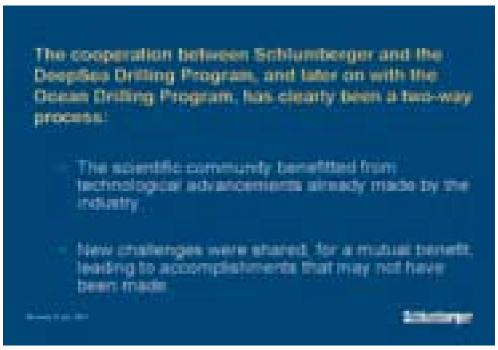
There are two monitoring approaches.

- Passive monitoring – listening to the Earth
- Active monitoring – using the subsurface ground as the lab.

In this case the downhole laboratory is instrumented and experiments made, e.g. inject air or water to produce a thermal event, then record the response.

The overhead presentation to accompany this talk is presented below.

Slide 1



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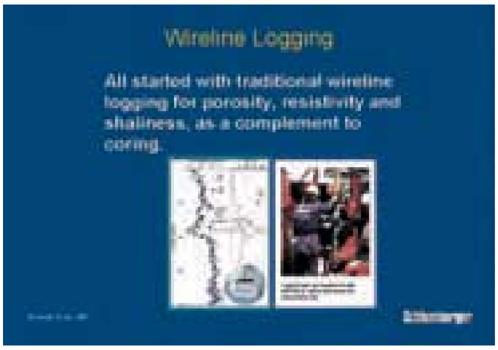

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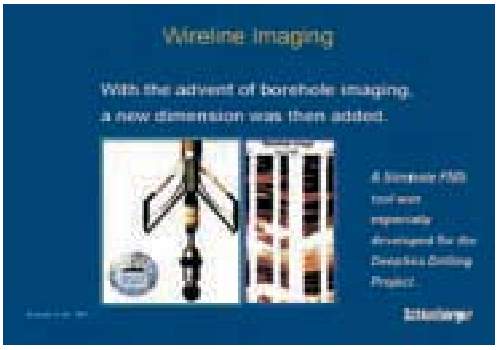

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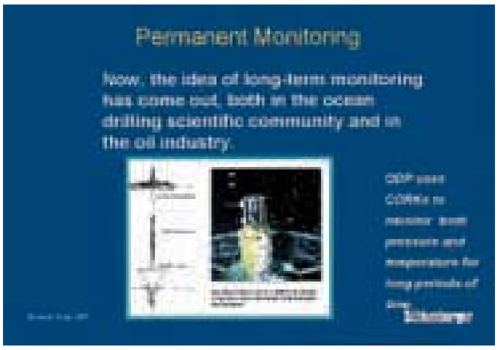

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Slide 8

Slide 9

Discussion

Summarised by Alister Skinner

Dave Roberts outlined his interest in the Ocean Drilling Program since DSDP days. However his recent work in deep-sea exploration leads him to believe that there was a lack of focus in the room with respect to fit-for-purpose technology that would help in achieving science objectives. He said that there were fundamental questions that needed to be asked for any project:

- Why is it important?
- What is necessary?
- When is it needed?
- What is the cost?

He was particularly struck by Gregory Mountain's eloquent presentation on New Jersey Margin Drilling with which he basically agreed. However, he believed that one could turn round at the end of the day and ask "if we fit *JOIDES Resolution* with anchoring and riser systems can we do it as well?" He thought there were a number of basic issues that needed to be challenged and that the same questionsh and issues applied to the Arctic.

He said that Industry sits on large chunks of data acquired over many years; it discards most 2D data, which is shot before 1990 and sits on large 3D seismic sets. For example it is routine in industry to shoot 10-20 000 km^2 of 3D and the academic community will never get within a million miles of this target! At the end of the day, the top one second of those data sets could be made available to the academic community and thus save time and effort in locating the optimum kinds of drill sites needed to develop the programme. In addition, other sets of technology are out there and could be made available, for example visualisation software for interpreting turbidite channel deposits and indeed a general knowledge of interpretation techniques for these new data packages. Another factor that is going to be crucial in this programme is the issue of database management as there are large data sets involved and academic systems may be inadequate for managing this.

He said that his organisation (BP Research and Engineering) dealt with many of these problems all the time. Establishing a dialogue at an early stage with people in the oil industry and also in the contracting industry would be of help in formulating the proposals and the way forward in delivering those proposals.

He therefore urged everyone to talk to industry about issues of project management. Precise logistical coordination is needed with multiple drilling platforms. Dialogue with people who establish project plans and negotiate contracts will be crucial in designing a workable programme with so many competing scientific priorities.

Harry Doust commented that if one is using vessels-of-opportunity, and thinking about multiple vessel operations – maybe a drilling ship and a couple of icebreakers together – planning for this sounded daunting. He thought that making use of vessels only when they are serendipitously available would require the most highly developed project management skills around.

Jan Backman agreed and stated that professional project management is required and there must be project management consultants that can be hired for this. **Harry Doust** replied that industry had learned that, sadly, project management skills are rare.

Greg Mountain remarked that industry could make a major contribution if a mechanism could be found to make these 3D seismic data sets available to the scientific community.

Jurgen Mienert spoke on academia-industry cooperation and spoke on behalf of some colleagues who were also in the room. He said that his department (University of Tromsø) had established a close link with industry concerning deep-water exploration on the Northern European Margin. This link is based on the exchange of information that the scientific community has from the deep-water margin sites, enhanced by 3D seismic data from industry to academia, so they have been working jointly with industry for some years, exchanging information and technology. The department has established training programmes for students in 3D seismics using industry software; 3D seismics is much more expensive than drilling holes and the information obtained from 3D seismic is far better than that from drilling. He emphasised that 3D seismics in a future IODP or in Europe cannot be just a side product; it is an essential for geology in the future. **Dave Roberts** stated that the typical cost of a 10 km x 10 km 3D seismic survey would be US$5 000, so collaboration with industry is vital. There are many targets that involve deep structures in passive margins that will require 3D seismic surveys. **Jean Pierre Henriet** confirmed that it is quite easy for advanced research groups to get access to the top portion of industry data sets. However, the first half-seconds of data cannot be calibrated unless you have core in the first few hundreds of metres, which industry does not have. But there are geotechnical boreholes available to calibrate this section and this is a good reason why science and industry should continue to work and cooperate.

Dave Roberts agreed and stated that the reason industry does not core in the first hundred metres of borehole is because it has to set the casing and the riser.

Shiri Srivastava said that an outcome of the Houston meeting with industry was that a group had been formed to plan two transects (on Scotian Margin and Grand Banks). Companies are prepared to make seismic data available to ODP. There is also company backing for addressing drilling targets also of interest to industry as very few groups have core-to-ground-truth 3D seismic data.

Jeroen Kenter thought that there should be a mechanism to achieve mutual goals. It was apparent that cooperation was happening individually between scientists and industry representatives to the benefit of various projects. He defended ODP's excellent record of project management but agreed that science can learn from, and cooperate with, industry.

Alister Skinner was delighted with the discussion and reminded everyone that one reason for this meeting was to try and do cost effective science. He questioned whether putting additions on a ship that is questionably fit-for-purpose in shallow water would be a way forward. One of the ways of getting high quality core is to keep the weight on the bit but at the same time to keep the weight off the drillstring, one should avoid using something that is capable of taking a 5-8 000 m drillstring when the objective is to drill only1-2 000 m in 1-200 m water depths. He said that by cutting that whole weight down it is possible to increase the sensitivity of the system and automatically increase core recovery.

Dave Roberts responded that he was simply pointing out that one needed to be flexible and imaginative in using existing resources.

Ted Moore responded to Alister Skinner's request for information on the Conceptual Design Committee which was set up to assess what the optimal capability of the *JOIDES Resolution* replacement should be.

The Conceptual Design Committee was set up because the National Science Foundation (NSF) charged the US Science Support to make a report on the conceptual design of a riserless drilling vessel. That report has been out for comment for eleven months. These comments have been compiled and catalogued and that compilation has now been forwarded to the NSF. These concept notes, plus comments on the report will be used by the National Science Foundation in constructing a request for proposals to be sent to industry to produce a ship. The responses they receive will determine the capability of the ship.

Philipe Pezard concurred with Alister Skinner on cost efficiency. He thought that cost efficiency was not just a sum of money but that figure divided by what you get back in science. He said that ODP had done something great; they had invented “alternate logging” with the appropriate use of Logging While Drilling (LWD) in compressional settings such as accretionary prisms. For many years, standard wireline logging had been used, and less than 50 m of data was recorded in more than ten years of effort. More than 500 m of data were obtained in a few days as soon as the correct tools (i.e. LWD), although expensive on a daily basis, were used. This advocates the use of alternate methods in IODP, whether concerning coring or logging operations.

He said that a lot of time and money was spent trying to record data but he had no doubt that the future lay with multiple platforms, and the science community should not just try to modify and extrapolate what was already in existence. One of the strong points that the long-range plan emphasises is the issue of studying processes, and to progress from a programme largely of exploration (domains, oceans) to a programme defining and understanding processes.

For this, the notion of monitoring is a key issue and, for this, access to cutting-edge technology in domains involving either logging or permanent sensors is important for IODP. He thought this provided a clear example of where industry and science can cooperate in a fruitful manner.

Herman Zuidberg returned to some of the remarks made earlier, discussing methods of coring, other platform types, difficulties of collection of sands etc. He said it seemed as though people had not been talking to each other. There are fundamental choices to be made when a vessel is being built and in the technology of how the drilling is done. To get industry and science talking together one should avoid talking about what has been done, and who is better than whom; there are lessons to be learnt from the past. There is need for a geotechnology focus, and open discussion on what can be done in a cooperative forum. One thing needed is to cooperate on the design of drilling and coring systems. An open mind and a good dialogue with industry and science is required.

Axel Sperber agreed and stated that fit-for-purpose means fit for a *specific* purpose or project. Normally the first stage should be to make available a database with key data and all available technical equipment, cross check the particular needs for each project and have screening. **Jeroen Kenter** re-iterated that this is why an inventory is needed.

