

INTER**RIDGE** NEWS

Promoting international cooperation in ridge-crest studies

Featuring:

Third Decadal
Plan for
InterRidge



Volume 21 • 2012



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**INTERRIDGE
NEWS**



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Kate Davis

FOR CONTRIBUTORS

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**DEADLINE FOR INTERRIDGE NEWS
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Letter from the Chairs

Bramley Murton and Jon Copley



Bramley Murton on a field trip in Cornwall, UK.

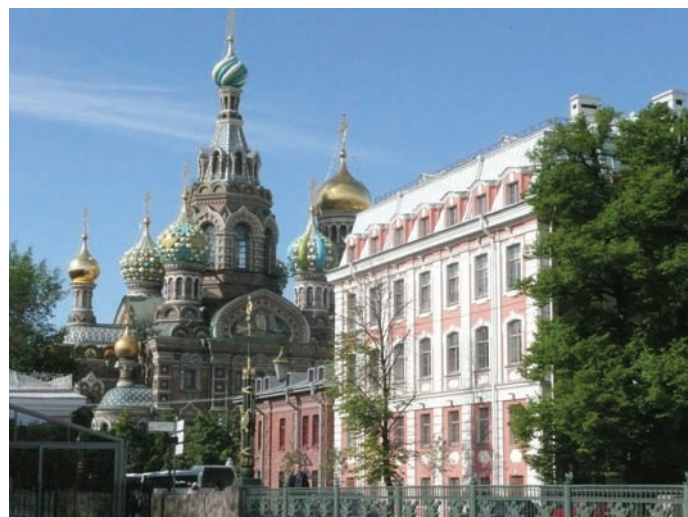
This is the last year that the InterRidge office is hosted by the National Oceanography Centre, Southampton, UK. From 2013, our new host is the University of Peking in Beijing, China; our new InterRidge Chair will be Prof. John Chen (School of Earth and Space Sciences, Peking University, Beijing) and our new co-Chair Dr Jiabiao Li (Second Institute of Oceanography, Hangzhou). Both John and Jiabiao have long and well-established careers in Marine Science and mid-ocean ridge research. The move of the InterRidge office to China is a wonderful opportunity for our community to share expertise and collaborate. Indeed, as a relatively recent full member of InterRidge, China has made rapid advances in ridge crest studies and is investing strongly in new technologies including a manned submersible. I would also like to thank, on behalf of everyone in the InterRidge family, our coordinator Dr Debbie Milton, who has done a fantastic job at increasing InterRidge's momentum and impact worldwide, keeping us all up to date with news, producing this fine Newsletter, ensuring meetings run smoothly and seeing that our numerous fellows and cruise bursary students are not left stranded on a roadside somewhere far from home.

In this issue, you will find the results of our consultation and writing efforts in the form of a plan for the third decade of InterRidge science. We present this to the community as a summary, not exhaustive or exclusive, of the big questions that we have all collectively identified. For me, two things are striking: how much basic exploration there remains, and the growing recognition that InterRidge must recognise and engage with those involved in seafloor resources. In response to the former, InterRidge has widened its scientific remit to extend from the ridge crest to the subducting slab: from the birth of the ocean crust to its death. This seems logical, as we are all increasingly aware that ridge crest science can only advance if we adopt a holistic global view of the ocean and

earth. As a direct result, we now have a working group for back-arc and arc systems. The links here are obvious: hydrothermal activity, mineralisation and biology, to name but a few.

In response to the second striking aspect of the new plan, InterRidge has been awarded observer status at the United Nations' International Seabed Authority. This is the body that oversees mineral exploration and exploitation in the high seas. We see our role as the voice that represents ridge crest scientists of an ocean floor that is of increasing commercial interest. We are here to consult the InterRidge community and present an objective opinion. We have already started this with the InterRidge 'Code of Conduct' and the recent consultation about identifying hydrothermal sites of special scientific and cultural interest. We have also started a process of initiating an industrial liaison group to help develop advice and best practice in any future deep sea-floor resource exploration.

Finally, this year has seen a huge increase in our scientific activity by deploying seven IR Fellows, of which three are sponsored by the ISA. We also deployed ten cruise bursary students in 2012, and we are indebted to our InterRidge cruise chiefs, for offering valuable places on their science programmes. When we started the cruise bursary scheme in 2010, there were some doubts that it would have much take-up. But we were determined to give it a try. So far, feedback from the cruise chiefs and students has been tremendous. My view is that InterRidge is here, not just to help make the ridge crest science of today happen, but to set in motion the science of tomorrow by bringing new researchers together in the most stimulating environment I know of: voyages of exploration out on the deep blue yonder. There is nothing more exciting and intellectually stimulating for a new researcher than to be closeted on a ship, with some of our best and most experienced ridge scientists, devoted to research, 24/7. Indeed, if there is to be any lasting legacy of our hosting of the InterRidge office at NOC, I hope it is the cruise bursary scheme and, ultimately, the new science and collaborations that it engenders.



St Petersburg, where the 2012 InterRidge StComm meeting was held.

From Ridge Crest to Deep-Ocean Trench: Formation and Evolution of the Oceanic Crust and Its Interaction with the Ocean, Biosphere, Climate and Human Society

A plan for the third decade of InterRidge science

InterRidge is the only scientific organisation that spans the single largest geological domain on the planet: the Earth's oceanic crust, representing more than 60% of the Earth's surface. The background for this framework is the recognition of a number of key areas of research that are needed to underpin our developing understanding of the formation and evolution of the oceanic crust and its interaction with the ocean, biosphere, climate and human society. The role of InterRidge has evolved from facilitating cooperation between ridge crest scientists to helping science focus on the major and fundamental aspects of ocean crust generation and evolution; from genesis at the ridge crest, to evolution on the flanks and under the abyssal plains to its fate at convergent margins, subduction zones, arcs and back-arc systems.

The following sections describe the results of a process of consultation of the InterRidge community that was initiated in 2011 through an online forum and culminated on December 3rd 2011 at an open meeting in San Francisco. Following summaries from the current and future working groups, the process of science prioritisation was led by the InterRidge Chair (Bramley Murton) with assistance from three previous Chairs (Colin Devey, Jian Lin and Roger Searle). All of the attendees were asked to post their key scientific questions on a bulletin board. These were then organised

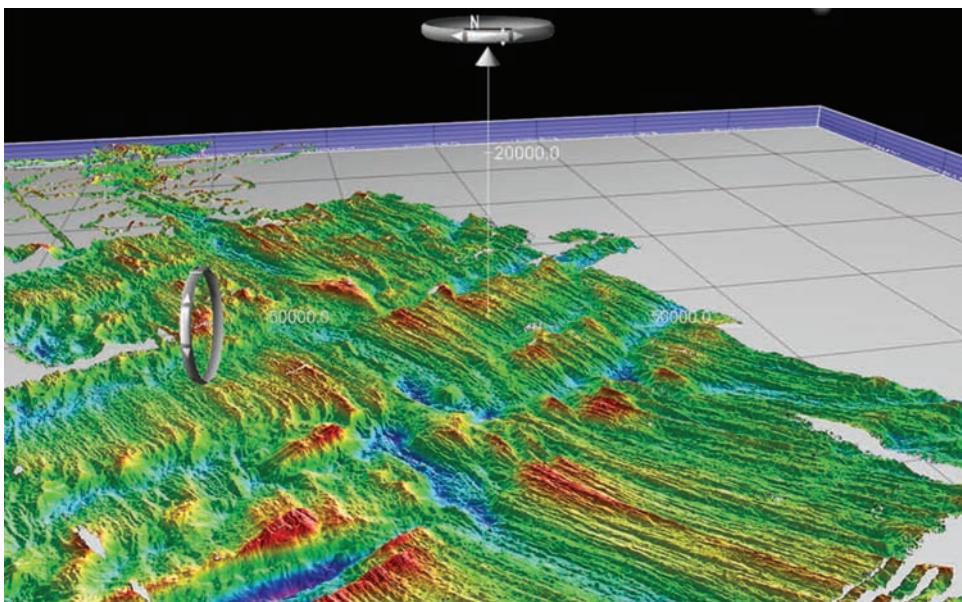
into broad scientific themes. Attendees were then asked to self-organise into groups under each of the science themes and draw up a list of the big scientific questions, their context and background, and how they might be implemented. Each group then elected one or two members that formed the writing group on the 4th December to compile each of the report sections presented here.



Past and present Chairs at the Third Decadal Plan meeting in San Francisco, December 2011 (Colin Devey, Bramley Murton, Jian Lin, Roger Searle).

Section A

Mid-Ocean Ridge Tectonic and Magmatic Processes



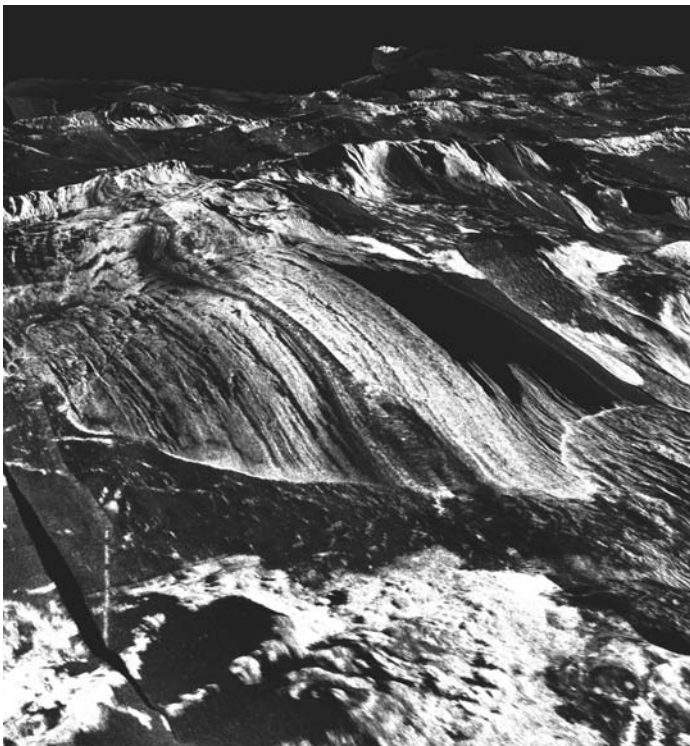
Three-dimensional perspective image of ridge-ridge-ridge triple junction in the Indian Ocean (Rodriguez triple junction, 25°30'S, 70°00'E). The deep valley in the bottom left corner is the Southwest Indian Ridge axial valley. A typical oceanic core complex and other domed features are located along the boundary of first and second segments of the Central Indian Ridge, where mantle and/or lower crustal rocks are exposed. Data acquired during KH93-3, KR00-05, YK01-15, YK05-16, YK09-13, KH10-6 (Japan) and previous French cruises in 1990's.

Background

The past ten years have seen a revolution in our understanding of the formation, structure and evolution of oceanic crust. In the same way that orbiting space telescopes have revealed the origins of the universe, and genetics have shown us the fundamental basis of life, new technologies for imaging and exploring the deep ocean crust have transformed our view of our planet.

Over 60% of the entire Earth's surface has been formed at active oceanic spreading ridges. During the latter half of the 20th century, our view of this deep seafloor was seen through a blurred lens. Sonar images were coarse and the resolution low. Visual observations were of limited extent and the recovery of rocks from below the seafloor was sparse. As a result, we developed a simplistic model for this oceanic crust. We thought all spreading ridges formed a similar type of structure: a layer-cake of volcanic lavas overlying coarse crystalline rocks that in turn rested on the mantle. Where there were differences, these were limited to local processes such as faults, hotspots and unusual plate boundary geometries.

With the birth of the 21st century, a new view has emerged. Informed by high-resolution geophysical imaging techniques, robotic underwater vehicles and deep-ocean drilling, we have discovered that the ocean crust is far from homogeneous. With decreasing spreading rate, the crust becomes increasingly complex. Large areas of the seafloor expose gaps in the volcanic portion of the crust and outcrops of mantle rock are exposed at the seafloor. Entire ridge segments are found to spread by long-lived, low angle extensional faulting. The exposed mantle rocks are found to contain multiple small bodies of coarse crystallised magmatic rock but the



13.30N MAR (JC007 Team: Searle, Murton, Macleod et al.)

overlying volcanic lavas are absent. Seawater reactions with the exposed mantle form serpentinite. Fluids released by this reaction are completely different to those at conventional hydrothermal vents: they have high pH, are rich in hydrogen and methane and, where hot, create complex organic molecules. These chemical and thermal fluxes have significant implications for the composition of the global ocean. The vents are also host to unusual species of macro and microorganisms whose genetic potential are just being explored. Mineral deposits formed at the hydrothermal vents are rich in non-ferrous metals such as copper, zinc and gold. The lack of volcanism allows such deposits to accumulate large tonnages. In turn, these have attracted the attention of industries interested in exploring for new, metal-rich resources to meet the growing global demand for raw commodities.

The heterogeneous structure of the oceanic crust is also expressed in time as well as space. Melt supply appears to vary through time at a given location, resulting in dramatic variations in crustal structure, thickness and hydrothermal fluxes. Even the spreading process, previously regarded as continuous, has been found to be episodic. Where new ocean crust is generated behind convergent margins, the ridges stop and start, often jumping to new sites by rifting older crust. Why this happens is unknown but is thought to link to changes in the structure and geometry of the subducting plate. The mantle wedge is affected and there are consequences for arc volcanism. Thus there is a connection to the entire Earth System: oceanic crust formed at spreading ridges is heterogeneous, evolves through interaction with the ocean, is modified by intra-plate volcanism, and as a result effects changes in convergent margins that in turn affect the formation of new oceanic crust in the arc and back-arc basins. This holistic approach is now recognised and embraced by InterRidge. The linkages between the mantle, lithosphere and biosphere are an integral part of the Earth system. The mineral resources formed by the oceanic crustal spreading are of growing economic importance. Hence, society at large is increasingly aware of the fundamental role played by the oceanic crust and its potential to meet the resource needs of the future.

Primary Questions:

- 1) What controls the structure of the oceanic crust?
- 2) What is the real extent of tectonic-dominated spreading?
- 3) How does oceanic spreading at slow and ultra-slow spreading rates work?
- 4) What is the diversity of structure and architecture of Oceanic Core Complexes?
- 5) What is the variation of oceanic crustal structure through time and how is this controlled?
- 6) What controls the variation and episodicity of spreading ridges in complex tectonic settings?

1) What controls the structure of the oceanic crust?

While the formation of heterogeneous oceanic crust is most prevalent with increasingly slow spreading rates, the link is not exclusive. New or dying rifts where the spreading rate is ultra-slow are not necessarily dominated by tectonic spreading. Is there a

mantle effect? And if so, what is this: composition, temperature or both? Or are there some other processes, maybe a crustal one, in which shallower processes cause the crust to become heterogeneous? Could there be positive feedback between faulting, hydrothermal cooling and the suppression of volcanism? Are there links to global sea level such that rapid changes result in fluctuation in melt supply?

2) What is the real extent of tectonic-dominated spreading?

Oceanic core complexes (OCCs) are the expression of tectonic-dominated spreading. These are the result of low-angle detachment faults that uplift and expose large sections of upper-mantle. Where they are identified, they occur as isolated features on the ridge flank. But are these merely the surface expression of deeper, inter-linked structures that extend for tens to hundreds of kilometres along the ridge? Are they related to vast areas of ocean crust, exposed on some ridge flanks, which are described as smooth? Likewise, are they related to the even larger areas of smooth ocean crust, which have been discovered beneath several kilometres of sediment, bordering continental margins?

3) How does oceanic spreading at slow and ultra-slow spreading rates work?

Where OCCs form and the crust spreads asymmetrically, how is this accommodated? What is the structure of the conjugate flank? Are all OCCs alike or are there significant differences in their structure and architecture? And what controls these differences?

4) What is the diversity of structure and architecture of OCCs?

Are all OCCs 'plum-pudding' structures with gabbro bodies embedded in a peridotite/serpentine matrix or are some completely peridotite? What is the proportion of magmatic material in OCCs and how does that compare with 'normal Penrose' oceanic crust?

5) What is the variation of oceanic crustal structure through time and how is this controlled?

Transform faults allow time slices through crustal sections to be exposed. Can they be used to allow studies of the variation in crustal architecture and melt supply? How does the lower oceanic crust form? Can we resolve the gabbro glacier model from that of the multiple intrusive sill? Can we resolve how the ocean crust cools and the magnitude of its effects on ocean chemistry through alteration? What is the depth of serpentinization where magmatic flux is low? How does serpentinization affect the seismic potential of fault zones and can we apply this information to seismogenic zones in continental settings and subduction zones?

6) What controls the variation and episodicity of spreading ridges in complex tectonic settings?

Backarc basin spreading centres are unstable and jump in space and time often with hiatus in spreading. What controls this? Are there

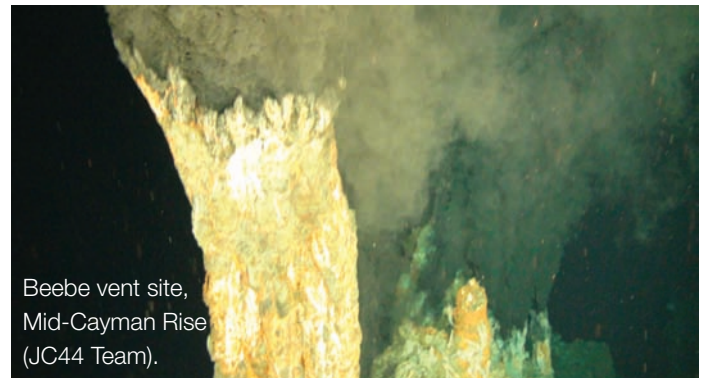
links to the subduction process and arc volcanoes? How does the mantle wedge link to backarc spreading? What are the ages of back arc spreading jumps and can we calibrate or unravel complicated magnetic anomaly signatures in backarc basins? Are there links between the structure, composition and morphology of the subducting slab of old oceanic crust and the formation of arc volcanoes and backarc spreading systems?

Implementation:

- New tools and observations: accessing the subsurface is essential to understanding the composition, structure and evolution of heterogeneous oceanic crust.
- IR will develop closer links with IODP drilling. Scientists should be encouraged to form closer links with engineers developing new emerging technologies such as active and passive EM, high-resolution seismic imaging and seafloor drilling.
- Areas where ocean crustal diversity and heterogeneity are well developed should be identified where a concerted and coordinated research effort can be applied. A variety of techniques are needed and these should be focused on particular areas where the combined effort exceeds the sum of the individual parts. This is the role of InterRidge: to coordinate and encourage collaboration.

Section B

Seafloor and Sub-Seafloor Resources



Beebe vent site,
Mid-Cayman Rise
(JC44 Team).

Background

Research into seafloor and sub-seafloor hydrothermal systems over the past ~30 years has focused primarily on active vent sites, because: 1) plumes from active vents can be detected at kilometre-scale distances from their source; 2) active vents host lush, unique chemosynthetic ecosystems; and 3) active vents provide the opportunity for direct measurements of fluid fluxes, compositions and temperatures. Current estimates of the number of vent sites along the oceans' neo-volcanic zones and the total amount of hydrothermal sulfide on the ocean floor are biased towards active systems.



Moytirra vent field, MAR.
(Dr. A.Wheeler (UCC,
Ireland) and VENTuRE
survey partners).

Growing evidence suggests that the total number of inactive/extinct vent sites, and total tonnage of sulfide from those sites, may be greater than that which has been discovered and estimated from active sites. The fate of seafloor sulfides after the hydrothermal system that fed them turns off is also poorly constrained. Little is known regarding the rate of sulfide oxidation on the seafloor or the biological communities that inhabit these deposits. The need for a better understanding of inactive sulfide deposits is further enhanced by the growing targeting of these deposits by exploration companies for their precious and base metal contents. Due to technical limitations and ecological concerns, inactive systems are a more likely source for metal resources than sulfides from active hydrothermal vent sites.

Primary questions:

- 1) How can inactive hydrothermal sulfide deposits be identified on the seafloor?
- 2) How much hydrothermal sulfide is contained in inactive vent deposits?
- 3) How old are seafloor massive sulfide (SMS) deposits?
- 4) What types of organisms inhabit inactive sulfide deposits?
- 5) What is the geologic fate of inactive sulfide deposits?
- 6) Does basement lithology and water depth affect the mineral resource potential and biology of seafloor massive sulfides (SMS)?
- 7) What is the potential toxicity of inactive SMS deposits to surrounding fauna?

1) How can inactive hydrothermal sulfide deposits be identified on the seafloor?

Unlike active vent sites, which we have learned to identify and locate using plume surveys, camera tows etc., inactive sulfide deposits can often be indistinguishable from volcanic structures. Methods for the detection of inactive sulfides using high-resolution mapping and remote sensing geophysical methods are critical to locating sulfide deposits that are invisible using many of the methods used to locate active deposits. Can we detect buried sulfide deposits? There is a

need to verify remote sensing techniques by characterising the sub-surface expression of mineral deposits and their altered host rock.

2) How much hydrothermal sulfide is contained in inactive vent deposits?

A number of recent publications provide estimates of the total global resource of SMS (seafloor massive sulfide) deposits. These estimates are based almost exclusively on data from known active deposits. Surveys of inactive deposits from different seafloor tectonic environments are required to update global resource estimates to include inactive sulfides. These estimates are critical to organisations that hope to either explore for, or regulate, the exploration and exploitation of seafloor sulfide resources.

3) How old are seafloor massive sulfide deposits?

What is the accumulation rate of sulfide, and how does it compare to the amount of sulfide that vents into the water column? What is the lifespan of a typical hydrothermal system? Are lifespans dependent on tectonic environment? How episodic is venting at a single vent site?

4) What types of organisms inhabit inactive sulfide deposits?

How do the ecosystems of inactive sulfide deposits compare with those of active sulfide deposits or normal basaltic substrates?

5) What is the geologic fate of inactive sulfide deposits?

What is the rate of oxidation? What are the effects of microorganisms on the breakdown of sulfide? How does the rate of oxidation compare to the rate of burial?

6) Does basement lithology and water depth affect the mineral resource potential and biology of seafloor massive sulfides?

Is there a systematic variation in chemistry and metal content of SMS formed at mafic-hosted or ultramafic-hosted hydrothermal systems? What is the chemical and thermal flux at slow and ultra-slow spread crust and does this vary with tectonic spreading and the formation of OCCs? What is the effect of different basement lithologies on vent biology?

7) What is the chemical toxicity of deposits and their sediments?

What biologically active, toxic elements are present in deposits and their associated sediments? Are there secondary enrichment processes, linked to diffuse fluid flow or redox fronts that might enhance the toxicity of deposits? What are the effects of plumes of detritus that might be introduced from seafloor mining activities, on the surrounding benthic communities?

Implementation:

- a. Many of these questions might be answered by large-scale, high-resolution characterisations of entire vent fields at ridge

segment scales and integrating those with basin-wide modelling. This could be accomplished using properly-instrumented AUVs and other distributed ocean observing platforms, supplemented by high-resolution seafloor surveys and monitoring. Awareness must be built and guidance provided as to what “properly-instrumented” means.

- b. Sub-seafloor assessment of mineral deposits and occurrences should involve new technologies such as seabed drilling and wire-line logging to characterise mineral and host-rock types and their geophysical properties. These data will also be used to both calibrate remote detection methods (active and passive electromagnetism, resistivity, magnetism and active seismic detection) as well as to document the chemotoxic nature of the deposits and their surrounding sediments.
- c. InterRidge should continue to work with other agencies such as the International Seabed Authority and the Underwater Mining Institute towards developing guidance for best practice in assessing, monitoring and minimising environmental impact from resource exploration and exploitation.

1) How are mantle heterogeneities expressed at different scales in time and space?

Ridges represent essential windows to image, quantify and map mantle heterogeneities at different scales in both space and time. Such heterogeneities include mantle provinces (e.g. at slabs or in mantle down-welling areas such as at the AAD), broader geochemical domains (such as the DUPAL anomaly) or dynamic features such as mantle hotspots or plumes. Where ridges interact with mid-ocean ridges, the spreading process leaves behind a trail of crust that records the history of interaction with the mantle anomaly. Here, the ocean crust records time varying fluxes of hotspot mantle, mantle plumes and their tectonic effects on the spreading processes.

An example of mantle controls of the spreading ridge system is ridge-hotspot interaction. Here, the plate separation process records the influence of adjacent mantle ‘hot-spots’. For example, the ridge and oceanic crust to the south of Iceland record the changing influence of the mantle anomaly beneath Iceland. Combining both geophysical studies of crustal and mantle anomalies south of Iceland with petrological and geochemical studies can test the presence or absence of an upwelling mantle plume beneath Iceland, leading to improved understanding of the dynamics and physical and compositional properties of the mantle.

Another emerging frontier of research is the extent and nature of small-scale mantle heterogeneities (10 to 50 km). Although these seem to be ubiquitous, their effects on the spreading process are poorly understood. Also unknown are origins of these small-scale mantle heterogeneities. How are they generated and preserved? How do they interact with the dynamic mantle melting processes beneath the ridge crest and what effect do they have on the resulting accretion of oceanic crust? These questions are relevant to both areas of high and low melt production (i.e. mantle hot and cold spots) as well as volatile rich regions (i.e. mantle wet spots).

2) What is the relationship between variations in ridge processes and mantle heterogeneity?

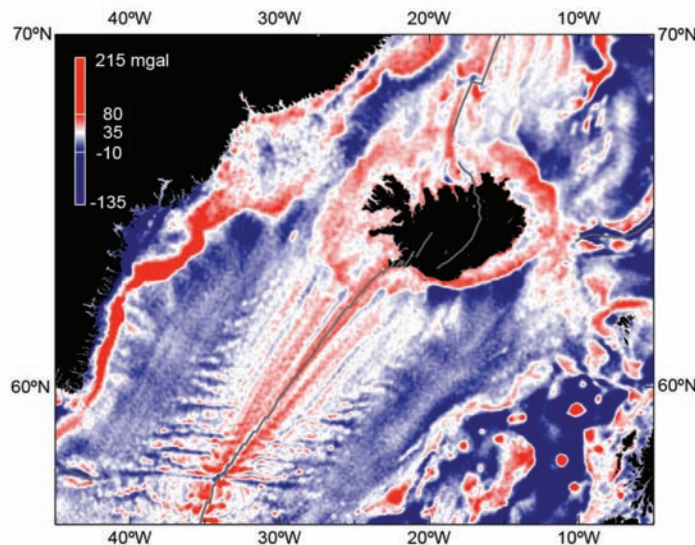
A better understanding of ridge processes requires addressing how the mantle processes and heterogeneities affect the mechanisms of melt generation and migration to form the oceanic crust. Equally important is how mantle processes and heterogeneities control the tectonics of seafloor spreading. For example, ‘amagmatic’ spreading and the generation of ocean core complexes are associated with E-MORB – enriched mid-ocean ridge basalts – resulting from either reduced mantle melting and/or enriched mantle. It is not known how this relationship develops: by what process is mantle thermal heterogeneity conserved or how does mantle heterogeneity affect the melt generation process and hence the spreading style.

