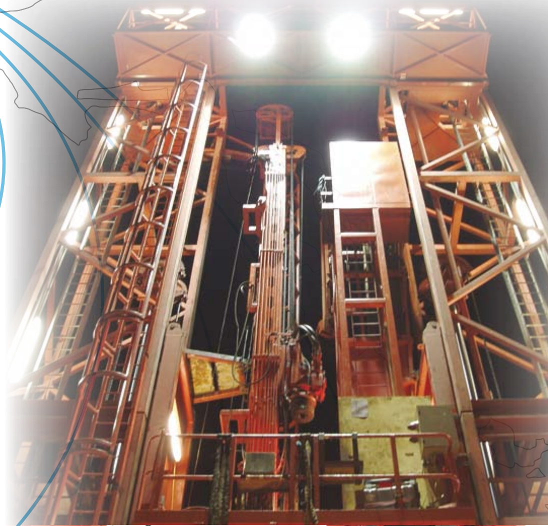
ECORD

Beyond 2013: the Future of European Scientific Drilling Research



Workshop Report

Conveners: G. CAMOIN, R. STEIN and M.WAGREICH

April 24-25, 2009

ECORD European Consortium for Ocean Research Drilling
European Science Foundation — Setting Science Agendas for Europe
IODP Integrated Ocean Drilling Program

This workshop was sponsored by the ESF Magellan Workshop Series - http://www.esf.org/magellan

Front cover images:
(top) Derrick of the drillship DP Hunter illuminated at night during drilling operations, (middle right) day shift of the driller team, (bottom) drillstring in the moonpool. All photos have been taken aboard DP Hunter during the Tahiti Sea-Level Expedition (© ECORD/IODP, world map © http://histgeo.ac-aix-marseille.fr)

Back cover image:
The 24 IODP country members (light blue) include the 17 ECORD partners (dark blue), which are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom, outline world map © http://histgeo.ac-aix-marseille.fr)

Report of the Workshop:

Beyond 2013: The Future of European Scientific Drilling research

Convenors: G. CAMOIN, R. STEIN and M.WAGREICH

held at the Geocenter, University of Vienna (Austria),

on April 24-25, 2009

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Introduction and Background

The Integrated Ocean Drilling Program (IODP) is funded for the period 2003–2013, and is now starting to plan the future of ocean drilling beyond 2013, including the development of new technologies, new emerging research fields and the societal relevance of this programme.
An interdisciplinary and multinational (USA, Europe, Japan, Asian and Oceanian countries), key conference – INVEST IODP New Ventures in Exploring Scientific Targets - addressing all international IODP partners is planned for September 23–25 2009 in Bremen, Germany (http://marum.de/iodp-invest.html) to discuss future directions of ocean drilling research and related aspects such as ventures with related programmes or with industry. The Steering Committee of the INVEST Conference includes W. Bach (co-chair; University of Bremen, Germany/ECORD), C. Ravelo (co-chair; University of California Santa Cruz, USA), J. Behrmann (IFM-GEOMAR Kiel, Germany/ECORD), B. Duncan (Oregon State University, USA), K. Edwards (University of Southern California, USA), G. Camoin (CNRS-CEREGE Aix-en-Provence, France/ECORD), S. Gulick (University of Texas Austin, USA), F. Inagaki (JAMSTEC, Japan), H. Palike (NOC Southampton, UK/ECORD), and R. Tada (University of Tokyo, Japan).

INVEST will be open to all interested scientists and students and will be the principal opportunity for the international science community to help shaping the future of scientific ocean drilling. The outcome of the conference will be the base to draft a science plan in 2010 and to define new goals and strategies to effectively meet the challenges of society and future ocean drilling.

The IODP Program Member Organisations (PMOs) have organised a series of events to prepare the INVEST Conference.

- The US PMO, USSSP, has organised a six-week on-line meeting, 'Charting the Future Course of Scientific Ocean Drilling (CHART)', from February 2 to March 13, 2009, to gather input from the U.S. science community regarding future research directions for scientific ocean drilling. The CHART Steering Committee has summarised more than 500 comments posted on the forum.The final report has been posted mid-May (http://www.oceanleadership.org/chart).
- In December 2008 the Japanese PMO, J-DESC, has organised a serie of workshops of 20 to 50 participants and concerning various scientifoc topics: Geohazards, Earth's Interior, Paleoenvironment, Deep Biosphere and Sub-seafloor Aquifer and Technology Development. The workshop reports have been assembled in a volume entitled 'Reports from Japanese domestic workshops for INVEST'.
- During its Fall 2008 meeting, which was held in Tübingen (Germany), the ECORD Science Steering and Advisory Committee (ESSAC) discussed the opportunity to organise two events related to the preparation of the INVEST Conference:
    - 1 - a Session of the EGU General Assembly 2009 in Vienna, Austria (SSP18/CL64/GMPV23/TS9.3), entitled "Beyond 2013 - The Future of European Scientific Drilling Research" (http://meetingorganizer.copernicus.org/EGU2009/session/1355) and convened by G. Camoin and R. Stein,
    - 2 - a two-day European Science Foundation (ESF) workshop specifically addressing the future of European scientific drilling research and convened by G. Camoin, R. Stein and M. Wagreich at the Geocenter of the University of Vienna immediately after EGU.

The steering committee of both events included: W. Bach (Univ. of Bremen, Germany), J. Behrmann (IFM-GEOMAR, Kiel, Germany), A. Camerlenghi (Univ. of Barcelona, Spain), J. Erbacher (BGR Hanover, Germany), U. Harms (GFZ/Potsdam, Germany), J. Kenter (Chevron-Texaco, USA), H. Pälike (NOC, Southampton, UK), R. Schneider (Univ. of Kiel, Germany).

The major objectives of the ESF workshop 'Beyond 2013 - The Future of European Scientific Drilling Research' were:

- to sharpen the European interests in a future international drilling programme,
- to give weight to the European propositions in the creation of a New Drilling Programme, both on science, technology and management,
- to prepare the INVEST Conference,
- to provide the participants with information about the status/process of ongoing discussions and negotiations regarding programme structure, and provide them with the expected framework (available drilling platforms and anticipated funding levels).

About 80 scientists from 15 countries attended the workshop that was conceived as a workshop widely open to all scientists with an interest in scientific drilling, including representatives of various scientific drilling and coring programmes (IODP, ICDP, IMAGES etc) and representatives from industry to discuss possibilities of future cooperation/exchange.

The format of the workshop has been designed based on the key items that were defined to be discussed and including :

- The Future of ECORD and IODP (science, technology, management).
- New Research Initiatives and Emerging Fields in Scientific Drilling (e.g. Arctic Ocean Drilling, Long term evolution, Geohazards etc).
- Relationships IODP/Other Programmes (e.g. ICDP, IMAGES etc).
- Collaboration between Academia and Industry.
- New Technologies and the Mission-Specific Platform Approach.

The "Beyond 2013" workshop has included breakout-group discussions and open discussions with all meeting participants.

The **first half-day** of the workshop (Friday April 24, 2009 afternoon) included overviews of those key items (the Future of ECORD and IODP [C. Franklin], the Deep-Sea Frontier Initiative [C. Mével], the New Research Initiatives and Emerging Fields in Scientific Drilling [J. Behrmann], the Relationships between IODP and Other Programmes [T. Johnson], and New Technologies and the Mission-Specific Platform Approach [D. McInroy]) and five breakout-group discussions based on those key items:

1 - Breakout session 1 : The Future of ECORD and IODP *(Chairs : J. Erbacher, C. Franklin)*

2 - Breakout session 2 : Emerging fields/new topics, including two sub-sessions:

- **Sub-session A : Solid Earth and Geohazards (***Chairs : W. Bach, J. Behrmann, D. Teagle)*
- **Sub-session B : Environment and Deep Biosphere** *(Chairs : J. McKenzie, H. Brinkhuis)*

3 - Breakout session 3 : The New Drilling Programme and its Relations to Industry and Other Programmes *(Chairs : U. Harms, R. Schneider)*

4 - Breakout session 4 : New Technologies and the Mission-Specific Platform Approach
(Chairs : P. Favali, D. McInroy)

The **second half-day** of the workshop (Saturday April 25, 2009 morning) was dedicated to the continuation of the breakout-group discussions.

During the **third half-day** of the workshop (Saturday April 25, 2009 afternoon), the chair persons of the breakout sessions (C. Franklin, D. Teagle, J. McKenzie, H. Brinkhuis, U. Harms, and D. McInroy) presented a summary of the relevant discussions in a plenary session. Time was given to workshop participants to comment those summaries.

The products from the breakout-group discussions were a list of important questions, ideas, suggestions and recommendations regarding the scientific objectives, the technologies and the management of the New Drilling Programme.

Session 1: The Future of ECORD and IODP

Session participants: *C. Franklin (co-Chair), J. Erbacher (co-Chair), S. Ahmad, R. Bernal-Carrera, G. Camoin, M. Coffin, S. Davies, O. Eldholm, H. Kuhlmann, C. MacLeod, C. Mével, M. Perrin, A. de Vernal, G. Wefer and B. Wolff-Boenisch.*

Introductory remarks

When discussions were initiated among the members of the Ocean Drilling Program (ODP) to prepare for the IODP, the European members of the ODP decided to form a consortium and join the IODP as a single member. The objective was two fold:

- to facilitate coordination among European scientists and to maximise their influence in the program,
- to pool funds to provide and implement mission-specific platform (MSP) expeditions, i.e., to play a major role as an operator (Implementing Organisation or IO) within the IODP.

Originally, the aim of the consortium was to become "the third leg of IODP" by financially contributing to the program at a level similar to the USA and Japan, and therefore to attain a 'lead agency' status. The European Commission (EC) was involved in the discussions, and joined the International Working Group as a member. Unfortunately, the EC ultimately decided not to financially support platform operations, but did fund an ERA-Net to help set up the structure of ECORD. This 57-month ERA-Net project ended on August 2008, and ECORD is now funded solely by the national contributions of the currently 17 ECORD member countries.

During the Vienna workshop, the Session 1 participants were tasked to discuss the possible structure of a new programme and the role of ECORD in it. The group posed six questions:

1 - Should the science be broader than that which can be accomplished by just drilling?

2 - Is the ECORD structure fit-for-purpose?

3 - What is the role of ECORD in a future programme?

4 - What should be the organisational structure of the New Drilling Programme?

5 - What should be the structure of the New Science Plan?

6 - What should happen to existing proposals?