Frank Bassinot said that in industry, projects are developed in a short time frame. Academia plans years in advance so therefore one should be able to predict what will be available in the future. **Mikhail Gelfgat** agreed and reminded us that industry; particularly offshore industry, is developing fast. IODP is preparing scientific drilling proposals for work two to three years hence, maybe ten and so science should be able to predict what technology would be around then.

Sergio Persologia said that his organisation (Osservatorio Geofisico Sperimentale di Trieste) frequently has the same goals of interest as oil companies and they have always been able to get data and technology from them. He thought that since there is such long-term planning in scientific programmes there should be no problem in determining whether industry has any interest. The flexibility should not be restricted by the platform. He believed that it was more important to create and disseminate information about technology and available data. After that it should work programme by programme. **Franz Neiberding** suggested that science should approach any company that has worked in the area to see if they will allow use of data.

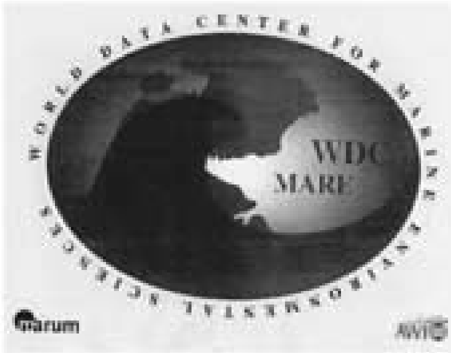
Gilles Ollier returned to the inventory comments. He was convinced that if a new scientific drilling programme is to be designed then the scientific community needed to identify what is available in the market and to keep this updated. He wanted to know the current status of this idea.

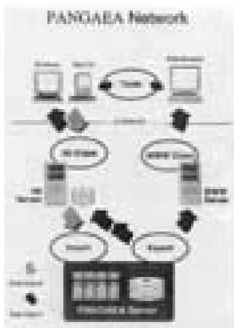
Philipe Pezard said that from the logging point of view, most of what Europe has to offer in the domain of logging equipment was being described at this meeting. There was a lot of authority here at this meeting about logging from alternate platforms. **Terry Quinn** reminded participants that the Shallow Water Workshop Report has tables of inventory that can give various parameters.

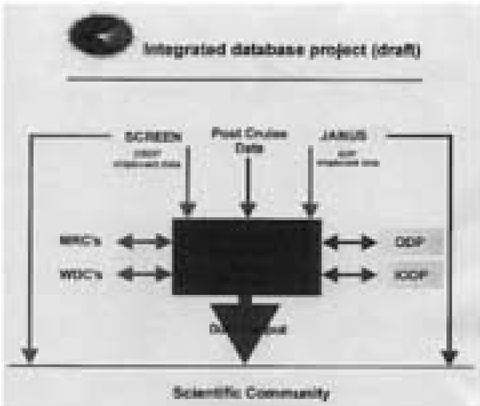
Helmut Beiersdorf said that science should be clear about what it wanted in the new programme. Multiple platforms means using multiple and alternative platforms; what is needed now are proposals that require alternate platforms; and after that, information from industry about what is available and the cost; and this type of information will be needed on an ongoing basis.

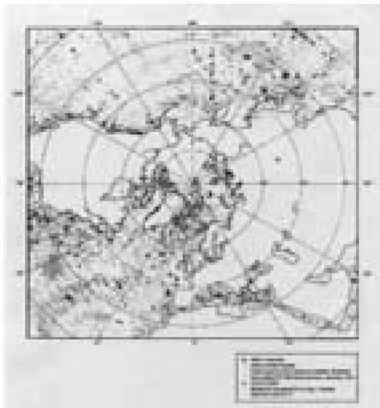
Dave Roberts concluded by stating that we need a paradigm shift in our thinking of how science can be done. For example he knows of a ship that is dynamically positioned, can drill in 1 000 m of water and has a riser which is on the ship.

Gerold Wefer wished to point out to the meeting that the scientific community is addressing the issue of data sets and archiving. There is now a World Data Centre for Marine Environmental Science (Pangea). The web at *www.pangea.de* should be consulted.









Closing Remarks

Summarised by Alister Skinner

Claus Chur presented his summary of the last two days with five points:

"**1.** All projects presented yesterday and today are technically feasible. This does not mean that it is not a challenge to do them. The execution may not be limited by tool availability but by funding. I really would emphasis that point. There may be a wrong impression/expectation that alternate platforms would be significantly cheaper than projects that require a drill ship.

2. Industry in interested in participating but clear requirements of timing and planning are important. It is likely that technical and financial resources over the next two years will be tight so proper planning is essential.

3. Drilling and coring equipment, including logging tools, required for project execution is already available and can be supplied by the respective service industries.

4. Select a scientific programme by screening against the availability of existing tools, and probably put in the ranking those projects that cannot be carried out by existing technology.

5. Recommend at the end that you decide for an ODP-type programme that ensures a one-year minimum and preferably longer contract as this would ensure quality samples and cost effectiveness."

Alister Skinner thought that he should make clear that all of ODP and IODP drilling is science driven and that this will continue. Proposals therefore have to be highly ranked scientifically before they can be considered as part of a drilling programme. Also, as in the case of the Arctic, a top-ranked science proposal may at present be shelved as being too expensive or not technically feasible – essentially because the present vessel cannot do it. Judith McKenzie has demonstrated that the initial science plan and all of the methodology towards selecting projects is within the context of this science plan. This is not going to change even if we consider alternate platforms.

A report of the current meeting will be prepared before the Lisbon meeting so that people can prepare themselves. Alister Skinner stressed that the overall scientific goals that to be addressed at the Lisbon meeting would be related to the initial science plan.

Shiri Srivastava commented that he had learned a lot over the past two days. Before he came he thought that there were not enough scientific problems to keep alternate platforms occupied for the next ten years. Now he knows that there are enough problems and also platforms and techniques to solve them but he saw a big task ahead regarding funding to participate fully in the programme. He wondered where the present situation left Canada. Should it plan to make an application for membership of a two-ship or a three leg IODP? This needs an answer soon, as no application for funding or funding continuation can be made until this is known.

Helmut Beiersdorf said that we still require more dialogue in one area where we may not have enough technical capability; i.e. in acquiring *in situ* samples at ambient temperatures and pressures for biological studies under natural conditions.

Jeroen Kenter summed up as follows: "This meeting has started a dialogue, which it is important to keep open, and will lead to joint efforts to tackle the projects described today.

We hope industry will supply us with information on technology resources so we can start an inventory/database. A report on this meeting will be available by mid April.

It is important to keep dialogue open with larger oil and gas companies. We need to collaborate with these companies to get access to data, and seek mutual scientific goals through projects.

It is important to review the procedures of the Science Advisory Structurer to identify mechanisms we could put in place to speed up the review process in order to accommodate industry's needs.

In my opinion there is nothing that has been conceived that is not possible to do".

Gilles Ollier thanked everyone for coming and for the many contributions to the meeting. His reading of this meeting, representing a funding agency, and an outsider, is that in addition to the two vessels being developed for IODP, namely the Japanese OD21 and the US vessel, he could also identify three main alternate platform requirements.

- An Arctic research vessel or platform.
- Development of the already existing alternative platforms e.g. the *Marion Dufresne* for shallow cores.
- Geotechnical vessels and equipment that can collect cores in sands and coarse sediments.

His concluding comment was that the science community should therefore work on a plan for integrating all these types of platforms into the one international programme.

Annex A

Some Industry Profiles

Annex A – Aquatics Marine Surveys and Drilling Operations

Why aluminium drillpipes of enlarged inner diameter?

The aluminium drillpipes (ADP – see table 1) were developed within the framework of the Russian continental scientific superdeep drilling programme. Large diameter drillpipes have enabled the implementation of downhole motor-driven coring systems.

Based on successful tests and application in superdeep hole drilling, the system has provided a basic means of performing the deep-ocean scientific drilling planned by the Russian Academy of Sciences for the drillship *Nauka.*

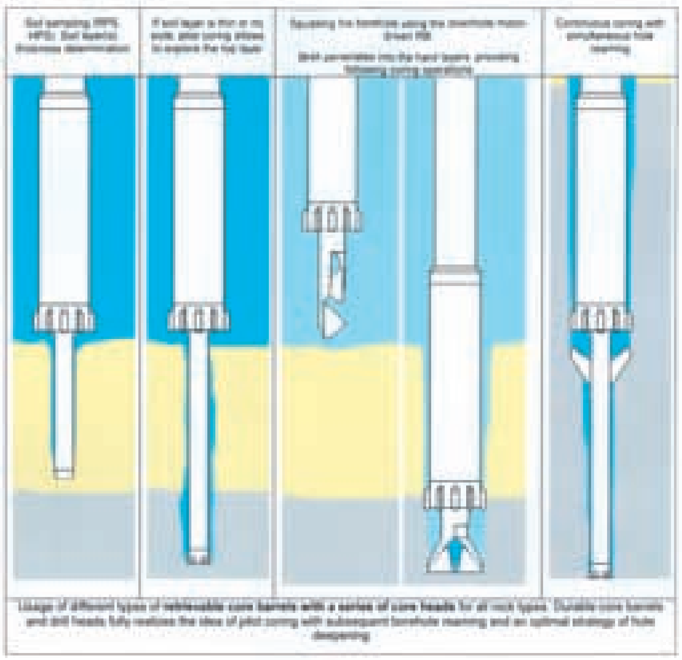
The Complete Coring System (CCS)

Prototype field trials were held in 1991 from the geotechnical drillship *Bavenit* at the sea mountains Josephine, Ampere and Gorringe in the Atlantic Ocean, which proved the predictions for this trend in deep-water scientific drilling. Since 1993 CCS (see Fig.1) has been used commercially by Aquatics in cooperation with Fugro Engineers BV.

Being an integral part of the CCS, the ADP of 164-168 mm OD, and of 146 mm ID, allows the use of 142 mm retrievable downhole motors (PDM and/or geared turbodrills) powerful enough to drive several corers and retractable drilling tools. Technical units (see Fig. 2), including durable core barrel/heads driven by high-speed downhole motors, allow high performance coring/drilling in hard formations.