Implementation:

- a. Various approaches will be used to address these questions. Of prime interest is mantle imaging through geophysical techniques such as seismic tomography, refraction and reflection,

Section C

Mantle Control



Iceland V-shaped ridges map (Steve Jones et al. University of Birmingham, UK).

Primary Questions:

- 1) How are mantle heterogeneities expressed at different scales in time and space?
- 2) What are the relationships between variations in ridge processes and mantle heterogeneity?

electromagnetic and potential field techniques. This is very demanding on resources and therefore requires international collaboration.

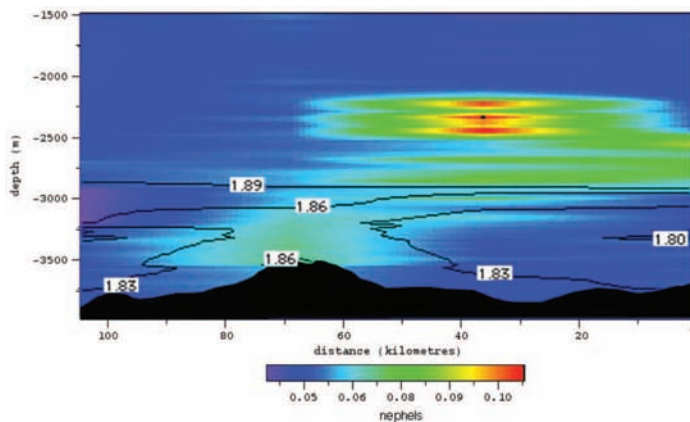
- b. Integrating both wider scale global tomography experiments with more local scale ones is essential, as well as improving imaging resolution at greater depth.
- c. High-resolution mapping of mantle heterogeneities through detailed geochemical studies of rock samples (drilled, dredged, or collected by deep-sea vehicles), complemented by near-bottom (i.e. AUV-type) multibeam surveys are needed for specific locations. This requires international collaboration.
- d. The collection of geophysical and geochemical data should be complemented by physical property analyses of mantle rocks, where available.
- e. Numerical geodynamic modelling should help to better understand the mantle mixing processes. Key to this approach is to combine geophysics with rock geochemistry to better constrain melt fraction, crustal thickness and hence to unravel the effects of mantle composition and melting history.



Olivine crystal collected from a dunite channel in the Horoman peridotite complex, Hokkaido, Japan. (Acknowl. Anna Suetake, Niigata University).

Section D

Ridge-Ocean Interactions and Fluxes



Megaplumes over the Carlsberg Ridge. (Murton et al. 2006).

Background:

From an oceanographic viewpoint, it has been generally assumed that geothermal heating has a small effect on global circulation. However, recent hydrographic modelling has demonstrated that this assumption is wrong. Instead, geothermal heating has a significant influence on mixing in the abyssal ocean with wider consequences for global thermohaline circulation. Although these modelling results, using coarse numerical grids, are based on passive heating above an impermeable seabed, they do not include the dynamic

uplift created by the hydrothermal plumes. These plumes may, through convective entrainment, provide an important mechanism to lift some of the densest water away from the bottom boundary layer. The models also neglect mixing caused by tidal and current flow across the rough sea floor of the mid-ocean ridges. Mixing of bottom water, the export of hydrothermal plumes and their chemical interactions may play a role in the transport of nutrients to the surface water and drawing down carbon. Over the next decade, ocean circulation models will increase in resolution and will be able to include more accurate bathymetry maps and geothermal flux models. Our challenge is to provide accurate estimates of the heat and mass fluxes at the ocean floor that can be integrated into these new models. Better models will lead to better prediction of the global circulation. We will be able to test the veracity of these models using geochemical tracers and through biological mapping using novel DNA mapping techniques.

Primary Questions:

- 1) Mixing and heating in the abyssal oceans
- 2) Biological/chemical tracer distribution - spatial/depth
- 3) Distribution of fluxes – focused vs. diffuse

1) Mixing and heating in the abyssal oceans

Heating of the abyssal ocean is necessary to maintain the global thermohaline circulation system that transport heat, nutrients (biological, chemical) around the globe. Cold abyssal water, formed at the poles, fills the deep ocean basins from depths of about 1000 to over 5000 m. This water has to be warmed to make it buoyant to rise to the surface to complete the circulation loop. To date, the

coarse resolution simulations of ocean circulation means that the large contrasts in the spatial distribution of geothermal and hydrothermal fluxes are not properly represented. Within the next decade ocean circulation models will achieve spatial resolutions capable of including more realistic seabed topography and distribution of geothermal heating, hence providing more reliable predictions of abyssal ocean circulation. Ridges provide three mechanisms that may drive this process:

- the rough topography that interacts with flow in the abyssal ocean caused by tides or by large-scale ocean currents. Recent measurements have shown increased levels of mixing that may mix heat down from the surface into the deeper water masses;
- direct thermal heating of the abyssal ocean by cooling of the newly formed ocean crust; approximately 70% of the Earth's heat loss is through oceanic lithosphere and, of that, most is through young oceanic crust at spreading ridges or along their flanks. Unlike surface heat fluxes, geothermal fluxes are unidirectional, always contributing towards increasing the buoyancy of the deep ocean;
- the flow of hydrothermal fluid focused at hydrothermal vents close to the ridge crests creates a third type of mixing through entrainment. It has been estimated that this process may increase the volume of water affected by the hydrothermal plumes by a factor of ten thousand.

2) Biological and chemical distribution (or tracers)

Flourishing biological communities usually accompany hydrothermal activity that, in turn, provides significant chemical fluxes to the ocean. Some of these chemical species are deposited close to the hydrothermal vents; others are entrained by hydrothermal plumes and transported by oceanic circulation. Understanding the transportation processes will improve our knowledge of global oceanic circulation, through recognition of global biogeographical provinces, population connectivity and hydrothermal tracer distribution. It will also yield direct measurement of the global hydrothermal plume flux and indirect knowledge of hydrothermal vent fields in hitherto unexplored areas, e.g. the Southern Ocean.

The deep-sea hydrothermal biological communities themselves attract interest, but they also provide much information about the environment of hydrothermal vents and invisible connectivity among hydrothermal vents, caused by a combination of hydrothermal plume and oceanic circulation. The animal distribution is closely correlated to environmental factors provided by hydrothermal activities. Understanding the ecological and physiological features of the animals will lead us to understand how animal distributions correlate with the physical and chemical properties around hydrothermal vents, and furthermore, the speciation and subsequent evolution processes around hydrothermal vents. Population studies require genetics on large numbers of specimens from type localities. Identifying those localities is difficult,

but will benefit significantly from higher resolution numerical modelling of ocean circulation, entrainment of hydrothermal plumes, their transport and eventual fate.

3) Distribution of fluxes – focused vs. diffuse

A challenge for more complete models of both heat and mass flux through the seafloor is estimating the distribution of the various forms of venting. There is strong spatial and temporal variation in heat and mass fluxes through the seafloor. There is also a paradox between the apparent deficit of hydrothermal cooling required to solidify the newly formed oceanic crust and the flux of hydrothermal discharge of key elements (such as Sr) to the ocean. One key to solving this paradox may be the partitioning between high and low-temperature fluxes. While the most spectacular vents, associated with high-temperature black-smokers that discharge mineral and chemical-laden fluids into the ocean in plumes, are found close to the ridge axis, over the past decade diffuse vents that discharge low temperature heat-fluxes with a much lower chemical flux have been located on the ridge flanks. These have lower heat and chemical flux rates and different heat/chemical ratios, but are spread over larger areas.

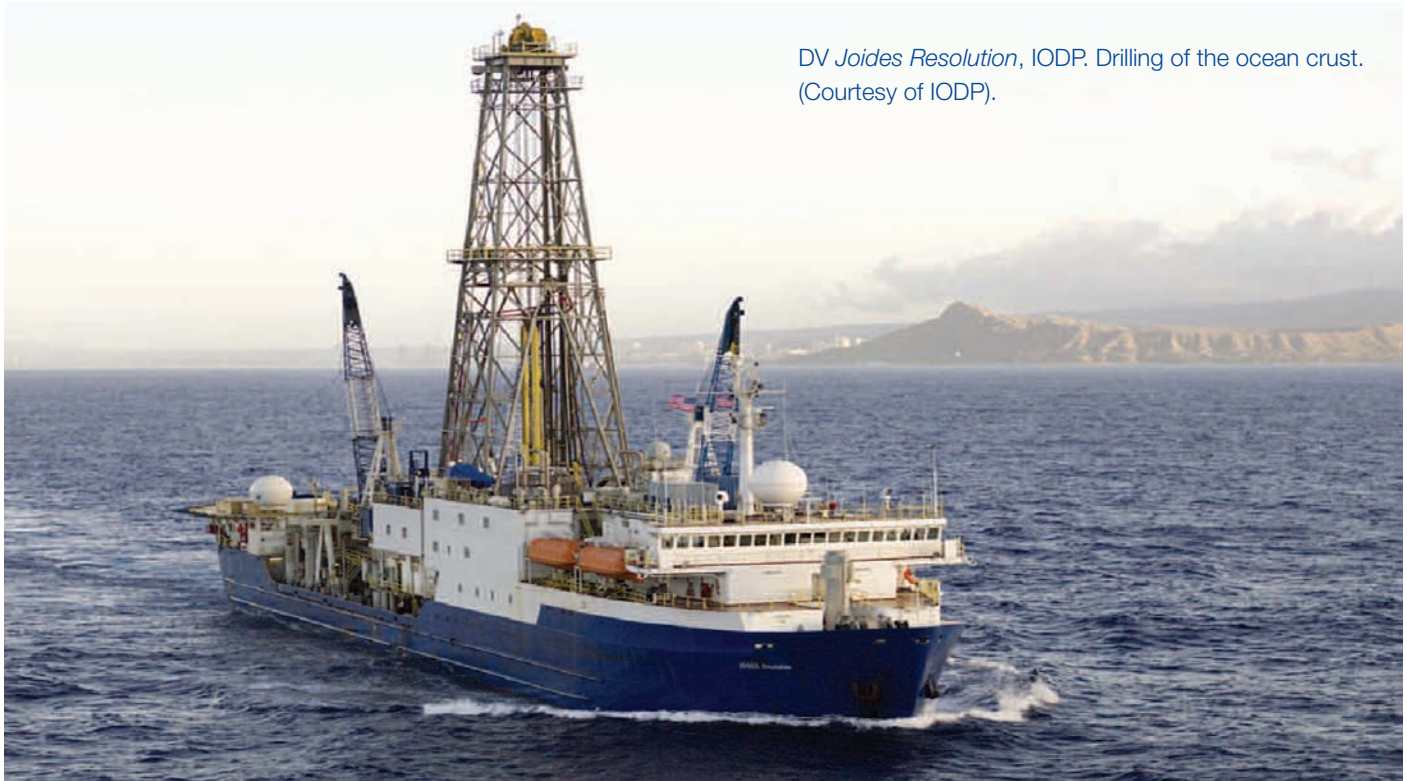
Many questions remain as to the role of low temperature venting relative to the total heat flux from hydrothermal systems. What is the proportion of heat and mass flux that occurs through discrete vents close to the ridge as opposed to diffuse vents on the ridge flanks? What methods can be developed for quantifying heat flux from low-temperature, diffuse flow? How are the spatial and temporal controls on low-temperature venting related to high-temperature venting? How do hydrothermal systems evolve through time from a volcanic eruption event to the off-axis? The hydrothermal plumbing in the ocean crust is likely to vary with spreading rate and spreading process. These variations need to be quantified to understand the nature and quantity of the fluxes in the deep ocean that can then be linked to improved circulation models.

Implementation:

- a. New high-resolution ocean circulation models to be built in collaboration with physical oceanographers.
- b. Long term observatories at both ridge and flank to monitor fluxes over a volcanic cycle.
- c. Integrated high-resolution studies incorporating numerical modelling of physical, chemical and biological data.
- d. Development of new syntheses of DNA data to map filters to the larval dispersal.
- e. The addition of new chemical/biological sensors to distributed observing platforms such as ARGOS floats and ocean gliders used to map the internal structure of the oceans.
- f. Involvement with policy makers to develop a common environmental policy.

Section E

Off-Axis Processes and Consequences of Ridge Processes for the Evolution of the Lithosphere



DV *Joides Resolution*, IODP. Drilling of the ocean crust. (Courtesy of IODP).

Background:

The on- and off-axis mid-ocean ridge processes have a major control on the formation and evolution of more than 60% of the Earth's crust. The oceanic lithosphere is where the ocean and the solid earth interact, with a large variety of implications ranging from the global heat and chemical budgets to the effects of the subducting plates on earthquake genesis. Previous IR science plans focused on axial ridge processes and greatly improved our knowledge of accretionary processes and hydrothermal fluxes. Detailed investigations have brought insights into volcanic and tectonic processes generating the new ocean lithosphere. In situ observatories have monitored hydrothermal fluxes at specific localities for more than 10 years now, collecting precious information on the evolution over time of heat loss, chemical fluxes, mineralisation and vent fauna. But we still observe a misfit between axial and global heat flux estimates, implying that the contribution of off-axis processes is significant. Hence it is time to investigate what happens on the ridge flanks.

The concept of “off-axis” evolution of the ocean lithosphere implies that we know the limit of the “axial” zone, which is not true, as its definition depends on which processes are concerned. Magmatism is active beyond the ridge crest at fast and slow spreading ridges, and fluid flow is active in crust that is tens of millions of years old. New technologies should help detect events and processes that become subdued away from the plate boundary, but remain significant at a planetary scale.

Primary Questions:

- 1) How do the accretion-driven processes (faulting, volcanism, hydrothermal circulation, and ecosystem dynamics) evolve, diminish, or change character with increasing distance off-axis?
- 2) Where is the edge of the “ridge crest”? How does it vary with time? How does it vary according to processes (tectonically active zone vs volcanically active zone vs hydrothermally active zone)?
- 3) What is the contribution of diffuse “cold” flow on the heat budget and on mineralisation?
- 4) What are the integrated processes that control the architecture of a subducting plate?
 - a. What is the extent of serpentinization and how far off-axis is this process active? Does it stop before the plate enters subduction?
 - b. What is the lifetime of an abyssal hill? How are abyssal hills “rejuvenated” far from plate boundaries?
 - c. What characteristics of the ocean plate architecture created near the axis influence the behaviour of the subducting plate?

1) How do the accretion-driven processes (faulting, volcanism, hydrothermal circulation, and ecosystem dynamics) evolve, diminish, or change character with increasing distance off-axis?

The formation of new ocean crust is focused at the ridge axis and as this crust moves off-axis it undergoes fracturing and faulting that is determined by the spreading rate. Major normal faults at slow-spreading ridges begin to grow at ~2 km off-axis, and complete most of their growth by perhaps 10 km off-axis. At fast-spreading ridges, signs of active faulting have been recorded up to 35 km off-axis. Fast-spreading ridges lack the deep fault controlled axial valley associated with slow-spreading ridges. These faults may provide conduits for deeper hydrothermal circulation on slow-spreading ridges. Most volcanism at slow spreading ridges is focused in a narrow (axis +/- 2 km) zone, and any outlying volcanism appears to be confined to the median valley (axis +/- ~20 km). At fast-spreading ridges, most lavas are erupted in a narrow axial zone, but some flow down the rise flanks to distances of kms or 10s of kms off-axis. At all spreading rates, off-axis, point-source volcanism (seamounts) can occur anywhere in the plate where there is a suitable magmatic source (e.g. Hawaii). Evidence is being gathered that show that there maybe some extrusive flows on the ridge flanks. Hydrothermal systems evolve by clogging of the fractures and faults in the ocean crust by mineral precipitation and by the reduction of mass-flux through the less permeable sedimentary cover whose thickness increases with crustal age. Off-axis seamounts that penetrate through this cover are still hydrothermally active and can be sites of either cold water inflow or warm water outflow.

2) Where is the edge of the “ridge crest”? How does it vary with time? How does it vary according to processes (tectonically active zone vs volcanically active zone vs hydrothermally active zone)?

The definition of the edge of the “ridge crest” is likely to be as fraught as identifying the continent-ocean boundary or the Moho. At the ridge, the volcanic, tectonic and hydrothermal zones are closely linked but the processes that determine their spatial extent are different and dependent on the spreading rate. However, hydrothermal activity can potentially occur anywhere there is a suitable heat source and permeability structure. For example, low-temperature hydrothermal activity occurs at the Lost City Vent Field, 15 km away from the magmatic axis of the Mid-Atlantic Ridge, while at the Mid-Cayman Spreading Centre high-temperature venting occurs on Mt. Dent, also 15 km from the volcanic axis.

3) What is the contribution of diffuse off-axis “cold” hydrothermal flow on the heat budget, mineralisation and alteration of the oceanic crust?

Diffuse heat flow from off-axis oceanic crust and around seamounts is likely to be significant and may account for more than that in the immediate vicinity of the ridge-axis, although few constraints exist on this topic. Attempts to quantify this contribution are required.

4) What are the integrated processes that control the architecture of a subducting plate?

Subducting plates are mostly comprised of oceanic lithosphere formed at a mid-ocean ridge. Their thickness, structure and evolution are dependent on several aspects including spreading rate,

off-axis volcanism, hydrothermal cooling, ridge segmentation and fracture zones. The mantle component of the plate is partly depleted in composition by extraction of the melt that formed the crust at mid-ocean ridge. The mafic part of the plate varies in thickness and structure from a layered ~7 km thick sequence (for spreading rates >5 cm per yr) to a mixture of peridotite and gabbro, often capped by basalt (for spreading rates <2 cm per yr). The mafic part of the plate also undergoes alteration, hydration and mineralisation. As the oceanic plate cools over time, while travelling towards the subduction zone, the lithosphere becomes thicker (being mostly defined thermally). Hydrothermal circulation continues to alter the upper plate chemically, with high-temperature hydrothermal circulation at the MOR, colder fluid interaction at abyssal seafloor, and again, greater fluid interaction just before subduction when bending of the plates induces extensional cracking. The specific questions in relation to these issues are:

a. What is the extent of serpentinization and how far off-axis is this process active? Does it stop before the plate enters subduction?

Serpentinization occurs when water is in contact with mantle rocks. It is observed at slow and ultra-slow ridges on axial valley walls, on ocean-core complexes and at fracture zones. It occurs again as the plate enters a subduction zone as bending opens fractures in the crust and provides a conduit for water to enter the upper mantle. This alteration may facilitate the subduction process by weakening the lithosphere and, as the downgoing slab is heated, provide a source of water to promote melting in the overlying mantle wedge. Observations from ophiolites show that serpentinization can occur down to 10+ km.

b. What is the lifetime of an abyssal hill? How are abyssal hills “rejuvenated” far from plate boundaries?

Once formed in the axial zone of a mid-ocean ridge by a combination of volcanic and tectonic processes, abyssal hills become progressively buried by sediment. The small abyssal hills formed at fast-spreading ridges are tens to ~200 m high, so could be buried under thick sediments after several tens of millions of years (depending on sedimentation rate). They can be rejuvenated by the bending and fracturing of the plate as it enters a subduction zone. It appears that new faults are formed in such situations, but perhaps some old ones bounding abyssal hills might be reactivated. Abyssal hills may also be rejuvenated by propagating ridges. The interplay between old axial faults and rejuvenated ones has implications for seismicity, fluid flow and possible mineralisation of the crust.

c. What characteristics of the ocean plate architecture created near the axis influence the behaviour of the subducting plate?

When the mid-ocean ridge axis is anomalously hot or fertile, mantle material may melt to a larger degree, and a thicker-than-normal oceanic crust is formed in the so-called 'aseismic ridges' (such as the Nazca and Juan Fernandez Ridge near South America, but also Iceland). Such a thicker crust is buoyant and tends to resist subduction, in a similar way as subducting continental blocks do. Extensive intraplate volcanism (i.e. erupted away from the mid-

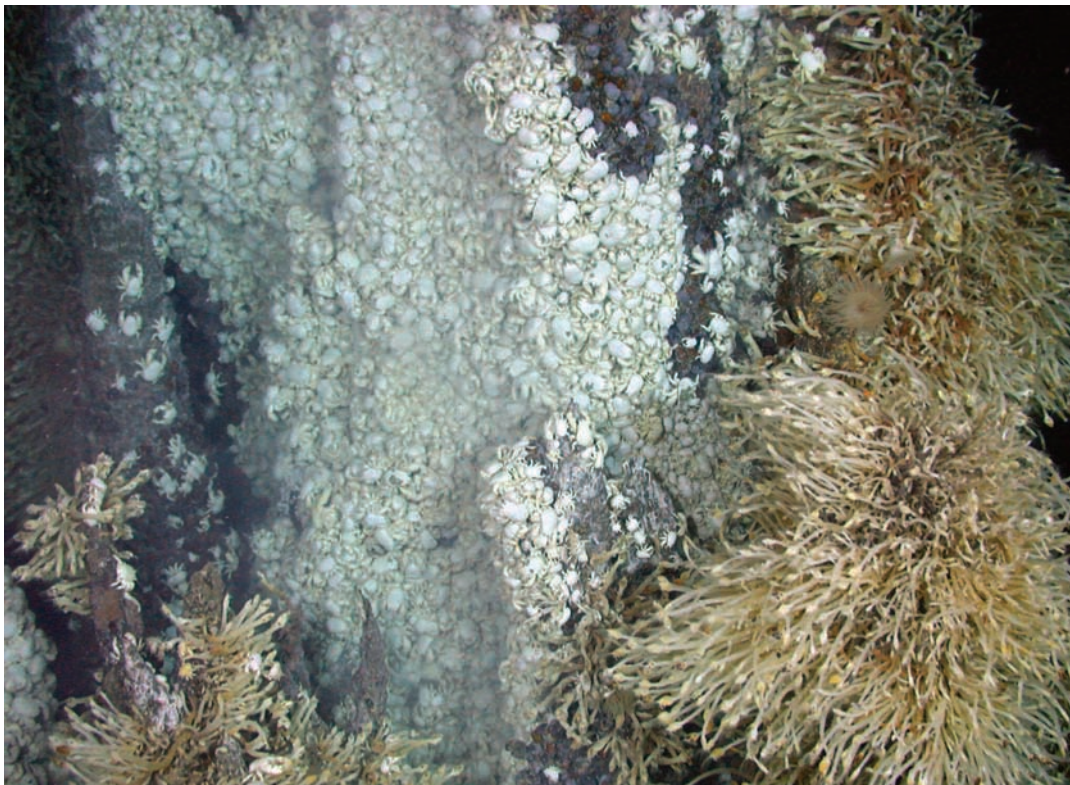
ocean ridges and subduction zones, such as Hawaii) can also cause a thickened crust with similar subduction-resisting properties. Seamounts, like those on the Louisville ridge, also disrupt the subduction process and may temporarily lock-up the subduction process, increasing the likelihood of major earthquakes when failure eventually occurs.

Implementation:

- a. Develop predictive models to identify critical areas where off-axis processes can be observed.
- b. In such a vast area every opportunity should be exploited to collect data off-axis.
- c. AUV surveys of near-axis areas with ultra high-resolution bathymetry and profiling.
- d. Better use of transit routes: systematic coverage of ridge flanks, and collection of bathymetry data for all cruises and transits.
- e. Develop methods and tests for extrapolation from local to regional or global estimations of fluxes.
- f. Improve monitoring of hydrothermal vents to capture spatial distribution and temporal variation of fluxes: better estimate of the global fluxes.

Section F

Past, Present, and Future of Vent Ecosystems



'Carwash' chimney, E9 vent field, East Scotia Ridge, depth 2400 m, imaged by the UK ChEsSo Consortium, January 2010. Mosaic image by Leigh Marsh, Jon Copley (University of Southampton) and the *ISIS* ROV Team (National Oceanography Centre, Southampton).

Background:

The past 30 years have seen hydrothermal vent communities revolutionise our view and understanding of deep-sea biology. These spatially restricted communities harbour biomass many orders of magnitude greater than that of surrounding deep-sea environs. Moreover, many of these communities contain endemic species of microbes to metazoans with specific adaptations to cope with the challenging environmental conditions. The ongoing discovery of new sites, in new ridge systems, adds species diversity and complements our understanding of these systems at large.

Recent years have seen the emergence of new techniques in DNA sequencing that have enabled genomic sequencing, transcriptomic, proteomics, and metabolomics from more and more species (microbes to megafauna). These technologies provide us with new perspectives and data to address fundamental questions regarding the evolution of vent species, the on-going processes of selection and speciation, the connectivity of vent communities, and the potential effects of global change on the survival of these biological assemblages. Recently, hydrothermal sulfide deposits have attracted a lot of attention from mining companies (both in national and

international waters), with exploration permits covering active and inactive sites. Exploitation could, in the near future, become widespread with mining activities in the Manus Basin scheduled to begin in early 2013. In this context, it is increasingly urgent to better understand the forces that drive species evolution and community structure at vents and consequently, the susceptibility of individual species, vent communities and the ecosystem function to anthropogenic impacts.

Primary Questions:

- 1) What are the molecular bases for physiological and life history adaptations to hydrothermal vent conditions? When did these adaptations occur?
- 2) How did these adaptations affect and yield the diversity of vent organisms?
- 3) How did past global environmental changes (e.g. global deep-sea anoxia) affect the evolution of vent species?
- 4) How does the dynamic nature of hydrothermal vents affect the evolution of species?
- 5) How resilient are vent species/communities and how may they be affected by deep-sea mining?
- 6) Could global change affect vent species and their function in the ecosystem? On what time scales?

The following questions represent some of our knowledge gaps regarding the evolution of vent communities, current connectivity and susceptibility to anthropogenic changes that can be addressed by the InterRidge community:

1) What are the molecular bases for physiological and life history adaptations to the hydrothermal vent conditions? When did these adaptations occur?

Vent conditions, including low oxygen, variable - and sometimes high - temperatures, radioactivity, potential toxins such as heavy metals and sulfide, and extreme gradients can all be challenging for the survival of organisms. This explains, at least in part, the very high degree of endemism encountered at hydrothermal vents. High throughput genome and transcriptome sequencing allows comparative genomics studies that can point to key mutations in the adaptation of vent organisms. Reconstruction of ancestral states during these analyses can allow the determination of the timing of such adaptations, and relate them to changes of environmental conditions or community composition. Symbioses have evolved in different taxonomic groups and they represent a very large proportion of the biomass. Understanding how they evolved and what are the molecular adaptations they require could be addressed with similar approaches.