These questions were debated and some suggestions and ideas have been put forward; they are summarised below. These should be considered as a basis for further discussions, at both the scientific (INVEST Conference) and the funding agency (ECORD Council and IWG+) levels.

1 - Should the science be broader than that which can be accomplished by just drilling?

The programme must be led and driven by science. It is premature to reach conclusions on the full breadth of the science. This is the objective of the INVEST Conference. However, it is obvious that, although drilling is a key tool in addressing scientific problems, in many cases it needs to be integrated with other approaches. This is particularly crucial for onshore-offshore transects, integration of observation and modelling, and long-term monitoring to address active processes.

Although the IODP and ICDP share tools and techniques, there has been limited progress towards a better integration of the two programmes. The ICDP has co-funded the operations of the New Jersey Shallow Shelf expedition (IODP Expedition 313), of common interest to both programmes, but this is a single IODP project that follows previous ODP-ICDP cooperation in the New Jersey sea-level drilling. The memberships of the ICDP and ECORD do not coincide, although there is a significant overlap. But more importantly, the funding differs in both structure and magnitude. The structure of the new

programme should facilitate development of concrete links between ECORD and the ICDP.
At the European level, ECORD has also promoted the 'Deep Sea Frontier' (DSF) initiative, to integrate ocean drilling with other programmes investigating the deep seafloor. The objectives of this initiative were in particular:

- to use geological records to understand past and present processes (such as climate change and natural hazards) and to better decipher the possible role of human impact,
- to evaluate the influence of sub-seafloor processes on deep seafloor ecosystems,
- to establish seafloor observatories for real-time and decadal time-scale monitoring of active processes in the deep ocean.

Following a workshop held in Naples on June 2006, a foresight paper 'The Deep Sea Frontier: science challenges for a sustainable future' was published by the EC (http://www.ecord.org/enet/deliverable_19.pdf).
A resulting project 'The Deep Sea and Sub Seafloor Frontier' submitted to the EC for a Coordination Action to support this initiative is under consideration. Cooperating with other programmes to solve scientific problems should be a goal ***(see also "Session 3 : The Integrated Ocean Drilling Program and its Relations to Industry and Other Programmes")***.

2 - Is the ECORD structure fit-for-purpose?

ECORD has demonstrated its ability to play a significant role in the IODP as a 'contributing member', i.e., both intellectually (proposal proponents, committee and panel members, expedition and planning workshop participants) and operationally (MSPs). At this stage, there is no need for substantial modification of the ECORD structure. The ECORD structure will follow from the structure of the new drilling programme at the international level. Continuing to be involved in an international initiative such as the IODP is clearly the preferred solution for ECORD. However, ECORD is prepared to sustain implementing ocean drilling at the European level, whether or not a full international programme results from discussions at the IWG+ level. A European Ocean Drilling Programme (EODP) would certainly focus on science drilling for societal impact.

An issue that should be considered is funding for scientists. Scientists are currently funded at the national level to participate in the IODP planning activities and expeditions as well as to conduct post-cruise science. Funding schemes vary from one country to another, and some scientists are confronted to serious challenges. The ESF-run EuroMARC programme was launched in coordination between ESF and some national agencies to help the funding of pre- and post-cruise science. In practice, it turned out that this 'à la carte' system is not easy to implement and is not very transparent for the scientific community. Moreover, the funding agencies decided to support only one call, and therefore there is currently no long-term solution for these challenges.

3 - What is the role of ECORD in a future programme?

In the current IODP structure, MEXT (Japan) and NSF (USA) play a major role as the 'lead agencies', because they have committed to share the cost of the program equally. ECORD, which funds the operations of MSPs, contributes at a lower level and is therefore considered as a 'contributing member'.
Initially, ECORD planned to implement one MSP operation per year; in reality, this figure will not be reached because costs of all activities related to ocean drilling have escalated dramatically in the past few years. This has also affected the operations of other platforms, which currently cannot operate twelve months a year due to the shortfall of funds. But even with reduced activity, the scientific impact of MSP expeditions has been tremendous. ACEX (IODP Expedition 302) retrieved the first drill cores from the Arctic Ocean seafloor and revealed the climatic evolution of the Arctic during the last 56 Myr. The Tahiti Sea-Level Expedition (IODP Expedition 310) allowed refinement of the global sea-level curve for the last 16,000 years and provided essential information on climate change during that time window. More information, to older periods, will come from the Great Barrier Reef Environmental

Changes Expedition (IODP Expedition 325) scheduled in November and December 2009. The New Jersey Shallow Shelf Expedition (IODP Expedition 313) which has been carried out in May to July 2009 will fill the gap between the holes drilled on land by the ICDP and the holes drilled on the lower slope by the ODP. It will decipher the respective roles of climate change and tectonic activity in sea-level fluctuations between 24 and 14 Ma.

ECORD aims to continue implementing MSP expeditions in a future programme. MSP operations in areas inaccessible to the other drilling platforms are critical to address outstanding scientific questions. But it is also politically essential for ECORD to play a visible role, to seek for funding from more diverse sources. In the IODP, MSP operations were restricted to shallow water and Arctic drilling. It is conceivable that this concept could expand to include tools and techniques allowing recovery of cores in the most efficient way (i.e., in the most economical mode and with the highest recovery), e.g., seabed drills to recover the section immediately beneath the seafloor, long piston coring and drilling techniques to improve recovery even where water depth exceeds 100 m (see also ***'Session 4 : New Technologies')***.

The Polar regions are a key topic of growing interest in the science community. An international workshop held in Bremerhaven on November 2008 highlighted key questions that require drilling in ice-covered areas of the Arctic. Another international workshop will take place in Granada (Spain) following the SCAR/ACE (Antarctic Climate Change) symposium, on September 12-13, to establish a framework for future (2013-2023) Antarctic margin drilling for sedimentary records of paleoclimate. A full Science and Operations Plan/Strategy will be developed and a subcommittee will be set up inside the SCAR/ACE that will foster future geological drilling for paleoclimate records. Arctic and Antarctic drilling should be a major thrust in the New Drilling Programme.

The ECORD Science Operator has demonstrated the feasibility of drilling under the ice pack. However, implementing such an expedition is very complex logistically. The *Aurora Borealis* project, initiated by AWI (Germany) and supported by BMBF, aims to build a multi-purpose icebreaker with drilling capabilities. The ship will be able to drill autonomously in ice. The *Aurora Borealis* project is included in the European Scientific Forum for Research Infrastructures (ESFRI) list. A Coordination Action to support the preparatory phase, European Research Icebreaker – Aurora Borealis (ERICON-AB) is funded by the EC, but funding for ship construction is not yet secured. *Aurora Borealis* is a potential Arctic (and Antarctic) platform that could be operated as an MSP by ECORD (see also ***'Session 4 : New Technologies'***). There is a rising demand for drilling Polar regions. The use of a dedicated platform for deep-sea drilling and other scientific tasks, in Polar and sub-Polar regions, will allow to plan Polar legs more systematically and with a significant multidisciplinary component. Up to now the chance to drill Arctic-sub Arctic and Antarctic-sub Antarctic waters averages one every 10 years. This is due to the difficult and expensive logistics and it is in conflict with the excellent quality of the proposals and with the crucial needs of a systematic data collection from both Polar regions to constraint global change prediction modelling.

ECORD should aim to be a 'major partner' in the new drilling programme. Because the structure of the new programme will likely differ from that of the current IODP, the concept of 'lead agency' could become obsolete. What is critical for ECORD is to be involved in all decision makin processes at the highest level. To reach this goal, there is a need to strengthen the consortium. This will be possible in particular if the funding for ECORD increases. During discussions to set up ECORD, the negotiating countries agreed that, in order to join the consortium, a country should contribute at least at the same level as in the ODP. Most countries increased their contribution by ~60% in 2008, when the *Chikyu* joined IODP operations.
The Session 1 of the Vienna workshop recommended a similar principle, i.e.: *'To keep national contributions in Europe at the current level as a minimum and aim to at least double contributions through other means (industry, EC, linking through projects with other programmes, national foundations, etc)'*.

4 - What should be the organisational structure of the New Drilling Programme?

It has been suggested that the current structure of the IODP is overly complex and consequently does not function satisfactorily. The organisational structure involves three separate entities: the SAS (Science Advisory Structure) that handles drilling proposals; IODP Management International (funding, operational oversight); and the implementing organisations (IOs) that operate the platforms. The SAS has not changed fundamentally over the years and is directly inherited from the ODP and DSDP. It is composed of multiple committees and panels with specific tasks; representation reflects the financial contributions of respective national and consortium members. The management structure was set up to accommodate a multi-platform programme, with several platform operators (IOs).

The issues identified are: the frequency of SAS meetings; the lengthy interval (average 76.3 months for the first 12 IODP expeditions) from proposal submission to implementation; the efficiency of decision making processes; and the respective roles of IODP Council (i.e., the funding agencies) and the IODP-MI Board of Governors.

For a future programme, it is essential to think outside of the current IODP structure. 'Mean and lean' should be the guiding philosophy for a new, streamlined structure. In particular, the most efficient parts of the ICDP concept should be considered and possibly adapted to suit a new drilling programme.

- **Proposal handling**

The mission concept was born at the IODP-MI Management Forum in Frascati, on May 2005. The aim was to help achieve important programme goals of the Initial Science Plan (ISP) in a timely fashion. It was suggested that in order to address specific science topics in the ISP, missions should be elaborated by the community at workshops and, very importantly, that operational, engineering, and technological requirements should be incorporated from the start. Although the concept was endorsed in principle by the SAS, the three mission proposals submitted to the IODP were rejected. Moreover, SASEC decided that this concept should not be implemented before 2013.

In a new structure, this mission concept should be revisited. To some extent, it has some similarities with the way the ICDP operates. The two main advantages of the mission concept are:

- to involve the science community at large in major topics of the science plan (through workshops), and to induce the progress of the science and the implementation plans in parallel,
- to allow partnership to be built into the projects from the start: with other programmes (seafloor observatories, for example, if long term monitoring is required to fulfil the science objectives); with the EC on specific identified projects; and with industry (see also 'Session 3 : The Integrated Ocean Drilling Program and its Relations to Industry and Other Programmes').

It was pointed out that it is also essential to encourage the submission of new innovative individual proposals.