Lightweight drillstring application greatly extends the ability of the relatively small and inexpensive geotechnical vessels. The ADP string allowed the realisation of multiple offshore drilling projects in deep water from 1993-2000 from a ship with a displacement of only ~5 000-6 000 tonnes (*Bavenit, Bucentaur, Norskald*). Drilling operations took place in areas of the Atlantic and Pacific Oceans at a water depth of up to 1 616 m. The maximum drillstring length of 1 981.5 m was achieved with a drill-rig lifting capacity of up to only 40 tonnes.

Fig. 1: Principal scientific drilling/coring CCS strategy.



The application of CCS drillpipes in geotechnical drilling with standard coring/testing tools designed for a 5-inch drillstring enchanced the operation performance. An enlarged clearance between wireline assemblies and the drillpipe greatly reduces hydraulic resistance and allows increased travel speed thereby saving time especially in deepwater operations.

Typically in scientific coring/drilling there is insufficient accurate information regarding geological conditions and the physical properties of formations. That is why the combined multifunctional integral coring systems are normally used for exploration and survey operations. As many different corers as possible are used as this flexibility adds to a research operation's strategy and tactics.

Table 1: The Basic Technical Characteristics of the Drillstrings

Description	Steel 5" ODP	AC aluminum (1953T1 alloy) ABT 131x13	CCS aluminum (1953T1 alloy) ABT 164x9
Pipe O.D., mm	127	131	164
Tooljoint OD, mm	177.8	178	195
Pipe I.D., mm	104.8	105	146
Tooljoint ID, mm	104.8	105	145
Weight per joint, kg	318	190	188
Joint length, m	9.66	9	9
String weight for 100m (in water), MT	2.88	1.45	1,43
Operating tension, MT	220	154	173
2000 m string weight, MT in water	65.8 28.5	57.6 41.8	42.2 28.6

An example of the successful jointing of technical units into one integral set of equipment is the Baikal-2 coring system (Fig. 3).

The Bailkal-2 coring system was developed by Aquatics at the request of Nedra GP (a State enterprise in Yaroslavl, Russia) for the Lake Baikal international deep-water drilling project. The system has been used with the standard 147 mm aluminium drillpipes with internal 105 mm upsets. The concept for the Baikal-2 system was based on ODP's and Aquatics' own experience in scientific deep-water coring operations. The system includes the universal outer core barrel with a core head and several changeable wireline corers/samplers. This system has been used successfully since 1998.

- Rapid Piston Sampler (RPS) – the modified and simplified APC version
- Hydropercussion Sampler (HS) – uses the hydraulic hammer (HH) for sample pipe driving

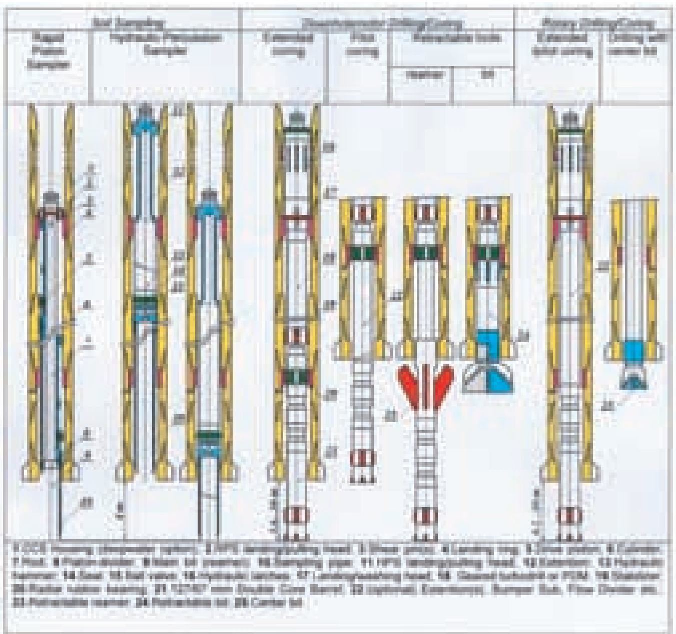


Fig. 2: CCS drilling/coring techniques basic set.

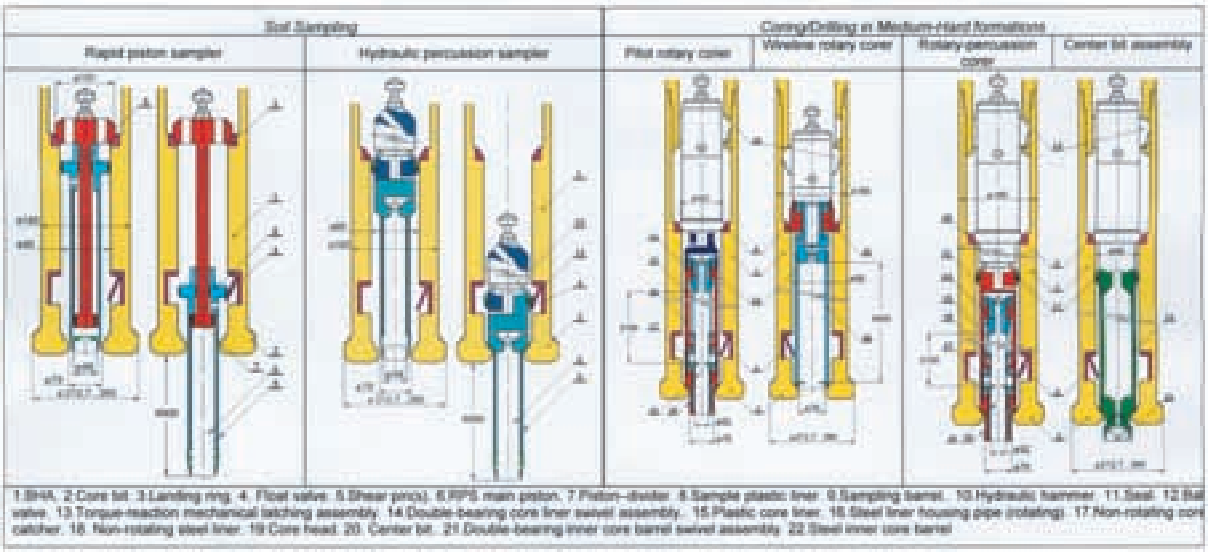


Fig. 3: "Baikal-2" coring system.

- Pilot Corer – simplified XCB operation
- Rotary Corer (RC)
- Rotary-Percussion Corer (RPC) – short PC uploaded by the HH
- Centre Bit assembly (CB) for full-face drilling.

The basic characteristic of the coring operation's efficiency is core recovery/quality. This depends on several factors, but one of the basics is the core durability. In consolidated rocks core durability is a function of D^2 (the core cross-section area). In fractured, fissured, weak formations the core durability increases in cubic progression with the core diameter. For this reason the core diameter increasingly guarantees better core recovery/quality under comparable conditions.

The main advantage of CCS drilling is clear when using the enlarged inner diameter for core-diameter enlarging.

The introduced alternate coring system (see the appendix) represents the Baikal-2 coring system adapted to the CCS drillstring.

Feasibility analysis demonstrates that this option would be the best from the point of view of core recovery/quality. Such a system could be newly developed or made up from a combination of parts available on the market: e.g. the core head, inner core barrel with core catchers, could be adapted from the 250P series core barrel; the hydraulic piston sampler assembly could be based on the CCS RPS design; bearing assemblies, latches, overshots etc. could come from any marine geotechnical system. The CCS's BHA allows the fitting of any additional existing corer from any other system. Increased core diameter promises time saved due to two- or even single-hole on-site coring strategy application. In our opinion, the proposed coring system of enlarged core diameter integrated with the aluminium CCS drillstring application as an alternate platform technique, could be the best solution.

Table 2: Marine Coring Systems – Technical Characteristics

Samplers										
	Long Stroke Push Samplers					**Hydraulic Percussion Samplers**				
	ODP APC	**CCS Rapid Piston Sampler**	**Baikal-2 Rapid Piston Sampler**	**Baikal-3 Rapid Piston Sampler**	**Fugro Rapid Piston Sampler**	**Fugro Small Hydraulic Percussion Sampler**	**Fugro Large Hydraulic Percussion Sampler**	**CCS Large Hydraulic Percussion Sampler**	**Baikal-2 Hydraulic Percussion Sampler**	**Baikal-3 Hydraulic Percussion Sampler**
Sample diameter	66 mm	93 mm	56 mm	~ 75 mm	58.2 mm	57 mm	96.8 mm	93 mm	56 mm	~ 75 mm
Length	9.84 m	4.0 m	6.0 m	~ 3m	3.0 m	1.8 m	3.7 m *3)	3.0 m	6.0 m	~ 3.0 m
Liner?	clear plastic	PVC liner	plastic	Yes	PVC liner	Yes	Yes	Yes	plastic	Yes
Length Tool	12.8 - 22.3 m	6.3 - 10.3 m	~ 7.5 to 13.5 m	~ 4 to 7 m	4.5 - 7.5 m	5.0 m	8.6 m	7.16 m	~ 8 m	~ 7.5 m
Driving Mech.	mud pressure	mud pressure	mud pressure	mud pressure	mud pressure	mud pressure percussion	mud pressure percussion	mud pressure percussion	mud pressure percussion	mud pressure percussion
Mud pressure (bar)	170	30/60/ 90/120	40/80/ 120	~40/80 /120	43/85 /126	45 bar	45 bar	40 - 60 bar	40 - 60 bar	40 - 60 bar
Max. Tool Diam.	95 mm	142 mm	101 mm	136 mm	92 mm	70 mm	129 mm	142 mm	95 mm	136 mm
BHA bit ID	96.5 mm	136 mm	79 mm	~ 95 mm	84 mm	> 78 mm	> 118 mm	136 mm	79 mm	~ 95 mm
BHA bit OD	257 - 290 mm	220 mm	213 mm	240 mm	244 mm	244 mm	244 mm	220 mm	213 mm	240 mm
J /Blow	n.a.	n.a.	n.a.	n.a.	n.a.	50	200	200	50	200
BHA	Comp. with XCB (ODP BHA)	CCS	Baikal-2	Baikal-3	Comp. with CCS, Fugro BHA	Comp. with CCS, XP Fugro BHA	Comp. with CCS, XP Fugro BHA	CCS	Baikal-2	Baikal-3