2) How did adaptations to vent conditions affect and yield the diversity of vent organisms?

The current biodiversity at hydrothermal vents is the result of complex processes that allowed speciation (allopatric and parapatric), with possible secondary connections of populations driven by tectonic events. The sharp gradients over small scales of

space and time, along with the succession of numerous extinctions and recolonisations, likely drive rapid speciation. The study of the connection between adaptation and speciation can be tackled at the molecular level (partial or whole genome sequencing), and can only be understood in a solid geological context of the history of plate tectonics (typically over the past 250 million years) to understand secondary contacts of populations.

3) How did past global changes (e.g. global deep-sea anoxia) affect the evolution of species?

Some of the great extinctions in the deep-sea were the result of global environmental change. These changes affected not only temperature but also oxygen concentrations. Reduced oxygen events may have been widespread in the deep sea during the Mesozoic era and consequently may have influenced the evolution of deep-sea fauna. However, there are considerable gaps in our understanding of the origin, evolution and divergence of vent species and/or their adaptations. In particular, phylogenetic relationships with other deep-sea fauna often remain unclear. Only the most emblematic taxonomic groups have been studied to date and only tell part of the story.

4) How does the dynamic nature of hydrothermal vents affect the evolution of species?

Hydrothermal vent chimneys and sites have a limited persistence, and their biological communities are also adapted to life in a short-lived habitat. These extinctions followed by recolonisations form a succession of founder effects that can reduce diversity at a given site but also allow gene combinations otherwise unlikely to occur. This could allow the exploration of the adaptive landscape and could have very strong effects on the evolution of species. The genetic diversity of colonisers at a new site and its relationship with other populations has not been studied to date. Only mature sites, with an overlap of generations, have been studied to date.



Biota at 'Marsh Towers', East Scotia Ridge; image from *ISIS* ROV

5) How resilient are vent species/communities and how would they be affected by deep-sea mining?

Although adapted to episodic extinction of sites, the ability of vent species to disperse, as well as the critical population size to allow recovery from perturbation, have not been studied in most species. A wealth of information is available on some species but they do not represent all taxa, or all reproductive strategies (eg. direct vs. indirect development, large vs. small oocytes). Reproductive and dispersal strategies need to be studied in a wide variety of species. The episodic disturbance that characterises vent sites will not affect all species equally and thus the ecological balance that sustains the coexistence of species with similar niches, and with similar function in vent communities, is likely to be sensitive to both the frequency and intensity of disturbance. This is particularly important in the context of deep-sea mining because long-term and large spatial scale effects are likely with the exploitation of sulfides that host the communities.

6) Could global change affect vent species, and if so on what time scales?

In the context of global change, the vent ecosystems seem far from harm. However, little is known of the potential effects of warming, acidification, and increasing hypoxia of the oceans on the vent communities. Although the deep-sea water surrounding hydrothermal vents is unlikely to be affected for many years to come, it is formed at the poles and its temperature is likely to increase. Once this water is formed, it will continue on its tracks and eventually reach the vent communities. The highly dynamic character of the environment (with different degrees of acidification, hypoxia and temperature) would suggest the effects would be minimal. However, if the species already live on the edge of their capacity to cope, then a minor change could have strong detrimental effects. This is especially true of symbiotic species that are dependent on fluid emissions for their symbionts and may not be able to cope with additional challenges. This would require thorough experiments on the physiology and response of a wide variety of species. The current genetic diversity within species (adaptive polymorphism) also needs to be evaluated to predict survival and adaptability of the species. The deep-sea water parameters will need to be monitored to determine the surrounding hydrothermal vents and the deep sea in general.

Implementation:

- a. The urgency due to the start of deep-sea mining requires an increased effort, in particular for studies of connectivity between populations, the function of the different species in the community and ecology in general.
- b. Connectivity studies would be facilitated with an increased effort towards transcriptome/genome sequencing. This sequencing effort will also benefit other fields of research including understanding adaptations to the vent environment and the evolution of these adaptations, as well as the history of vent phyla and communities. Understanding the evolutionary history of these species will help us predict their future.
- c. Experimental work on live animals to determine their physiological limits remains a basic need and many species need to be studied to better understand the spectrum of adaptations.
- d. Studying the physiology of animals under pressure remains a technological challenge and InterRidge could help in the dissemination of such technology.
- e. Although some species have been very well studied, most have not. We need to increase the phylogenetic coverage of studies of physiology, tolerance, reproductive/dispersal strategies and their ecological function in the community.



Hydrothermal vent chimney on the East Scotia Ridge imaged by the UK ChEsSo Consortium, January 2010. Mosaic image by Leigh Marsh, Jon Copley (University of Southampton) and the *IS/S* ROV Team (National Oceanography Centre, Southampton).

Coordinator Update

Debbie Milton

Many of the aims and projects that were started by the UK InterRidge Office at the beginning of its term of office came to fruition in 2012. The main aims were to extend InterRidge's support of active ridge science, to build up InterRidge membership, to increase InterRidge's influence with policy makers at a time when many nations are showing an interest in the resources of mid ocean ridges and to set future goals through the development of the next decadal plan for InterRidge.

- IR Student and Postdoctoral Fellowship Programme - four researchers have been made IR Fellows in 2012.
- The International Seabed Authority has committed its support to the InterRidge Fellowship programme with a further grant of \$45,000 that will support nine students from developing countries between 2012-14.
- The cruise bursary scheme has become fully established and we have supported ten students this year.
- Steering Committee membership - we welcomed Portugal and Canada back into Associate membership.
- Working Groups – four new WGs are now operating, plus an extension of three years has been granted to the Seafloor Mineralisation WG.
- InterRidge: Third Decadal Plan 2014-23 was developed and formally accepted during 2012.
- InterRidge has been granted observer status at the ISA.

Steering Committee

The annual IR Steering Committee was held in St. Petersburg, Russia, in June 2012. The report of this meeting is posted at: <http://www.interridge.org/stcom/reports>. We welcomed two nations back into membership – Canada (Kim Juniper) and Portugal (Pedro Ferreira) and we are currently in negotiations with others, at a time when interest in seafloor resources at the ridge crest is rapidly increasing.

Liaison panel on exploration guidelines

One new initiative arising from the 2012 StComm meeting was the need to develop guidelines on vent exploration, in collaboration with invited NGOs and industry. These would be similar to the Code of Conduct developed a few years ago, but more outward-looking to all stakeholders, rather than just scientists. It was thought that by bringing all stakeholders together from the beginning, there would be ownership of the guidelines and that this represented the most likely way to a successful outcome. A liaison panel has begun work on these matters and will report back to the IR community in due course. The members are: Georgy Cherkashov, Cornel de Ronde, Chuck Fisher, Lyle Glowka, Kim Juniper, Jiabiao Li, Catherine Mevel, Sven Petersen, Joe Resing and Andrew Thaler.

Below: IR Steering Committee in St. Petersburg, Russia, June 2012

Back row, L-R: John Chen, Jiabiao Li, Hide Kumagai, Kats Fujikura, Kim Juniper, Aquila Tawake, Michinari Sunamura. Front row, L-R: Sergei Silantsev, Georgy Cherkashov, Debbie Milton, Xianglong Jin, Sven Petersen, Bramley Murton, Javier Escartin, Ricardo Santos, Richard Hobbs.



New National Correspondent

National Correspondents play an important role in the communication of international ridge science. The IR Office is pleased to welcome **Kim Juniper** (Canada), who has been a Professor in the School of Earth and Ocean Sciences and the Department of Biology at the University of Victoria, and holder of the BC Leadership Chair in Ocean Ecosystems and Global Change since 2006. He went to UVic from the Université du Québec à Montréal where he was Professor of Biology and Director of the GEOTOP Research Centre. He received his BSc from the University of Alberta (1976) and a PhD from Canterbury University in Christchurch, New Zealand (1982).



The primary focus of his research has been the biogeochemistry and ecology of submarine hydrothermal systems. His interdisciplinary publications on deep-sea vents encompass the fields of microbial ecology, biomineralization and benthic ecology. Other research areas have included the microbial ecology of deep-sea sediments, and the seasonal dynamics of arctic sea-ice microbial communities.

Juniper previously served the NEPTUNE Canada project as Co-Chief Scientist in 2004-2006, and was President of the Canadian Scientific Submersible Facility from 2001 to 2011. He is currently Associate Director, Science, at NEPTUNE Canada.

Working Groups

Since last year's IR News, there have been significant changes in the number and range of Working Groups. The Mantle Imaging WG has finished its work and has now disbanded. Four new WGs have formed:

- Island Arc and Back Arc (BI-ARC) (Chair: Maria Seton, Australia)
- Circum-Antarctic Ridges (Co-Chairs: Anne Briais, France; Jian Lin, USA; Sung-Hyun Park, Korea)
- Oceanic Detachment Faults (Co-Chairs: Pablo Canales, USA; Javier Escartin, France)
- South Mid-Atlantic Ridge Targeted Exploration (SMART) (Chair: Colin Devey, Germany)

Due to its relevance to current interest in seafloor resources, the Seafloor Mineralisation WG has been given a 3-year extension. Progress updates can be seen in the Working Group Updates section of this volume.

Workshops and Conferences

InterRidge supported a number of related workshops in 2012, including the VentBase meeting in Ireland and in Kiel, both in April 2012. Reports can be seen in the Workshops and Conferences section of this volume, as well as at:

<http://www.interridge.org/science/IRmeetings>.

InterRidge: Third Decadal Plan 2014-23

Discussion on this began in late 2011 and has culminated in its publication in this volume. The IR Office extends its thanks to all who contributed to making this document a powerful statement for the next phase of mid-ocean ridge research.



Participants at the InterRidge Third Decadal Plan discussion meeting, Dec 2011.

InterRidge gains observer status at ISA

InterRidge was granted observer status at the ISA in July 2012, allowing InterRidge to be present at public meetings of the Assembly and by invitation, to make oral statements on issues of concern, although it will not be able to participate in decision-making. This increases our links with the ISA and will strengthen our ability to engage with developing countries, which remains one of InterRidge's main challenges.

Goodbye

This volume marks the end of three years as InterRidge Coordinator. It has been a privilege to work within this very exciting scientific field, and I would like to give special thanks to Bram and Jon for giving me the opportunity to be involved. The role has been a stimulating and challenging one, and I would also like to thank the IR Steering Committee and Working Group Chairs, as well as all the individuals who have helped in continuing to give InterRidge a significant voice in mid-ocean ridge science and policy. I wish John and Jiabiao, together with the new coordinator, every success as they continue the work of representing InterRidge worldwide.

Education and Outreach Update

Debbie Milton

2012 InterRidge Student and Postdoctoral Fellows

In accordance with InterRidge's mission to encourage and support young ridge researchers in international, collaborative and interdisciplinary studies, annual Fellowships of \$5000 USD are awarded to students or postdoctoral researchers, allowing them the opportunity to work overseas in established laboratories and to develop partnerships with key scientists in their field of interest. The past three years has seen the successful establishment of a partnership between InterRidge and the ISA Endowment Fund, designed to support early career scientists from developing countries in collaborative marine scientific research. Further information on this can be seen at: <http://www.interridge.org/isapartnership>.

The InterRidge Student and Postdoctoral Fellowship Programme continues to develop and reach out to the global community of early-career ocean scientists. InterRidge acknowledges the continued support from the ISA Endowment Fund, which has committed a further \$45,000 during 2012-14 to support students from developing countries. Due to the large number of high-quality proposals submitted this year, we were able to award four InterRidge-funded Fellowships, together with three ISA Fellowships. Therefore, seven awards of \$5000 USD each were given to develop young scientists' careers. The IR Steering Committee thanks all involved in this programme, in particular the many reviewers.

The IR Steering Committee is pleased to announce that in 2012, InterRidge Fellowships have been awarded to:

Catherine Cole



Cole is a PhD student at the National Oceanography Centre, Southampton, UK, and is supervised by Drs. Rachael James and Doug Connelly. She will visit both the research labs at LabHorta, University of the Azores, where she will work with Raul Bettencourt and Ines Martin, and the University of Nantes, where she will be sponsored by Richard Cosson. Her proposal is entitled: "When do essential metals turn toxic? A proteomic study of metal-induced oxidative stress on the hydrothermal vent-living mussel, *Bathymodiolus azoricus*". Cole will examine how the presence of cadmium, a non-essential, toxic metal, influences the mussel's ability to tolerate elevated concentrations of essential metals, iron and copper. The build-up of metals in key tissues, and the production and activity of anti-oxidant enzymes will be quantified in response to controlled metal exposure. This will enhance current understanding of metal tolerance in these chemically extreme environments.

"I am doing a PhD in hydrothermal vent geochemistry and am eager to continue to broaden and expand my experience. This InterRidge Fellowship will give me the opportunity to learn new techniques in state-of-the-art molecular biochemistry within the unique research facilities of the University of the Azores and the University of Nantes. This will contribute crucially to my PhD and open a door into a new aspect of science with far-reaching applications".

Emanuele Fontana



Fontana is a postdoctoral researcher at the Università degli Studi di Milano, working with Paola Tartarotti. He will travel to Williams College & Williams Mystic, Connecticut, USA, to study with Lisa Gilbert on a proposal: "Structural and petrophysical analysis of the lava/dike boundary at intermediate to superfast-spreading ocean crust: Integration between present-day ocean crust and ophiolites". This project proposes a comparative analysis of data from Troodos ophiolites (Cyprus), DSDP/ODP Hole 504B, and ODP/IODP Hole 1256D. An integration of geophysical, petrographic,

structural and microstructural data will provide insight into the roles of faulting and fracturing during crustal accretion and evolution of the oceanic crust, especially at the boundary between volcanics and sheeted dykes.

"Since I remember I've been always fascinated by the curious and almost incredible opportunity to observe on land, or even on rugged mountains, what was long before formed on the ocean floor: the ophiolites. These rocks contain the history of planet Earth and express all its strength. The InterRidge Fellowship gives me the opportunity to study and compare the ocean relict, still preserved in the ophiolites, with present day seafloor rocks. Somehow, it will be like bringing back these old rocks, which have been travelling for a long time, to their original environment".

Alessio Sanfilippo



Sanfilippo is studying the petrological processes controlling the first phases of generation of the lower oceanic crust, tracking the minerals' chemical evolution from the mantle to the primitive gabbroic rocks, together with Prof. R. Tribuzio and Dr. M. Tiepolo at the University of Pavia. Sanfilippo will take part in a scientific cruise to the Mid Atlantic Ridge and he will work

with Dr. Henry Dick at the Woods Hole Oceanographic Institution, USA. His proposal is entitled: "The role of the melt supply variability in the development of a detachment fault system".

"I have always been attracted by the complexity of the geological processes constraining the formation of the oceanic crust at spreading ridges. The detachment faults are an important component of lithospheric creation along oceanic ridges and provide windows into the oceanic lithosphere. The InterRidge Fellowship will enable me to take part in a research cruise to study the role of magmatism in the development of a detachment faulting system at the Mid Atlantic Ridge. I am excited by the possibility of sampling portions of the lower oceanic crust and mantle, constraining the deep processes that generate the detachment faulting".

Jessica Till

Till received her PhD from the University of Minnesota in 2011 and has participated in an IODP drilling expedition to sample lower crustal rocks in superfast spreading crust. She will visit Imperial College, London, UK to work with Dr. Adrian Muxworthy on her Fellowship proposal: "Quantification of Fe-oxide exsolution microtextures in silicates to constrain cooling history at a superfast

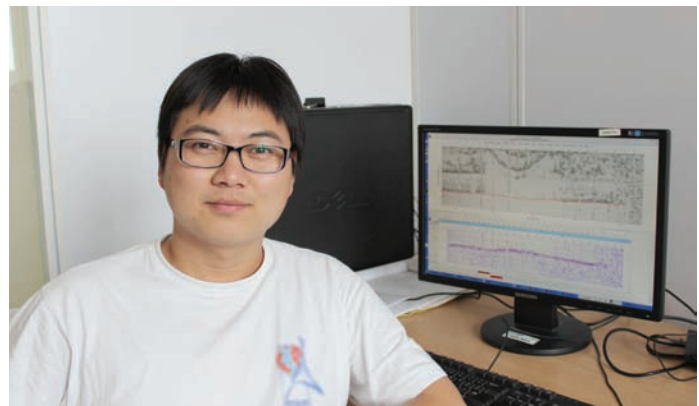
spreading ridge". Currently she holds a postdoctoral post at IMPMC, Paris, working with Dr. Yohan Guyodo.



"The lower oceanic crust is an exciting frontier in ocean research and the microscopic Fe-oxide mineral intergrowths that occur throughout the lower crust have interested me for years. The InterRidge fellowship gives me a great opportunity to investigate the origins of this intriguing mineralogical system. Their textures could provide a wealth of information about magma emplacement mechanisms and thermal history at ocean ridges".

The following are InterRidge/ISA Endowment Fund Fellows 2012:

Hanchao Jian



Hanchao Jian will work on full-waveform inversion of 3D seismic data collected at the ultra-slow spreading Southwest Indian Ridge, which is the first 3D seismic experiment conducted over an ultra-slow spreading ridge. This is part of a Sino-French joint project, where 40 Chinese and French ocean bottom seismographs were deployed for a 3D active-source OBS experiment on Chinese R/V "Dayang Yihao" in March 2010. He is going to work at IPGP on the analysis of the 3D seismic data and will be jointly supervised by Prof. Satish Singh (seismologist) at IPGP and Prof. Y. John Chen (geodynamicist) at Peking University.

"I am interested in the seismic and geodynamic study of mid-ocean ridges (MORs). The IR/ISA fellowship will give me an opportunity to investigate the detailed seismic structure and geodynamic

processes of the ultra-slow spreading Southwest Indian Ridge and to work with top marine geoscientists. The result will improve our knowledge about the ultra-slow spreading MOR. I am very grateful to the IR/ISA fellowship for this opportunity".

Sanitha Sivadas



Sivadas is presently a CSIR-Research Associate at the Biological Oceanography Division, National Institute of Oceanography, Goa, India, working with Dr Baban Ingole.

Her proposal title is: "Functional diversity of the benthic community from hydrothermal vent regions". The shallow water hydrothermal vents are considered to be "hot spots" of biodiversity. The discovery of minerals in the hydrothermal vents, depletion of resources on land and growing demand has resulted in increased interest for mining this fragile and unique ecosystem. However, the exploitation of resources will have significant impact on the vent biodiversity. Most of the studies on the vent communities are focused on the structural diversity. Studies on the biodiversity-ecosystem functioning and the influences of environmental parameters are few. Understanding the role of biodiversity in ecosystem functioning is important for protection and management of vent ecosystem.

"My research to date has focussed on the role of macrobenthos in the ecosystem functioning of coastal habitat and evaluating its usefulness for environmental monitoring. Though hydrothermal vent research is relatively new to me, the InterRidge/ISA fellowship gives me an opportunity to join one of the most experienced researchers in the field of vent ecology, Dr. Ana Colaço, and study the benthic diversity-ecosystem functioning of shallow water vents in the Azores, Portugal. Effective management of marine habitats requires assessing the link between biodiversity and ecosystem functioning. Limited study has been carried out from the hydrothermal vents of Indian Ocean; the expertise gained during the fellowship will help to study the Indian Ocean hydrothermal vent community".

Andrew Thaler

In 2012, Mr. Freddie Alei, will enrol on a 5-week summer course at Duke University Marine Lab, to study conservation and

management. Thaler will serve as his research mentor, training him in molecular approaches to ecology and population genetics at hydrothermal vents, and developing his professional skills. The objective of this proposal is to support a capstone experience for Mr. Alei, to present the results of his research at the 13th International Deep-Sea Biology Symposium in Wellington, New Zealand. Here he will increase his knowledge of deep-sea ecosystems and tools of environmental management and network with potential future collaborators and employers.

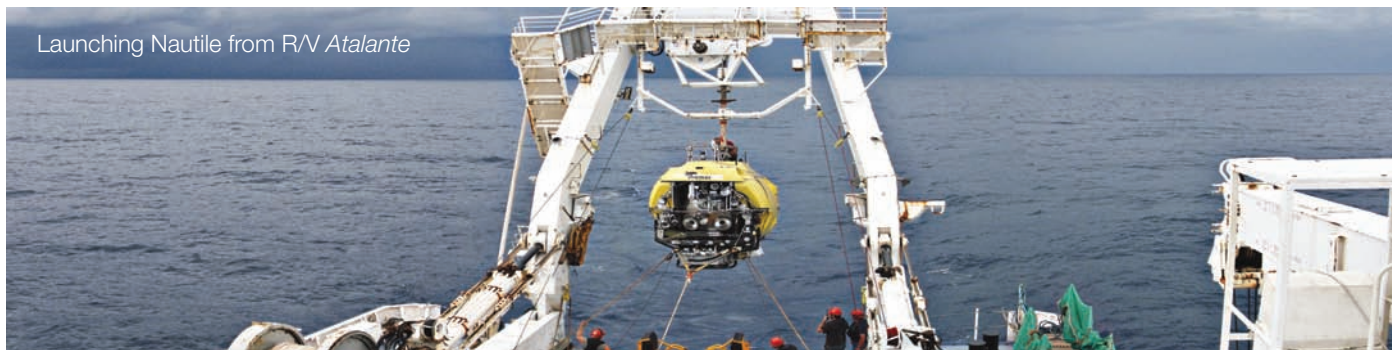


Thaler's proposal: "Capacity building: Training and professional development for a visiting scholar from Papua New Guinea" is supported by his advisor, Prof. Cindy Van Dover, based at Duke University Marine Lab, NC, USA. Thaler wrote: "I've always felt strongly that we should ensure that the knowledge we gain benefits the nations we work in, especially when our research takes us to developing countries. This InterRidge/ISA fellowship will help me train a visiting student from Papua New Guinea, Freddie Alei, and develop and enhance international collaborations".

News of 2011 Fellows

Donato Giovannelli

I started my InterRidge fellowship at Rutgers University in September 2012. However, within the collaboration with Prof. Costa Vetriani (Deep-sea microbiology lab, Rutgers University), I was lucky enough to participate in the oceanographic expedition MESCAL-2,

Launching Nautilie from R/V *Atalante*

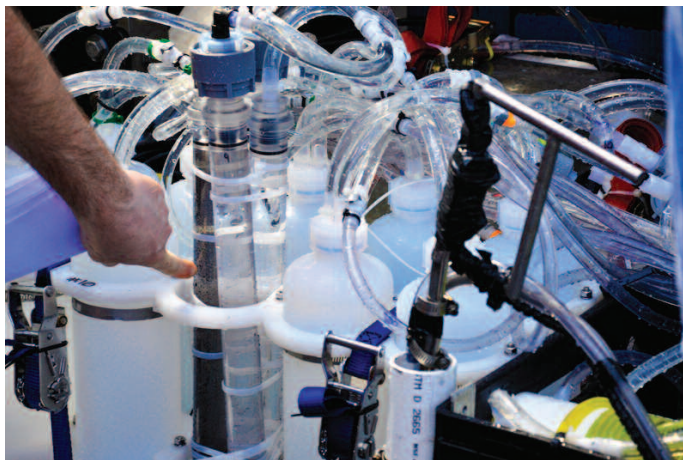
at EPR 9°N onboard the French R/V *Atalante* (Chief Scientist Prof. Nadine Le Bris). My current PhD thesis is focused on shallow hydrothermal vents and this was my first oceanographic expedition with the use of a deep submergence vehicle, and my first experience with deep-sea hydrothermal vents. Scientists and crew onboard were welcoming and, for a first timer like me, the whole experience was exciting and extremely interesting. The work onboard was informative and the Nautilie dives were exceptional. The expedition was a success and, with Prof. Vetriani, we obtained numerous samples that I will analyze whilst at Rutgers within the IR fellowship. I collected enrichment for the isolation of prokaryotes from different hydrothermal vent samples and participated in two high-pressure experiments involving the episympions of *Alvinella pompejana*. I would like to thank Prof. Vetriani for the great opportunity to participate in the cruise, Prof. Le Bris for hosting me onboard and InterRidge for its efforts in keeping the fellowship programme running every year.

Eoghan Reeves

As part of my InterRidge Postdoctoral Fellowship award, I am collaborating with hydrothermal plume researchers Dr. John 'Chip' Breier and Dr. Chris German (WHOI), as well as Dr. Sarah Bennett (NASA/JPL), to assess the nature of particulate organic matter forming in ascending hydrothermal plumes. Specifically, the award will allow me to examine if this organic matter incorporates hydrothermal sulfide, which would have implications for the sequestration of trace metals (such as iron) and their delivery to the deep ocean.

While the award was originally intended to fund only sample shipment costs and analysis, with additional funds from my institution (MARUM) I was very fortunate to be able to participate in the January 2012 R/V *Atlantis* and ROV *Jason II* expedition to hydrothermal systems in the Mid-Cayman Rise and Cayman Trough, where, together with Drs. Breier and Bennett, we planned to collect plume particulates using the WHOI SUSPended Particulate Rosette (SUPR) sampler. The SUPR device is deployed on the ROV *Jason* and pumps plume water through filters to collect samples of particles at precise points in the rising hydrothermal plume, which is visible to the ROV and scientists. A successful vertical transect of 6 filtered samples was collected above high temperature Beebe vents at the ~5 km deep Piccard vent site, and these samples were

processed and stored under low oxygen conditions prior to being shipped frozen at the end of the cruise. The nature of these unique and highly novel samples will permit, at a minimum, an examination of the quantities of particulate organic matter present in the initial stages of hydrothermal plume formation, and hopefully, compositional information (sulfur to carbon ratios), should sufficient quantities of organic matter be present. Thus, the sample collection portion of this project was extremely successful, and processing and analysis of the samples will now proceed at the MARUM Center for Marine Environmental Sciences, University of Bremen, with results expected Summer 2012.

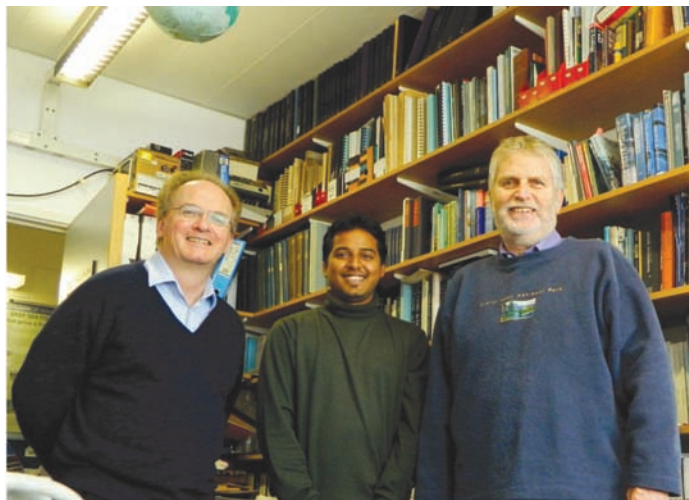


The WHOI SUSPended Particulate Rosette (SUPR) sampler fitted to the ROV *Jason II*, with recently collected samples of hydrothermal plume particles (visible) from the Cayman Trough (Photo by Julia DeMarines).