- **Management**

The current system was developed to accommodate a multi-platform programme. IODP commingled funds support Science Operation Costs (SOCs), while each country or consortium providing a platform is responsible for its respective Platform Operation Costs (POCs). Integration is achieved by the Central Management Office (the CMO, namely IODP-MI), tasked with overseeing scientific evaluation, integrating operations, and ensuring the legacy of the programme (databases, publications, core repositories) at the international level. It is contracted to manage the SOCs, but has no control over the POCs.

For the future, three models can be explored:

- strong central management, with central funding;
- limited central management, with limited central funding;
- no central management.

It was clear from the discussions during the session that some integration is necessary. This requires an umbrella body with a clear mandate.

The workshop also concluded that continuous (year-round) operation is important, particularly for non riser drilling.
Whatever solution is decided, a mechanism for allocating berths among the different platforms needs to be agreed.

5 - What should be the structure of the New Science Plan ?

The New Science Plan must emphasise "the Big Picture" of science relevant to society.
It should be an enabling document, not closed to any new, significant science that should arise, and it should assume that all types of drilling platforms are available. The Science Plan should also document potential mission opportunities. Missions should not necessarily be big projects requesting to commit big funding and extensive ship time. They should address key science questions endorsed by the science community and that the programme wants to investigate and solve as a priority.
In parallel to the Science Plan, a separate Implementation Plan should describe how to prioritise missions. It should be developed with co-funding options considered. It is important to realise that implementation of missions will depend on a wide range of factors (e.g., logistics of the ships, funding, progress in technology, partnerships). Therefore, the Implementation Plan should be flexible.

6 - What should happen to existing proposals ?

There are currently more than a hundred proposals in the IODP system, and more than twenty currently reside at the Operation Task Force awaiting implementation. Given the remaining opportunities for drilling, only a fraction of them will be implemented before the end of the IODP in 2013. In parallel, to ensure that new ideas can be evaluated by the programme, scientists have been encouraged to submit new proposals.
The New Drilling Programme will have a New Science Plan, but key topics within the existing ISP will likely remain. The question of what to do with existing proposals needs therefore to be addressed.
The current SAS should take a first step towards preparing for the future. It must be more forceful in rejecting proposals. Although a major measure of the health of a programme is proposal pressure, it is important not to encourage scientists to resubmit proposals if their proposal is not of sufficient scientific quality to be implemented. The current nurturing process has reached its limit.
The preferred solution would be to start afresh, to clearly convey that it is a new programme. Proponents of existing highly ranked proposals that fit into the New Science Plan should be encouraged to resubmit in the new system. New topics should be mentored by a workshop approach.
A major question concerns the transition period. If the programme immediately succeeds the IODP, some projects need to be ready to go. Therefore, guidelines for submitting proposals need to be set up well before the new programme is agreed (in 2011 at the latest).

Session 2: Emerging Fields/New Topics
Sub-Session A: Solid Earth and Geohazards

Session participants: *W. Bach (co-Chair), J. Behrmann (co-Chair), D. Teagle (co-Chair), M. Andreani, D. Aslanian, A. Camerlenghi, A. Delacour, L. Desantis, H. Dypvik, J. Geldmacher, M. Godard, B. Ildefonse, J. Lissenberg, C. MacLeod, M. Moulin and R. Urgeles-Esclasans.*

Introductory remarks

This session, charged with outlining 'Emerging Fields' for future scientific ocean drilling, principally comprised scientists with lithospheric, tectonic, biogeochemical and geohazards perspectives. It was accepted that there are many important aspects of the IODP Initial Science Plan, with scientifically well advanced proposals, that have yet to be addressed by drilling in Phase 1 of the IODP (e.g., Monsoon records, 21st Century MoHole). Such topics were not discussed in this session under the understanding that important aspects will continue to feature in future planning documents and that the associated proponents will robustly continue with the pursuit of long term science goals.
The following key points were assumed to be necessary by the Working Group:

- Any future Science Plan will have to be a **flexible**, inclusive document that advertises the current "State of the Art" of scientific understanding rather than being a rigid, exclusive, and constraining document. Flexibility, for which a mechanism of periodic revision needs to be created, will allow new science themes and changing priorities to develop within the lifetime of the Science Plan.
- The future programme must be **open to new ideas** (e.g., geo-hazards, that are poorly represented in the present ISP).
- Scientific ocean drilling is one of the most successful international research programmes and must continue to have a true **global reach**. Member groups should avoid promoting regional interests unless these can be objectively justified.
- This requires that **all drilling technologies** be able to be deployed to wherever the best targets to solve scientific issues occur.
- It was felt that it is important to '**integrate**' scientific ocean drilling in terms of **science** as well as **management**, to improve efficiency and add great value to the operations of expensive resources in rarely visited remote regions (e.g., shallow basement drilling in paleoclimate sites). At times this may require greater top-down science planning. Nevertheless such an approach could be acceptable to the scientific community at large, provided it is transparent, well informed, thoroughly objective and truly independent.

Emerging themes

The emerging themes discussed can be clustered under five principal headings:

1) Planetary Cycles,
2) Sustainable use of the sub-seafloor as a resource,
3) Geohazards,
4) Extreme Events,
5) Experimentation with the seafloor.

These headings will be discussed in turn and there are clear linkages between these themes as well as other topics discussed during Session 2B.

1) Planetary Cycles

This theme concerns the exchanges and interlinked feedbacks between the major Earth reservoirs (crust, mantle, biosphere, hydrosphere and atmosphere).

- **The Serpentinite Sea** *(Figure 1)*

Serpentinite-hosted hydrothermal systems are one of the most exciting discoveries of the past decade. It is now increasingly recognised that serpentinised mantle peridotites make up a significant proportion of the ocean floor, particularly along slow spreading ridges and at the intersections between active ridge axes and transform faults (20-25%). Serpentinised mantle peridotites also occur on rifted continental margins (e.g., Iberian-Newfoundland margins) as well as in fore-arc settings (e.g., serpentine mud-volcanoes in Marianas Fore-arc).

The low density and shear strength of serpentine minerals has a profound effect on the mechanical behaviour at the scale of active and passive plate margins, in an intimate interplay between tectonics and hydrology in these environments. The hydration and serpentinisation of olivine and pyroxene that comprise the ultramafic rocks of the upper mantle is exothermic, lending partial energy support to hydrothermal circulation and chemical reaction. The highly reduced nature of these rocks can lead to the production of hydrogen (H_2) and abiotically generated hydrocarbons (e.g., methane). Fluid-rock interactions lead to unusual, very high pH (>10) fluids and the precipitation of carbonate hydrothermal mounds and chimneys. These unusual environments host microbial communities, that are adapted to conditions that possibly mimic those of the early Earth and other planetary bodies (e.g., Europa). Mantle rocks exposed at the seafloor constitute a potentially important CO_2 sink. The precipitation of carbonate minerals following reaction with ocean-floor peridotites has been suggested as a possible mechanism for the solid sequestration of carbon dioxide.

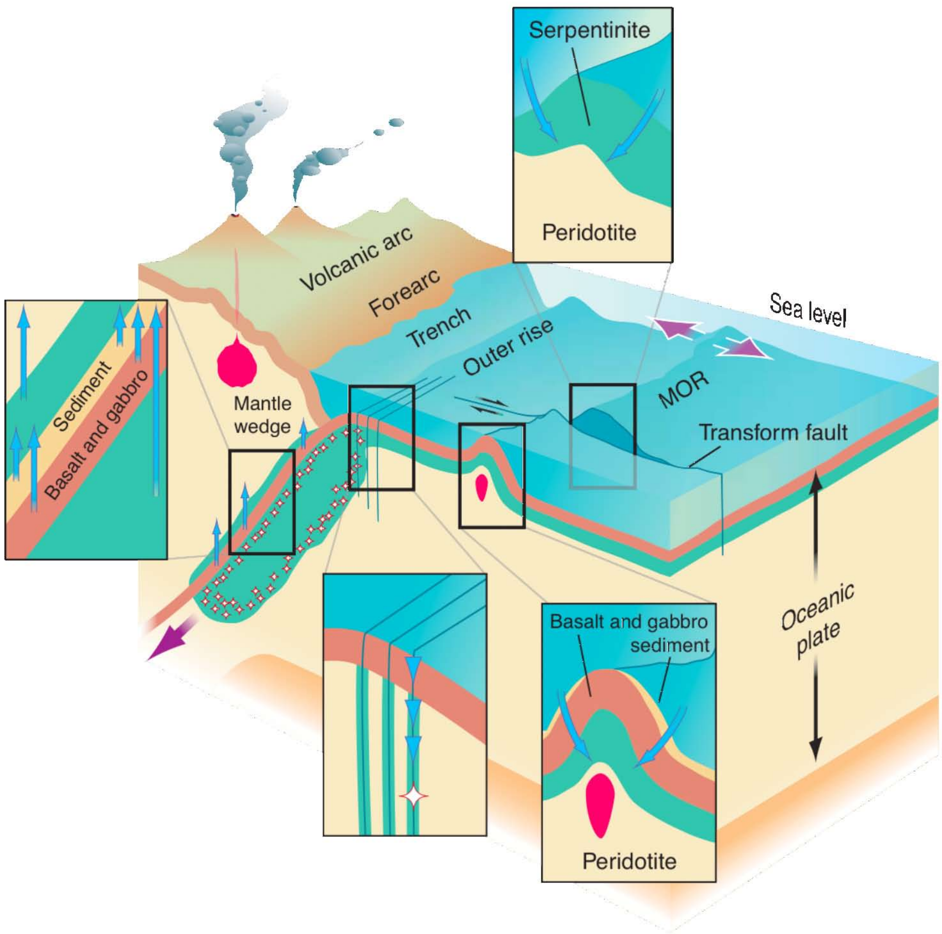


Figure 1. Serpentinisation is a common process that affects the Earth's water cycle, the deep biosphere, and seismogenesis (Source : Kerrick, D. Science 298, 1344-1345, 2002).

