InterRidge Deep-Earth Sampling Working Group

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Introduction. WG focus and main issues

The proposed 'Deep Earth Sampling' (DES) Working Group is an interdisciplinary group comprising petrologists, structural geologists, petrophysicists, geochemists and geophysicists. It aims to plan a global strategy, oversee monitor and guide the passed or ongoing drilling (IODP, ICDP) projects, and incite/support/develop new projects. It may be viewed as a logical follow-up to the work achieved by the ODP "Architecture of the Oceanic Lithosphere" PPG (see report in the DES working group page at www.interridge.org). In summary, our mandate is, quoting the Interridge Steering Committee, "to determine where to drill with regard to mid-oceanic ridges, and then come out with proposals that will feed in to other initiatives such as IODP".

There are currently (November 2004) 126 active pre-proposals and proposals residing in the IODP SAS (http://www.iodp-mi-sapporo.org/active.html). 18 of these (including 2 Atlantic rifted margins projects) have objectives relevant to the InterRidge Science Plan (see appendix 1). Most of these projects were initiated during the end of the ODP, and all of them are thought as conventional, non-riser operations. Design of new integrated, multi-platform projects, as outlined in the Science Plan for Mission Specific Platforms (http://www.bgr.de/ecord/index.html) for example, should be encouraged by the DES Working Group.

Rationale

excerpted from the InterRidge Science Plan, 2004-2013 :

InterRidge should seek to promote interdisciplinary investigations of the 4-D architecture of the ancient and modern ocean crust and shallow mantle at all scales, and explore the extent and diversity of the sub surface biosphere of the oceanic lithosphere. This would be best achieved by the formation of an InterRidge Working Group with a focus on promoting the development and use of different drilling platforms ranging from over-the-side rock drills to riser drilling, and land-based platforms. It would be instrumental in formulating a new international drilling project that will seek to achieve total penetrations of in situ ocean crust in the Atlantic and Pacific within 20 years, and partial sections of crust and mantle in different tectonic settings. Drilling of active hydrothermal systems and young ocean crust and mantle at the ridge axis and in tectonic windows would be a high priority for the working group. These holes should also be used as laboratories in themselves allowing, for example, experiments with, and long term monitoring of, hydrologic systems within the crust. Recognizing the value of ophiolite studies to understand the ocean lithosphere, the working group should promote onland drilling to acquire long sections of the ocean crust and shallow mantle in well understood ophiolite complexes thought to represent key end-members for mid-ocean and arc environments.

More specifically, the working group should focus on the following items (see InterRidge Science Plan for more details, www.interridge.org).

1. Drilling of Active Hydrothermal Systems
2. Zero-age Ocean Crust and Axial Mantle
3. The Deep Biosphere
4. Drilling in Ophiolites
5. An International Crustal Penetration Drilling Project

Drilling the whole ocean crust has been an objective of the marine geoscience community since the late 1950's. This objective started with the Mohole project (Phase 1 drilled in 1961), and was followed in 1968 by DSDP/ODP. To date, the deepest hole in the ocean crust is ODP Hole 504B, at the depth of 2111m. Achieving a complete coring of the oceanic crust remains one of the priority objectives in the IODP initial science plan (http://www.iodp.org/downloads/IODP_Init_Sci_Plan.pdf) with the 21st century Mohole initiative.

excerpted from the InterRidge Science Plan, 2004-2013 :

Understanding global geochemical fluxes from the Earth's interior to the crust, oceans and atmosphere, the relationship between the seismic structure of the ocean crust and its stratigraphy, as well as the economic potential of the oceans requires a full knowledge of the composition and structure of the ocean crust and shallow mantle. This goal can only be achieved by drilling representative end-member crustal types formed in a variety of tectonic settings. Drilling in one ocean basin or one type of ocean crust alone cannot achieve this objective. This drilling must include total penetrations into the mantle

at both fast and slow-spreading ridges, as well as drilling long partial sections in tectonic windows representing the diversity of oceanic environments. This, then, rather than a single deep drill hole is the goal of an International Crustal Penetration drilling project that the working group will promote through IODP.