An additional fortuitous aspect of my participation in the expedition was to continue collaboration with my former advisor from graduate school at WHOI, Dr. Jeff Seewald. Given that SUPR sampling was limited to certain dives on the cruise, the remainder of my time aboard *Atlantis* was spent assisting Jeff's hydrothermal fluid sampling team. I was able to continue my research into another aspect of organic sulfur chemistry in hydrothermal systems, specifically measuring the abundance of methanethiol (methyl mercaptan) at these novel vent sites. Key datasets on methanethiol were collected from both the Von Damm and Piccard vent sites and will soon be submitted for publication.

The opportunity to conduct two projects simultaneously with two research groups on this expedition, both of which form part of the international community of hydrothermal research, highlights the tremendous scientific benefit of InterRidge-sponsored international collaborations, as well as the global connected nature of our research community. I am very grateful to InterRidge for the opportunities this fellowship has allowed, and thus far the fellowship project has been a tremendously beneficial experience.

Sabyasachi Sautya



Above - Sautya with Prof. Paul Tyler (right) and Dr. David Billett
Below - with Dr. Daniel Jones (right) and Dr. Andrew Gates

2011 was a great opportunity and memorable year for me when I visited the National Oceanography Centre (NOC), Southampton, UK to carry out my project entitled: "Exploration of the megabenthic assemblages of the Carlsberg Ridge, Indian Ocean", under the guidance of Dr. Daniel Jones. I aimed to learn how to conduct biological analysis of underwater video (quantify megafaunal density, diversity and assemblages structure in different habitats on the Carlsberg Ridge, Indian Ocean) using modern techniques.

I learnt proper methods of how to prepare a habitat and species guide which helps to identify the organisms or habitat from the Carlsberg Ridge region and is also useful for many other areas. Furthermore, I quantified the megafaunal assemblages from video data that will help to estimate the biodiversity in the particular region, and I learned habitat mapping using a GIS technique.

This fellowship gave me the opportunity to learn skills required to obtain quantitative data on the benthic environment from images that were not previously available in India. The fellowship provided me with technical training in image analysis and interpretation at one of the world-leading centres for deep-water image-based ecology. During my month at NOC I met experts in various field of marine ecology and invertebrate taxonomy such as Prof. Paul Tyler, Prof. Andy Gooday, Dr. David Billett and Dr. Roger Bamber, and had many discussions with them and received helpful suggestions.

Finally, I give my sincere thanks to the InterRidge/ISA Fellowship programme for giving me this wonderful opportunity, which has greatly helped in my early research career and will also benefit the ongoing Ridge Research Program of India. I became familiarized with British people and their various cultures and I visited some beautiful places in the UK that will be unforgettable for my whole life.

Srinivas Rao

Srinivas is currently at Universität Bremen, working under the supervision of Dr. Maren Walter. His report will be published on the website after completion of his Fellowship.

Girish Beedessee

I was able to visit the Japan Agency For Marine-Earth Sciences and Technology (JAMSTEC) to work under the supervision of Dr. Ken Takai and Dr. Hiromi Watanabe. The purpose of the visit was to generate and analyse data from invertebrates collected from four different hydrothermal vent sites along the Central Indian Ridge (CIR) in order to get a better understanding about their dispersal abilities over long geographic distances. The study involved the analysis of genetic data using multiple bioinformatics software and the results obtained are now under discussion and will be submitted soon as a scientific paper. I wish to thank both these scientists as well as my numerous JAMSTEC friends for helping and making my stay comfortable and successful. Special thanks go to Dr. Daniel Marie of the Mauritius Oceanography Institute for providing the necessary platform for me to conduct my research initiatives.

Beedessee is also a joint author of a recent paper: Discovery of New Hydrothermal Activity and Chemosynthetic Fauna on the Central Indian Ridge at 18°–20°S, available at:

<http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0032965>.

InterRidge cruise travel bursaries

The InterRidge Cruise Travel Bursary scheme was instigated by the UK IR Office, and now in its second full year, has proven to be very successful. The aim is to link early career scientists with established scientists from other nations, to develop international collaborations and to enable participation in mid-ocean ridge research cruises. We advertise opportunities when we are informed of spare berths on cruises and we welcome applications from students for whom we then try to find a placement on an upcoming cruise. Details are at: <http://www.interridge.org/cruisebursary> or contact the IR Office.

Juan de Fuca Ridge to Trench

Three early career scientists - **Berta Biescas** (Halifax, Canada), **Guillermo Bornstein** and **Jhon Mojica** (both from Barcelona, Spain) – took part in an experiment led by Suzanne Carbotte. There were two research vessel involved in the "Juan de Fuca Ridge to Trench" survey: RV *Marcus Langseth*, which was in charge of the multichannel seismic reflection data acquisition and the RV *Oceanus*, which was in charge of the ocean bottom seismometers. The RV *Marcus Langseth* is one of the most advanced seismic vessels available in the academic community worldwide and provides seismic data of excellent quality. The team also had the opportunity of acquiring XBTs and XSVs simultaneously with the seismic acquisition and applying these data for seismic inversion. Besides, the RV *Oceanus* offered the opportunity of doing CTD space-coincident casts (not in time) of the seismic acquisition, in order to detect the thermohaline structure with better resolution than with the expendable probes and to have an accurate temperature-salinity relationship of the area.



Above left - right, Berta Biescas and Jhon Mojica.
Below, Guillermo Bornstein.



**InterRidge Student and
Postdoctoral Fellowships
\$5000 USD**



<http://www.interridge.org/fellowship>

Call for Proposals for the 2013 Fellowships will be released in January 2013

Deadline: 31 March 2013

Awards announced in June 2013

We (Biescas, Bornstein and Mojica) are very grateful to InterRidge and its cruise bursary scheme for giving us the opportunity of living this unforgettable scientific and human experience. We want also to deeply thank Suzanne Carbotte and Juan Pablo Canales for sharing their data with us and letting us learn from them and their teams. Finally, we want to thank all the staff of the RV *Marcus Langseth* and RV *Oceanus* for their help during the data acquisition.

Atlantic Hydrophone Project, Equatorial Atlantic

Debbie Smith from WHOI, invited **Camilla Palmiotto** (Italy), **Ross Parnell-Turner** (UK) and **Alex Zheleznov** (Russia) to participate on her cruise to the Equatorial Atlantic. This cruise deployed 3 hydrophones in the equatorial Atlantic to complete an array of 8 hydrophones. Five hydrophones had already been deployed during NOAA servicing cruises of the PIRATA buoys. The array will be in place for approximately 2 years, monitoring the seismicity of this tectonically interesting region. During the cruise, multibeam bathymetry data was also collected from along the Mid-Atlantic Ridge in regions that currently are not mapped.



Parnell-Turner, Palmiotto and Zheleznov onboard R/V *Atlantis*.

Wiring the Abyss 2012 cruise

Daphne Cuvelier is aboard the R/V *Thompson G. Thompson* as this volume goes to press. An in-depth comparison of two ridges, characterised by different spreading rates, with the NEPTUNE observatory will be carried out, with the main objective being to compare the variations in the structure (composition, density) of hydrothermal vent communities and the link with temporal variations of abiotic factors between the Atlantic and the Pacific.



Easternmost Coral Sea and Lord Howe Hotspot cruise



Daniela Wolf (Germany) joined this cruise, aboard the *Southern Surveyor*, under the leadership of Maria Seton, the Chair of the Arc-Backarc Systems Working Group. The cruise is investigating the "Tectonic framework for the easternmost Coral Sea and northern extent of the Lord Howe hotspot". Wolf is a M.Sc. student at the University of Hamburg and is currently working on submarine volcanism at the Azores triple junction. The cruise is currently in operation as this volume goes to press.

Tasmantid Seamounts: volcanic, tectonic and carbonate record

In November and December 2012, **Lara Kalnins** will be joining the Australian research vessel *Southern Surveyor* for a 26-day expedition to the Tasmantid Seamounts, one of three major hotspot tracks in the region. This seamount chain is almost completely un-surveyed and un-sampled, so the expedition has been designed to be as diverse and interdisciplinary as possible, from dredging and swath mapping to magnetics and oceanography measurements. Post-cruise, she will be studying the age progression along the chain, the geomorphology, and looking at the plate velocity, the spreading rate, and the varying interaction of the magma with oceanic lithosphere in the south and thinned continental crust in the north.

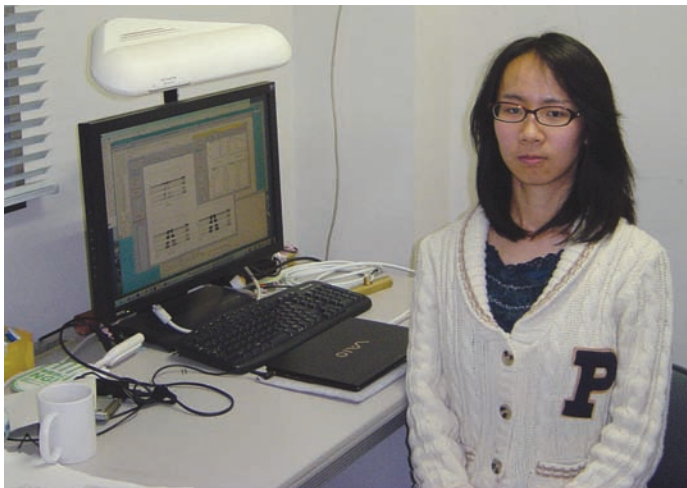


Acknowl: Christoph Beier, IODP Exp. 330

InterRidge student prizes

Student awards at: Ocean Mantle Dynamics: from Spreading Center to Subduction Zone” workshop, October 2011

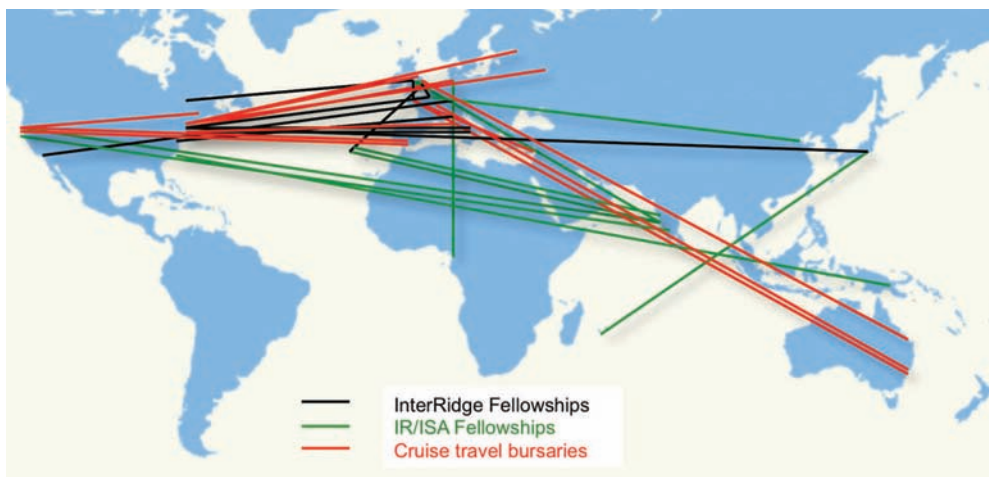
Akiko Takeo (Earthquake Research Institute of Tokyo University) received an IR best poster award for her work entitled: “Seismic anisotropy in the uppermost mantle beneath oceanic regions from data of broadband OBSs”. She is interested in the seismic velocity structure in the uppermost mantle, as it is one of the keys to understanding plate tectonics. Takeo analyses data from broadband ocean bottom seismometers deployed in oceanic regions such as the Shikoku Basin, south of Japan. 1D radially anisotropic structures beneath the Shikoku Basin can be obtained by measuring phase velocities of surface waves, indicating deformation at depths greater than 50 km.



Of the Mantle Imaging workshop, she said: “It was a good experience for me to attend the workshop because I could discuss both methods and results with seismologists, geomagnetists and petrologists. Also I learnt from other presentations about structure and processes in the mid ocean ridges and subduction zones. The field trip was also a good chance to study the composition and deformation of peridotite by seeing real rocks”.



Shusaku Yamazaki (Niigata University, Japan, working with Prof. Sumio Miyashita), was also awarded an IR student poster prize for his poster: “Formation of incipient oceanic island arc crust: geology and geochemistry of the late intrusive rocks in the Oman Ophiolite”. Oman ophiolite is considered as an analogue for fast-spreading oceanic crust and upper mantle sequences. Yamazaki’s interest in the Oman ophiolite is the petrogenesis of late intrusive rocks with island arc type characteristics in the lower gabbroic crust. New mapping in the lower oceanic crustal sequence allows recognition of the detailed distribution of late intrusive plutonics and boninitic dike swarms. In the poster, it is argued that their petrogenesis is based on petrography and geochemistry, and proposes that the complex of late intrusive plutonics in the mapped area can be regarded as a good example for early stage evolution of an intra-oceanic island arc crust.



InterRidge-sponsored collaborations 2008-12

Since 2008, InterRidge has been supporting early-career researchers across the world, and has built up an impressive network of collaborations, as can be seen here. The next challenge is to involve South America!

International collaborations sponsored by InterRidge through its Fellowship and cruise bursary programmes between 2008-12.

Seismicity of the Equatorial Mid-Atlantic Ridge and its Large Offset Transforms

R. Parnell-Turner¹, C. Palmiotto^{2,3}, A. Zheleznov⁴, D. Smith⁵, M. Fowler⁶, D. Bonnemains⁷, K. Bursaw⁸, C. Holly⁹, R. Dziak⁶

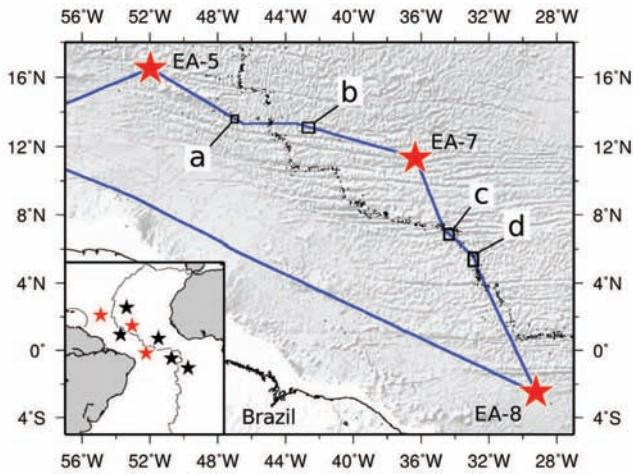
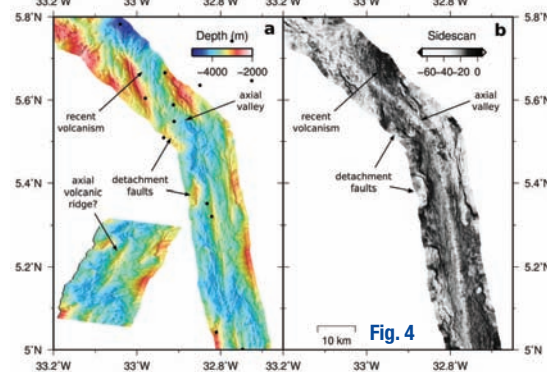
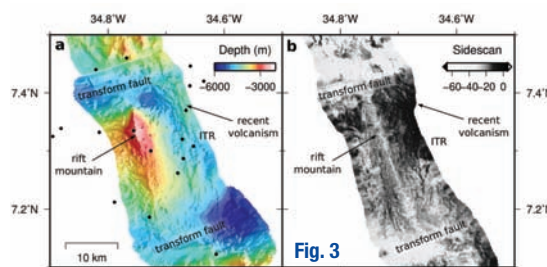
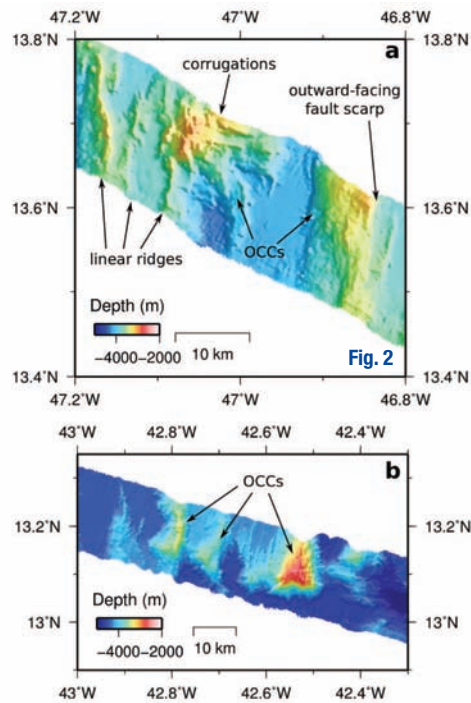


Figure 1. Map showing route of Cruise AT21-03. Blue line = cruise shiptrack; red stars = hydrophone deployment locations; black stars in inset = existing hydrophones; black dots = teleseismic earthquakes; black boxes = location of maps in Figure 2 (boxes labelled a and b), Figure 3 (box c) and Figure 4 (box d).

Figure 2. Examples of extinct OCCs located more than 200 km off-axis. (a) OCCs on the western flank of the MAR. Note the corrugations (labelled) on the western core complex. Linear ridges marking the tops of rotated faults are also labeled. (b) Three extinct OCCs located on the eastern flank of MAR. These core complexes were active at the 13°N segment and indicate that detachment faulting has been common on both sides of the MAR in this region.

Figure 3. Intra-transform ridge located at 7°N. (a) Multibeam bathymetry data. Black circles = teleseismic earthquakes; ITR = intra-transform ridge. An axial volcanic ridge is observed on the eastern edge of the data. (b) Sidescan backscatter image derived from the multibeam



data. The high backscatter of the axial volcanic ridge indicates that the ITR is magmatically active.

Figure 4. Single ship track along the MAR near 5°N. (a) Multibeam bathymetry data. Black circles = teleseismic earthquakes. An area of high backscatter indicating recent volcanism is marked. An axial volcanic ridge is observed between 5.1 and 5.4°N. Two features that we interpret as detachment faults are labeled on the western flank of the axis. (b) Sidescan backscatter image derived from the multibeam data.

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Abstract

The equatorial Mid-Atlantic Ridge is distinctive for its long-offset transforms and an inferred mantle thermal minimum south of Romanche fracture zone, resulting in overall low melt production. In addition, the North America-South America-Africa triple junction has migrated through the region. Consequently, the equatorial Atlantic provides an ideal laboratory for testing ideas about modes of spreading, short-term earthquake predictability and triple junction dynamics at slow-spreading ridges. The centerpiece of this project is an autonomous hydrophone array, which will obtain a two-year, continuous record of seismicity at the equatorial Mid-Atlantic Ridge. The temporal and spatial patterns in seismicity will be exploited to answer questions regarding the role of detachment faults in plate accretion, earthquake nucleation in oceanic lithosphere and deformation associated with triple junctions. Here we present the regional multibeam bathymetric dataset, collected on the transit legs of Cruise AT21-03 in June/July 2012, during which two hydrophones were deployed and maintenance carried out on a third instrument. We also suggest that in the future, the community could benefit from the opportunistic acquisition of valuable multibeam data through sharing information on the planned routes of upcoming cruises.

The hydrophone instrument and mooring

Autonomous hydrophones continuously record data, sampling at 250 Hz with a 110 Hz cut-off and a 16-bit analog/digital resolution. The hydrophone element is a single ceramic hydrophone attached to a titanium pressure case, with a pre-whitening filter to reduce the effects of ambient noise. Timing is constrained with a Q-Tech crystal oscillator clock (accurate to <1 s/yr) that is GPS synchronized before deployment and after recovery. All data are processed by logging computer, and then written to industrial hard drives rated to -20°C . A total of 164 standard alkaline D-cell battery packs provide the power required for up to 24-month deployments.

In the equatorial Atlantic, the hydrophones have been deployed about 300-500 km away from each side of the ridge axis, typically in water depths of 4000-5000 m. The instrument package is moored at a water depth of approximately 850 m, which is appropriate for surface-reflected sound propagation in the Sound Fixing and Ranging (SOFAR) channel. The hydrophone is suspended 50 m below a 37" syntactic foam flotation package, and the pressure case is attached to a seafloor anchor via 1/4" Vectran and low stretch 5/16" Yalex mooring cable. The design is intended to reduce strumming noise from the cable that can be generated by local currents. After deployment, an accurate anchor location is obtained by ranging on the acoustic release transponder. The entire mooring is recovered via an acoustic release attached to a degradable iron anchor. Additional information on the hydrophone moorings, instruments and data processing can be found at:

http://www.pmel.noaa.gov/vents/acoustics/haru_system.html.

AT21-03 multibeam bathymetry

Transit legs between the three hydrophone deployment sites

provided an excellent opportunity to map regions of the equatorial Atlantic Ocean and MAR axis previously unexplored. During the 18-day cruise, over 110,000 km² of multibeam bathymetry and associated acoustic backscatter data were acquired using a Kongsberg EM122 echosounder, operating at 12 kHz. The multibeam data collected during the expedition have provided new insights into crustal accretion and evolution and argue for having multibeam echosounder systems operating during all expeditions whenever possible. In future, with information on upcoming cruises and proposed ship tracks published prior to sailing, valuable multibeam data could be collected in areas of interest to the community. In the following sections we describe some of the observations made from our newly collected multibeam bathymetry.

Off-axis Oceanic Core Complexes (OCCs)

OCCs are massifs in which lower-crustal and upper-mantle rocks such as gabbros and serpentinized peridotites are exposed at the seafloor on long-lived faults known as detachment faults [Blackman et al., 1998, Tucholke et al., 1998, Smith 2008]. We now understand that detachment faults, which involve significant fault rotation and the formation of core complexes, may account for close to 50% of the extension at the northern MAR between 12° and 35°N .

Smith et al. (2006, 2008) and MacLeod et al. (2009) described the 13°N segment of the MAR in which a number of detachment faults extend for 75 km along the western flank of the spreading axis, and a field of extinct core complexes extends westward away from the axis for at least 100 km. What was not known was how far off-axis extinct detachment faulting could be found, nor whether the east flank had a similar history dominated by detachment faults and core complex formation. We took advantage of our transit to collect additional multibeam data in the region in order to answer these questions.

Based on the multibeam data alone, we identified extinct OCCs on the eastern and western flanks of the MAR near 13°N (Figure 2). The characteristics used to identify these features included one or more of the following: a domed surface dipping gently toward the ridge axis; corrugations on the domed surfaces oriented parallel to the spreading direction [Cann, 1997]; outward facing scarps created by the flexural rotation of an originally steep inward facing fault [Buck, 1988], and narrow linear ridges, which are produced at the detachment fault breakaway as the top of the fault rotates. Two extinct core complexes were identified on the western flank of the MAR about 220 km from the axis (Figures 1 and 2a). The OCC at 47.05°W has distinctive linear ridges associated with it, as well as corrugations parallel to the spreading direction. The feature at 46.85°W is backed by a characteristic outward-facing fault and looks to be the southern section of a larger feature to the north, similar to other OCCs seen closer to the axis.

On the eastern flank of the axis, a series of three extinct core complexes was identified about 75 km from the axis. In addition, a similar set of OCCs was identified farther off axis, about 220 km east of the axis (Figures 1 and 2b). Although no corrugations were

identified, the three features shown in Figure 2b have steep slopes of between 20° and 25° facing away from the axis and slightly domed, gently dipping surfaces facing west towards the axis.

The occurrence of OCCs east of the MAR at the 13°N region indicates that core complex formation is not limited to the western side of the axis and may have been occurring on both sides of the spreading center simultaneously. The identification of core complexes as far as 220 km from the MAR on both sides of the axis suggests that detachment faulting has been occurring at this section of the MAR axis for the past ~20 Myrs.

Intra-transform spreading center, 7°40'N

Segmented transform systems consist of several faults offset by short axial rifts referred to as intra-transform spreading centers (ITSCs) [Menard and Atwater, 1969; Searle, 1983; Pockalny et al., 1997], where active seafloor spreading and crustal accretion are occurring [Fornari et al., 1989; Hekinian et al., 1992; Perfit et al., 1996]. Intra-transform spreading centers are believed to result from plate motion changes over the last few million years that has caused extension within the transform. The spreading centers may have begun as 'leaky' transforms and later evolved into organized spreading centers with continued extension [Pockalny et al., 1997].

We mapped the western portion of the spreading center which joins two transform valleys within the Doldrums FZ near 7.3°N, 34.7°W (Figure 3). The axial valley is oriented NW-SE, and is about 30 km in length. Hummocky terrain on the valley floor forms an axial volcanic ridge with high backscatter as seen in the sidescan data derived from the EM122 and suggests recent volcanic activity in this short spreading segment. The northern intersection of the axis and transform fault contains a nodal basin about 5000 m in depth, which curves to the west. The southern nodal basin, which is only partially imaged, reaches depths of 5600 m. The western rift mountain at 7.3°N rises to a height of ~2.5 km above the axial valley floor, and has a NW-SE trending crest. Teleseismic earthquakes in this ridge segment (Figure 3) are mostly located off-axis although a small number of events are located in the axial valley itself. Since teleseismic earthquake error locations are large, we will have to wait for the hydrophone-recorded seismicity to know if these earthquakes are associated with movement on the transform faults or some other process at the spreading center.

Mid-Atlantic Ridge, 5°N

Data were acquired over the ridge axis in the region of 5°N, approximately 90 km of which is shown in Figure 4. High backscatter, hummocky terrain and circular features are indicative of widespread present day volcanism in the axial valley. Between 5.2 and 5.4°N, the center of the axial valley is dominated by a ~35 km-long ridge, which rises to a height of ~200 m above the valley floor. The symmetrical shape of its flanks and the hummocky texture suggest the ridge is volcanic in origin, although the sidescan data are inconclusive since the ridge is directly beneath the ship centerbeam. To the west of the axial valley, we have noted two

features, ~10 km in length, which may indicate active detachment faulting. They show a curved geometry in plan view, and their smooth backscatter signature suggests they are not hummocky and thus, not volcanic in origin.

Next steps

In the next stage of this project we will recover the hydrophone moorings in 2014 after two years of data acquisition. The data will be analyzed to identify earthquake locations, and used to interpret the seismicity at the ridge axis and fracture zones in the context of what we know about the geologic structures. The hydrophone data will be made available soon after completion of the cruise. The earthquake locations will also be made available once they are obtained.