- **Integrated Earth System Approach**

There is need for greater synergy between efforts to understand and quantify exchanges between the major Earth reservoirs and close the gap between studies of geochemical and biogeochemical approaches. The youth (< 200 Ma), unradiogenic nature and relatively homogeneous composition of crust formed at the mid-ocean ridges compared to the old and complicated geology of the continents, provides an opportunity to define one end member for a number of important elemental (e.g., C, S, Mg, K) and isotopic (e.g., Sr, Os, Tl) global chemical cycles reflected by the evolving composition of seawater. Efforts to date, however, have been hamstrung by a paucity of deep holes into the ocean crust, an absence of penetrations into early Tertiary and Cretaceous age ocean crust, poor and unrepresentative core recovery, and nascent core-wireline logging integration techniques. For example there are virtually no drill holes more than 100 m into intact ocean crust older than 15 Ma, despite discernible hydrothermal convection occurring out to 65 Ma on average, the age of average ocean crust being ~65 Ma, and the average age of subducting ocean crust ~73 Ma. Because seawater conditions and compositions may have been very different in the Mesozoic to the Tertiary it is important to sample with deep (~500 m?) drilling Paleogene ocean crust that has fully matured due to prolonged hydrothermal circulation. Paleogene sediments are common targets for paleoclimate studies because the Paleocene-Eocene is a period in Earth's history when our planet for the last time experienced concentrations of atmospheric CO_2 similar to those estimated to result from the continued burning of fossil hydrocarbons on modern Earth. Such sites would also be of great interest for microbial and geochemical crustal experiments. In current IODP drilling, however, holes addressing paleoclimate objectives are rarely extended to any significant depth into basement.

To date most efforts to understand and quantify exchanges between the oceanic basement and seawater have concentrated on crust formed at normal mid-ocean ridges in major ocean basins. However, crust formed and altered in forearcs and back arc basins make up ~10% of the Earth's surface and evidence to date indicates that these sites are subjected to different tectonic and magmatic processes, and intensities of alteration relative to mid-ocean ridge derived basement. Contrasting magma types and the presence of vast amounts of subduction-derived fluids and volatiles leads to highly variable styles of hydrothermal alteration, mineralisation and biological communities. To date fore-arc and back-arc crust of convergent plate margins as well as their associated hydrothermal vent systems remain greatly under-sampled and under-investigated. Mineralisation and alteration related objectives here could be excellent targets for seabed drilling-type drilling operations.

Similarly, there has been little attention towards investigating processes of intra-plate volcanism or deformation. Seamount chains provide important constraints on mantle dynamics and polar wander, and their architecture and hydrogeology may make important contributions to some global chemical cycles. Importantly some seamounts provide basement ventilation through the sedimentary blanket that allows the ingress and egress of hydrothermal fluids on the vast ridge flanks. The vigour, transit distances, chemical changes and significance of these systems remain unquantified. Other volcanism in the ocean basement appears unrelated to either the standard Wilson cycle or mantle plumes (e.g., Line Islands in Western Pacific, seamounts east of Mariana Trench). Although, progress could be made through rock dredging and high-resolution seabed mapping, ocean drilling will play a key role in the investigation of such systems.

- **Climate and tectonics**

There are recognised feedbacks between climate and tectonics, with the uplift of mountain belts greatly influencing the major climate patterns (e.g., growth of the Himalaya and Asian monsoons). Conversely asymmetric weather and climate patterns control the cross-sectional shape of mountain ranges, leading to rapid tectonic uplift and denudation on the windward sides.

The first feature can be analysed by deep drilling of depositional fans, to yield high-resolution records of uplift and erosion, and the resulting changes in globally significant climate systems. Similarly, changes in

sediment characteristics over time can be used to establish the initiation of uplift and establishment of rain shadows around mountain belts in convergent and collisional plate margin settings.
The second feature lends itself to application of mass balance and source-to-sink concepts of study, which will not be successful without deep-ocean scientific drilling. There are a number of well regarded drilling proposals presently residing within the IODP science advisory structure but the pursuit of this topic of great societal relevance has not moved forward at an adequate pace or scale.

2) Sustainable use of the subseafloor as a resource

The seafloor provides both resource opportunities but also unique geological and biological environments that are yet to be understood and may need protection from unfettered exploitation. Some resources (e.g., gas hydrates) have major associated geohazards and detrimental climate feedbacks.

- **Gas Hydrates**

The formation processes, stability, distribution, and response to climate change of submarine gas hydrates all remain poorly understood and with increasing need for quantification. Although bottom-simulating reflectors are commonly associated with gas hydrates, such regional geophysical features cannot be confidently used to estimate gas hydrate resources without associated drilling. Gas hydrates most commonly occur on continental margins. Although the P-T phase diagram is well established by experimental data, the extent and stability of gas hydrates on continental slopes, and the response to the documented warming of oceanic bottom waters is poorly understood. Irrespective of whether this relates to changes at the end of the recent glacial cycle, or to even more recent changes, the possibility of destabilisation of large regions of continental margin sediments with resulting tsunami hazard remains of serious concern.

Regarding deep sources of methane-bearing fluids, the slow leakage at mud volcanoes and cold vents supports microbial and macrofaunal communities, and rising fluids provide windows for investigation of deep diagenetic and metamorphic processes. Importantly, methane is a potent green house gas, and catastrophic release of very large quantities of methane due to the destabilisation of gas hydrates on continental margins has greatly impacted past climate and would further exacerbate current warming trends associated with anthropogenic fossil fuel consumption. In the Arctic regions, where the changing climate is particularly evident in the warming of deep and intermediate water as well as in the melting of permafrost, natural methane gas emissions are expected to increase dramatically also as methane hydrate phase change both in the sub-seafloor and on the continent. Flooding of low lying land as a consequence of sea-level rise would result in the very rapid and significant temperature change leading to the melting of the permafrost and potentially the release of methane and other gases presently trapped beneath the impermeable permafrost. An integrated investigation of the stability of permafrost at the Arctic continental margin through to the response of deep water gas hydrates on the associated continental shelf would form an excellent opportunity to collaboratively link research IODP-ICDP in a field of investigation of great societal relevance.

- **Deep-sea mining of base and precious metals**

Previous scientific drilling of seafloor hydrothermal fields (e.g., TAG, Middle Valley, PacManus) has provided great insight into the operation of these systems. These are active analogues of major mineral resources preserved on land and nowadays exploited to supply industry. Demand for commodities continues to grow due to the development of China and India with concomitant increase in base-metal mining and processes. This may make the exploitation of metals from active hydrothermal systems economically viable. Large areas of the south-western Pacific Ocean have already been staked by seafloor mining companies (e.g., Neptune Minerals Co., Nautilus Minerals Inc.), with mining to possibly commence as early as 2010. Although deep-sea mining will extract required resources, it potentially could greatly damage or obliterate highly variable, poorly understood mineralisation systems, and associated unique micro- and macro-biological communities before many of these phenomena are even identified, let alone understood. These hydrothermal systems cannot be understood by surface observations and sampling alone, because many of the fluid mixing and mineralisation processes occur in the sub-surface. Shallow (10s m) drilling using seabed drills and deeper (10-100s m) drilling using the *JOIDES Resolution*, coupled with detailed site survey and fluid sampling would greatly enhance our understanding of these systems and communities. Such investigations could provide industry with improved exploration vectors, better grade control, and provide predictive models that will minimise the impact of deep-sea mining on these fragile submarine ecosystems.

- **Carbon Sequestration**

At present there is significant societal, industrial and governmental interest in the capture and sequestration of carbon dioxide generated during production of electricity, industrial processes and human transport. Most industrial efforts made today are focussed on pumping CO_2 into exhausted hydrocarbon reservoirs. Alternative approaches for CO_2 sequestration and storage include the use of submarine gas hydrate reservoirs in the deep offshore. CO_2 may be stored within the clathrate structures, in which it replaces CH_4 that could be extracted by mining. Success of this approach depends largely on improved petrophysical and geotechnical characterisation of prototype gas hydrate reservoirs – an objective that is critically dependent on drilling.
Another opportunity for long-term storage of CO_2 are seafloor hydrothermal systems that show evidence of large-scale precipitation of carbonate minerals. Some calcium carbonate precipitation occurs on the mid-ocean ridge flanks through reaction between dissolved HCO_3^- and Ca^{2+} liberated from the seawater alteration of basaltic minerals and glass. Additionally, serpentinite-hosted hydrothermal systems precipitate carbonate minerals as evidenced in ophicalcite (carbonate-cemented serpentinite breccia), common in the geological record. Drilling ancient systems on-land and into active systems on the ocean floor could lead to better understanding of the heat sources and reaction processes of these systems. Potentially the processes occurring on the ridge flanks or within exposed ocean floor peridotites could be enhanced to improve the sequestration efficiency.

3) Geohazards

The IODP Initial Science Plan expiring in 2013 does not address openly geohazards among the program scientific objectives. Hazards are referred to mainly in relation to earthquakes and initiatives towards the understanding of seismogenesis. Notably, the only drilling initiative presently under way is the multi-platform drilling of the Nankai Seismogenic Zone.

Natural submarine geohazards (earthquakes, volcanic eruptions, landslides, volcanic island flank collapses) are geological phenomena originating at or below the seafloor *(Figure 2)* leading to a situation of risk for off-shore and on-shore structures and the coastal population. Addressing submarine geohazards means understanding their spatial and temporal variability, the pre-conditioning factors, their triggers, and the physical processes that control their evolution. Such scientific endeavour is nowadays considered by a large sector of the international scientific community as an obligation in order to contribute to the mitigation of the potentially destructive societal effects of submarine geohazards.

The study of submarine geohazards requires a multi-disciplinary scientific approach:

- Geohazards must be studied through their geological record,
- Active processes must be monitored,
- Geohazard evolution must be modelled.

Ultimately, the information must be used for the assessment of vulnerability, risk analysis, and development of mitigation strategies.

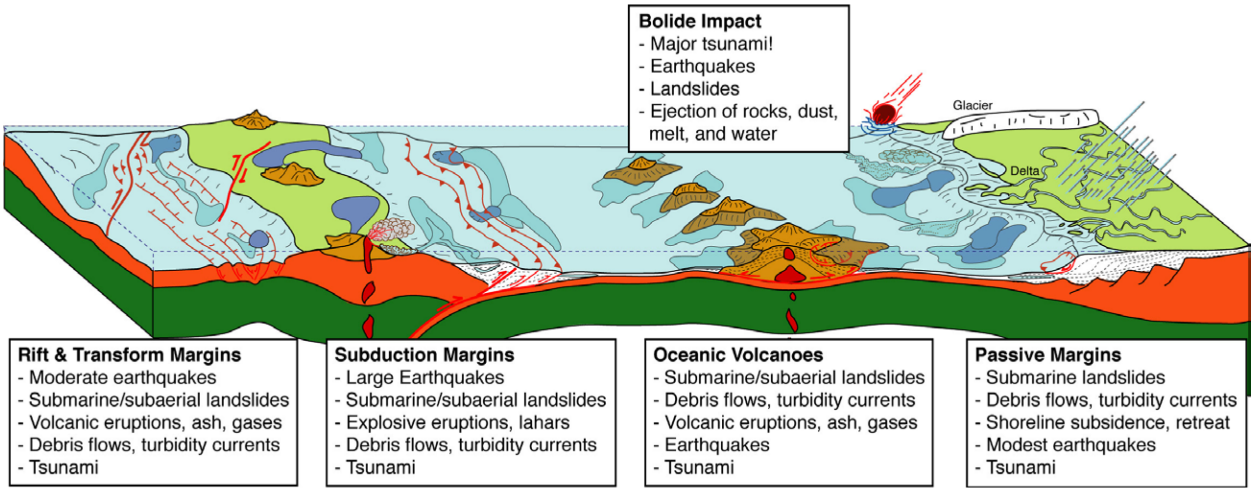


Figure 2. Geologic settings in which oceanic geohazards may be generated (after Morgan et al., Scientific Drilling No.7, March 2009, pp. 15-31).