Core Barrels										
	Rotary Core Barrels				**Extended Core Barrels**					
	ODP Rotary Core Barrel	**Baikal-2 Rotary Corer**	**Christensen MWCB**	**Baikal-3 Rotary Corer**	**ODP XCB**	**Baikal-2 Pilot Rotary Corer**	**Baikal-2 Rotary Percussion Corer**	**Baikal-3 Rotary Pilot Corer**	**CCS (SKV-127/ 67) Double Core Barrel**	**Christensen MWECB**
Core diam.	58.7 mm	79 mm	76.0 mm	~ 95 mm	60 mm	52 mm 65 mm	52 mm 65 mm	~ 73 mm	67 mm	66.7 mm
Length	9.5 m	~ 6.6 m	~ 4.0 m	~ 3.5 m	9.5 m	~ 6.6 m	>3.1 m	~ 3 m	4.5 m	~ 4.0 m
Liner?	Yes	No	No	Yes	Yes	plastic	Plastic	Yes	No	Steel liner
Length Tool	11.6 m	~ 8 m	~ 5.0 m	~ 5 m	12.8 m	~ 8.5 m	~ 8.5 m	~ 5 m	5.6	~ 5.0 m
Driving Mech.	drill string rotary	drill string rotary	drill string rotary	drill string rotary	drill string rotary	drill string rotary	drill string rotary	drill string rotary	rotary downhole motor (DM)	drill string rotary
Mud Pressure	n.a.	5-10 bar	n.a.	5-10 bar	n.a.	5-10 bar	40- 60 bar	5-10 bar	5(rot.), 40-60(DM)	n.a.
Max. Tool Diam.	95 mm	101 mm	108 mm	136 mm	95.3 mm	101 mm	101 mm	136 mm	127 mm	108 mm
BHA Bit ID	62 mm	79 mm	76 mm	~ 95 mm	96.5 mm	79 mm	79 mm	~ 95 mm	136 mm	76 mm
BHA Bit OD	251 mm	240 mm	216 mm	240 mm	257 - 290 mm	213 mm	213 mm	240 mm	217- 240 mm	216 mm
Coring bit OD	n.a.	n.a.	n.a.	n.a.	~ 93 mm	76 mm	76 mm	~ 93 mm	133.3 mm	~72 mm
WOB	1-7 ton	<12 ton	1-5 ton	<12 ton	1-7 ton	0.5-1.5 ton	<1 ton	~ <1 ton	1-5 ton	1-5 ton
R.P.M.	50-70	<120	70-90	<90	30-70	<90	<90	<90	<400	70-90
J/Blow	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	50	n.a.	n.a.	n.a.
BHA	ODP BHA	Baikal-2	Christensen	Baikal-3	Comp. with ODP APC	Comp. with RPS and HPS	Comp. with RPS and HPS	Baikal-3	CCS	Christensen

An Alternate Coring System Concept

The proposed Baikal-3 coring system is the improved Aquatics Baikal-2 coring system used successfully in the International Lake Bailkal Drilling Project and includes the universal outer core barrel with a core head and several interchangeable wireline corers/samplers.

- Rapid Piston Sampler (RPS) – the simplified APC version
- Hydropercussion Sampler (HS) – used the hydraulic hammer (HH) for sample pipe driving
- Punch Corer (PC)
- Rotary Corer (RC)

The PRS (Fig. 1) runs into the drillstring and lands in the BHA. The sample pipe with the core catcher and plastic liner is fixed on by shear pins to the piston rod through the main body of the piston. The main piston closes the annular space between the outer core barrel and the piston rod. When the mud pumps are activated the pressure above the main piston rises to 40-120 bar, depending on estimated formation properties and the mud pump's ability, and cuts the pins. The sample pipe, forced by the energy of the compressed water, hits the bottom at a speed of up to 8 m per second and penetrates into the soil.

The RPS is intended for sampling in oozes and soft clays.

The HS (Fig. 2) includes the sampling pipe (the same as for RPS), and the hydraulic hammer with the honed rod and pulling-head on the top. The landing/piston head is displaced on the rod. The HS assembly runs down into the drillstring and falls directly on the hole bottom. The free-moving piston-head, being forced by the water flow, lands in the seat and closes the circular space between the BHA and the rod, and directs the flow into the HH which then activates. The sampling pipe penetrates into the soil under impact. After the full sample-pipe has been retracted, the HH is no longer affected by the hole bottom; it opens automatically and the mud pressure reduces and indicates the end of the stroke.

The proposed HS option does not generate a drillstring reaction force because the rod cross-section area is smaller than that of the piston head. Fugoro-Corer, the similar (but smaller diameter) sampler was successfully tested by Fugoro Engineers BV.

The HS is intended for sampling in soft-medium clays and in sand.

The wireline rotary corer (Fig. 3) is intended for coring in consolidated medium-hard formations. The core barrel is suspended in the BHA by a bearing assembly. The latching assembly keeps the RC on the landing seat.

The proposed backup coring system (Fig. 5) is based on the dual-string coring concept realised in piggy-back and ODP's DCS coring systems. It includes a secondary drillstring assembled from lightweight aluminium 121 x 111 OD/ID drillrods and extended to the required length with standard HQ drillrods. Standard Longyear HQ wireline core barrel could also be used.

The primary drillstring can be supported by a heave compensator or fixed on the drill deck. The secondary drillstring with the core barrel runs down into the primary one. The inner drillstring can be rotated by the high-speed 'piggy-back' or by main top drives.

The CCS downhole motor-driven core barrel could be used also as a backup technique for coring in very hard formations.