During the recovery cruise, additional multibeam data will be collected to add to the existing bathymetry database; these will be made available through the National Geophysical Data Center (<http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html>). We are now in the process of obtaining all existing bathymetry data to generate a map of the equatorial Atlantic region as a resource for the entire community.

Acknowledgements

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A tale of two blocks: New insights on the evolution of the Zambales Ophiolite Complex, Luzon Island, Philippines

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Introduction

For the past decades, our research team has been involved in the studies of ophiolitic sequences across the Philippine archipelago (e.g. Yumul et al., 1998; Tamayo et al., 2001; Suerte et al., 2005; Andal et al., 2005; Faustino et al., 2006; Dimalanta et al., 2009). Recent investigations have been done to better constrain the emplacement history of one of the more studied ophiolites in the region, the Zambales Ophiolite Complex (ZOC). Geological, petrological and paleontological data presented here provide new insights on the tectonic evolution of the ophiolite terrane.

Zambales Ophiolite Complex (ZOC)

The ZOC is a complete crust-mantle sequence that occurs as a north-south trending ridge in western Central Luzon (Figure 1). Previous works regard this ophiolite to have been formed during the Eocene on the basis of fossil assemblages observed from the

pelagic Aksitero Formation that overlies the ZOC along the western foothills of southern Zambales Range (Amato, 1965; Villones, 1980; Schweller et al., 1983). The Eocene age derived from fossils is supported by the K-Ar dating of diabase and granodiorite dikes in Coto Mine that yielded 46.6 (± 5.1) Ma to 44 (± 3.5) Ma (Fuller et al., 1989) and by the U-Pb dating of tonalite (Acoje Block) and leucocratic tonalite and hornblende quartz diorite (Coto Block) that yielded 45.1 (± 0.6) Ma to 44.2 (± 0.9) Ma (Encarnacion et al., 1993), respectively. Thus, an Eocene age had been adopted for the entire ZOC.

Two blocks of contrasting petrological and geochemical characteristics comprise the ZOC: the Acoje and the Coto Blocks. The Acoje Block exhibits an island arc signature whereas the Coto Block is of transitional mid-oceanic ridge basalt to island arc signature. The difference between these two blocks is further highlighted by the chromite types they host. The Acoje Block

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exhibits an island arc signature whereas the Coto Block is of transitional mid-oceanic ridge basalt to island arc signature. The difference between these two blocks is further highlighted by the chromite types they host. The Acoje Block contains metallurgical chromitites, in contrast to that of Coto Block's refractory type. Because of these differences, the ZOC has been modeled as an arc-back-arc pair that amalgamated to the Philippine archipelago prior to the rifting of South China Sea Basin (Hawkins and Evans, 1983; Yumul et al., 1998).

The Middle Miocene Cabaluan Formation is widely exposed along the Cabaluan River and the mountainous terrain along the road leading to the Acoje Mines. It is mainly composed of thick to very thick conglomerate beds with peridotite and chert clasts derived from the underlying Acoje Block of the ZOC (Figure 2). Broken shell and coral fragments sporadically occur as detrital fragments within these deposits, while huge chert blocks interpreted as olistoliths also occur within the conglomerates. These cherts are believed to have been derived from the sedimentary carapace of the Acoje Block.

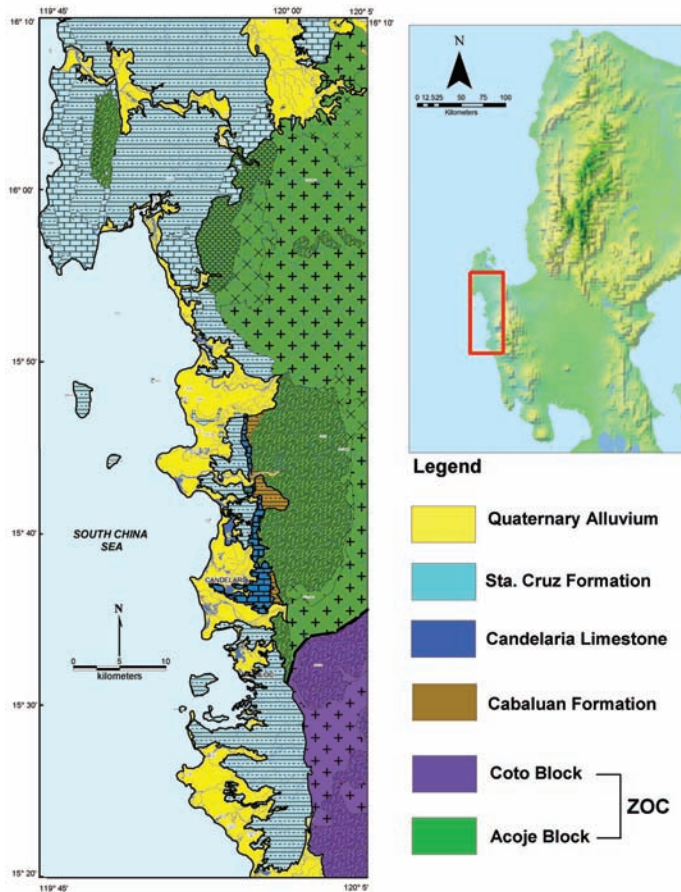


Figure 1. Geological map of the northern portion of western Zambales Range. The Zambales Ophiolite Complex is overlain by three sedimentary formations: Cabaluan Formation, Candelaria Limestone and Sta. Cruz Formation.

The overlying sedimentary rocks

Recent investigations were done on the sedimentary rocks that overlie the ZOC. Three sedimentary formations were recognized: Cabaluan Formation, Candelaria Limestone and Sta. Cruz Formation. Both the Cabaluan Formation and the Candelaria Limestone occur to the west of and geographically proximal to the Acoje Block. In contrast, the Sta. Cruz Formation exposes along the west of all the older formations, including both the Acoje and the Coto Blocks.

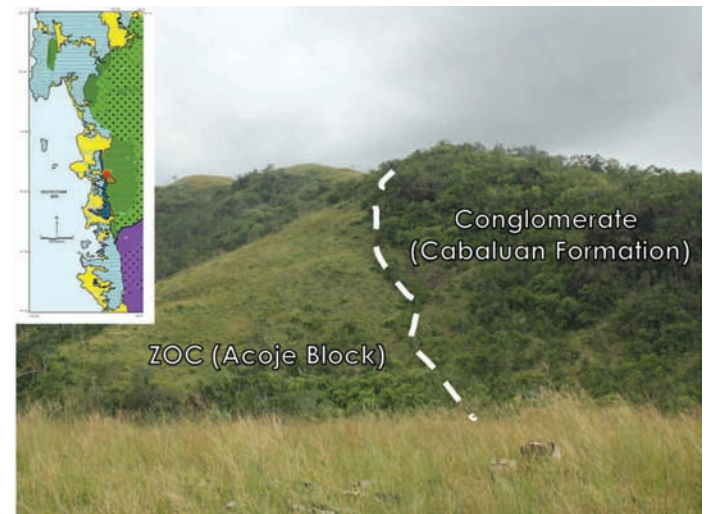


Figure 2. Photo of overlying sedimentary rocks. In Tocon Sta. Cruz, Zambales, the contact of the west-dipping Cabaluan Formation with the Acoje Block of the Zambales Ophiolite Complex is observed.

The Candelaria Limestone unconformably overlies the Cabaluan Formation and is composed of thickly bedded, buff-colored karstic and reefal limestones. This unit distinctly juts out of the terrain as it forms a north-south trending ridge to the west of the Cabaluan Formation and the Acoje Block.

The younger middle Late Miocene Sta. Cruz Formation was observed unconformable to the Candelaria Limestone and is also assumed to unconformably overlie all the other formations. It is composed of sandstone and mudstone interbeds that exhibit compositions: tuffaceous in some layers and calcareous in others. The sandstones contain broken shell fragments, detrital quartz and significantly fewer peridotite fragments as compared to the Cabaluan Formation.

Two distinct ophiolites of the Zambales Ophiolite Complex

Examination of the chert blocks contained within the Cabaluan Formation, presumably derived from the deep marine sedimentary carapace of the Acoje Block, suggests a Middle Jurassic to Early Cretaceous age (Figure 3); this age is significantly older than what was previously reported for the ZOC (i.e. Eocene). With contrasting geochemical signatures of the Acoje and Coto Blocks and different

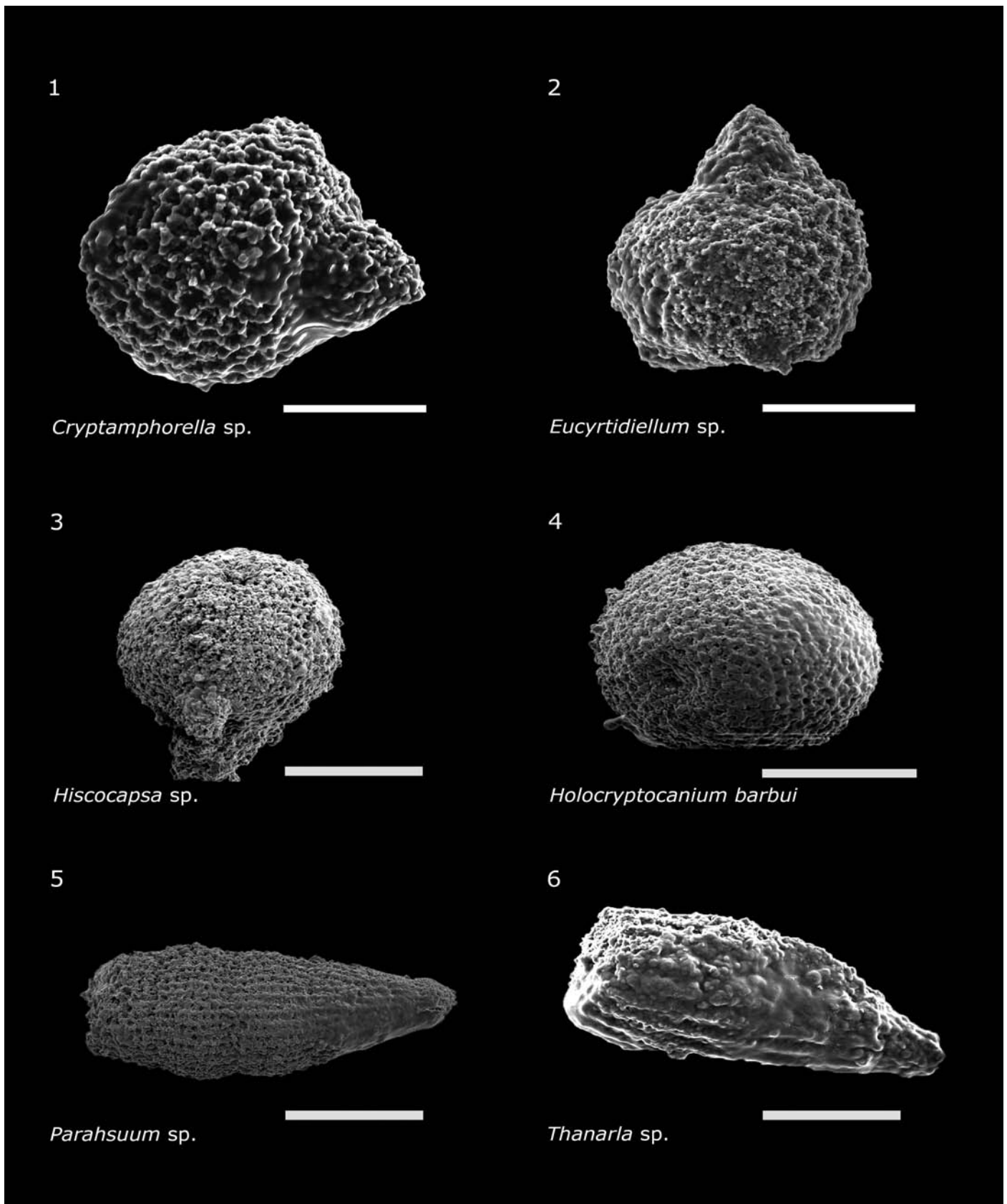


Figure 3. Photomicrographs of some radiolarians extracted from chert olistoliths of the Cabaluan Formation. Scale bar = 100µm.

ages, this study suggests the possibility that two distinct ophiolites exist in the region: the Middle Jurassic to Early Cretaceous Acoje Ophiolite and the Eocene Coto Ophiolite.

Reconstructing the Zambales Ophiolite Complex

The radiolarian age derived from the sedimentary carapace of the Acoje Ophiolite is similar to that obtained from the ophiolitic bodies in Ilocos Norte (Queaño et al., 2007), 300 km north of the ZOC. This preliminary correlation with the northern crust-mantle sequence opens two possibilities for the probable source of the older component of the ZOC (Queaño et al., 2007). First, the existence of a proto-Manila Trench east of the current location of the present-day Manila Trench during the Jurassic to Cretaceous can be hypothesized. Through time, the trench migrated towards its present position due to trench rollback. The existence of a proto-Manila Trench can be supported by the tectonic mélange of the Dos Hermanos Formation recognized along the northern coast of Ilocos Norte. The second model suggests the possible sourcing of the ZOC from the Izanagi Plate. Such a scenario is supported by previous tectonic reconstructions proposed by Hall (2002) and Queaño et al. (2007).

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Interactions between fluids, minerals, and organisms in sulfur-dominated hydrothermal vents in the eastern Manus Basin, Papua New Guinea – A report from RV *Sonne* Cruise 216

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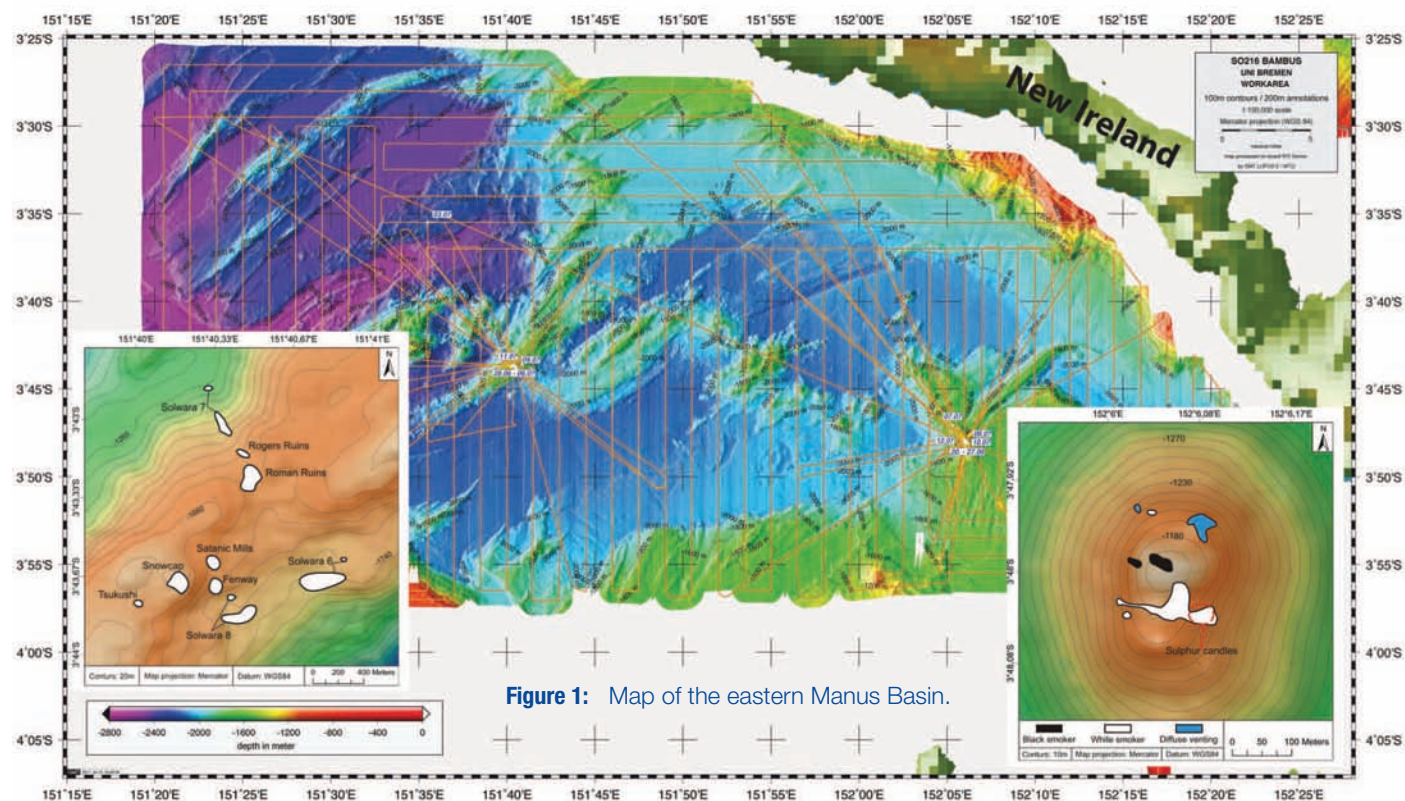


Figure 1: Map of the eastern Manus Basin.

Background

Magma-hydrothermal systems in backarc basins are variably affected by slab-derived flux. The Manus Basin is located in a tectonically particularly active area and exhibits frequent neovolcanic centers of extreme geochemical variability (Sinton et al., 2003). Intense hydrothermal activity in water depth of 1200-1700 m has been observed at many of these volcanic structures, in particular in the Eastern Manus Basin.

The PACMANUS (PacificAustraliaCanadaManus) hydrothermal area – situated on the dacitic to rhyodacitic Pual Ridge and

comprising numerous hydrothermal fields – was discovered roughly 20 years ago (Binns and Scott, 1993). Additional French, German and Australian expeditions sampled sulfides and drill cores from the PACMANUS area. The sulfide accumulations were found to be rich in copper and gold (Moss and Scott, 2001) and it was argued that PACMANUS might be a modern analogue of volcanogenic massive sulfide deposits. To test this hypothesis, the PACMANUS field was drilled during Leg 193 of the Ocean Drilling Program, with boreholes reaching as deep as 387 m below the seafloor (Binns et al., 2002). In the mid-1990s, occurrences of sulfide, sulfur, and bleached felsic rock had been observed in the SuSu Knolls area by dredge and TV-sled surveys. Suzette, the northernmost edifice of SuSu Knolls,

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corresponds to the Solwara1 mining target of Nautilus Minerals. The cone-shaped North Su volcano south of Suzette features large accumulations of sulfur and abundant rock bleaching resulting from acid-sulfate fluid venting. In close proximity to these sulfuric acid vents, black smoker type systems were observed (Tivey et al., 2006). The reasons behind the large range in style and composition of hydrothermal venting and the consequences of this variability for life at these vents remain poorly identified.

Cruise report

We report on the most recent expedition to the Manus Basin, the primary goal of which was ROV-based sampling of hydrothermal systems in the eastern Manus Basin. Cruise SO216 of the German RV *Sonne* took place between June 14th and July 23rd, 2011. The cruise was a follow-up on an RV *Melville* cruise with ROV *Jason2* in 2006, when geophysical mapping, rock sampling and reconnaissance fluid sampling were the primary goals (Tivey et al., 2006; Craddock et al., 2010; Reeves et al., 2011). The specific focus of the SO216 cruise was on vent fluid and biota sampling. The two working areas

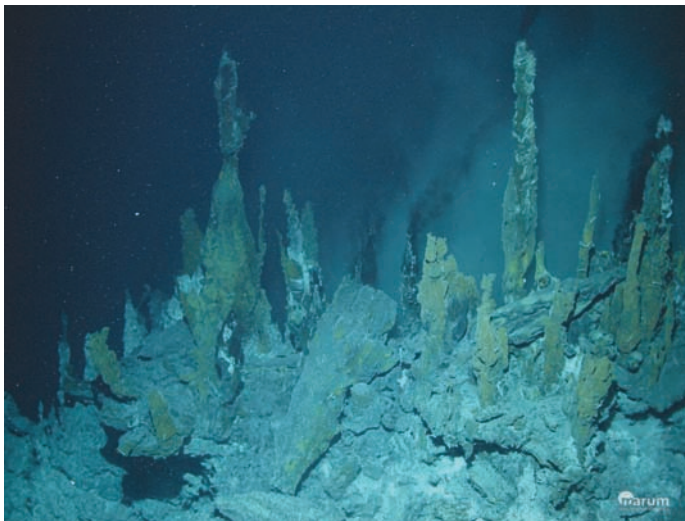


Figure 2: Black smokers at North Su.

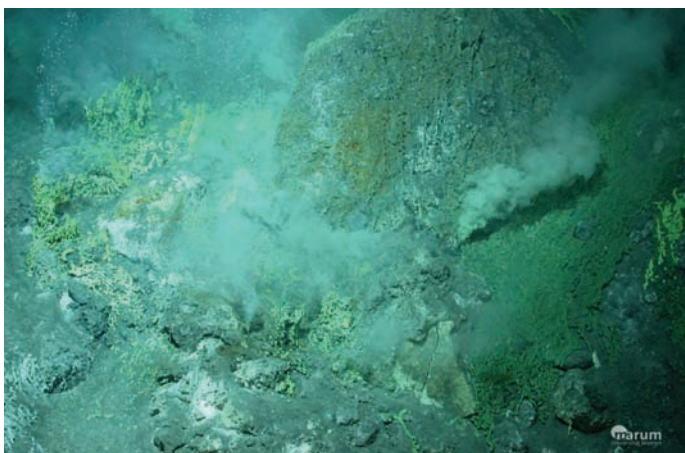


Figure 3: White smokers in the Sulfur Candles area.

comprised North Su at 3°48.0'S, 152°06.05'E in about 1200 m water depth and PACMANUS at 3°43.5'S, 151°40.4'E in ~1700 m water depth. During nightly echosounding surveys with the ship-based EM-120 system, a comprehensive and detailed map of the eastern Manus Basin could be completed (Fig. 1). Twenty-two dives with the ROV *MARUM Quest 4000m* were conducted, ten in the PACMANUS and twelve in the North Su area. Samples collected include hydrothermal fluids (using isobaric gas-tight 'Seewald' samplers and teflon KIPS bottles), biological specimen of vent macrofauna, microbial filaments and biofilms, as well as volcanic rocks and hydrothermal precipitates. A range of vent systems was sampled in both working areas (Fig. 1). Geological mapping was carried out throughout the dives, and sections of some dives were specifically committed to mapping certain structures.

A summary of the preliminary observations is provided here. This report supersedes a communication in the previous issue of InterRidge News by Adam Schaen, whose account of participation in SO216 with an InterRidge travel bursary was inadvertently published as the cruise report. A detailed cruise report can be downloaded from:

<http://elib.suub.uni-bremen.de/edocs/00102250-1.pdf>

North Su

The North Su volcano host countless hydrothermal vent sites, which fall into three categories: (i) black smoker vents, (ii) white smoker vents, and (iii) diffuse vents. While the black smokers cluster in the summit area, white smoker vents are common in a 120 m long and 50 m wide, east-west-trending area south of the main summit. The dense coverage with thick white smoke (most likely made up of sulfur particles) renders mapping and sampling in this area particularly challenging.

The black smokers are up to 9 m high spires and occur in water depths ranging from 1150 to 1200 m (Fig. 2). They show an inner lining of dense chalcopyrite, surrounded by a pyrite-sphalerite-rich outer layer and a Fe-Mn-oxide coating. In the westernmost extension of the black smoker clusters, a vent at 1190 m water depth was found, which shows flashing typical of fluid boiling. The temperatures measured (332°C max.) correspond to the boiling temperature of seawater at 124 bar. The chimneys at the summit are hosted mainly in volcanic ash, which is often cemented by barite to form hard slabs. Where these slabs are broken up, clear fluids vent at the seafloor. More fluid seepage has been observed in numerous locations downslope, in particular in large patches of diffuse venting 90 m northeast of the summit in 1200 m water depth. This site features a diverse fauna (snails, mussels, tubeworms, fish, barnacles), which is associated with the venting of 14-30°C warm fluids through fans of poorly sorted talus.

A prominent ash cone is located 100 m south of the summit and features numerous small craters on the top and smooth flanks with more blocky pyroclastic deposits. The cratered summit features extensive white staining and currents have created ripples in the fine

ash. This cone was not observed when North Su was mapped during the Magellan cruise in 2006. The new ash cone buried steep walls and talus slopes with countless white smoker vents, some of which were sampled in 2006.

The newly discovered Sulfur Candles area is the easternmost and most spectacular of the white smoker clusters. It features hundreds of white smoker vents, many of which also emanate what appears to be gas bubbles, but is likely liquid CO_2 (Fig. 3). We hypothesize that the slowly rising bubbles contain liquid CO_2 , forming when the temperature drops below 31°C . At 3°C (ambient temperature at 1200 m depth), liquid CO_2 converts to CO_2 -clathrate at the interface with seawater. This behavior was documented by collection of liquid CO_2 bubbles at Sulfur Candles. Prominent bubble flares were also visualized using the ship-based Parasound system. The Sulfur Candles site is situated in volcanoclastic sediments, which are impregnated with liquid sulfur around the vents. The sulfur is exuded when water and bubbles vent at the seafloor where it forms sub-meter-high, chimney-like structures (Fig. 3). The sulfur chimneys grow fast (in minutes), but do not grow tall. Most of the

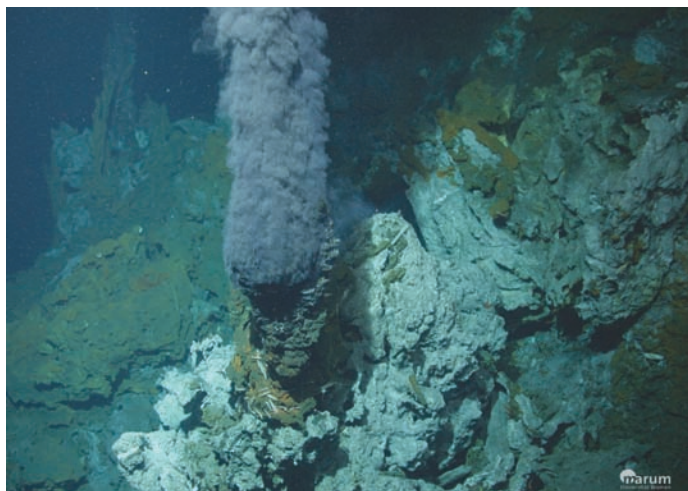


Figure 4: Venting at Big Papi, in the Fenway hydrothermal field.

sulfur is hence not located in chimneys. Additional sulfur trickles downslope and pools in certain areas, where it forms dense aggregates composed of thousands of anastomosing sulfur fingers that coalesced to meter-thick irregular pods and flows.