Scientific drilling through the IODP (including the related pre site-survey investigations, sampling, logging and in-situ measurements capability, and as a platform for deployment of long-term observatories at the surface and downhole) can be viewed as the centre of gravity of an international, coordinated, multi-disciplinary scientific approach to address submarine geohazards.

Within the global-ocean geohazards, worth of note is the attention given in this preparatory phase to submarine geohazards in the European continental margin including the Arctic. More specifcally, due to the combination of abundance and diversity of geohazards (earthquakes, vocanic islands, submarine landslides) and high concentration of anthropogenic activity and population, the Mediterranean Sea is a highly vulnerable region and can be viewed as a natural laboratory for the study of submarine geohazards. This provides potential opportunities for IODP to tackle hazards of global importance of direct societal relevance to Europe and provides clear opportunities for co-mingling IODP, ICDP and EU research priorities.

The rate of change of sea-level and sea-level response to changes in the Earth system remain poorly constrained and badly represented in many of the climate models that are currently used to inform policy makers. Sea-level investigations have been high on the agenda in the initial phase of the IODP but principally from paleoclimate perspectives. Establishing the rapidity of past sea-level rise and the causes are essential for assessing the risks associated with the present global climate change.

4) Extreme Events

In contrast to geohazards, extreme events can be defined as geologically rare events of global significance, such as extraterrestrial impacts (on land and sea), super earthquakes and super volcanic eruptions. The latter two types are known to have affected plate margins (like the 1960 M=9.5 Chile earthquake; or the 93,000 b.p. Los Chocoyos eruption in Central America, to quote two young examples). So far, many of such events remain undetected and undocumented due to the fragmentary spatial and temporal record of scientific ocean drilling. Generally, drilling is required to both understand the processes and quantify the consequences of such extreme events, but also to use the debris/geological effects resulting from such events as global timelines to calibrate the geologic time scale. Impact craters, of which there are many in the oceans, are a new scientific target (e.g. the Svalbard ICDP Workshop on the Mjønir impact structure in the Barents Sea). Objectives are drilling into the impact structure to understand cratering processes themselves, and further drilling to investigate far-field environmental effects related to the impact.

Extreme events capture the public and media imagination in a unique way, and provide intense outreach opportunities to further engage the general public in the scientific investigation of the processes that have formed our planet and the oceans, and how life has evolved.

5) Experimentation with the seafloor (Figure 3)

Expeditions in connection with scientific ocean drilling increasingly make use of boreholes for the collection of long-term observational data. This approach often requires new types of well design, substantial engineering development, and the possibility to revisit sites, recover data, carry out servicing and repair of installations, or reenter boreholes in order to replace or upgrade installations. Future promising and desirable developments include the connection of sub-seafloor borehole observatories to seabed cable installations, for energy supply and recovery of data in real time. Also, the performance of long-term perturbation (e.g., push-pull experiments) and in situ incubation experiments in sub-seafloor systems can be envisaged as a goal. This is instrumental for understanding the extent and rates of microbiological activity in rocks, or shed light on diagenetic and alteration processes in a wide range of environments.

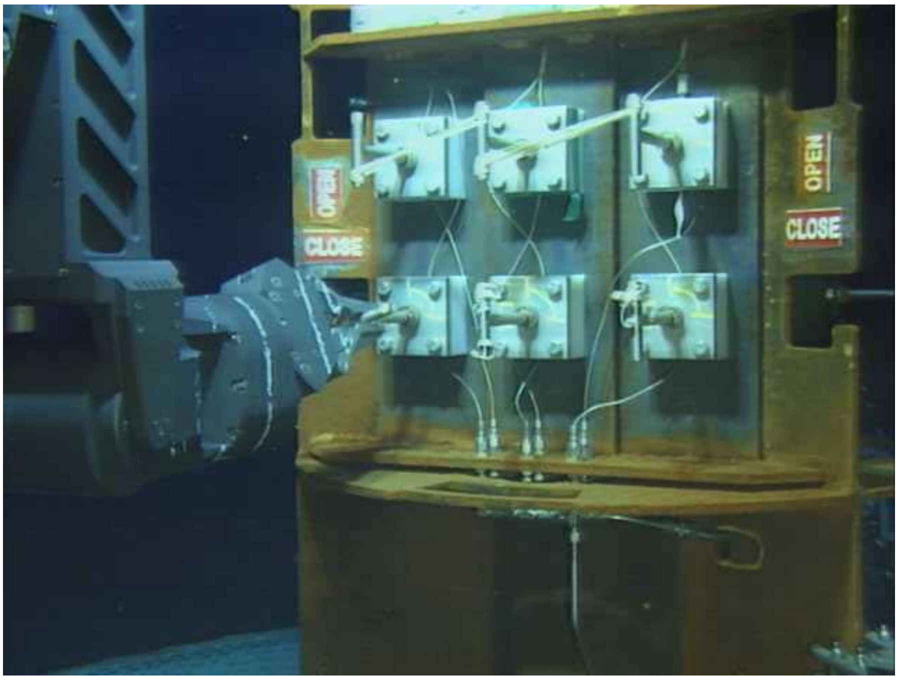


Figure 3. CORK observatory at the eastern flank of the Juan de Fuca Ridge. A remotely operated vehicle opens valves to retrieve fluid samples from a basaltic aquifer. (Photo by Geoff Wheat.).

Session 2: Emerging Fields/New Topics
Sub-Session B: Environment and Deep Biosphere

Session participants: *H. Brinkhuis (co-Chair), J. McKenzie (co-Chair), K. Alain, B. De Mol, L. Desantis, H. Dypvik, A. Foubert, G. Gennari, C. Gorini, J.-P. Henriet, K. Husum, C. John, N. Khélifi, J. Lofi, K. Mangelsdorf, W. Piller, M. Rabineau, J. Raddatz, U. Roehl, A. Rueggeberg, M. Sarnthein, V. Spiess, R. Stein, C. Stickley, B. Teichert, A. Voelker and M. Wagreich.*

Introductory remarks

The Session 2B was charged with outlining 'Emerging Fields' for future scientific ocean drilling and principally comprised scientists with microbiological ('deep biosphere') and/or palaeoenvironmental and biogeochemical ('exogenic') perspectives.
We identified one overarching goal with regard to any new science plan, viz. 'Quantifying system Earth: determining tipping points and gradualism in Earth's history'.
Besides the generalities reported on by the Session 2A, which we touched on and discussed as well, the following key points are considered to be important prerequisites by the Session 2B:

- The records generated by the new drilling programme should allow quantified parameters suitable for model-data comparison.
- The new programme should generate high-resolution, continuous, quantitative records of relevant global biogeochemical cycles.
- The new programme should focus on portrayal of past extreme climates at sub centennial resolution.
- The new programme could potentially also be using larger core diameters, selection of key sites, meridional transects coming from CCMs.

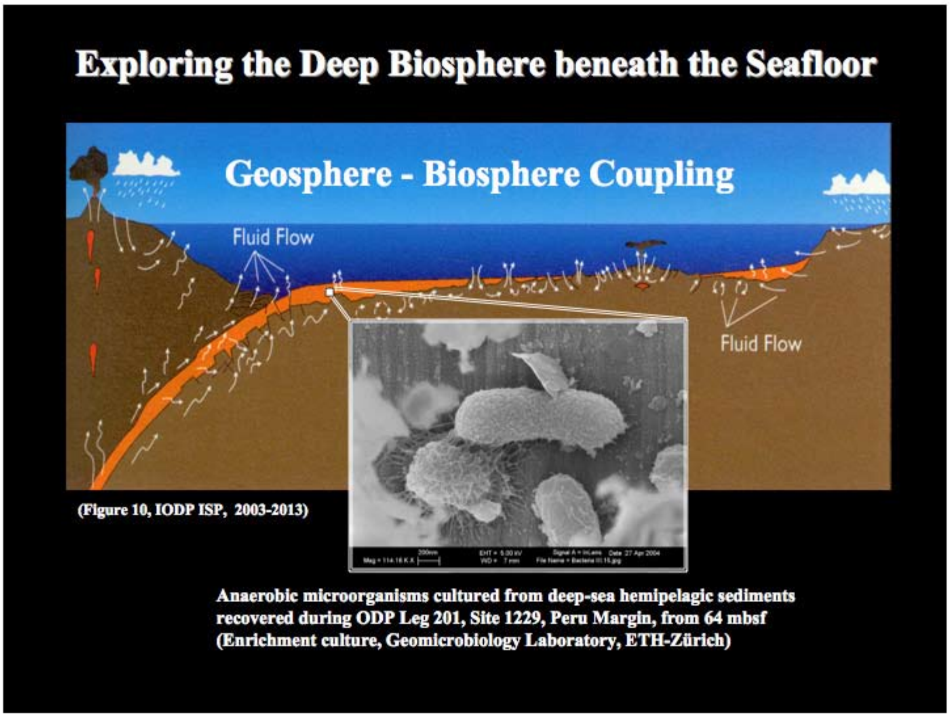
Emerging themes

The emerging themes discussed within Session 2B are subdivided into two basic categories:

1) Deep Biosphere and Subseafloor Ocean,
2) Exogenic Processes and Biogeochemical Cycles

1) Deep Biosphere and Subseafloor Ocean: Dynamics, Interactions and Consequences of Subseafloor Biotic and Abiotic Systems

One of the three main research themes identified in the IODP Initial Science Plan 2003-2013 was the study of the biosphere living within the subseafloor ocean found circulating in all geographic regions of the world's oceans.
Within the current IODP, the study of the deep biosphere has been limited, but highly ranked drilling proposals dedicated to the deep biosphere exist, such as 662-Full 'Southwest Pacific Gyre Microbiology' and 677-Full 'Mid-Atlantic Ridge Microbiology', and will hopefully be drilled before the end of the program.
To achieve continued progress in the field of deep biosphere research, the theme must be included with high priority in the post-2013 scientific drilling plan, e.g. as outlined in the following four subthemes and natural laboratory proposal.