The Baikal-3 Coring System – *Alternate coring system feasibility analysis*

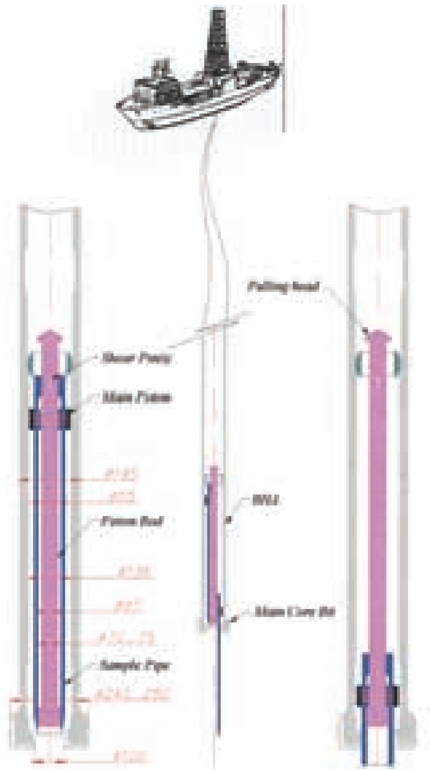


Fig. 1: Rapid Piston Sampler

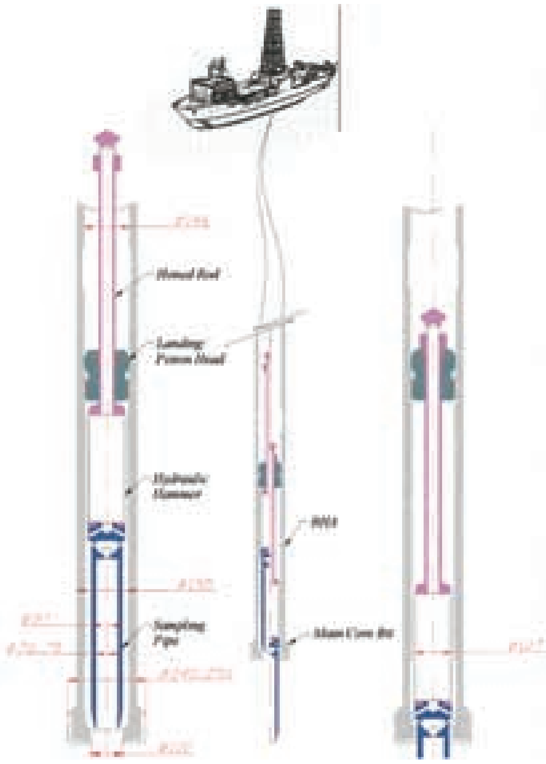


Fig.2: Hydropercussion Sampler

The Baikal-3 Coring System – *Alternate coring system feasibility analysis*

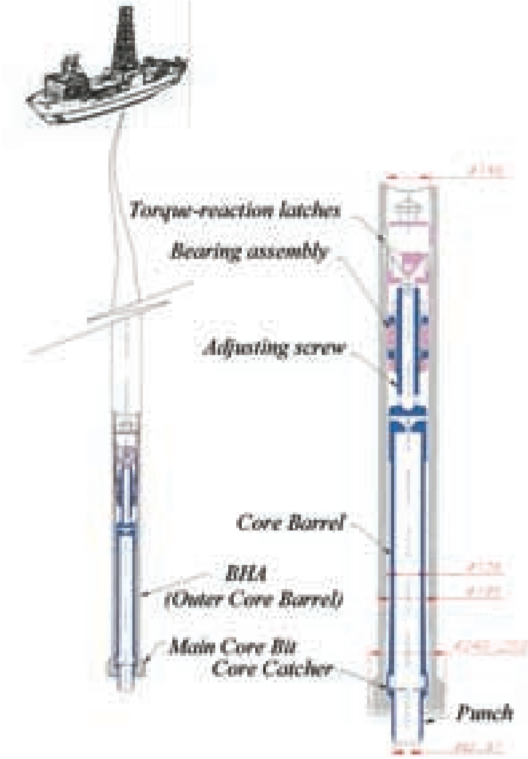


Fig.3: Punch Corer

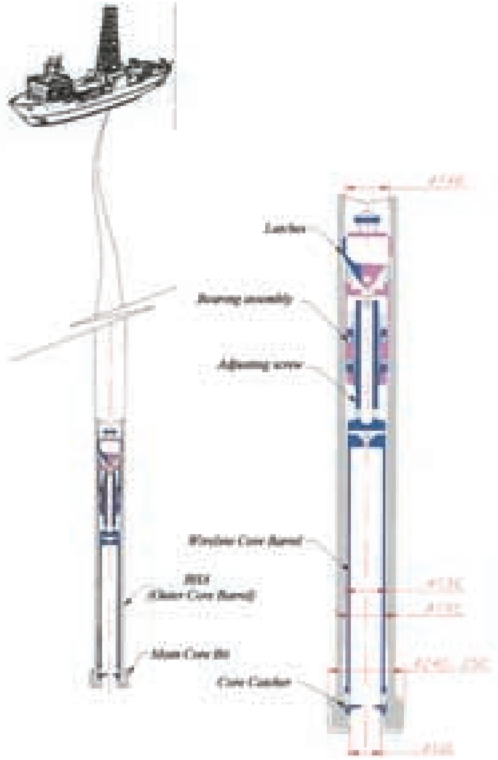


Fig.4: Rotary Corer

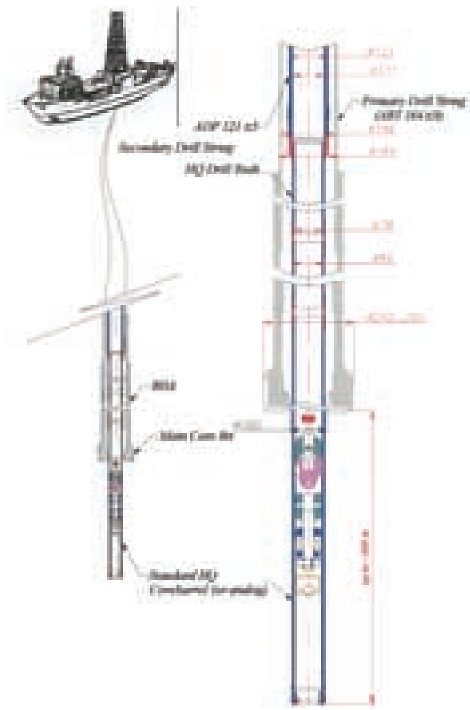


Fig.5: Dual string coring system

DSND Subsea AS

COMPANY PRODUCTS
& SERVICES

March 1999

DSND Subsea AS

MAIN MARKET AREAS

- EPCI Contracts
- Pipelaying and Subsea Construction in deep water.
- Well Maintenance and Light Well Intervention
- Geotechnical Services
- Survey and ROV Services
- Tie-in Solutions and Equipment.

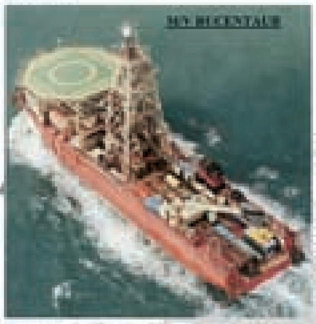
DSND Subsea AS

Geotechnical Services

DSND owns and operates Bucentaur and Norskald. These are dynamically positioned drilling vessels operating world wide in up to 2000m of water. The main marked is geotechnical and geological surveys including shallow stratigraphic drilling. Other marked areas are subsea module handling, wellhead maintenance, pilot holes for shallow gas detection/ventilation, pile and conductor installation and drill string operated jetting tools for excavation and removal of material from clay fraction up to boulder size.

The advantages of these vessels are:

- Very accurate depth control of drillstring relative to seabed by use of an advanced active heave compensation system which also correct for tidal variations.
- Short mobilisation, 12-24 hrs in port.
- Very experienced crew, all key persons have 8-20 years experience from this kind of operations.
- Operates independently up to 4 weeks without new supplies.
- Can pull of location in less than 1 min in case of gas blow-out.
- Operation in water depth ranging from 15m to 2000m.
- Safe operation by use of automatic pipe handling system and remote controlled operation of sampling and testing tools.
- Very competitive day rates compared to drilling rigs.


M/V BUCENTAUR

DSND Subsea AS

Survey and ROV Services

DSNDs mission is to provide relevant information and solutions from reliable data, on time, every time.

The new designed ROV – Stealth 3000 is built for high performance on survey tasks, which are achieved by incorporating the following features :

Streamline hull shape (length 3 meters), with low drag coefficient, and small diameter umbilical, resulting in stable motion at high speed (3 knots forward).

Low hydroacoustic noise emission from propellers and hydraulic system (100 Hp, dual pump).

Hull integrated actuators and booms for sensors like cameras, pipetracker and doppler.

Integrated Dolphin™ with interface for all known sensors.

Redundancy of and continuous quality check on critical sensors like depth and motion reference.

Powerful telemetry system, specifically built for survey sensors with very high data rates.

High quality video system with uninterrupted transmission of Y-C signal from Camera to recorder.

Intervention : The Stealth also features powerful intervention/construction capabilities, such as: Flexible and powerful hydraulic system, all flow and pressure settings remotely operated and monitored, through-frame lift 2000 kg (upgradeable), very stable and functions, can operate in heavy current conditions, State-of-the-art manipulators (Titan III and RigMaster).

Annex A – Fugro and Marine Coring Operations for Science

Herman Zuidberg,
Fugro
Engineering,
Netherlands

Introduction

The Fugro group, a multinational consulting firm of about 5 500 people specialises in geoscience data collection and related consultancy. Disciplines include marine geotechnics, oceanography, hydrography, marine and airborne survey and positioning as well as onshore counterparts of all these. The group operates from about 200 offices in 45 countries.

The marine geotechnical companies of Fugro operate from the Leidschendam group head office in the Netherlands, from Hemel Hempstead UK, Houston Texas USA and from Singapore, using support from companies in various other countries. Total staff amounts to about 400 and includes geotechnical engineers and geologists and, for field operations, marine superintendants, drillers and tool technicians backed up by mechanical and electronic design engineers.

Marine geotechnical services include sampling, coring and *in situ* testing of marine sediments and consultancy on geohazards and the stability of man-made structures and cables on the seabed and how to achieve this. The clients are primarily linked to offshore the oil and gas and telecommunication industries.

Geotechnical data collection involves the use of vessels, drilling rigs and sampling and testing systems. To effectively operate these, geoscientists need to programme the cruises and operation managers need to prepare and control the field operations and the logistics around it. Fugro is competent in all the managerial disciplines required for successful offshore cruises.

Fugro operates its own drilling vessels in the Far East and the Gulf of Mexico. It has the *MS Bavenit* on long-term charter and frequently acts as the cruise manager for the *MS Bucentaur*. Sometimes it sets up a coring cruise using its drilling systems onboard a vessel-of-opportunity, for instance for operations in the Caspian Sea.

The main technical responsibility for Fugro during field operations on all vessels is the supply and operation of downhole coring and testing systems (besides the scientific supervision). Most of the downhole systems have been developed in-house and Fugro systems for push and piston sampling and *in situ* testing are the world's standard.

One of the key quality elements for marine coring and testing is the vertical stability of the drillstring during coring. To enhance this Fugro played a key role in the development of marine geotechnical drilling. It had a great input in the design of the vessels since 1972 and designed innovative drilling and heave compensating systems. Fugro supplied all the geotechnical testing systems for the *Bavenit, Bakerit* and the *Samudra Sarvekshak*. Fugro also introduced piggy-back coring and pilot rotary coring techniques on geotechnical vessels.

In 1997 Fugro joined the EU-sponsored HYACE project to develop pressure coring tools for coring gas hydrates. Fugro developed the HYACE percussion corer that was tested successfully on the *JOIDES Resolution* in January 2001. It is based on the use of the Fugro Corer, a new percussion corer making use of a downhole hydraulically driven hammer. The latter was specifically developed to take long cores in the Japanese Nankai Trough gas hydrate boreholes.

One of the reasons to co-sponsor developments such as the HYACE tools is that Fugro is convinced that in time the technology required for scientific coring can also be used for geotechnical data collection, and vice versa, geotechnical expertise has proved to be very applicable for development of such scientific tools. Fugro is therefore convinced that cooperation between the geotechnical industry and marine science in general will be mutually beneficial.

Geotechnical vessels, attractive alternative platforms

Various drilling vessels of the geotechnical industry can be used for scientific coring as an alternative to the *JOIDES Resolution* (or successor) and the new Japanese drilling vessel. The drilling systems and procedures on board these geotechnical vessels are in essence the same as those used on the *JOIDES Resolution*. The capabilities of the geotechnical vessels are generally lower than those of the above two vessels, making them excellent platforms for limited programmes in shallower water.

About ten vessels are dedicated fulltime to geotechnical drilling in water depths in excess of 30 m of which some four have dynamic positioning for operations in deep water up to 1 500 m. Other platforms can be formed by a combination of a marine drilling rig with a suitable vessel or, in shallow water, with a jack-up platform. *Ad hoc* combinations are only occasionally used as costs of preparing such combinations are hardly ever lower than the cost of mobilising a dedicated drilling vessel.

The above-mentioned vessels are primarily used to serve the offshore oil and gas industry to collect seabed data as a basis to give advice on burial of cables and pipelines, design of seabed support for underwater wellheads or platforms, etc. Due to the nature of the oil and gas industry, occupancy of geotechnical drilling vessels is intermittent. This explains the interest from the geotechnical industry to offer these vessels for scientific coring programmes. Contrary to most industrial projects scientific cruises are less fixed in time and form the ideal ingredient for a suitable mix of work for these platforms.

As geotechnical drilling vessels already exist, science funding agencies would not have to invest in marine plant to undertake scientific coring work. Even if not enough vessel time were available because of excess demand the geotechnical industry would be interested in investing in more vessels and eventually in higher capabilities. An expansion of the total capacity with one vessel is a small percentage of total investment in marine plant for offshore geotechnics; investing in one vessel would be a major expenditure for funding agencies if built for scientific coring only.

The above is true only if the water depth and drilling depth capability of the geotechnical vessel fits the scientific programme. With European vessels the maximum is at present limited to 1 500-1 700 m of combined water and drilling depth.

The geotechnical drilling systems are designed to cope with soft seabeds as these offer the most challenging geotechnical problems. The drilling systems therefore use quite sensitive heave compensation systems and most vessels use a template at seabed to stabilise the drillstring vertically. Both aspects are important to recover quality cores in soft sediments or soft rocks.