PACMANUS

The PACMANUS hydrothermal area comprises several hydrothermal vent sites on the Pual Ridge in a 2.5 km^2 area in 1640 to 1780 m water depth (Fig. 1). The Fenway, Snowcap, Tsukushi, Satanic Mills, Roman Ruins, and Roger's Ruins hydrothermal vent sites were visited. Nautilus Minerals discovered additional hydrothermal vent sites in the area (Solwara 6, 7, and 8), from which we collected first high-temperature fluid samples.

The Fenway hydrothermal field comprises an anhydrite-hosted black smoker complex (Big Papi), two small chimney clusters 50 m northeast and northwest of Big Papi, and a large patch of diffuse

venting in the northern part. Big Papi vents 304°C black smoker fluids through sparse chimneys around the base of the anhydrite mound (Fig. 4). The activity of venting is much weaker than in 2006, when boiling (358°C) black smoker fluids emanated from countless orifices at the mound's summit. The Fenway hydrothermal mound is partly collapsed and covered with anhydrite blocks and sand. Through these deposits, venting of $70\text{--}110^\circ\text{C}$ hot, clear fluids occurs and several fluid samples were collected. The sulfide chimney at Fenway exhibits a thick chalcopyrite lining and outer parts that are rich in sphalerite and marcasite with a Mn/Fe-oxide coating. Fenway is hosted predominantly in fine pyroclastic sediment, in particular the diffuse patch north of Big Papi. That area was a focus point of biological sampling and Symcatcher incubation experiments. It features snails (mainly *Ifremeria nautilei*), mussels (*Bathymodiulus manusensi*) and several species of tubeworms, commonly in a patchy style of distribution.

Solwara 8 is located 300 m southeast of Big Papi and features clusters of up to 12 m high and Cu-rich chimneys and porous, more bulbous Zn-rich ones. We recorded a temperature of 304°C when

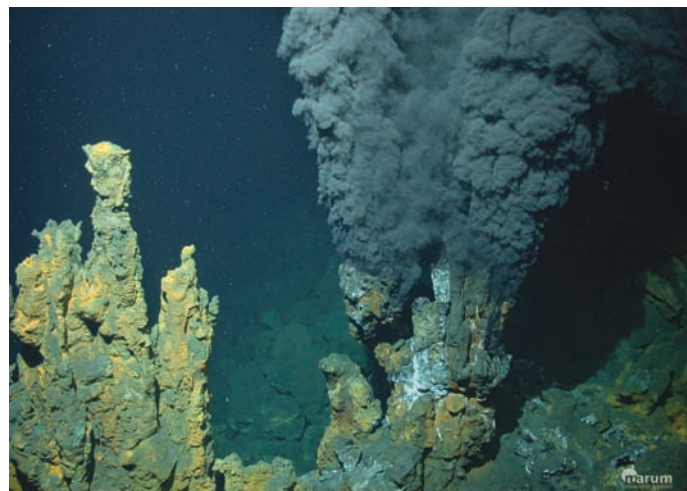


Figure 5: Vigorous venting of black smoker fluids at Solwara 7.

sampling fluid venting from a chalcopyrite-lined orifice sticking out of a beehive structure.

The top of the Snowcap knoll is decorated with countless patches of diffuse fluid seepage. Two reentry funnels mark the ODP Site 1188 drilled to depths up to 387 m in 2000. On the northwestern side of Snowcap lies a small field of sulfide chimneys (variably Cu- and Zn-rich) populated with snails and *Paralvinella*. These chimneys vent clear to light gray fluids with temperatures of $\leq 224^\circ\text{C}$, but the presence of abundant dense chalcopyrite suggests higher venting temperatures in the past. Immediately southwest of the chimney cluster is a mound of native sulfur, which is densely populated by snails and is surrounded by sediments.

Satanic Mills features numerous clusters of sulfide chimneys; the largest one extends for 60 m from north to south and is about 10 to 15 m wide. The chimneys grow directly on top of fresh block lava, in particular near flow fronts of lava with little chimney debris lying

around. Fluid temperatures up to 345°C and local CO₂ bubbling were observed. Tsukushi was relatively inactive, though venting of moderate-temperature clear fluids and oxide mounds were observed, similar to 2006.

Roman Ruins, Roger's Ruins, and Solwara 6 and 7 form a northwest-southeast trending line, roughly perpendicular to the strike of Pual Ridge. Solwara 7 is hosted in a field of block lava and consists of a 50-m diameter main cluster of vents and a smaller accumulation of active chimneys just south of it. The highest temperature of venting (348°C) was measured here in vigorously venting black smoker fluids issuing from a small chimney that grows on top of sulfide rubble (Fig. 5). Roger's Ruins, located 200 m southeast of Solwara 7, comprises a small cluster of mostly inactive vents. Its activity was much greater in 2006, in particular in the area of Marker 8, which was very active in 2006, but appeared inactive in 2011. Extensive areas around Roman Ruins are covered with Fe-oxyhydroxide deposits that occasionally form chimneys. Although there is abundant venting of shimmering water through these mounds, no macrofauna could be observed here. The northeastern part of Roman Ruins is mostly inactive, in contrast to the situation in 2006, when lots of black smoker activity was observed there. The central part of Roman Ruins features copious amounts of sulfide chimney rubble, which is exposed on the southeastern flank of the ridge with the active black smokers. In contrast, the southwestern extension of Roman Ruins has volcanic rock talus exposed on the slopes. This part is also more hydrothermally active than the northeastern end of the field. The area between Roman Ruins and Solwara 6 is covered by variably sedimented block lava. Solwara 6 is also situated in block lava flows. There are a few inactive chimneys in the western part of the system; other areas show diffuse venting. Nautilus Minerals reported more activity in this area during their 2007 survey, including active black smokers.

Summary and outlook

The hydrothermal systems in the eastern Manus Basin reveal an extraordinary variability in fluid chemistry, both on a spatial and on a temporal scale. This variability is obviously tied to the changes in magmatic activity including magma degassing of SO₂ and CO₂. At North Su, we were able to document a volcanic eruption that must have happened between 2006 and 2011 and led to a drastic change in the location and style of acid-sulfate fluid venting. At PACMANUS, activity, temperatures and gas contents of fluids have undergone marked changes since 2006.

With the samples collected, we will address a number of questions: What are the gas-water-rock interactions and fluid mixing processes in the subsurface and how do they mediate mass flux to the seafloor? What energy sources in volcanic magma-hydrothermal systems reach the seafloor and how are they used by microorganisms? And how do they determine the physico-chemical environment of the vent fauna? Moreover, we would like to know how the different chemical compositions of vent fluids influence the composition of biocoenoses. What are the dominant metabolic reactions in the different habitats and how much biomass can potentially be produced? Finally, we will investigate what kinds of symbiotic

relationships have evolved within the different hydrothermal systems of the Eastern Manus Basin and how they are influenced by the variable fluid chemistry. Characterization of sulfur species in fluids, with emphasis on sulfur redox intermediates and their roles as electron donors and/or as electron acceptors for microbial growth is another goal of post-cruise studies. We are also interested in learning what sulfur-oxidizing asymbiotic microorganisms dominate the geochemically distinct diffuse vents and how they fix carbon.

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National News

Australia



Jo Whittaker

Australia has one of the world's largest marine territories, much of which remains unexplored, with only one blue-water research vessel available to our marine research community. In an exciting development, Australia has commissioned a new research vessel, the RV *Investigator*. The Marine National Facility's new state-of-the-art research facility is currently under construction. Following a commissioning year in 2013-2014, RV *Investigator* will be available for research in 2014-2015. The new vessel will be capable of operating continuously for 60 days at sea, cruising at 12 knots over a range of 10,000 nautical miles.

RV *Investigator* will be a highly advanced research vessel with a broad range of scientific equipment to support marine scientists, including a wide range of marine geosciences, oceanography and climatology, and fisheries, marine ecosystem and marine environmental research. Additionally, through the AuScope's Australian Geophysical Observing System (AGOS), Australia has committed to acquiring 20 Ocean Bottom Seismometers by 2014, an addition that will be invaluable to geophysical exploration of the ocean basins surrounding Australia.

In November 2011, Dr Simon Williams from the University of Sydney led a successful international team on a scientific voyage to the Perth Abyssal Plain. The Perth Abyssal Plain is one of the more poorly understood ocean basins surrounding Australia. The cruise collected magnetic, bathymetric and dredge data to address knowledge gaps regarding the nature and evolution of the basin. The voyage achieved its scientific aims including the collection of six magnetic anomaly profiles across the Perth Abyssal Plain, and the collection of swath and dredge data from seven sites on the Batavia Knoll, Gulden Draak Ridge and Dirck Hartog Ridge. Continental material was recovered from the Batavia Knoll and Gulden Draak Ridge indicating that these features are micro-continents rifted from India during the breakup between Australia and India.

In May-June 2012 Dr Richard Arculus from the Australian National University led a scientific voyage to the northern Lau Backarc Basin to investigate magmatism, tectonics and hydrothermal activity. The northern Lau Basin is a region of rapidly extending and newly-forming crust, seamed by multiple zones of sea-floor spreading, rifting and faulting consequent to the clockwise rotation of the Tonga Arc away from the Fiji-Lau Ridge. The demise of the former Vitiaz Arc has led to the establishment of a new Australian-Pacific plate boundary that wraps around the north end of Fiji, and



RV *Investigator* in progress
(Acknowl. www.csiro.au)

connects with the Tonga Trench via a set of ridges (e.g. Futuna Spreading Centre, Northwest Lau Spreading Centre), rifts (e.g. Rochambeau Rifts), transform faults and extension zones. The voyage explored these tectonic elements and the accompanying magmatism and hydrothermal activity.

In Oct-Nov 2012, Dr Maria Seton of the University of Sydney will lead a voyage to the eastern Coral Sea. The main objectives of this voyage are to investigate (i) the nature of the crust (continental/volcanic/oceanic) underlying Rennell Island, East Rennell Island Ridge, South Rennell Fracture Zone and d'Entrecasteaux Zone, and (ii) the age and structure of the Santa Cruz/Torres and d'Entrecasteaux Basins. We will also explore whether the basins formed in a back-arc setting related to Cretaceous or Eocene subduction or whether they preserve a piece of oceanic crust from the Panthalassa Ocean, and (iii) the extension of the Lord Howe hotspot trail into the eastern Coral Sea, north of the Bellona Plateau.

Dr Maria Seton from the University of Sydney is the Chair of the new Back and Island Arc (BI-ARC) Working Group. The working group hopes to foster a holistic approach to address fundamental questions about intra-oceanic arc and backarc basin processes by examining the long-term and short-term evolutionary cycles using geochemical, hydrothermal, biological, tectonic and subduction dynamics approaches. In addition, we aim to bridge the gap between geologists who study onshore, accreted island-arc and back-arc systems and marine geoscientists who study in-situ backarc systems. The working group seeks to bring together experts from both the observational and modeling communities to facilitate the linkage between surface processes and the deep earth.

China



Y. John Chen and Jiabiao Li

Riding on the rapidly growing Chinese economy, the ridge program in China is moving ahead with a momentum in 2012, completing nine cruises to the global mid-ocean ridges and adding a new research vessel R/V “*Science*” to the Chinese national fleet of deep-sea research vessels.

Ridge-Crest Surveys

On board R/V “*Dayang Yihao*”, Chinese scientists have collected more evidence for active hydrothermal vents during 9 consecutive ridge cruises on the East Pacific Rise, South Mid-Atlantic Ridges and the Southwest Indian Ridges. Evidence for 5 new hydrothermal vent fields was collected at South Mid-Atlantic Ridge, and in particular the one at 26° South is probably the southernmost hydrothermal field in the global database. For 2012-13 the Chinese ridge program will use two research vessels during 11 cruises, conducting research at the Indian and Mid-Atlantic ridges. Scientists from WHOI, USA and the Institute of VNIIOkeangeologia, Russia, are invited to participate in some of the cruise legs for joint research.

A New Research Vessel

The body construction of a new research vessel, R/V “*Science*” was completed in October 2011 and all the furnishings and installation of the equipment will be finished in the summer of 2012. The new ship is now scheduled for delivery to the Institute of Oceanography, Chinese Academy of Science, Qingdao in August 2012. A test cruise is planned for conducting research in the western Pacific in the last quarter of 2012. By the end of 2012 the Chinese national fleet of deep-sea research vessels will have three ships including R/V “*Dayang Yihao*” (5600 tons) operated by COMRA, R/V “*Ocean #6*” (5827 tons) operated by Chinese Geological Survey at Guangzhou, and R/V “*Science*” (4864 tons) operated by Institute of Oceanography, Chinese Academy of Science. Another new ship, R/V “*Xiang Yang Hong #10*” (4500 tons) is planned to be delivered to the Second Institute of Oceanography at Hangzhou for deep-sea cruises.

After successfully completing five test dives to 5000 m depth in July 2011 the Chinese manned submersible “Chinese Dragon” is now scheduled to conduct a test dive to the 7000 m depth, a target depth designed for the Chinese manned submersible, in late 2012.

Symposiums and National Conference

1. A symposium called “Global mid-ocean ridge spreading processes and implications for the South China Sea evolution” was held in Guangzhou, October 9-11, 2011. It was attended by about 200 students and researchers from various parts of China. Distinguished international keynote speakers included Dr. Jian Lin (Woods Hole

Oceanographic Institution, USA) and Dr. Anne Briais (CNRS - Lab. Geosciences Environment, Toulouse, France).

2. The 2nd International Symposium on Scientific and Legal Aspects of the Regimes of the Continental Shelf and the Area, Hangzhou, China, 8-9 November 2011. Over 100 scientists and government officers participated in this 3-day conference and both Co-Chairs of InterRidge-China, Drs. Jiabiao Li and John Chen, were invited to give key-note speeches discussing important questions and issues in oceanic crust and the ridge-crest process.

3. The second national conference of “Deep Sea Research and Earth System Science Symposium” with a strong focus on Ocean Sciences was held at the Conference Center in Shanghai, China on July 2-4, 2012. It is estimated that over 600 scientists and students participated in this national conference (in Chinese).

IR Office moves to Beijing, China

Drs. John Chen and Jiabiao Li are teamed up again to host the InterRidge Office at Peking University for 2013-2015. This relocation of the InterRidge Office to Beijing will further boost China’s ridge program, which is at its energetic stage with a very strong momentum riding on the rapidly growing economy of China, and will allow it to give a much stronger contribution to the InterRidge community and global mid-ocean research.



Third test dive to a depth of 5,188 m by *Jiaolong 7000* in the East Pacific, July 2011.

France



Jérôme Dymont



M/V L'Astrolabe at dock in the French Antarctic station Dumont d'Urville, after having crossed the Southeast Indian Ridge between Tasman and Balleny FZs during experiment TACT (Feb-Mar 2012). (Source: J. Dymont).

In 2012, the French ridge community is pursuing projects over different spreading centres spanning the World Ocean.

The Mid-Atlantic Ridge (MAR) remains a favourite target, with the MoMAR (Monitoring the MAR) observatory being a major focus of interest. This standalone seafloor observatory, installed on the Lucky Strike volcano, was serviced during the 11 day MOMAR 2012 cruise (P.I. M. Cannat and P.M. Sarradin) with R/V *Thalassa* and ROV *Victor*. The following components were successfully maintained and reinstalled: the two seafloor SEAMON (Sea Monitoring) seafloor stations and their connected instruments, i.e. a 3-components seismometer and a hydrophone for seismic event detection, two pressure probes for geodetic measurements, a turbidimeter, a video camera, a dissolved-iron analyzer, and an optode (oxygen and temperature probe) for ecological time-studies; and the BOREL transmission buoy, equipped with GPS and meteo station. The buoy communicates acoustically with the seafloor stations and relays the data via satellite every 6 hours to the Ifremer node of the EMSO (European Multidisciplinary Subsea Observatory) data center.

Cruise HYDROBSMOMAR (P.I. J. Perrot) was scheduled on R/V *Thalassa* in August 2012 to redeploy the hydrophone network that monitors the seismicity of the Azores area as part of the MoMAR project.

Beyond the MoMAR project, cruise COLMEIA (P.I. M. Maia), scheduled on R/V *L'Atalante* in January 2013, will investigate the Equatorial Atlantic “cold spot” in St Paul-St Peter area, in collaboration with Brazilian scientists. Other cruise proposals on the MAR have been ranked high and will probably be scheduled in 2013. They plan to investigate the heat flux in the Oceanographer FZ area (cruise OCEANOGRAPFLU, P.I. F. Lucazeau), to further study the 15°N oceanic core complexes (cruise ODEMAR, P.I. J. Escartin), and to collect and conduct experiments on hydrothermal mussel *Bathymodiolus Azoricus* (cruise BIOBAZ Centrale, P.I. F. Lallier).

In the Pacific Ocean, cruise MESCAL 2 (P.I. N. Lebris & F. Lallier) used R/V *L'Atalante* and deep-sea submersible *Nautile* in March 2012 to complete a series of biological dives on the East Pacific Rise between 9 and 13° N – a former attempt in 2010 had been interrupted for technical reasons.

Cruises FUTUNA 2 and 3 of R/V *L'Atalante* (P.I. Y. Fouquet), in November-December 2011 and May-June 2012 respectively, have been devoted to the exploration of hydrothermalism and mineral resources in the French EEZ of Wallis and Futuna Islands, in the SW Pacific, and supported by the industry. Cruise Futuna 2 was a reconnaissance cruise, whereas cruise Futuna 3 used AUV *Idef-X* and deep sea submersible *Nautile* to further explore potential targets.

In the Indian Ocean, experiment OHASISBIO (P.I. J.Y. Royer) used R/V *Marion Dufresne* from January to March jointly with other experiments to service the hydrophone network moored between Reunion and the French Austral and Antarctic Territories and listening for earthquakes on the Indian Ridges and in the Central Indian deformation zone, as well as for sea-mammal vocalizations.

Later this year, cruise RHUM-RUM (P.I. G. Barruol and K. Sigloch), a French- German experiment scheduled in September and October

2012 on R/V *Marion Dufresne*, will drop about 55 OBSs between Madagascar, the Southwest Indian Ridge (SWIR), and the Central Indian Ridge (CIR), in an effort to image the mantle beneath the Reunion hotspot and the ridge-hotspot interaction between La Réunion and the CIR under the Rodrigues Ridge area.

A cruise proposal (Cruise SISMOSSMOOTH, P.I. M. Cannat) has been ranked high to investigate seismically the structure of the SWIR and ultraslow accretion processes.

Cruises

| Completed in the end of 2011 and beginning of 2012 | | Scheduled for 2012 and early 2013 | |
|---|------------------------|--|--|
| FUTUNA 2: 4/11-14/12/2011 Apia - Suva | <i>L'Atalante</i> | HYDROBSMOMAR 31/07-13/08/2012, Ponta Delgada – Las Palma | <i>Thalassa</i> |
| MESCAL 2: 11-26/03/2012, Manzanillo - Manzanillo | <i>L'Atalante</i> | RHUM/RUM 21/09-26/10/2012, Réunion - Réunion | <i>Marion Dufresne</i> |
| OHASISBIO 20/01-12/03/2012, Réunion - Réunion | <i>Marion Dufresne</i> | COLMEIA January 2013 | <i>L'Atalante</i> |
| FUTUNA 3: 16/05-23/06/2012, Suva - Nouméa | <i>L'Atalante</i> | Expected in 2013 | |
| MOMAR 2012: 12-25/07/2012, Ponta Delgada – Ponta Delgada | <i>Thalassa</i> | BIOBAZ CENTRALE OCEANOGRAPFLUX ODEMAR | MOMAR 2013 HYDROBSMOMAR SISMOSSMOOTH |

Germany



Colin Devey and Nicole Dubilier

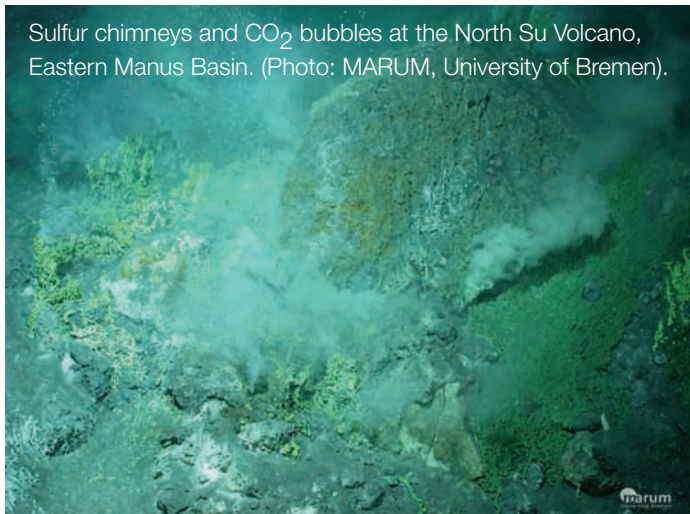
Germany still has no centrally organised ridge program since the SPP1144 ended in 2009, nevertheless there is significant ridge-related research occurring and planned in the near future. Cruises with a spreading axis focus have been carried out in the Red Sea this year (as part of the Jeddah Transect project together with the King Abdulaziz University in Jeddah, see <http://www.jeddah-transect.org>) and are planned for the Northern Kolbeinsey Ridge (RV *Poseidon* cruise 436, July 2012) and again the Red Sea (RV *Poseidon* cruise 442, November 2012).

In the summer of 2011, the BMBF-funded cruise "BAMBUS" on the RV *Sonne* with the ROV *MARUM-Quest* studied numerous vents in the Manus Basin back-arc system with a focus on geochemical

and biological processes. At the end of 2011, a joint cruise from Geomar, the University of Hawaii and Nautilus Minerals explored the bathymetry and hydrothermalism of the Northern Lau back-arc system. German researchers from University Bremen/MARUM are involved in hydrological-microbiological-geochemical observatory studies of a young ridge flank off the Mid-Atlantic ridge ("North Pond" 22.45°N, 46°05'W, see also IODP Leg 356) with RV *Merian* cruises in 2012 and probably early 2014.

German ridge research in the polar regions will start taking shape beginning in 2012 thanks to the Alfred-Wegener-Institute for Polar and Marine Research (AWI) funding of several cruises with the RV *Polarstern*: a) Vera Schlindwein from AWI will lead two cruises to the

Sulfur chimneys and CO₂ bubbles at the North Su Volcano, Eastern Manus Basin. (Photo: MARUM, University of Bremen).



ultra-slow spreading Southwest Indian Ridge in Dec 2012 and Dec 2013, b) Gerhard Bohrmann from MARUM will head a cruise to the Sandwich Plate in March 2013, and c) Antje Boetius (AWI and

MPI-Bremen) will head the AURORA cruise to 83°N on the Gakkel Ridge in June 2014 using a new hybrid ROV/AUV system developed by WHOI for under-ice diving in a collaboration with Chris German from WHOI.

And many plans are afoot to continue and expand German ridge-related research. An international workshop held in Kiel in April 2012 looked at the science drivers for a return to the TAG area and generated significant interest in a multi-year, multi-national effort to do a segment-scale study. Also in April 2012, a new transatlantic graduate school (Helmholtz School for Ocean System Science and Technology, HOSST: see www.hosst.org), proposed jointly by Geomar and the Halifax Marine Research Institution in Nova Scotia, was funded by the Helmholtz Association. The call for the first 11 PhD positions was announced in June and included the possibility of working on the Mid-Atlantic Ridge. The Universities of Bremen and Kiel have, together with Geomar, taken the first steps towards formulating a proposal to the German Science Foundation for a 12-year special research program on the deep seafloor.

Japan



Kyoko Okino

In reaction to the M9 earthquake on 11 March 2011, a substantial amount of ship time was devoted to monitoring radioactive levels offshore of Fukushima until September, and many urgent studies including aftershock surveys by OBSs, sea-bottom crustal displacement, surface environmental change etc. were carried out in 2011. In this context, some ridge-related studies were forced to change schedule, but we try to continue our efforts to promote ridge-related studies in Japan and to expand our community. The outline of ongoing projects and other activities are described below.

Domestic and International Meetings

An InterRidge-Japan symposium was held on 1-2 November 2011, at the Atmosphere and Ocean Research Institute (AORI), University of Tokyo. About sixty scientists participated in the symposium to share recent research activities. The second day of the symposium was dedicated to reviewing the Japanese ridge studies in this decade, and we discussed our scientific goals and strategies for the InterRidge third decade. We also had a business meeting on 22 May 2012 at the Japan Geoscience Union Meeting, where we shared information on budget, cruise, workshops and international affairs, and discussed the InterRidge-Japan annual activity plan.

We hosted the international workshop on ‘Ocean Mantle Dynamics: From Spreading Center to Subduction Zones’ led by the IR Mantle Imaging WG, 4-6 October 2011. 77 scientists from six different countries gathered at AORI to discuss recent developments in the

study of the dynamics of the oceanic lithosphere, melt production at oceanic spreading centers and islands arcs, and associated topics. The meeting was supported by several organizations, including the Japanese TAIGA project, the US Geoprisms program, AORI and the Ocean Alliance of the University of Tokyo, as well as InterRidge. The meeting was preceded by a field trip to the Horoman Peridotite Complex in Hokkaido led by Eiichi Takazawa from Niigata University. The field trip party visited several outcrops of fresh lherzolite, harzburgite and dunite along the Horoman River uplifted and exposed by thrust faulting. The field trip party also had several presentations on the petrology and seismic imaging of the Horoman complex. The first day of the scientific meeting focused on the structure of the oceanic lithosphere and asthenosphere, with an emphasis on results of recent imaging studies and laboratory experiments. The second day’s topic was melt migration beneath spreading centers and the formation of oceanic crust. The third day reviewed geochemical and experimental evidence for the transport mechanism and distribution of water in arc/backarc systems. 26 poster presentations, many of them from students and younger scientists, were a key part of the meeting, and they provoked a lot of good discussions at the poster time. InterRidge sponsored two awards for the best student poster presentations. Shusaku Yamazaki from Niigata University and Akiko Takeo from the Earthquake Research Institute of Tokyo University won the awards. The entire meeting program, including abstracts is available at: http://ofgs.aori.u-tokyo.ac.jp/intridgej/WS_2011/.



Onboard scientists observe and discuss the BMS (deep sea Boring Machine System) cores collected in the Middle Okinawa Trough hydrothermal area.