- Sub-theme 1. Microbiology, (deep) subsurface fluids and biogeochemical cycling, and (paleo) ecologic monitoring

To date, most, if not all, of the questions pertaining to the deep subsurface biosphere outlined in the IODP Initial Science Plan 2003-2013 remain unanswered or even unaddressed.

Exploration of the deep subsurface biosphere requires the active engagement of the geomicrobiology community to help design and initiate relevant drilling programmes. In particular, a routine microbiology programme of measurements and sample collection must be established if progress is to be achieved in our understanding of the extent and nature of the population present within the subseafloor sediments and crust.

Fundamental questions and topics of interest include:

- Limits of life in terms of physico-chemical constraints, habitability, etc;
- Origin, evolution and dispersal of micro-organisms, including viruses,
- Quantification of geosphere-biosphere interaction processes,
- Populations (nature of communities), processes (metabolism at starvation conditions) and products (geological expressions),
- Carbon and energy sources in the deep subsurface.

- Sub-theme 2. New insights in controls on carbonate factories (cold/warm) past and present, and relationships to the carbon cycle

Recently, the discovery of cold-water carbonate mound systems, supporting cold-water coral ecosystems, has added a new dimension to the concept of carbonate factories, serving as a complementary counterpart to warm-water carbonate build-ups. The widespread occurrence of these deep-water structures presents a challenge to understand their development and preservation and possible importance in the geologic record.

Research into these deep-water ecosytems is still at an early stage and will require ocean drilling to fully explore their potential importance for the global carbon cycle.

Topics of interest include:

- Interactions between fluids and deep carbonates through time (carbonate precipitation - dissolution),
- Diagenetic pathways : from early to late diagenetic processes;
- Microbially-driven diagenetic processes,
- The impact of diagenetic processes on paleoenvironmental records,
- Microbiolites – stromatolites: link to early life?

- Sub-theme 3. Controls and feedbacks of terrestrial and marine methane emissions

Advancement in our understanding of marine methane hydrates has been a major achievement of ocean drilling and has demonstrated the critical importance of subseafloor hydrogeologic processes in their formation.

Methane hydrates studies require a multidisciplinary approach with the integration of hydrogeology and microbiology. These investigations in both terrestrial and marine environments link the study of the geosphere to the biosphere in the evaluation of such diverse topics as climate change, geohazards and potential energy supplies.

Topics of interest include:

- The quantification of methane occurrences,
- The impact of global warming on methane hydrate along continental margins and permafrost regions and the feedback on global climate and ecosystems,
- Link to ICDP,
- Industry-Academic links.

- Sub-theme 4. Critical monitoring and evaluation the (dynamics of) storage of greenhouse gases

Carbon dioxide capture and storage in deep subseafloor reservoirs is an actuality and will undoubtedly increase in the future. Marine research drilling can provide essential knowledge of the hydrogeology, geochemistry and microbiology of these reservoirs, which will be useful to monitor and predict the potential effects of introducing carbon dioxide into the subseafloor ecosystems.

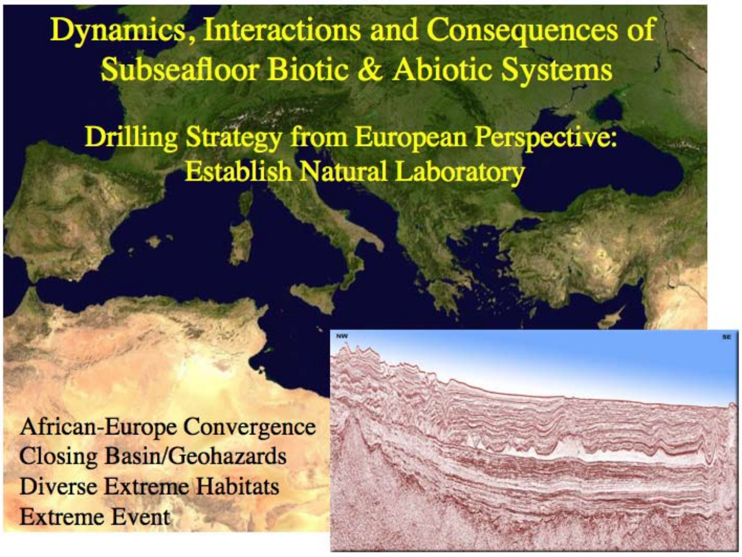
Topics of interest include:

- The possible impacts of greenhouse gas storage on ecosystems as learned from other drilling experiments,
- Industry-Academic links

- New Drilling Strategy from European Perspective: To Establish a Natural Laboratory in a Convergence Zone with Basin Closure

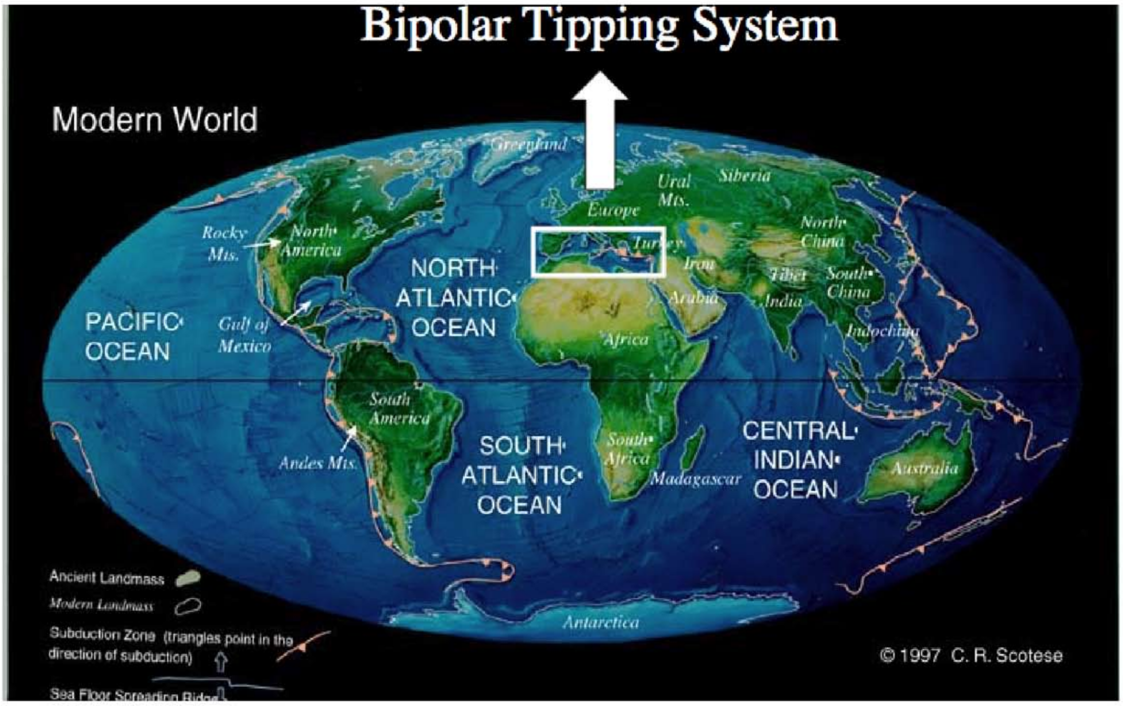
The Mediterranean Sea, a young basin with a high-resolution record, is strategically located at a "bipolar tipping point" at Fulcrum Point between the Arctic and Antarctic regions and potentially holds keys to trace past climate change on decadal to centennial scales. Its tectonic setting is ideal to study active geologic processes linking hydrogeology and microbiologic phenomenon in the subsurface. Thus, the Mediterranean is an ideal area in which to study the following important scientific and societal relevant topics:

- Deep biosphere and subseafloor oceans in a convergent marine system, e.g., exploration of carbonate mounds/mud volcanoes associated with vigorous gas and fluid escapes,
- Geohazards on dynamic active margins,
- Link to ICDP – Source to sink approach,
- Region of rapid and extreme climate change, particular sub-century (rapid) changes in ocean circulation and hydrosphere,
- Messinian Salinity Crisis – extreme geologic event offering an extreme DBH.



The instrumentation of that natural subseafloor laboratory in the Mediterranean realm would involve:

- The installation of a subseafloor microbial observatory in subsalt formations, and the remote study of microorganisms and their products in ultra-extreme environment,
- The monitoring of biotic/abiotic processes in a deep hole in young basin with variable sedimentary sequence,
- The drilling through the Messinian evaporite which would require a multiplatform approach, particularly a riser drillship (*Chikyu*) to penetrate and core through the salt.