The technical match between capabilities of the geotechnical vessels and scientific coring is not 100%. The main difference is in the actual coring tools. While these represent less than 0.5% of the investment it is an important aspect. In geotechnics the objective of the investigation is primarily related to strength testing of sediments and cores are preferably short (!) and taken in between *in situ* strength tests. In contrast, scientific objectives usually call for long continuous cores. Care should be taken therefore to discuss the programme far enough in advance to prepare the proper coring tools.

Industrial programmes last from a few days to one month, exceptionally a few months. The vessels move around in large areas to have maximum occupancy. The *MS Bucentaur*, owned by DSND Norway, covers mostly the Atlantic margin of north-west Europe; the *MS Bavenit*, owned by Amige and chartered by Fugro, covers the area from the Middle East and Mediterranean to West Africa. Other Fugro vessels cover the Far East and the Gulf of Mexico.

Because of the short-term nature of most oil/gas projects the vessels move through their respective areas rather frequently. The chance that a vessel passes a site of scientific interest is therefore reasonably high. If the scientific programme does not have a strict time schedule attractive mobilisation fees can be obtained.

The main obstacle to achieving the benefits described above is the lack of a suitable funding mechanism. If the IODP Third leg can be developed the geotechnical industry is well prepared to cooperate in an active supportive role and we are sure that suitable *modi operandi* can be developed.

Annex A – Containerized Drilling System, CDS®

Karl Oscar Sandvik,
Geo Drilling ASA,
Norway

Introduction

CDS® is a modular drilling/coring system comprising the drill rig "Marine Resolution", a trained drill crew of seven people, and equipment and tools for geological and geotechnical investigations of the uppermost part of sub-sea formations.

The whole system is adapted to 8-10 ISO certified containers. Truck, train, ship, or even airplane can easily transport these containers to the selected port of mobilisation. The vessel has to accommodate a total weight of 80-105 metric tonnes, dependent on the number of drillpipes and how much consumables (mud, fuel, etc.) are needed. The heaviest container is the 24-tonne drilling unit.

Mobile cranes or ordinary harbour cranes can normally handle all units. The drill rig with its supporting facilities can be mobilised on a classified vessel within 36-48 hours provided the ship has been inspected/accepted by Geo Drilling beforehand. In order to minimise the interfacing with the vessel the concept is self-supported with necessary electric and hydraulic power as well as spare parts and a workshop.

Vessel

CDS® can be operated from a multitude of vessels, and the drilling can take place from different onboard locations: through a moon pool or cantilevered over the side. The moon pool position with the least vertical displacement at sea, normally represents the optimal location. In order to have reasonable downtime due to the sea state at open sea, the drilling should preferably be conducted from vessels longer than 60 m.

The vessel's specifications will depend on the local conditions in the project area such as water depth, sea state, currents etc. In order to be kept on location a dynamic positioning or anchoring system must be available. The drifting of the vessel's surface position should not exceed 8-10% of the waterdepth.

In inshore or sheltered waters even barges and ferries can be used.

Heave compensation

The drilling unit is heave compensated by an active position controlled compensator. This compensator allows the drilling unit to move 5 m in the vertical field, with an accuracy of +/- 2-4 cm.

Seabed frame

A heave compensated seabed frame is lowered to the seabed. As a part of the local reference system, a beacon on the frame is given the accurate position of the hole. Other instruments on the seabed frame give information about the tilt of the frame (max 20°) while the bit is entering through the frame, and a video picture of the hole opening.

The seabed frame is connected to the vessel by a wire under constant tension and a plastic riser.

Riser

The main function of the riser is to act as a support for the drillstring and to make it possible to re-enter the hole during the drilling operation (for instance to change the bit). The riser is a double plastic tubing put together by 5 m pipes with 2.5 m overlap and clamped to the wire between the seabed frame and the vessel. This tubing is connected to the vessel by an 8 m long slip joint. The specific gravity of the tubing is 0.98, giving the riser a slight uplifting force, i.e. there is no tension in the riser.

The riser system has been used several times both during scientific projects in Antarctic, Arctic and during our test cruise off Trøndelag in 1999.

Drilling equipment

During the design of the CDS® drilling and coring system the objective has been to core any geological formation with the best possible core recovery using a standard wireline set up for sampling of any geological formation, from the softest clay to the hardest bedrock.

The drilling unit is a heavy duty Longyear wireline-coring rig. It is computer controlled and equipped with a pipe manipulator. In addition to the active heave compensator, the bit is kept in position by a bitweight control of +/- 150 kg.

The rig is at present set up for the standard BQ, NQ, HQ, and PQ dimensions with hole diameter in the range of 60-122.6 mm and core diameter 33.5-85 mm. The maximum drilling capacity (from drill floor to the bottom of the hole) is approximately 2 000 m depending on the preferred sampling mode.

Main characteristics of the part of the Series Q Wireline System we are using (diamond coring mode):

Core barrel	Hole diameter, mm	Core diameter, mm
AQ	48.0	27.0
BQ3	60.0	33.5
NQ3	75.8	45.0
HQ3	96.0	61.1
PQ3	122.6	83.1

In difficult formations, or in deep holes, combinations of the available dimensions can be applied, if necessary. One option could be to start with a HQ drillstring in a possible upper unstable formation and then go on with a NQ drillstring in the deeper part of the hole.

For all these hole sizes CDS® is equipped with:

- standard wireline
- triple tube wireline with split tube and/or a transparent plastic liner (for loose formations in order to prevent damage to the core)
- cutting nose wireline, the sampler is advancing ahead of the bit
- non-coring system, in order to quickly proceed through unstable formations or formations where cores are of no interest

For both geotechnical and geological investigations the main tools are adapted to the standard HQ3 outer tube. In cooperation with Leon Holloway, senior engineer Ocean Drilling Program (ODP), and Boart Longyear, we have composed a multi-purpose coring system with interchangeable core barrels for:

- push sampling
- piston sampling
- percussion sampling
- punch sampling
- diamond coring

The piston sampler is an adaptation of the APC (advanced piston corer) developed by ODP.

The punch sampling is a modification of the diamond coring method. The inner barrel includes a coil spring, split tubes, and drive shoe. The spring provides the tension necessary to keep the drive shoe up to 6 seconds in front of the bit in softer formations. Thus the soil samples are virtually undisturbed and uncontaminated by drilling fluids. If an obstruction is encountered, the spring retracts to allow the bit to drill through or displace the obstruction. It then returns to its position in front of the bit.

All these five options are available for drilling through the standard HQ3 drill bit. In this mode the core diameter varies from 49.23 to 55.50 mm dependent on the core barrel in use (Option 1). The correspondent area ratio varies from 50-18%. The smallest diameter occurs when liners and core catchers are in use. (The area ratio is the volume of the displaced soil as a percentage of the volume of the sample.)

If a modified drag bit is used instead of the standard diamond coring bit, push and percussion samples with core diameters of 58.75 to 65.63 mm can be collected (Option 2). Here the corresponding area ratio varies from 21-13%.

The common sample diameter for geotechnical investigations of soft sediments in the North Sea is 75 mm. The Shelby tubes for our HQ3 wireline samplers have an inner diameter of up to 65.63 mm as mentioned above.

Geo Drilling is pursuing a development of tools for wireline *in situ* measurements (CPT in particular), but has so far not decided on what should be developed to become a commercial service.

Mud

All drilling will be carried out using mud, consisting of water, polymer, weight-controlling materials (bentonite, baryte etc.) and filtercake. Different recipes will be used dependent on the properties of the actual geological formations.

Cementing

If required, any hole can be cemented.

Logging of drilling data

The drilling unit has an automatic data logger for display and storing of all relevant parameters collected during the operation:

- penetration (cm/min)
- weight-on-bit/total weight of drill pipes (kg)
- system pressure for the drilling unit
- rotation velocity (r/min)
- number of drill pipes
- mud consumption (l/min)
- mud pressure (bar)
- motion/working pressure/load of the heave compensator
- working length and tension of the main wire
- time (clock), date, locality, customer, etc.

All this data will be submitted to the client if required. In addition it can be used to give input to the driller during the drilling operation. This logging also provides continuous physical measurements of the parts with bad core recovery.

Well logging

The wireline winch used to retrieve the core barrels can also be used for wireline logging. The digital counter provides the length of the wire in hole with an accuracy of +/- 4-cm.

Dependent on the required parameters to be measured and stored, wire line logging subcontractors will be involved to carry out the measurements.

Laboratory

An important part of CDS® is a 20-ft laboratory container equipped for sample description, subsampling/packing and simple geological or geotechnical testing.

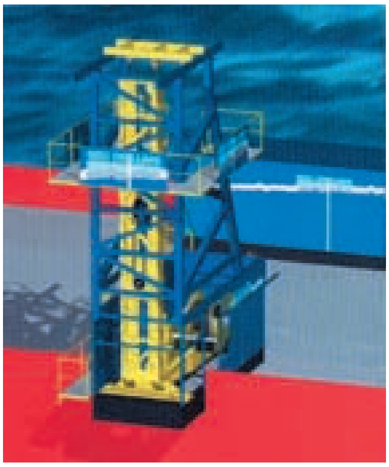
Crew

The average crew comprises seven people, of whom one is the drilling supervisor, acting as our party chief, responsible for quality assurance, and is our liaison with the client during the operation.

Certificates

The rig as a unit and several parts of the system is classified by DNV (Det Norske Veritas).

Illustrations of the Cantilevered Rig, the drilling drive and two varieties of core bits are shown below.

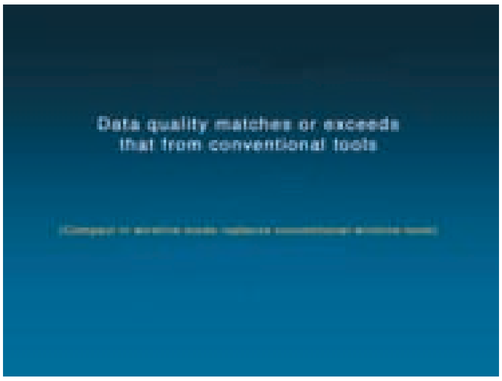


The rig mounted on a survey vessel is shown in the figures below.