Implementation

The DES working group will lead/conduct discussions, and take actions on the following items

1. Use and development of existing rock-drill technology
2. Effective use of multiple platforms
3. Nurturing of IODP proposals
4. Guide/focus future IODP proposals to target specific items (see these under Rationale)
5. Promoting/organizing InterRidge-IODP workshop
6. Providing an official liaison to IODP

A workshop on the evolution of oceanic lithosphere (see appendix 2) is currently proposed to USSSP, Interridge and Ridge 2K by David Christie (Oregon State university, Corvallis). It is planned for Fall 2005. In particular, the workshop aims to "identify aspects of oceanic crustal accretion that can be addressed with current technology, and will begin the process of community prioritization for tackling these via ocean drilling. A particular focus will be on ways in which IODP can partner with InterRidge and with national mid-ocean ridge science programs to achieve common objectives". This workshop falls completely into the InterRidge DES Working Group objectives, and we welcome the opportunity to use it as the starting point of our work.

Appendix 1

List of currently active IODP proposals (http://www.iodp-mi-sapporo.org/active.html) related to InterRidge (Nov 2004)

Proposal #	Short Title	Proponent
522-Full3	Superfast Spreading Crust	Alt
531-Pre2	Max Spreading Rate Core Complex	Snow
532-Full	Kane Megamullion	Tucholke
535-Full4 *	735B Deep	Dick
545-Full3	Juan de Fuca Flank Hydrogeology	Fisher
547-Full4	Oceanic Subsurface Biosphere	Fisk
551-Full	Hess Deep	Gillis
570-Full	East Pacific Rise	Haymon
574-Full	Rainbow Hydrothermal Field	Fouquet
584-Full2	TAG II Hydrothermal	Rona
591-Full3 *	Conical/Desmos Hyd., PNG	Herzig
632-Pre	Lamont Seamount	Lundstrom
640-Pre	Godzilla Mullion	Ohara
646-Full *	Iceland Hotspot	Murton
655-Pre *	Juan de Fuca Observatories	Davis
657-Pre *	Galicia Rifted Margin	Sawyer
659-Full *	Newfoundland Rifted Margin	Tucholke
662-Full *	South Pacific Gyre Microbiology	D'Hondt

* : submitted Oct 1st, 2004

Appendix 2

Proposal for a USSSP – InterRidge – Ridge2000 Joint Workshop

Evolution of Oceanic Lithosphere

(excerpted from the original proposal by Dave Christie)

Conveners and Correspondents:

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We propose to convene an international workshop to enunciate and prioritize the key scientific problems concerning the formation and evolution of the oceanic lithosphere that can be achieved by IODP using available technology. Agreements are in place for the workshop to be jointly sponsored by USSSP, InterRidge and by Ridge2000. If USSSP supports this proposal, we intend to approach other national and regional IODP sciencefunding entities and national "ridge" programs. Several of the latter have informally expressed interest in co-sponsorship.

Because we are in the process of building international collaboration, we have deliberately not finalized some of the decisions requested in the JOI/USSSP proposal guide. In particular, we have not identified all members of the organizing committee, contacted key participants or specified the timing and location. These issues are, however, discussed in general terms in the proposal text and we are continuing to work on them. The problem is circular - international participation is, in effect, dependent on whether USSSP funding becomes available, as the workshop is unlikely to proceed without it. Until USSSP funding is in place, final decisions from some partners may not be possible.

Introduction and Rationale

The potential for IODP to contribute to an improved understanding of the composition, structure, and evolution of the ocean lithosphere is enormous and has been enunciated in planning documents since ocean drilling began. Yet, the number of active "ocean crust" proposals in the IODP system at the present time is very small, and the great majority of these are focused on a single class of problem -- seafloor exposure of gabbroic and peridotite sections that form where extensional tectonics dominates accretionary style rather than magmatic intrusion/extrusion. The reasons for this limited community engagement in IODP are unclear, but it may partially reflect a perception that IODP contributions would come mainly from two end-member objectives that are not immediately achievable – so-called "zero-age" drilling and drilling to the Moho. This workshop will identify aspects of oceanic crustal accretion that can be addressed with current technology, and will begin the process of community prioritization for tackling these via ocean drilling. A particular focus will be on ways in which IODP can partner with InterRidge and with national mid-ocean ridge science programs to achieve common objectives.