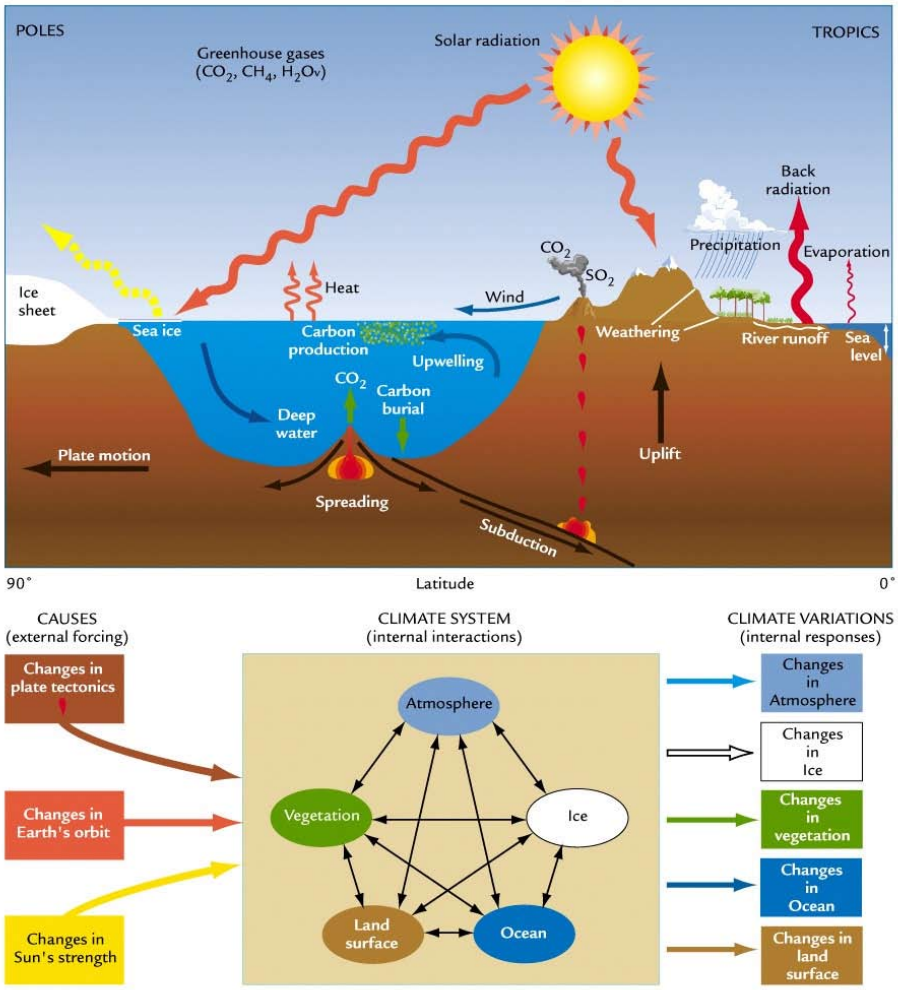


2) Exogenic Processes and Biogeochemical Cycles

Four emerging sub-themes have been identified:

- Dynamics of the carbon cycle – source to sink,
- Darwin in the ocean,
- Dynamics of Polar regions and climate impacts,
- Probing unique cases, extreme events and oscillations.

These headings will be discussed in turn and there are clear linkages between these sub-themes as well as other topics discussed during the sessions 2B and 2A, as illustrated by the following figure. Critical and unknown regions have been identified and include: the Artic Ocean, the Antarctic and the Southern Ocean, the East African and the East South American margins, the subsalt Mediterranean and critical marine fan systems, e.g., Indus.



- Sub-theme 1. Dynamics of the carbon cycle – source to sink

There is need for greater synergy between efforts to understand and quantify exchanges between the major Earth reservoirs and close the gap between studies of geochemical and biogeochemical approaches. Particularly prominent should be efforts to monitor the dynamics of the Carbon cycle, from source to sink. Besides obtaining critical knowledge of potential sources like volcanism, hydrates, etc., such would also include studying the feedbacks between climate, weathering, and tectonics, with e.g., the uplift of mountain belts greatly influencing the major climate patterns (e.g., rise of the Himalayas, and intensification of the Asian monsoons). It should be noted that already, there are a number of well regarded drilling proposals presently residing within the IODP science advisory structure but the pursuit of this topic of great societal relevance has alas not moved forward at an adequate pace or scale.

Another important issue is the necessity to generate more, highly resolved, millennial scale atmospheric CO_2 records using the novel technologies locked in, e.g. Boron isotope and biomarker analysis. Equally important is to better constrain the biological factors involved, and to enhance our understanding of the greenhouse-icehouse transition, including high priority areas like the Antarctic and the Arctic.

In summary, these key issues can be formulated as follows: *Generating quantitative records of the evolving carbon cycle and other relevant global biogeochemical cycles, processes, and related biotic and climate response – sources to sinks.*

Potential targets include:

- The reconstruction of atmospheric CO_2 on millennial timescales past 120 Ma,
- Causes and consequences of Ocean acidification,
- Eukaryotic biota and biogeochemical cycling in space and time,
- New approaches regarding the mechanisms underlying sea-level change,
- The use of improved geochronology/timescales to better understand biotic evolution,
- The dynamics of Polar regions: controls, feedbacks,
- Portraying extreme climate change sub century scale, inclunding the Paleocene-Eocene Thermal Maximum (PETM),
- Source to sink: siliciclastic sedimentary systems and carbon cycle dynamics,
- Short and long-term effects of impact cratering,
- New insights in controls on carbonate factories (cold/warm) past and present, and relationship to the carbon cycle (high carb – low carb diets),
- Marine overturning and the reconstruction of carbon cycles on short timescales,
- Role of organic matter sequestration vs weathering,
- Sources of CO_2 : volcanism, gas hydrates, vs other sources.

- Sub-theme 2. Darwin in the ocean

Besides the items discussed above, and in addition to the need to quantify and better constrain the dynamics of the roles of eukaryotic biota in past oceans, including productivity, nutrients, etc., and related biogeochemical cycles, there is the issue of gaining critical knowledge on biotic evolution, and e.g., dispersal of biota, biogeography, etc.

Now, and only through IODP, there is the potential to retrieve, recognise, and precisely date first and last occurrences of particular biotic groups (typically calcareous, siliceous or organic-walled microplankton), and therefore begin to basically map cases of evolving and dispersal of species, particularly marine biota, but potentially even including evolution of continental life, through e.g., palynology. Some of the thus generated topics are very much in the public eye, like e.g., relationships between Human evolution and central African tectonic and climatic evolution.

In summary, we formulated this key issue as: *Temporal and Spatial evidence of 'Darwin in the Ocean'; reconstructing biotic evolution and biodiversity.*

Potential targets include:

- Improved geochronology,
- Paleogeographic reconstruction,
- The Human Evolution and Africa – links to increased amplitude of climate variability in the past,
- Biotic response to extreme climate transitions (e.g., KTB, PETM, EOB).

- Sub-theme 3. Dynamics of Polar regions and climate impacts

There is an urgent need to enhance our understanding of the greenhouse-icehouse transition, and in particular to gain better insight in the dynamics of climatic sensitive, and important regions like the Antarctic and the Arctic.

IODP is perhaps the only means available to generate long-term archives of the history, evolution and dynamics of the Polar regions. The so far available DSDP/ODP/IODP database is extremely limited, and of too low-resolution to allow for accurate, high-resolution reconstruction of Polar climates and environments. Although we applaud IODP's achievements in the Arctic, and the planned expedition to Wilkes Land – vast areas are still unknown.

In summary, we formulated this key issue as: *The Dynamics of the Polar regions; reconstructing high latitude climates and links to global change*.

Potential targets include:

- Bipolar linkages,
- Arctic and Antarctic as amplifier and response to global climates,
- Impact of ice sheet and sea ice changes on ecosystems and climate feedbacks,
- New approaches regarding the mechanisms underlying sea-level changes.

- Sub-theme 4. Probing unique cases, events and oscillations

There is a need to improve our understanding of unique episodes of Earth's history – probing unique cases, and/or 'extreme events' (defined as geologically rare events of global significance, such as extraterrestrial impacts, on land and sea), super earthquakes and super volcanic eruptions (see also Session 2A 'Solid Earth and Geohazards').

Extreme events capture the public and media imagination in a unique way, and provide intense outreach opportunities to further engage the general public in the scientific investigation of the processes that have formed our planet and the oceans, and how life has evolved.

In summary, we formulated this key issue as: *Probing unique cases, events and oscillations – applying new approaches, new tools*.

Session 3: The New Drilling Programme and its Relations to Industry and Other Research Programmes

Session participants: *U. Harms (co-Chair), R. Schneider (co-Chair), S. Davies, H. Dypvik, H. Gaonac'h, M. Hovland, T. Johnson, F. Rack and A. Voelker.*

Introductory Remarks

The Integrated Ocean Drilling Program and its predecessors are outstanding examples of pioneering scientific discoveries, international cooperation, and ground-breaking scientific and technical operations.
The research topics addressed and the operational capabilities attract interest in cooperation with both, industry and research programmes with similar goals and needs. Furthermore, the ocean drilling program created unprecedented expertise, human resources, and fed scientific curiosity serving science and industry at large.

Relationship to Industry

The New Drilling Programme should be set up very flexible to allow for various kinds of co-funding for joint drilling targets/projects and technology development through industry groups and firms. In the early 1980's, for example, the national oil company of Norway, sponsored the Norwegian Research administration to secure Norway's membership in ODP. Today, academic institutions are organised differently and are often administered through large systems. Similar structures also occur in the industry. If a joint investigation has to be performed, several companies get together and form a Joint Industry Project (JIP), as they have done to solve problems within gas hydrate research. However, if the New Drilling Programme is going to become part of systems like these JIPs, it has to choose fields that are interesting and prospective for the industry. This may comprise topics such as:

- Resources, drilling, and logistics in polar regions,
- Unconventional energy resources, i.e., geothermal heat, gas hydrates,
- The origin of deep-ocean salt,
- Hydrothermal minerals, ores, etc,
- Early generation of hydrocarbons in rifts and hydrothermal systems,
- Deep-water geohazards,
- Deep microbiology and extremophile environs (hypersaline, anoxic),
- Fluid flow through the seafloor, serpentinisation, brines and gases,
- Climate change

Different models for co-funding should be considered including:

- General co-funding of the New Drilling Programme by industry for a certain time-frame in which scientific targets and cruises are devoted to topics of specific industry interest as outlined above.
- The co-funding of individual projects by industry. An interesting model is the plan to drill the Mjölnir Impact Crater off Norway for which a proposal exists and the principle investigators are about to assure industry participation in form of operating and co-financing a suitable drillship.
- The advantage taken by Industry regarding the operational and scientific capabilities of scientific ocean drillships and the funding of single projects or missions as it has been done in the past for the operations for India. All kinds of participation of ocean drilling science may be involved as service or participation according to needs.

In any case, it will be necessary that the New Drilling Programme is capable to act in rather short time frames and is flexible with its policies and protocols taking into account industry needs such as timing, moratorium, data policy, and proprietary issues.

Relationship to Other Research Programmes

IODP's great success in the past is based on:

- Outstanding ideas and individuals driving cruises and dragging the program,
- New technical and analytical developments often brought to the program with external funding,
- The willingness to attempt exciting high-risk science which has great potential irrespective of 'rules' or 'policies',
- An outstanding science advisory with prioritised goals in themes and regions.

If the New Drilling Programme is capable to maintain this successful avenue of its predecessors, it will be extraordinarily attractive for other research programmes. Current examples of potential cooperation partners for ocean drilling are: ICDP, IMAGES, ANDRILL, PAGES, ocean observatories, and also individual initiatives in long-term or large-scale projects.