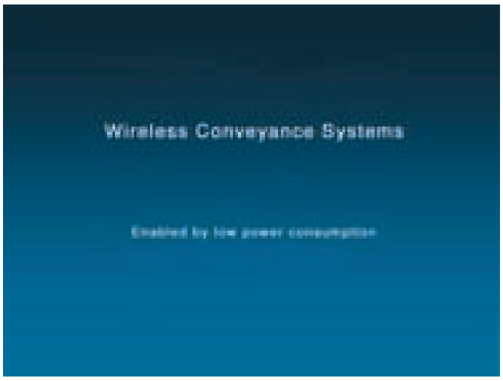
Slide 1

Reeves Wireline

Reeves Wireline use innovative downhole logging technology to increase efficiency and reduce costs. An example is our open hole borehole logging system that needs no wireline, so takes minimal deck space and support equipment. We will be looking for any areas of common interest between ourselves and IODP.



Slide 2



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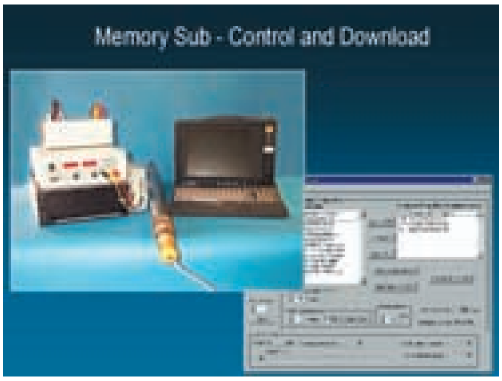

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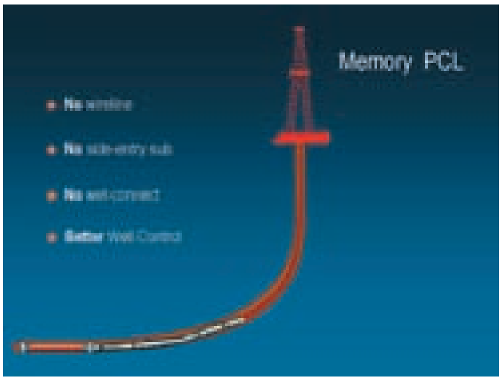

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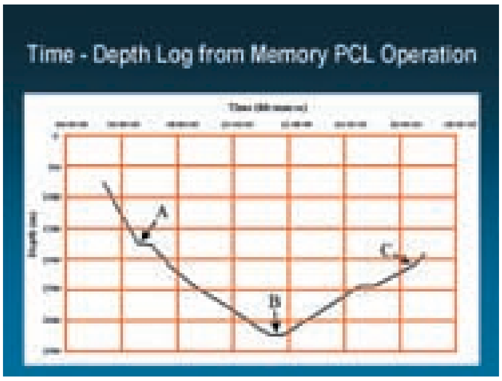

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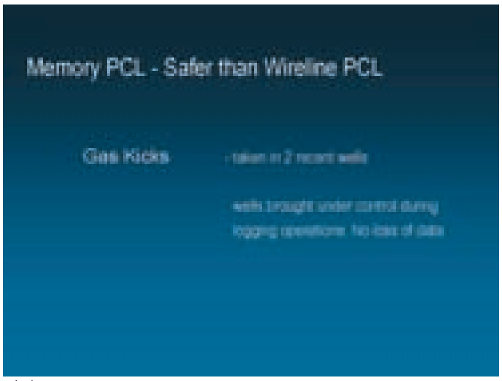

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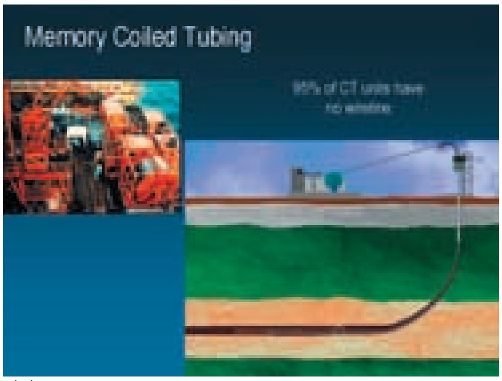

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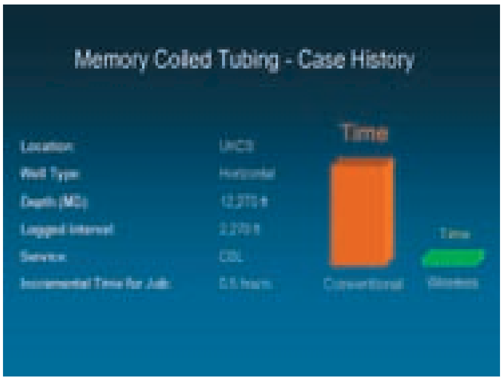

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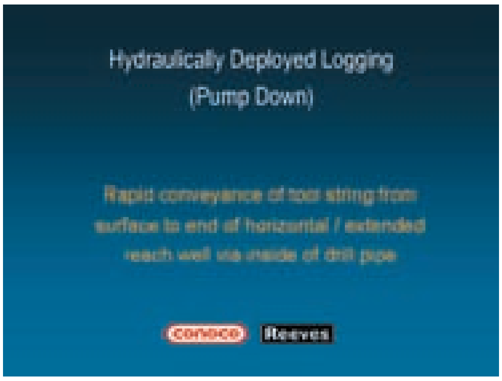

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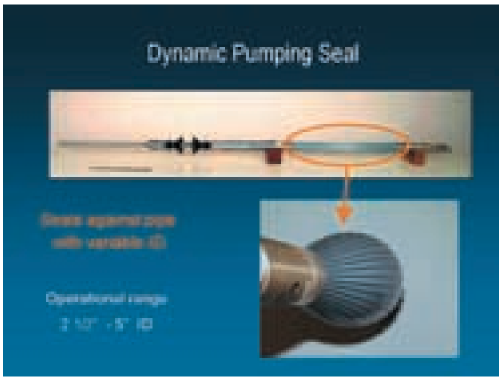

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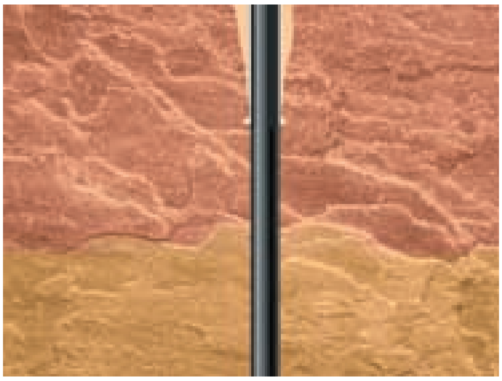

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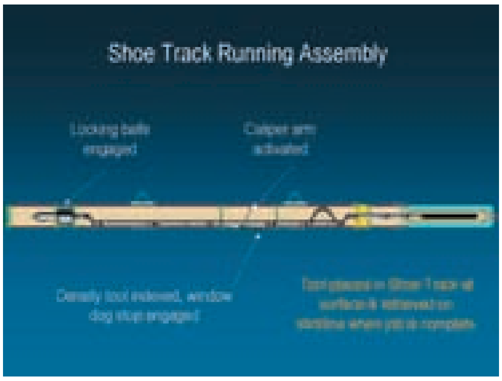

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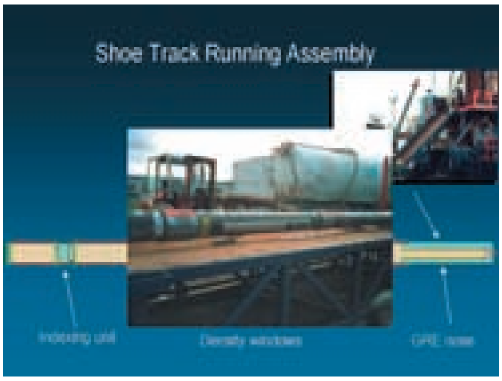

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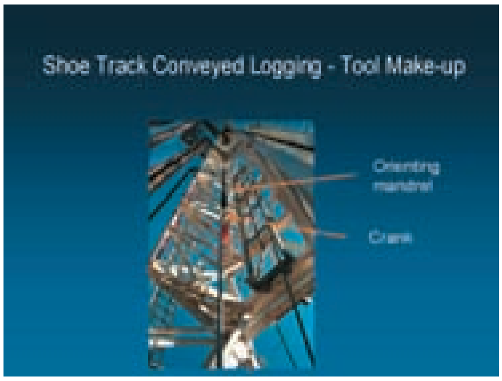

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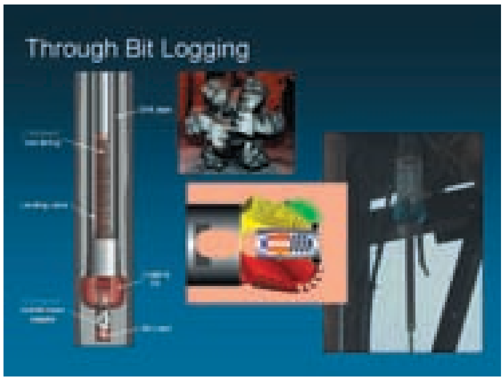

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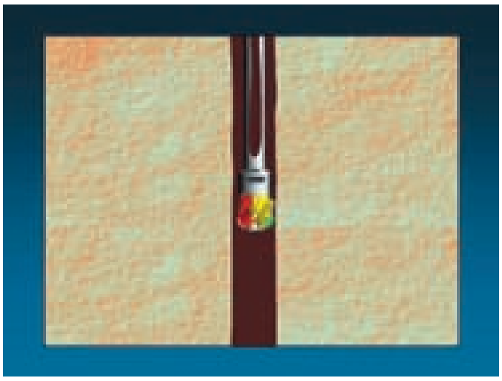
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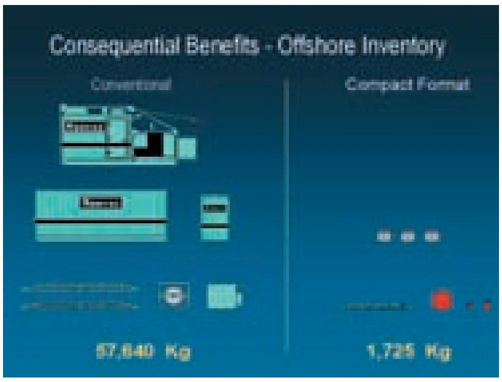