Project "TAIGA" is in the final phase

The interdisciplinary research project TAIGA, Trans-crustal Advection and In-situ biogeochemical processes of Global sub-seafloor Aquifer, was launched in 2008. The project is funded by MEXT (Ministry of Education, Culture, Sports Science and Technology) from FY2008 to FY2012 and now we approach its final phase. As we outlined in the last IR news, we are focusing on subseafloor fluid advection which carries huge heat and chemical fluxes from the interior of the earth and supports growth of biosphere (beneath and on the seafloor). Three integrated study sites have been selected: the southern Mariana Trough as TAIGA of sulfur, the Indian Triple Junction as TAIGA of hydrogen, and the Okinawa Trough as TAIGA of methane. More than fifty scientists joined the project, and many seagoing studies are planned, mainly in the integrated study sites. Further information can be obtained at the project website (<http://www-gbs.eps.s.u-tokyo.ac.jp/~taiga/en/index.html>). The latest results will be presented in a special InterRidge-sponsored session at the AGU Fall meeting, "Deep sub seafloor biosphere" chaired by Ishibashi, Takai, Urabe and Edwards.

Cruises in FY2011

Although our cruise plan was changed by the emergency cruise due

to the earthquake, we had 7 short cruises in the hydrothermal areas in the Okinawa Trough and 3 short cruises in Izu-Ogasawara-Mariana arc in FY2011. Post drilling surveys at Iheya North field using ROV, a surface drilling cruise by BMS, an acoustic survey by AUVs and a wide area survey by ROV were conducted in the Okinawa Trough.

Cruises in FY2012

In reaction to the M9 earthquake, the R/V *Yokosuka* cruise in the Indian Triple Junction scheduled in 2011 was postponed to January-March 2013. Twenty dives of *Shinkai 6500* are planned to clarify the characteristics of geology, geochemistry and ecosystem around the hydrogen-rich Kairei hydrothermal site and two newly discovered hydrothermal sites in the Central Indian Ridge Segment 15/16 (Nakamura et al., 2012, PLoS ONE). We also plan to conduct crust and upper mantle imaging around the triple junction by OBSs and OBEMs. This cruise is dedicated to the memory of Prof. Kensaku Tamaki, the former IR chair, and his pioneering works in the Indian Ridge system. Several short cruises in the hydrothermal areas in the Okinawa Trough and the Mariana Trough backarc spreading centers will also be scheduled.

Korea



Sung-Hyun Park

Korea completed three ridge-related cruises on the Antarctic, Western Pacific and Indian Oceans. The good news is that KOPRI is starting a large three-year project on the exploration of the Australian-Antarctic Ridge (South of Tasmania). We are planning two more cruises on the Australian-Antarctic Ridge including AUV surveys.

1) Australian-Antarctic Ridge

KOPRI (Korea Polar Research Institute) conducted a research cruise on one segment (KR1) of the Australian-Antarctic Ridge in December 2011. 32 MAPRs and rock cores were done and a hydrothermal vent site was located more precisely. Also a multi-beam map was expanded around the axis. We tried CTD sampling from a potential vent site and found the signals of methane and ^3He . The next cruise is scheduled in Jan-Feb 2013, and we will try more CTDs, camera tows and dredges.

2) Central Indian Ridge

KORDI (Korea Ocean Research Institute) performed an exploration for hydrothermal vents along the northern Central

Indian Ridge (CIR), 8° - 12°S in November-December 2011. The exploration was focused on the identification of a location of hydrothermal plumes that were investigated by previous cruises using CTD Toyo attached with MAPRs. During the survey, at least 8 hydrothermal plumes were identified along the 7 ridge segments of the northern CIR. Most plume signals were hosted by ultramafic rocks exposed on the seafloor by the formation of Ocean Core Complexes (OCC).

3) Tonga Arc

ROV (*ROPOS* of CSSF) surveys were performed along the hydrothermal vents on the two seamounts of Tonga Arc in January-February 2012. Detailed bathymetric data were obtained by ROV-mounted multibeam survey in the 1st leg. Visual surveys and sampling of active and inactive hydrothermal vents were performed in the second leg. During the ROV survey, more than 100 individual hydrothermal vents were observed in the two submarine calderas.

Mauritius



Daniel E.P. Marie

Recent joint collaborations between scientists of the Mauritius Oceanography Institute (MOI), Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and University of Tokyo have resulted in the discovery of new hydrothermal sites on the Central Indian Ridge (<http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0032965>). Further geological and biological investigations have been undertaken since then. Thus the existence of four known hydrothermal sites on the Central Indian Ridge (CIR) provided a unique opportunity to look at the ecological settings as well as faunal composition. Preliminary results have also been presented during the 7th WIOMSA Symposium held in Mombasa, Kenya (24th - 29th October 2011) with the title "Biodiversity at Hydrothermal Vents along Central Indian Ridge Revised: New Discoveries, New Perspectives". Recent data analysis by Mr. Girish Beedessee (MOI), Dr. Hiromi Watanabe (JAMSTEC) and Dr. Ken Takai (JAMSTEC) has tried to explain the dispersal abilities of several invertebrates from these four vent sites. The Central Indian Ridge has been poorly investigated, in terms of its geology and biology when compared to other ridge systems and such studies aim



to attract the scientific community for further explorations within the CIR. A cruise devoted to re-visit the new hydrothermal vents is planned for 2013 and this collaboration is a fine example of how scientists can work together to unravel the hidden chemical and ecological diversity. We hope the next cruise will bring exciting news, revealing new insights of the CIR.

Daniel Marie, Mauritian
National Correspondent for
InterRidge

New Zealand



Richard Wysoczanski, Christian Timm and Malcolm Clark

The past year has been an extremely busy year with a new research initiative announced, a further research cruise conducted and several planned, and the added excitement of multiple volcanic eruptions from the Kermadec Arc. As well as continued activity from Monowai and new activity from the active White Island volcano, there was an eruption from Havre Volcano, which has had no known recent activity. This eruption produced an extensive (482 km x 48 km) raft of pumice, which was spotted and sampled by the HMNZS *Canterbury* on route from Auckland to Raoul Island. Satellite imagery confirmed an ash plume over Havre Volcano on the 18th and 19th July that coincided with a cluster of earthquakes.

Research voyages

A survey in April 2012 (TAN1206: Clarke, voyage leader) was completed to the northeast of New Zealand, which sampled depths between 700 m and 1500 m with various combinations of towed camera, beam trawl, epibenthic sled, multicorer and boxcorer gear. The sites included 3 seamounts in the southern section of the Kermadec back-arc, two of which are hydrothermally active. Notable on these latter features were the first observations of live vent fauna on Tangaroa seamount, comprising stalked barnacles (*Vulcanolepis o'sheai*), bathymodiolid mussels (*Gigantidas gladius*, Fig. 1) and alvinocarid shrimps. Stalked barnacles were also seen on Clark seamount, but the extent of these appears much reduced from previous records from submersible dives as part of the Ring of Fire Expedition in 2005.

The information on faunal communities will be incorporated into an assessment of the vulnerability of the different habitats to human activities. This is largely directed at the effects of bottom trawl fisheries, but there is increasing interest within New Zealand to mine polymetallic sulphides, which are mainly found on the Kermadec arc volcanoes.

In September 2012 the GNS scientist Fabio Caratori-Tontini will join the R/V *Roger Revelle*, which will include scientists from University of Washington, NOAA/PMEL, Oregon State University, SOEST (Hawaii), Australian National University (Australia), WHOI and University of Bremen (Germany) to investigate the seafloor in the NE Lau Basin using Bremen's ROV *Quest*.

A research voyage (TAN1213 or 'NIRVANA') to the Kermadec arc will be conducted in October 2012 (Wysoczanski, voyage leader) by scientists from NIWA, GNS and Auckland University. This voyage will conduct further multichannel seismic surveys of the Kermadec Arc region to add to surveys completed during the TAN1007 ('KARMA') voyage. Deep (> 2500 m) basins will also be sampled for geological and biological specimens. This voyage is also the first opportunity to investigate the recent Havre Volcano eruption, with



Figure 1: *Gigantidas gladius* retrieved from Tangaroa volcano during the research voyage TAN1206. Photo courtesy of Rob Stewart, NIWA.

multibeam mapping and possible sampling of the volcano to be undertaken.

InterRidge Island Arc and Back arc (BI-ARC) working group

Cornel de Ronde (GNS) and Richard Wysoczanski (NIWA) were involved in establishing a new InterRidge working group, chaired by Maria Seton and Cornel de Ronde. The first meeting was held at the IGC conference in Brisbane in August.

Special Issue of Economic Geology

Cornel de Ronde (GNS), Dave Butterfield (NOAA/PMEL) and Matt Leybourne (GNS, now at ALS Geochemistry, Canada) guest edited a special issue on the metallogeny of intraoceanic arcs. Eleven papers were accepted and the special issue will appear in December this year.

New Zealand/German-led IODP workshop to drill the active hydrothermal system at Brothers volcano, Kermadec arc

The workshop, funded by ECORD (European consortium for ocean research drilling), will be held in Lisbon, Portugal and aims to prepare an IODP proposal to drill into an active hydrothermal system hosted by a submarine intraoceanic arc volcano offshore New Zealand. Both the workshop and IODP proposal will be led by Cornel de Ronde (GNS Science, New Zealand) and Wolfgang Bach (University of Bremen, Germany) with 30 scientists invited from around the globe.

Arc systems play an important role in the elemental budget of the oceans derived from the lithosphere (upper mantle, ocean crust and sediment coverage) and they have become increasingly recognized as potential resources of metals. Active seafloor hydrothermal systems pump acidic and extremely metal-rich high temperature fluids into the ocean that leads to the formation of one of the most extreme environments of life on earth.

An exceptional example to study an active Au-Co-Ag-rich hydrothermal system is the Brothers volcanic center, southern Kermadec arc, located ~400 km north of New Zealand within New Zealand's extended economic zone (EEZ).

With a total length of 22,000 km and typically several hydrothermal vent sites per 100 km, volcanic arcs are as equally important as mid ocean ridges in overall hydrothermal mass transfer from the lithosphere to the mantle. In addition, high concentrations of S species gases, CO₂ and metals can potentially lead to the formation of ore deposits of different style/type to those discovered along

mid ocean ridges and be host to unknown microbes. The difference in the style and type of hydrothermal mineralization along arcs is essentially a result of the different composition and volatile-rich nature of the host lava, which contributes magmatic vapors (including metals) through magma degassing in shallow magma reservoirs to the expelled fluids.

Recent investigations of arc hydrothermal vents have provided the first insights into varied magma-hydrothermal-biological feedback within the systems, but little is known about subseafloor mineralization and microbial habitats. Furthermore, knowledge on the potential to form subseafloor ore deposits on hydrothermally active volcanoes is entirely lacking.

Drilling of the hydrothermal system of Brothers volcano would provide missing information about the potential to form subseafloor mineral deposits and will give new insights into unknown microbial environments at these volcanoes.

Philippines



Graciano P Yumul, Jr. and Dr. C.B. Dimalanta

The Philippine report is by means of a paper, published in the International Research section of this volume.

Portugal



Pedro Ferreira and Ricardo Santos

From mid-August to mid-October 2012, the Task Group for the Extension of the Continental Shelf (EMEPC) conducted an oceanographic cruise aboard the Portuguese Navy Vessel NRP *Almirante Gago Coutinho*, to the mid-Atlantic ridge axis and off-axis area located between the Oceanographer and Hayes fracture zones. As in previous missions led by the EMEPC, the cruise was

The following are current projects:

Funded by Portuguese National Science Foundation:

| Project Title | PI | Start Date | Duration |
|--|---|------------|-----------|
| DEEPFUN - Biodiversity and functioning of the deep-sea hydrothermal field Menez Gwen- a contribution to management policies. | Ana Colaço (IMAR-DOP/UAç) | 01-04-2011 | 36 months |
| CARCACE - Colonization of mAmmal caRCasses in the deep Atlantic ocEan | Ana Hilario- Cesam (IMAR-DOP/UAç partner) | 01-06-2010 | 36 months |
| TerRiftic project - unraveling melting processes and volcanism on the Terceira Rift, Azores: a melting inclusion study. | Filipa Marques-CREMINER | 01-03-2011 | 36 months |

characterized by a multidisciplinary approach under the scope of the extension of the Portugal's continental shelf program. A team of geology, macro and microbiology, oceanography and geophysics researchers from several national institutes and universities were onboard to work in-situ with samples and data collected by the *Luís*, a 6000 m-rated ROV.

Azores Science Foundation projects:

| Project Title | PI | Start Date | Duration |
|--|---|------------|-----------|
| OceanA-Lab - Ocean acidification studies in the Azores: using a shallow-water hydrothermal vent as a natural laboratory. | Marina Carreiro e Silva (IMAR-DOP-UAç) | 30-03-2012 | 36 months |
| Marine Enzymes from the Azores: Using metagenomics and metatranscriptomics to identify biotechnologically relevant enzymes of marine bacterial origin. | Raul Silva Bettencourt (IMAR - DOP-UAç) | 30-03-2012 | 24 months |

FP7:

| | | | |
|---|-------------------|------------|-----------|
| Hermione - Hotspot Ecosystem Research and Man's Impact On European Seas | Phil Weaver (NOC) | 01-04-2009 | 36 months |
|---|-------------------|------------|-----------|

Missions at sea

2012 MoMARSAT cruise - maintenance of the Lucky Strike observatory - PI Mathilde Cannat - July 2012 (R/V *Thalassa* - ROV *Victor*)

2012 DeepFun cruise - habitat mapping, biodiversity and ecosystem function studies at Menez Gwen- July 2012- PI Ana Colaço (R/V *Thalassa* - ROV *Victor*)

Russia



Sergei Silantyev

The following events occurred during early 2012, outlining the activities of the Russian scientific community related to investigations of Mid-Oceanic Ridges:

The regular expedition of the Russian RV “*Professor Logachev*” (Ship Owner - Polar Marine Geological Expedition, PMGE) to the Central Atlantic took place. The main goal of the expedition was the exploration of polymetallic sulfide ore deposits at the MAR crest zone. This cruise carried out geophysical prospecting and sampling within the bounds of exploration provided by the Russian application for the prospecting of polymetallic sulfides, claimed on the Seventeenth Session of the International Seabed Authority (11-22 July 2011, Kingston, Jamaica). The Russian prospecting area is located at the axial part of the Mid-Atlantic Ridge between 12°48'-20°55'N and includes 100 separate blocks (100 km² each).

The operations of the cruise were focused on the most northern part of the Russian prospecting area: in Rift Valley between 20°00'-20°55'N. During the cruise, hydrophysical profiling, electrical exploration for prospecting of ore edifices, dredging and coring were carried out.



Russian National Correspondent Sergei Silantyev onboard the French R/V “*Pourquoi pas?*” during the Russian-French Cruise SERPENTINE to MAR, 12-17° N.

A new Russian Ridge website was prepared during the last few months, including news of current RR/IR activities, publications, meetings, members and photographs. The address is: <http://russianridge.ihed.ras.ru>

SOPAC Division of the Secretariat of the Pacific Community

Akuila Tawake

Deep Sea Minerals Activities in the Pacific Islands Region

1. Background

Some Pacific Island Countries, namely Papua New Guinea (PNG), Solomon Islands, Vanuatu, Fiji and Tonga are located along the southwestern part of the Pacific Rim of Fire and they host world-class mineral deposits such as porphyry copper-gold deposits [e.g. Ok Tedi (PNG), Panguna (PNG) and Namosi (Fiji)], and epithermal gold deposits [e.g. Lihir (PNG), Porgera (PNG), Vatukoula (Fiji) and Gold Ridge (Solomon Islands)]. Based on previous studies, the southwestern part of the Pacific is also host to potentially significant Seafloor Massive Sulphide (SMS) deposits in back-arc basins (e.g. Manus Basin, North Fiji Basin and Lau Basin) and the fore-arc basins (e.g. Kermadec Ridge).

Seabed mineral research and exploration were reported to have commenced in the Pacific Islands region in the late 1960s and continued to the mid 1970s concentrating on the assessment of manganese nodules. During the mid 1970s to mid 1980s, other commodities such as precious coral, metalliferous sediments and phosphate were explored, together with manganese nodules. Additionally, a cobalt-rich crusts (CRC) survey was first conducted in the region during the Kiribati Phoenix Island Group expedition in the early 1980s. In 1982, and again in 1984, hydrothermal vents were discovered in the Lau Basin, but the first black smoker was found in the Manus Basin, PNG, in early 1986. Further assessments of manganese nodules, CRC and SMS were ongoing in the region from mid 1980s to mid 2000. With the persistent research efforts of Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), the presence of high grade SMS deposits in the Manus Basin PNG was confirmed in the early 1990s.

These previous studies have confirmed the occurrence of SMS, CRC and manganese nodule deposits within the Exclusive Economic Zones (EEZ) of most Pacific Island Countries (PICs) (Table 1) and some of these deposits have very good potential to be further investigated for mining.

2. The SPC-EU Deep Sea Minerals Project

With the recent growing interest in further exploring these seabed minerals in the region for commercial exploitation, PICs have regarded this as an excellent economic development opportunity. While this new development is exciting, some stakeholders are concerned at the lack of necessary legal instruments and the likely adverse impacts of deepsea mineral activities on marine living resources. Further, there is a need for harmonised legal,

| Country | MN | CRC | SMS |
|----------------------------------|----|-----|-----|
| Kiribati | √ | √ | |
| Cook Islands | √ | | |
| Tuvalu | √ | √ | |
| Samoa | | √ | |
| Tonga | | | √ |
| PNG | | | √ |
| Solomon Islands | | | √ |
| Vanuatu | | | √ |
| Fiji | | | √ |
| Republic of the Marshall Islands | | √ | |
| Federated States of Micronesia | | √ | |
| Niue | √ | √ | |

Table 1: Deep seabed mineral occurrence within the EEZ of PICs.

environmental and fiscal regimes for the management of offshore mineral resources in the region. With limited resources and capacity in the region to deal with this new industry, the implementation of a regional cooperative approach for the governance and management of deepsea mineral resources was evident, hence the SPC-EU Deep Sea Minerals (DSM) Project was conceived.

The overall objective of the DSM Project is to expand the economic resource base of Pacific ACP States by facilitating the development of a viable and sustainable marine minerals industry. This regional project is funded by the European Union and is implemented by the Applied Geoscience and Technology (SOPAC) Division of the Secretariat of the Pacific Community (SPC).

Apart from the inaugural DSM Project Regional Workshop that was held in Nadi, Fiji in June 2011 and related meetings (reported in InterRidge News 2011), major activities of the Project in the last

year are listed below, including collaborative efforts with implementing partners:

- An international workshop on “Environmental management needs for deep seabed minerals exploration and exploitation” was held in Nadi, Fiji between November 29th and December 3rd 2011, and was organised by the International Seabed Authority (ISA) in collaboration with the SPC through the DSM Project, and the Fiji Government (Figure 1);
- The 2nd meeting of the Pacific marine mineral assessment technical steering committee was held soon after the ISA workshop in December 2011 in Nadi, Fiji to discuss the draft chapters and the final outline of the report. UNEP/GRID-Arendal is contracted to undertake this activity and the report is expected by December 2012.
- Five country-specific information brochures, each summarising the deep sea mineral potential of Tonga, Kiribati, Fiji, Samoa and the Republic of the Marshall Islands (RMI) have been completed and disseminated to the respective countries and interest groups;
- In consultation with stakeholders and interest groups, the “Pacific ACP States Regional Legislative and Regulatory Framework (RLRF) for Deep Sea Minerals Exploration and Exploitation” (Figure 2) was developed and finalised.
- The RLRF was officially launched during the Pacific Forum Leaders meeting in Cook Islands in August 2012;
- Tonga Seabed Minerals Bill has been drafted and is currently going through a stakeholder consultation process and is expected by December 2012.
- Ongoing support to assist Nauru, Kiribati and Tuvalu on developing national deep sea minerals policy and/or legislation;
- Legal Internship commenced in January 2012 whereby law graduates are contracted on a short-term basis to assist the DSM Project Legal Advisor and to be trained on the legal aspects of deepsea minerals. This capacity building initiative will be ongoing for the duration of the Project;
- Support for Pacific ACP State candidates to participate in regional consultation and training workshops;
- In collaboration with the Human Development Programme of SPC, four candidates were financially supported to attend the Pacific Mining Conference in Noumea in November 2011;
- Provide funding support for marine safety training and will provide further financial assistance for shipboard training in collaboration with States and exploration companies.
- A regional training workshop on “Pacific ACP States Regional Training Workshop on Geological, Technological, Biological and Environmental Aspects of Deep Sea Minerals” was held in August 2012 in Nadi, Fiji (Figure 3);
- Two DSM experts [Dr Jim Hein (USGS) and Prof Chuck Fisher (PSU)] were contracted as resource scientists during this training workshop. Dr Malcolm Clark (NIWA) presented on DSM and fisheries and Mr Kris Van Kijen (OceanFORE) also gave a talk on marine technology development;
- The production of a DSM documentary is in progress in collaboration with the ISA, Woods Hole Oceanographic Institute (WHOI), National Science Foundation (NSF) 2000 and Neptune Minerals (US). The documentary is expected by December 2012.

- Thirteen national stakeholder consultation workshops were held in the last year, one in each of the following countries: Cook Islands, FSM, Fiji, Kiribati, Nauru, Niue, Palau, RMI, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.
- Ongoing information sharing through information procedures, progress reports, press releases and websites.

3. Recent Seabed Exploration in the Pacific Islands Region

Three exploration companies are currently active in the region, namely Nautilus Minerals Inc, Bluewater Metals and Korea Ocean Research and Development Institute (KORDI), and they share a common interest to explore and mine SMS deposits. Nautilus Minerals is exploring in PNG, Solomon Islands and Tonga, and it has been granted exploration licenses in Vanuatu and Fiji. A subsidiary of Neptune Minerals (US), Bluewater Metals is based in Australia and has been conducting exploration activities in PNG, Solomon Islands, Vanuatu and Tonga and the company has submitted an application to explore in Fiji. KORDI, a state-sponsored ocean science research institute is currently exploring in Tonga and Fiji.

3.1 Nautilus Minerals Activities

The Government of PNG granted a Mining Lease to Nautilus Minerals in January 2011 following the issuance of an Environment Permit in December 2009. Nautilus has been reported to have awarded contracts for the construction of mining equipment and construction works are in progress, as well as the development of an Environmental Management Plan (EMP) for the Solwara 1 project site. Mining is expected to commence at Solwara 1 in the 4th quarter of 2013.

The pioneering of deep sea mining in PNG will lead to improved future deep seabed mining technology, hence the development of new and robust technologies will increase the economic viability of exploiting manganese nodule and cobalt-rich crust deposits.

3.2 KORDI Activities

KORDI has been actively exploring in Tonga in the last four years and the company intends to carry out resource definition activities in 2013 to better understand the geological potential of its licensed areas. According to the company’s work plan, an Environment Impact Assessment (EIA) will be carried out at the end of 2013 and an application for a mining license is expected in 2014. This will be followed by preparation for commercial mining including the construction of mining equipment and facilities between 2014 and 2016, with commercial mining to commence in 2017.

According to KORDI Minerals Limited based in Suva Fiji, the company believes the work plan is achievable but it will largely depend on the resource definition that is scheduled in 2013 to determine the geological potential of KORDI’s tenements. KORDI is supported by its joint investment partners, namely Samsung Heavy Industries, Daewoo Shipbuilding & Marine Engineering, LS-Nikko Copper and SK Networks. These joint investment partners are well established and well resourced to assist KORDI in realising its vision.



Figure 1: Participants at the international workshop in Nadi, Fiji, November 2011.

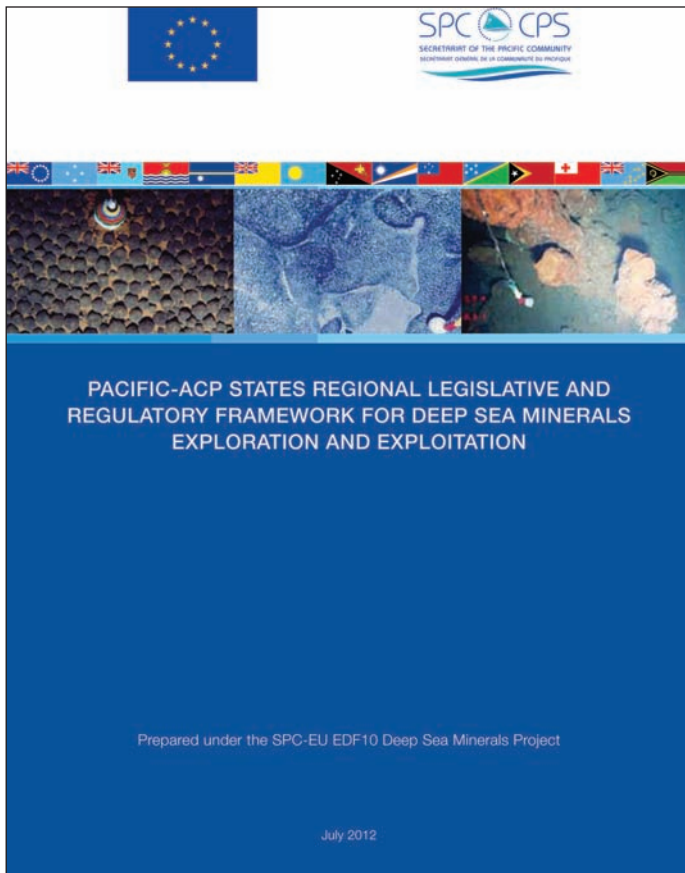


Figure 2: Legislative and Regulatory Framework on Deep Sea Minerals document.

4. Recent Deep Sea Minerals Interest in “the Area”

In recent years, some PICs have expressed their interest in participating in the exploration and possible exploitation of deep sea minerals in the International Seabed Area (“the Area”). Nauru and Tonga were the first two countries to provide sponsorship, as required under UNCLOS, to two exploration companies. Nauru Ocean Resources Incorporation (NORI) is sponsored by Nauru, and Tonga Offshore Mining Limited (TOML) is supported by Tonga. The ISA has granted both companies exploration licenses in the reserved areas of the “Clarion-Clipperton Fracture Zone” (CCFZ). Marawa Research and Exploration Limited, a state owned company in Kiribati, has recently been granted exploration licenses on the CCFZ with Kiribati Government sponsorship. Other PICs such as Tuvalu and Fiji have also shown interest in participating in deepsea mineral activities in “the Area”.



Figure 3: Participants at the regional training workshop in Nadi, Fiji, August 2012.

UK



Richard Hobbs

Arc - back-arc systems

Large areas of the submarine parts of the active South Sandwich Island arc and its back-arc spreading centre have been mapped using multibeam bathymetry. Maps are being prepared for publication. Geochemical and petrological work is currently concentrating on silicic lavas from seamounts in collaboration with Birkbeck College, London, and on magmatic processes on the extinct West Scotia Ridge, and the early structure of the East Scotia and Central Scotia Seas in collaboration with Cardiff University, the Instituto Geológico y Minero de España and University of Grenada.