The formation and evolution of the oceanic lithosphere is a dominant process in the chemical differentiation of our planet. It encompasses the transfer and transformation of material and energy from the mantle to the crust and from the crust to the oceans (and eventually to the

atmosphere). From its time of formation until it returns by subduction to the mantle, the oceanic lithosphere interacts with seawater, continuously recycling surface materials, especially water, back into the mantle. This evolution must be documented and quantified before a realistic understanding of the ongoing transfer of energy and materials among the major Earth reservoirs can be achieved. To develop such an understanding, well integrated, multi-disciplinary studies encompassing many branches of the earth and biological sciences are essential. Aspects of such studies include documentation of geophysical, geochemical, and biological properties and quantitative modeling studies: of deep earth structure and material flow; of magma formation and magmatic evolution; of volcanic and tectonic construction of oceanic crust; of fluid circulation and fluid-rock interactions within the oceanic lithosphere; of fluid behavior and chemical interactions near the seafloor, and within the overlying water column. Wherever fluid-solid interactions occur, at water-rock interfaces or at deposition sites in veins and at seafloor vents, broad-ranging ecological and biological studies are required. At these sites, microbial ecosystems that exploit and/or mediate a wide variety of chemical reactions form the bases of complex food chains, independent of the sunlight that supports the vast majority of life forms elsewhere on our planet.

Many of the most effective tools for direct scientific sampling and measurement in the remote and hostile environments of the deep seafloor are those provided by IODP. Deep-sea drilling is the only tool for direct sampling of hard rock, consolidated sediment and fluids at significant depth below the seafloor, and the resulting drillholes also provide a valuable access for short- and long-term sub-seafloor monitoring. IODP tools can and should be effectively combined with those available from conventional surface ships and from submersible vehicles. Deep-sea vehicles, while limited to materials exposed at the seafloor (or in some cases to very short cores) can provide spatial and temporal context to the largely one-dimensional environments of deep drill holes. Multi-kilometer scale structure of the seafloor and subsurface can be obtained from shipboard geophysical mapping and on-bottom instrument arrays of, for example, ocean bottom seismographs or electro-magnetic sensors. Effective use of drilling, shipboard, and instrumentation resources is required to maximize the scientific return-- true advances in understanding of the suite of processes involved and the interdependence of the various physical, chemical, and biological aspects.

Why another workshop? -- Relationship to the IODP Science Planning

The goal of drilling a complete section through the oceanic crust and into the upper mantle has been reiterated throughout the history of ocean drilling and is embedded in the IODP Initial Science Plan as the “21st Century Mohole”. Inherent in this goal, is the tripartite need for: a clearly defined scientific strategy; for parallel development of essential operational experience; and for phased development of the essential improved technologies, all of which are essential for it to be fully realized. Despite this clear mandate for a broad range of crustal drilling projects, the community response in terms of proposals has not been forthcoming. The reasons for this lack of response are unclear. But they may lie in part in disillusionment with the endmembers of ocean-crustal drilling and in part in a lack of recognition that there is compelling science in the middle ground. At one extreme, attempts to penetrate “zero-age” crust along the East Pacific Rise under ODP were not successful and this important, but elusive, goal continues to require substantial technological development. At the other extreme, the ultimate “Mohole” through the entire ocean crust also requires technological development and it seems unlikely to be achieved in the next decade. Between these extremes, however, there is a wealth of critical scientific problems. The fundamental goal of this workshop is to enunciate these problems and to energize and empower the community to become active in their solution.

A seemingly mandatory component of community-based science plans, such as those for IODP and the various national and international “ridge” and “margins” programs is an expression of the need to synchronize and leverage efforts among the different programs. In reality, true synergy between or among such programs is very rare. A second goal of this workshop will be to identify opportunities for true collaboration of IODP with InterRidge and its constituent national programs.

The studies of the formation and evolution of oceanic lithosphere required to meet this goal are inherently integrative and interdisciplinary. Both operationally and scientifically, they depend on

contributions from many disciplines and from many facets of the science planning documents that guide IODP. Here we point out some of the links to key planning documents, but no attempt is made to reproduce the detailed materials that those documents contain.

The IODP Initial Science Plan

The scientific scope of this workshop brings together aspects of two of the three broad research themes enunciated in the IODP Initial Science Plan – "The deep biosphere and the sub-seafloor ocean" and "solid Earth Cycles and dynamics". Within these themes, integrated studies of the oceanic lithosphere will expand upon key aspects of two of the eight initiatives – "Deep Biosphere" and "21st Century Mohole".