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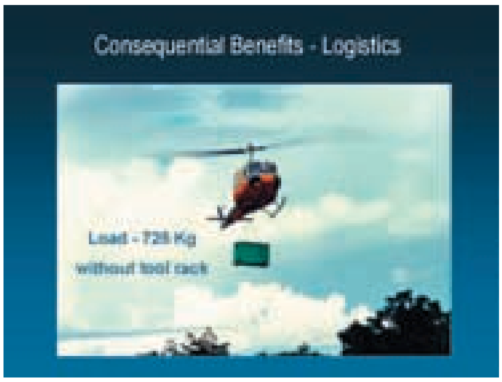

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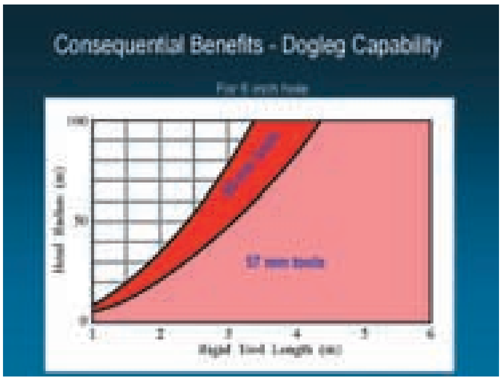

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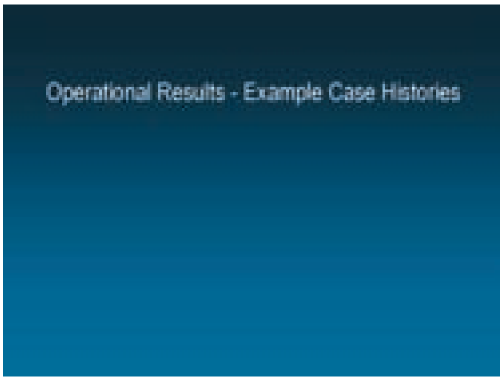

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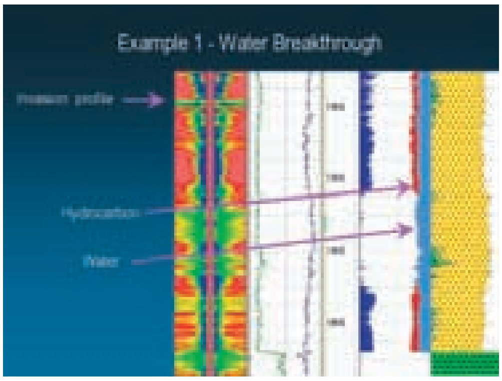

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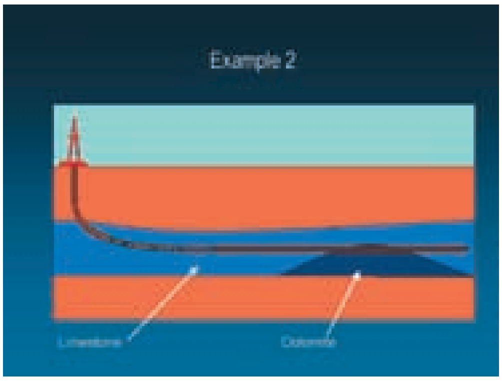

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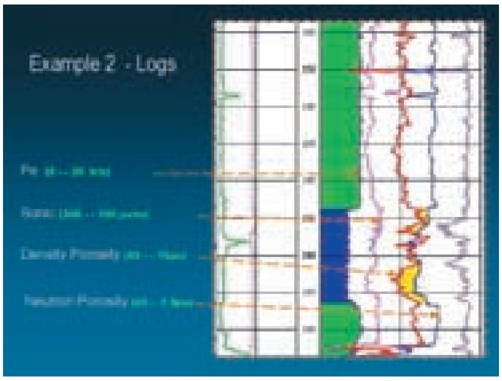

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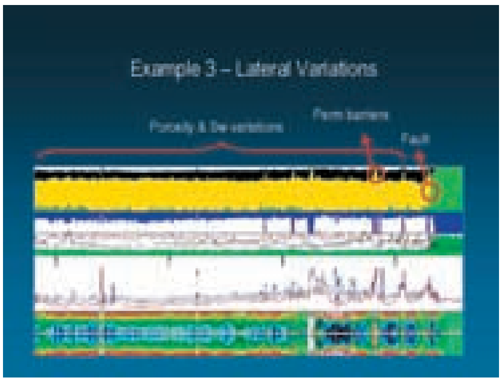

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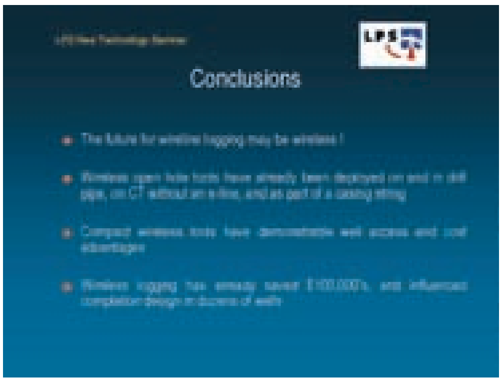

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Annex A – Seacore

The company

Seacore Ltd., specialist marine exploration civil engineering contractors, was established over twenty-five years ago and is registered in the UK, based in Cornwall, but works on projects all over the world. The personnel comes from all areas of the industry.

Examples of our equipment and types of work are shown below and on the following pages.

Offshore drilling and coring system
Vessel: MS Bucentaur
Bucentaur dedicated drill system with Wirth top drive power swivel

Offshore piggy-back system
Vessel: MV Norskald
Seacore API drilling system; Seacore piggy-back coring system

Mobile marine drill systems

The marine drill system is based on the concept of temporarily adding drilling capabilities to standard offshore vessels without the need for expensive permanent conversions. It also allows shipping and other companies access to specialist markets without the need for technical expertise and expensive dedicated departments with associated annual overheads.

C100 Marine Drill on M.V.
Lowland Cavilier

Derrick:
Dimensions: 24.4 m x 2.4 m x 2.6 m
Capacity: 100 tonnes

Mobilisation data:
The C100 Marine Drill may be mobillised in 6 x 12.2 m x 2.4 m x 2.6 m freight containers and 5 x 6.1 m x 2.4 m x 2.6 m freight containers

The equipment and personnel are simply mobilised onto a suitable vessel on a project-specific basis. Various activities can be undertaken using the Marine Drilling system, the drilling of high quality cored holes for scientific purposes, from geotechnical drilling and sampling in soft soils to large diameter drilling for rock sockets, bulk sampling or dredging purposes. As the equipment can all be container freighted the spread can be rapidly mobilised in a cost effective manner.

C200-65 Marine Drill on *Sea Sorceress*

Derrick:
Dimensions: 27 m x 2.4 m x 12.19 m – Capacity: 200 tonnes

Modular design jack-up rigs

Skate 1 is a lightweight, road transportable jack-up drilling package, incorporating a unique freighting system. The hull's three pontoons are equipped with container frames and locks. These allow the complete package including platform, legs and drilling plant, to be transported by sea or road as the equivalent of two standard 12 m containers. This design provides a rapid and cost effective mobilisation, particularly overseas. The craft can be assembled in less than a single shift by two people with the assistance of a 30 tonne mobile crane.

Skate 1

Skate 1's compact size and shallow draught allows the craft to operate at locations inaccessible to large jack-ups, while providing a stable working platform above the influence of waves and tides. Skate I has a dedicated marine drilling system, including powerful percussive and rotary equipment. This is operated by qualified and experienced marine drilling engineers, ensuring a high-quality, productive service is provided. The jack-up and drilling system are driven by Seacore designed hydraulic power packs, silenced to better than 80db(A) at 5 m, enabling 24 hour working in built up areas without noise interference.

Skate 2C/2D jack-ups

Skate 2C and Skate 2D are compact, modular, container transportable jack-up platforms. They were designed and constructed by Seacore to meet increasing market demand for small jack-up platforms with low international transport costs, coupled with high performance capabilities. Skate's modular design means that jack-ups can be provided in a variety of sizes, with deck areas ranging from 105 m^2 to 177 m^2 and the capability of operating in water depths between 1-26 m. Each craft in the Skate range has a rapid deck elevating system and is equipped with four legs mounted externally to provide maximum stability and the larger ones can operate in exposed sea areas.

Skate 2 jack-up

All pontoons, components and equipment are designed around the container freight concept. When freighting the pontoons double as containers in which the jack-up legs, power units and all other ancillary equipment are housed. Assembly and commissioning of the jack-up is achieved in under two shifts. The jack-ups can be fitted with one of the range of Seacore hydraulic thrusters to provide self propulsion. In compact configurations, these fast elevating, self propelled jack-up craft are ideal for confined intertidal areas, where swift, accurate moving and positioning is required.

Each craft in the Skate range has a rapid deck-elevating system and is equipped with four legs mounted externally to provide maximum stability. All pontoons, components and equipment are designed around the container freight concept. When freighting the pontoons double as containers in which the jack-up legs, power units and all other ancillary equipment are housed. This allows cost-effective international transportation by road, rail or container ship. Assembly and commissioning of the jack-up is achieved in under two shifts.

The jack-ups can be fitted with one of the range of Seacore hydraulic thrusters to provide self propulsion. In compact configurations, these fast elevating, self- propelled jack-up craft are ideal for confined intertidal areas, where swift, accurate moving and positioning is required. In their larger configuration Skate 3 jack-ups are capable of working safely in exposed open seas.

Skate 3 jack-up

The Skate 3 range consists of medium sized, high payload, container transportable jack-up platforms.
These platforms have a low international transport cost coupled with high performance capabilities. Skate 3's modular design means that jack-ups can be provided in a variety of sizes, with deck areas ranging from 178 sq. m to 238.1 sq. m and the capability of operating in water depths between 1-30 m. In their larger configuration Skate 3 jack-ups are capable of working safely in exposed open seas.

Each craft shares the following common characteristics:
- Leg size: 762 mm diameter
- Elevating system: hydraulic ram and duo pin rack
- Accommodation: workshop / canteen container

Annex B – List of participants

Workshop on Alternate Drilling Platforms, Brussels, Belgium, 8-9 January 2001

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