Although the New Drilling Programme must be science led, this summary does not consider scientific thematic bridges very much but rather takes into account the general and structural needs to enable active links with other research programmes which can be further developed. Key arguments in the deliberations were that the structure and management of the New Drilling Programme, as well as the policies in major funding agencies and other stake holders should have:

- Low viscosity (i.e. react fast),
- High permeability (i.e. be open for new partners),
- Great flexibility (i.e. adapt to novel needs),
- Be receptive and responsive for innovation and cooperation,
- Out-of-the box thinking (i.e. being an open system).

Instead of attempting to create top-down created linkages between the New Drilling Programme and other research programmes there should preferentially be a project by project cooperation set up. This seems to be an effective approach to start with and to elaborate possible principle pathways for longer commitments in cooperative work. While the latter is specifically valid for common scientific interest, it should also be considered to organise and stepwise built-up a resource pool including experts and tools to be used jointly with other programmes. A multi-platform ocean programme and particularly Mission-Specific Platform drilling will provide the best means for cooperation and for joint projects. In order to implement such possibilities from the very beginning of the New Drilling Programme a common access point for external relationships and exchanges should be created or should be available.

Summary

- The New Drilling Programme should allow for flexible joint technological infrastructure (tools, personnel, exchange of different platforms, knowledge transfer, engineering capacity and development).
- The advisory, planning, and decision structure of the New Drilling Programme should enable multi-platform drilling targets (incl. other platforms, observatories).
- Mission-Specific Platform operations must be included in the New Drilling Programme to ensure involvement with other research programs and to allow, e.g. land-ocean, shelf-slope, high-risk areas drilling.
- The New Drilling Programme should be able to provide funding or in kind contributions to multi-partner projects.
- The structure of the New Drilling Program should explicitly enable external links (port of entry/interface) to allow development and implementation of joint projects, missions, or expeditions.

Session 4: New Technologies and the Mission-Specific Platform Approach

Session participants: *P. Favali (co-Chair), D. McInroy (co-Chair), F. Bosch, T. Freudenthal, L. Lembke-Jene, R. Person, F. Schmidt-Scheirhorn and R. Urgeles-Esclasans.*

Introductory remarks

The first important item was to define what 'New Technologies' is, all agreed with the following definition. *'New Technologies are existing technologies currently not used in IODP and technologies that need development or to be built'.*
Then the discussion was concentrated to define the existing technologies and the technologies that need development or to be built.

Existing technologies not (enough) used in IODP

The discussions focused on the following technologies:

- Shallow penetration drilling (seafloor rock drills, 1-100 mbsf),
- Thin-wall samplers,
- In-situ CPT,
- Instruments for downhole observatories,
- Sensors in casing,
- Logging-while-drilling or other real-time data transfer (e.g. intelligent pipes).

1) Shallow penetration drilling

A variety of research targets in marine sciences including the investigation of gas hydrates, slope stability, alteration of oceanic crust, ore formation and paleoclimate can be addressed by shallow drilling. However, drillships are mostly used for deep drillings, both because the effort of building up a drill string from a drillship to the deep seafloor is tremendous and control on drill bit pressure from a movable platform and a vibrating drill string is poor especially in the upper hundred meters.
During the last decade a variety of remotely operated drill rigs have been developed, that are deployed on the seabed and operated from standard research vessels. These drill rigs reach drilling depths between 1 and 100 m. For shallow drillings remotely operated drill rigs are a cost-effective alternative to the services of drillships and have the major advantage that the drilling operations are performed from a stable platform independent of any ship movements due to waves, wind or currents.

2) Thin wall samplers

Thin wall samplers are mainly used in industry for sampling soils. They are an alternative to the use of advanced piston coring for getting nearly undisturbed samples from soft sediments when working on industrial platforms.

3) Cone Penetration Testing

The Cone Penetration Test (CPT) is conducted in order to measure the pore pressure and the resistance to penetration (cone resistance and sleeve friction) of a cone that is pushed into the ground. This in-situ test allows the analysis of the physical and mechanical properties of the subsurface strata and is widely used in geotechnics.
Generally two different modes exist to deploy a CPT in the deep sea:

- The down-the-hole-mode is used from drilling vessels and the cone penetrometer is pushed into the ground at the bottom of the drill hole,
- The seabed mode can be used from pushing devices that are deployed on the seabed like the Ronson seabed rig, coiled mini-CPT-rigs or seabed drill rigs.

Other in-situ geotechnical tests include e.g. vane shear tests, ball penetrometer and t-bar penetrometer.

4) Instruments for downhole observatories
A non-exhaustive list of instruments for downhole observatories includes: inclinometers, strain meters, seismometers, accelerometers, gravimeters, magnetometers, pressure, temperature, fluid flow.
Instruments chosen on a project-by-project basis have to be added to this list.

5) Logging-while-drilling
Logging-while-drilling is mainly used in well drillings in order to replace wire-line logging operation. The logged data are stored in an autonomous memory tool and transmitted in real-time by mud-pulser. This method is faster than wire-line logging but has the disadvantage that it cannot be used in combination with core drilling and the data quality is affected by the drilling process.

Technologies that need development or to be built

The discussions focused on the following issues:

- Drilling in sea ice (*Aurora Borealis*),
- Development of seabed drills to handle new tools (logging/LWD/imaging/sampling/fluid sampling/monitoring),
- Mud return system (to increase borehole stability, under development),
- Seabed-based mud circulation system (overcomes riser depth limitations and cost),
- Improving coring, stability and recovery in hard substrate/deep crust/high temperature,
- Long-term monitoring at high temperatures/corrosive environments,
- Multiple downhole instruments (e.g. thermistors for heat flow measurements),
- Fluid sensors for geochemistry for downhole observatories,
- Improvement of data transfer methods/rates for downhole observatories,
- Near seabed logging
- .....plus everything on the EDP's development list!

Other points of discussion were how to :

- Overcome the current limitations on *mission-specific platform* (MSP) expeditions,
- Expand the IODP scientific activities beyond the drilling,
- Improve financial, managerial and technical collaborations between stakeholders.

1) Lift current 'restriction' on MSP expeditions
The discussions related to the MSP approach led to the following questions:

- Do any science that can be done more efficiently or flexibly with another vessel (i.e. not just in shallow/icy seas as indicated in the current Initial Science Plan)?
- Are MSP better suited as 'test grounds' for new developments?
- Could MSP offer a better route for development and testing of new tools in the New Drilling Programme?

2) Expansion of science activities beyond drilling:

- Geophysical surveys, long-term monitoring;
- Maintenance of downhole observatories without need of a drillship.

3) Improvement of financial, managerial and technical collaborations between stakeholders

- Ocean observatories initiatives in Europe (ESONET, EMSO, EuroSites), ICDP, SAON, Industry, ERICON, ANDRILL;
- Sharing of experience, personnel, equipment, calibration, joint purchases etc.

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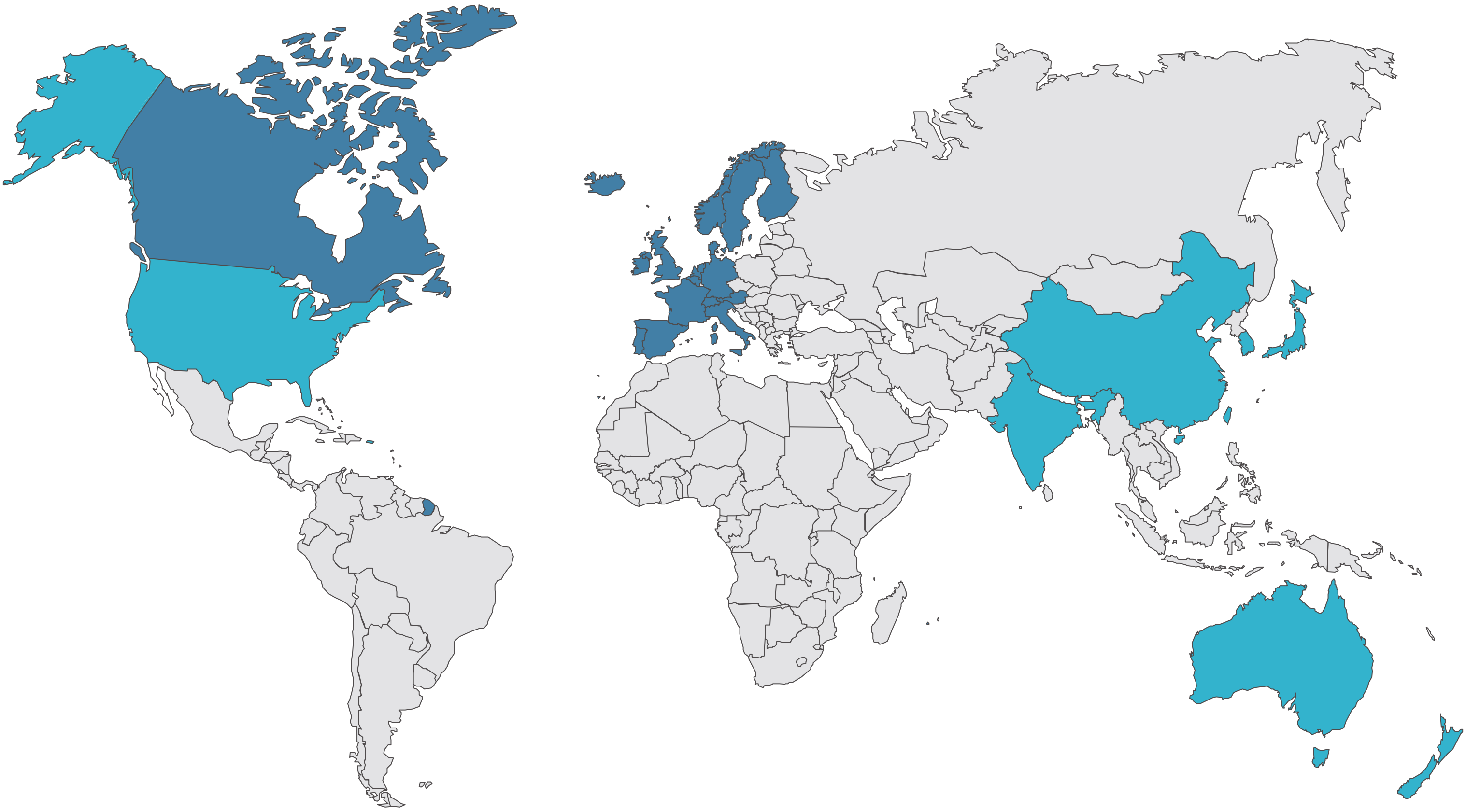

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