Opportunities in Geochemistry for Post-2003 Ocean Drilling

This JOI/USSSP workshop report provides much of the broad scientific rationale for this proposal. In a section entitled "Road to the MOHO" it merges disparate parts of the initial science plan to lay out a rationale for a well-integrated, multi-year study of the ocean lithosphere, that would ultimately define both scientific context and lead to site identification for the ultimate Mohole objective, penetration through the full thickness of the ocean crust.

The key questions are summarized below, and the relevant text from the workshop report is appended to this proposal.

Lithosphere Structure and Aging.

• How extensively do fluids penetrate and react with ocean crust and mantle?

• Is seismic Layer 2a equivalent to the pillow lava section of the ocean crust? Does the relationship change as seafloor age increases away from the spreading axis?

• What is the petrological nature of the Mohorovicic seismic discontinuity and are there mechanical and petrologic changes in this boundary as the lithosphere ages?

• Does the Moho deepen as fluids transform fresh peridotite to serpentinite?

Lithosphere Magnetization.

• How is the source of seafloor magnetic anomaly "stripes" distributed through the crust and mantle?

• How is the source partitioned between tiny grains of primary titanomagnetite in basalts and secondary magnetite in altered gabbro and serpentinite?

Hydrothermal Exchanges.

• How deeply do seawater-derived fluids penetrate into the oceanic lithosphere and what are the thermal consequences of this hydrothermalism?

• What are the nature and extent of geochemical reactions that transform wall rock and fluid compositions along fluid pathways?

• How does fluid circulation evolve as porosity, tectonic stress and sediment burial change as the lithosphere moves away from the spreading axis?

• How do the magnitudes of thermal, and chemical exchange between the ocean and older seafloor evolve as the lithosphere ages? (Two-thirds of all heat loss from the oceanic lithosphere occurs through seafloor older than 1 million years.)

Deep Biosphere.

• How do the species compositions and abundances of microbial communities evolve as porosity and thermal structure changes laterally and with depth?

• What are the thermal and physiochemical boundaries to the distribution of individual microbes and communities?

Relationship To InterRidge, Ridge 2000 and Margins Objectives

One way to maximize the scientific return from major national and international programs is to identify priority scientific problems that match or intersect the goals of two or more programs and to encourage scientifically compelling proposals to address those problems. For example, the US Ridge 2000 program has targeted three “Integrated Studies Sites” -- areas within which multiple, tightly focused, multi-disciplinary projects will be focused in order to develop a whole-system “mantle-to-microbe” understanding of crustal accretion. Many of key questions concerning the evolution of oceanic lithosphere can potentially benefit from the accumulated knowledge at such sites. The more knowledge we have of the spreading center at the present time, the better we will be able to design experiments and develop our understanding of crustal evolution on progressively older seafloor. Similar correspondences can and should be found with emerging European interest in a Mid-Atlantic Ridge (MOMAR) observatory site and with Korean, Japanese, Ridge2000 and national and international “Margins” program interests in the back-arc basins of the western Pacific. A key component of these, and of Margins’ Subduction Factory theme, is an improved characterization of the chemistry and structure of oceanic lithosphere.

Workshop Partnership

The US Ridge 2000 Program has agreed to contribute $20,000 to support US participants attending the proposed workshop.

InterRidge has also agreed to endorse the workshop and to contribute $2-3,000 from its very limited budget.

In personal discussion, representatives from Japan and Korea have been supportive in principle and copies of this proposal have been forwarded to key individuals in these countries and in Europe. Discussions will continue as this proposal is reviewed by USSSP. Responsibility for final negotiations may be passed to or shared with JOI/USSSP when funding is in place.

Workshop Particulars

We envisage a 2.5-day workshop for 60 (ideal) to 80 (max.) participants. We have budgeted on the basis of 50 US participants. We anticipate that overseas attendance would be 10-30 people, funded from their own national resources. The exact numbers and national representations will depend on funding levels approved by the various entities.

We have avoided specifying dates and venues, as these details should be dealt with in cooperation with the other international participants. The most cost effective venue will be readily accessible from Europe and Asia, possibly in southern California or Seattle WA.

Because InterRidge and Ridge2000 are already well into their current 10 year programs, there is some urgency to this workshop, given a minimum 2-3 year time lag between the workshop and drilling of even the most compelling proposals arising from it. We propose to hold the workshop at the earliest reasonable date, most likely in fall 2005. We will advertise the workshop in EOS, but primarily through the email lists and websites of JOI/USSSP, IODP, Ridge 2000 and InterRidge. The various national organizations will likely advertise to their constituents trough their own resources.