Vent Ecology

Investigations of vent biodiversity and ecology in the East Scotia Sea back-arc spreading centre are continuing, funded by the NERC ChEsSO grant (NE/DO1249X/1). The first paper reporting the hydrothermal sites and vent communities has been published (Rogers et al., 2012). They have discovered new hydrothermal vent communities that are probably the first to be found in Antarctic waters. The communities include new species of crab, barnacles, limpets, snails, sea anemones, and a predatory seven armed starfish. They claim that this is a new biogeographic province created by the environmental conditions of the Southern Ocean. Tyler (National Oceanography Centre) has another cruise to the sites identified by Rogers et al (2012) at the end of 2012 (JC080). The ROV *Isis* will be used to characterise the chemosynthetic fauna and microbes and the environmental conditions that sustain them at a range of sites of active seafloor fluid-flow and will include: a complete a thorough mapping and documentation at each site; sampling of the of the vent/seep fluids and plume; a microbial and metazoan sampling programme; and fish traps. The material will be used for subsequent lab analyses.



Recently completed cruises:

Rogers (JC066) November 2011. The objectives were to survey, sample and identify the benthic fauna of seamounts on the southwest Indian Ridge and map the distribution of species in relation to topography, hydrography and primary production. It also assessed Benthic Protected Areas (BPAs) recently proposed by the fishing industry for conserving the regional biodiversity of seamount communities. The project represents a major collaboration between U.K. scientists (Institute of Zoology; Natural History Museum; Scottish Association for Marine Sciences), the Census of Marine Life programme (CoML), the World Conservation Union (IUCN), the UN Food and Agricultural Organisation (FAO) and the fishing industry (Southern Indian Ocean Deepwater Fishers' Association; SIODFA).

Copley (JC067) December 2011. ROV made dives at a deep-sea hydrothermal vent field on the Southwest Indian Ridge (SWIR), to test key hypotheses relating to the global biogeography and ecology of chemosynthetic ecosystems.

Henderson (JC068) December 2011/January 2012. The concentration of seven critical ocean micronutrients (Fe, Zn, Co, Cd, Ni, Cu, Mn) were mapped at high spatial resolution for the full water column on a zonal section across the Atlantic at 40°S, including the mid-ocean ridge. This research included: determination of the variations in physical and chemical speciation of these micronutrients; sources and fluxes, influences of advection and mixing; and phytoplankton ecosystem structure and functioning.

Leat (JR259) February-March 2012. British Antarctic Survey cruise on RRS *James Clark Ross* to Scotia and Weddell Seas. Cruise Report: Leat, P.T., Tate, A.J., Buys, G., 2012. Geology and Bathymetry, Scotia and Weddell Seas, RRS *James Clark Ross* JR259 Cruise Report. British Antarctic Survey Report AD6/3/JR259. Most of the cruise science time was spent in the Weddell Sea, doing multibeam bathymetry in collaboration with biological sampling, but some work was carried out on the West Scotia Ridge, on segment W5, and in the South West Scotia Sea near the East Scotia ridge back-arc spreading centre. Multibeam bathymetry and dredge samples were collected.

Forthcoming cruises:

- Tyler (JC080) end 2012 (see above report on Vent Ecology)
- Copley (JC082) early 2013. We propose to test hypotheses relating to hydrothermal emissions and associated chemosynthetic faunas on the Mid-Cayman Rise. This is the deepest known seafloor seafloor spreading centre and is located in a poorly ventilated and geographically isolated deep ocean basin. It specifically targets a

region identified as a priority for investigation by the International Census of Marine Life to advance the understanding of global vent biogeography. In addition, its unique samples will provide resources for the wider marine biotechnology and microbial metagenomics research communities.

- Hobbs cruise to Costa Rica Ridge to investigate the effects of hydrothermal circulation on both the geophysics and oceanography in the Panama Basin is still awaiting scheduling, expected early 2014.

Further details of cruises can be obtained from the UK NERC Marine planning website:

<http://www.noc.soton.ac.uk/nmf/mfp/mfp.php>

Proposals in review:

Searle, Reston and Macleod have a joint proposal under consideration at NERC to do a major geophysical experiment (active and passive seismic + Autosub bathymetry and magnetics) over an ocean detachment fault at MAR 13°N.

USA

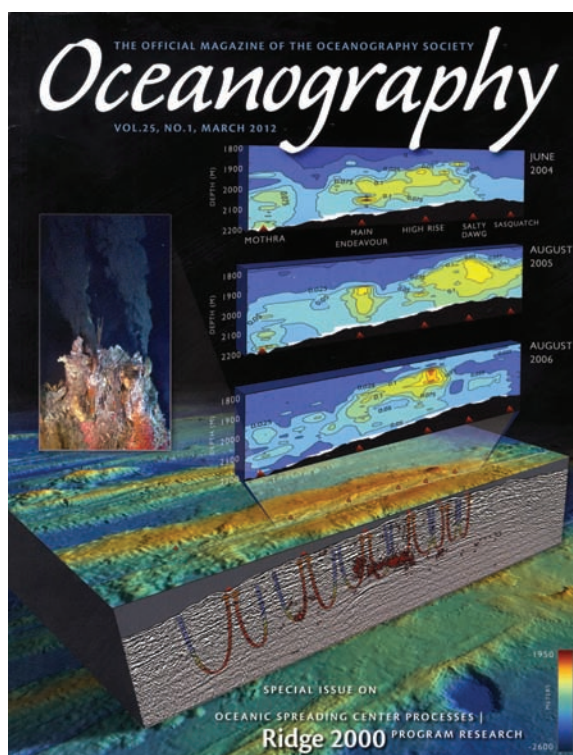
Dan Fornari, Ridge 2000 Chair, WHOI



The Ridge 2000 Program in the US formally ended in early FY2011, while dedicated funding for R2K science ended in late 2010. The primary goal of the Ridge 2000 Program (R2K) has been to achieve an integrated, holistic understanding of global mid-ocean ridge (MOR) processes. This ongoing work is building on the substantive body of knowledge that has been derived from past and current R2K field, laboratory and modeling efforts. In addition, R2K research and engineering has played a formative role shaping current Ocean Observing (OO) science and technology programs and related focused research programs like the Center for Dark Energy Biosphere Investigations (C-DEBI).

Research resulting from R2K studies continues to be published in peer-reviewed journals that will serve as part of the intellectual legacy of R2K. In addition, a special issue of Oceanography Magazine, focused on R2K research results was published in March 2012. The full issue and individual articles are available online at: <http://tos.org/oceanography/archive/25-1.html>.

Achieving outstanding R2K programmatic goals requires data sharing among investigators across disciplinary boundaries and collaborative efforts to find causal linkages and to develop cross-disciplinary models to better understand underlying processes. The MGDS R2K Data Portal has made such data sharing far more efficient and easier for PIs and students. Many R2K PIs have made substantial progress in publishing the results of field studies and



Special issue of Oceanography, highlighting R2K research results.

making those data sets available for comparative studies across geographic and process-oriented boundaries (e.g. at Integrated Studies Sites (ISS) and elsewhere). All environmental metadata and field data from R2K-funded cruises are archived and discoverable through the R2K Data Portal. The R2K data portal is administered by the Data Management Office (DMO), part of the Marine Geophysical Data System (MGDS) at Lamont-Doherty Earth Observatory (LDEO). See: <http://www.marine-geo.org/portals/ridge2000/>.

Ridge2000-related US cruises

There is currently no umbrella organization in the U.S. now to coordinate MOR research, but several other programs are ongoing and include field studies at ridges. First, the National Science Foundation's Ocean Observatories Initiative (OOI) is establishing a Regional Scale Node (RSN) at Axial Volcano on the Juan

de Fuca Ridge. The UNOLS Office also maintains current and past catalogs of scheduled research cruises for US investigators in all branches of the ocean sciences. http://strs.unols.org/public/Search/diu_all_schedules.aspx?ship_id=0&year=2011

US support for InterRidge

Funding was secured for US participation in InterRidge during 2012 and our dues have been paid. Future funding is uncertain given the state of US NSF budget levels and expected cuts in NSF-OCE; however, several US investigators are working towards securing continued funding for US participation.

Working Group Updates



Island Arc and Back Arc (BI-ARC)

Chair: Maria Seton (USYD, Australia); Co-chair: Cornel de Ronde (GNS Science, New Zealand)

Activities:

- The working group was approved in January, 2012.
- An initial working group planning meeting was scheduled during the International Geological Congress (IGC) meeting in Brisbane (6-10 August, 2012).
- Members were involved in convening themes/symposia at the IGC 2012:
 - Theme: Mineral Deposits and Ore Forming Processes (Large, de Ronde)
 - Symposium: Volcanic and basin-hosted ores (Fe, Zn- Pb, Cu, U) (Gemmell, de Ronde, Bull, Leach)
 - Symposium: Marine minerals in Oceania (Cronan, de Ronde, Exon)
 - Symposium: Subduction zone magmatism including a special session on magmatism in the SW Pacific (Wysoczanski, Handler, Wilson)
 - Symposium: Plate tectonics, plate-mantle coupling and associated deformation (Seton, Iaffaldano)
 - Theme: A Dynamic Earth (Müller)
 - Symposium: Linking deep earth to plate tectonic and surface processes (Müller, Gurnis, Zhao)
- Members are involved in convening a session at the AGU 2012 Fall Meeting on “The Dynamics of Island Arcs and Backarc Spreading Centers” (Wiens, Seama, Stern, Seton).
- Members are involved in organising the SW Pacific IODP workshop to be held at the University of Sydney (9-11 October, 2012). The workshop aims to bring together ~70 scientists actively involved in research in the SW Pacific for the purpose of planning an IODP submission. The workshop is being organized by Exon, Seton and Gallagher and is funded through the IODP-MI, Ocean Leadership and ANZIC. InterRidge working group members will be encouraged to attend the workshop.
- Members were involved in organizing a workshop on “Mariana Vent Larvae (MarVeL)” to discuss studies of connectivity between deep-sea hydrothermal vents, which was held in Okinawa, Japan on 10-11 May 2012. The workshop was organized by Beaulieu, Mitarai and Watanabe and funded by the NSF and OIST.
- University of Sydney hosted a workshop between 7-8 June 2012 on “Plate configurations in SE Asia based on evidence from the deep earth”, organized by Müller, Suppe and Wu.
- Established joint supervision of an honours project between GNS (de Ronde) and the University of Sydney on arc volcanism in the Kermadec region.
- Website is currently under construction as a portal for more detailed information about the working group. A link will be made available from the InterRidge website.

Hydrothermal Energy Transfer: its impact on the Ocean Carbon Cycles

Co-Chairs - Nadine Le Bris (France) and Chris German (USA)

Hangzhou meeting

The second WG group meeting was held in Hangzhou, China on 10-11 October 2011. It was hosted by the 2nd Institute of Oceanography. Xiqiu Han, also a member of the WG, has been a greatly appreciated local organiser. The visit included additional

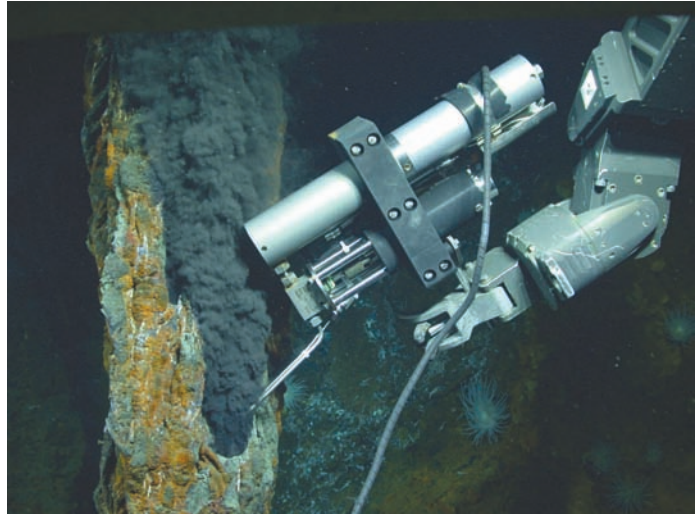
exchanges with colleagues and seminars for students for several meeting attendees. The group of attendees involved L. Bharathi (India), T. Gamo (Japan), C. German (US), G. W. Luther (US), X. Han (China), N. Le Bris (France), L. Legendre (France), S. Sander (NZ) and S. Sievert (US).

The first objective of the meeting was to initiate discussion on the two review papers that aim at synthesizing knowledge on : 1) seafloor and subseafloor carbon fixation processes and transfer in the ecosystem, and 2) subseafloor to upper ocean impact on ocean carbon budgets. The second objective was to discuss the synthesis of this information into a conceptual model, allowing us to address the role of ridge hydrothermal systems on the ocean C biogeochemistry on a more quantitative basis. Discussion of the modelling approach was led by L. Legendre on the second day. The two subgroups set the frame for a conceptual basis to these approaches.

Modelling

The first subgroup addressed the productivity of vent ecosystems, from the perspective of estimating the amount of carbon that is fixed chemosynthetically and can be transferred to consumers or to the water column. The second subgroup considered the potential role that hydrothermal systems may play in regulating global scale carbon budgets and related biogeochemical cycles (notably for the micro-nutrient Fe) in the deep ocean. The building of the two conceptual models has already generated interesting discussions on the priorities and necessary degree of simplification of the first models.

Following the Hangzhou meeting, the two sub-groups have been focusing upon formalizing the model approach, guided by L. Legendre. A preliminary version of the water column model was completed by early 2012 and a revised version of the modelling is now being undertaken. A similar approach has been drafted for the seafloor ecosystem model and is being refined. As done for the



Vent-fluid sampling using isobaric gas-tight samplers from the 403°C Beebe Vent #3, Piccard Hydrothermal Field, Mid Cayman Rise. Photo courtesy of C.R. German, copyright WHOI.

water column model, the need is on constraining the unknowns for such complex systems that involve a variety of chemoautotrophic pathways and related abiotic conditions/ energy sources. Further plans will be to circulate draft paper versions to the whole WG, to allow integration of contributions from WG members not attending the workshop.

International workshop

Early 2013 is being considered for the organisation of this event at a European venue.

Mantle Imaging

Chair – Nobukazu Seama (Kobe University, Japan)

The WG for Mantle Imaging was formed in 2008 and disbanded in 2012. The formation of the WG was timely because recent progress in long-term observational technology on the seafloor enables the imaging of regional mantle structure using both seismological and electromagnetic techniques. The key scientific questions to be addressed by imaging the mantle beneath spreading centers are 1) clarifying mantle dynamics associated with different ridge systems, and 2) identifying the parameters controlling various lithospheric features at different types of ridge systems. The WG organised a workshop in Japan in October 2011 as the main event of the WG, and the report below was summarised by Douglas Wiens, Kyoko Okino and Nobukazu Seama. The real experiments to image the mantle beneath spreading centers has taken time and very few were done during the WG activity; a limited number of high quality

images of the mantle structure beneath spreading centers were provided through analysis of data only from previous experiments. But, the importance of mantle imaging was well understood and reconfirmed through the workshop. Further, the "mantle" is one of the key words for ridge research as described in the "Mantle Control" section of InterRidge's Third Decadal Plan. Thus, the WG recommendation is to re-form the "mantle" WG with new members offering a variety of specialisms, which will be in line with the new InterRidge plan.

Ocean Mantle Dynamics: From Spreading Center to Subduction Zone

77 scientists from six different countries gathered at AORI in Chiba, Japan on 4-6 October 2011, to discuss recent developments in the

study of the dynamics of the oceanic lithosphere, melt production at oceanic spreading centers and island arcs, and associated topics. The meeting was supported by several organizations, including the Japanese TAIGA project, the US Geoprisms program, AORI and the Ocean Alliance of University of Tokyo, as well as InterRidge. The scientific organizing committee consisted of the members of the InterRidge Mantle Imaging Working Group, and the local organising committee was chaired by Kyoko Okino and Nobukazu Seama.

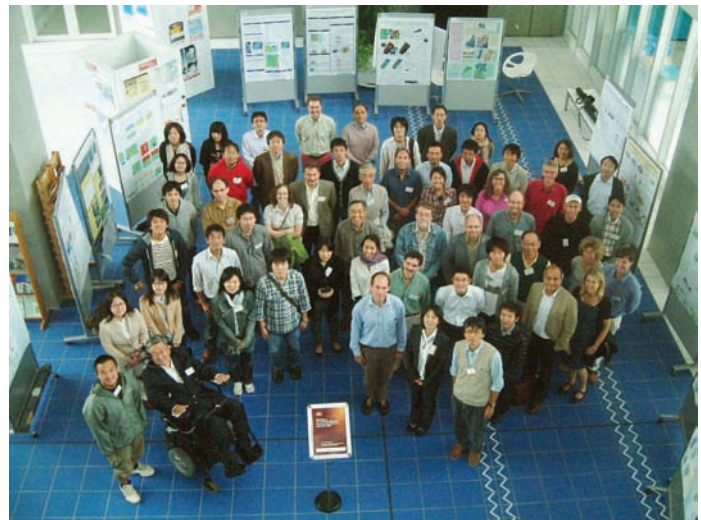
The meeting was preceded by a field trip to the Horoman Peridotite Complex in Hokkaido led by Eiichi Takazawa from Niigata University. The field trip party visited several outcrops of fresh lherzolite, harzburgite, and dunite along the Horoman River, uplifted and exposed by thrust faulting. The field trip party also had several presentations on the petrology and seismic imaging of the Horoman complex.

The first day of the scientific meeting focused on the structure of the oceanic lithosphere and asthenosphere, with an emphasis on results of recent imaging studies and laboratory experiments. Is the development of older oceanic lithosphere controlled only by thermal conduction, or are compositional variations also important? There was considerable debate about recent observations of discontinuities in the oceanic lithosphere and asthenosphere. How are the relatively sharp seismological discontinuities related to changes in electrical conductivity with depth? Are the changes with depth primarily thermal in origin or do they represent compositional changes associated with the depth of melt extraction? Another important topic was the depth variation of anisotropy in the lithosphere and asthenosphere, a question that will hopefully be addressed by ongoing and future ocean bottom seismic and EM deployments.

The second day's topic was melt migration beneath spreading centers and the formation of oceanic crust. Imaging studies have begun to provide constraints on the extent of the melt formation region and the mechanism of melt migration to the ridge axis. Recent results show that the regions of primary melt production and melt ascent are not always localized immediately beneath the spreading center axis. Complexities in ridge tectonics, such as oceanic detachment faults were also discussed. Important constraints come from geochemical studies as well as studies of ophiolites and abyssal peridotites. Highly depleted regions of the mantle may be preserved for long periods of geological time and will be poorly sampled by melting, so inferences from basalts may not always produce a good indication of average mantle composition. Models of melt migration can describe many of the observed features, but raise important questions about the mechanism of melt collection at the ridge axis and the role of a "freezing boundary" at the bottom of the lithosphere in focusing the melt supply. There was also a lot of debate about the melt ascent rate in the mantle and its implications for melt porosity and geochemistry. Are seismic and EM imaging results compatible with

geochemical and modeling results indicating rapid melt ascent and extremely low melt porosity?

Water certainly plays a key role in magmatic processes, particularly for island arc volcanism and backarc spreading centers. The third day reviewed geochemical and experimental evidence for the transport mechanism and distribution of water in arc/backarc systems. Several presentations discussed the physical properties of serpentine and their effect on the transport and release of water in subduction zones. Water enhances melting in both mid-ocean ridge and backarc spreading centers, but the geochemical signature in terms of the apparent extent of melting is different. The effect of water on backarc spreading centers decreases with increasing distance from the arc and slab. Seismological images of the upper mantle beneath Japan, taking advantage of dense seismic networks, provide unprecedented resolution of mantle processes beneath volcanic arcs. EM and seismic images of the Mariana system provide constraints on mantle flow and the distribution of melt in volcanic arcs and backarc spreading centers, and help to understand the dynamics of arc/backarc systems. Numerical models are increasingly important for understanding complicated observations of anisotropy as well as the magma production system.



Twenty-six poster presentations, many of them from students and younger scientists, were a key part of the meeting, and they provoked a lot of good discussions at the poster time. InterRidge sponsored two awards for the best student poster presentations. Shusaku Yamazaki from Niigata University won an award for his poster "Formation of incipient oceanic island arc crust: Geology and geochemistry of the late intrusive rocks in the Oman Ophiolite". Akiko Takeo from the Earthquake Research Institute of Tokyo University won an award for her poster "Seismic anisotropy in the uppermost mantle beneath oceanic regions from data of broadband OBSs". During the poster session there was also an interesting presentation via Skype from Teras Gerya, who was unable to come to Japan for the meeting. He presented recent modelling results constraining the mechanism producing orthogonal oceanic spreading center and transform fault patterns.

At the end of the meeting there was a general discussion about future projects and cooperation in ocean mantle studies. There was an agreement that ship time should be used as efficiently as possible so combining several types of measurements, such as seismic and EM, on the same cruise should be encouraged. Scientists should allow opportunity to use extra ship time to collect samples for petrological and geochemical analysis. The InterRidge cruise

database is useful and should be expanded to include cruises related to oceanic lithosphere research. International collaboration and planning may allow very ambitious projects in the future that are beyond the capability of individual nations.

The entire meeting program, including abstracts is available at: http://ofgs.aori.u-tokyo.ac.jp/intridgej/WS_2011/

Oceanic Detachment Faults

Co-Chairs: J. Pablo Canales (WHOI, USA) and Javier Escartin (CNRS-IPGP, France)

The InterRidge Oceanic Detachments WG Was put in place in January 2012, following the results and recommendations of the 2012 AGU Chapman Conference on “Detachments in the Oceanic lithosphere”: (<http://www.ipgp.fr/rech/lgm/jc/Chapman2010>)

The aim of this group is to foster research and collaborations within the community to advance the understanding of the processes that control oceanic detachment faulting and associated geological, chemical, and biological phenomena.

On-going activities of the WG are:

- Special Theme on Oceanic detachments in AGU G-cubed electronic journal: Set up in November 2010, and to date, this Theme has collected 17 articles. The WG will discuss with AGU to

maintain the Theme open till 2014, and encourages the submission of relevant articles by the community.

- Dec. 2012 Meeting at AGU among the Members to establish a 2-year roadmap of WG activities.

- Convene a thematic session in 2013 AGU Fall Meeting (session proposal probably due in April 2013) and EGU Spring 2015.

- Organize a 2-3 day InterRidge Theoretical Institute on a specific topic related to oceanic detachment faulting, (e.g., mechanics of detachment faults). Tentative dates: Spring or Fall 2014.

- Organize an IODP-detachment related workshop in 2013 or 2014

The WG will actively share information regarding on-going projects and planned cruises to facilitate exchanges in the community.

Seafloor Mineralisation

Chair – Maurice Tivey (WHOI, USA)

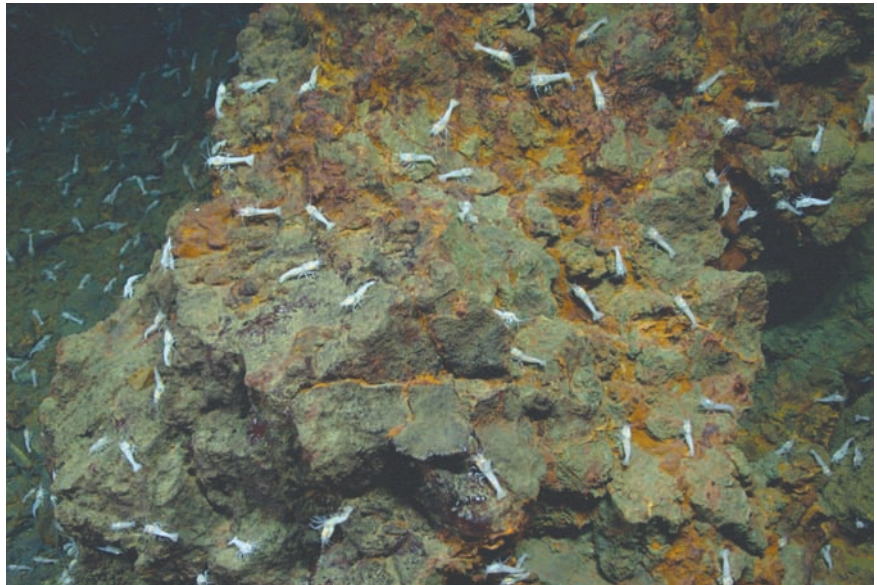
The Seafloor Mineralisation Working Group was renewed for a second term at the last InterRidge meeting in San Francisco in December 2011. Interest in the mineralisation resources at mid-ocean ridges has continued unabated with the price of metals such as copper, gold and silver near historic highs and nations beginning to look at options for exploration of seafloor areas for polymetallic sulfide resources in “the area” under the regulations of the International Seabed Authority (ISA). Last year, the ISA approved license plans for China Ocean Minerals Resources Research and Development Association (COMRA) for work in the Indian Ocean. It is expected that the ISA will approve plans submitted by the Ministry of Natural Resources and the Environment of the Russian

Federation for work on the central Mid-Atlantic Ridge (Logatchev region) at the upcoming ISA meeting in July. Other countries are actively considering submitting license requests before the end of the year.

In April, several members of the SMWG (Cherkashov, Hannington, Petersen, Tivey) attended a workshop hosted by GEOMAR in Kiel, Germany to discuss initiating a program for studying “the metal potential of a slow spreading ridge segment,” which will attempt to address some of the original topics of the working group including the spatial controls and timescales of evolution of seafloor metallic sulfide deposits.

In other related news the US National Science Foundation officially closed down the RIDGE2000 program, which had focused research efforts to study mid-ocean ridge processes including hydrothermal systems and their mineral resources. Future research funding in these areas is expected to be directed through the core science budget of the various sections of the Ocean Sciences (OCE) division. To close out the program, the RIDGE2000 office organized a special issue of *Oceanography* magazine on oceanic spreading center processes (<http://tos.org/oceanography/archive/25-1.html>) that compiles results of several major RIDGE2000 efforts.

Finally, a special session at Ocean Sciences in Salt Lake City (Feb 19-24, 2012) was convened on “Deep-Sea Conservation Imperatives in the 21st Century” chaired by Lisa Levin, Cindy Van Dover, Jeff Ardron and Craig Smith.



Regularly spaced *Rimicaris hybisi* shrimp swarming over massive polymetallic sulphide deposits, Beebe Woods mound, Piccard Hydrothermal Field, Mid Cayman Rise. Photo courtesy of C.R. German, copyright WHOI.

South Mid-Atlantic Ridge Targeted Exploration (SMART)

Chair - Colin Devey (IFM-GEOMAR, Germany)

The Long-Range Exploration WG report (see http://www.interridge.org/files/interridge/LREWG_Report_Final_web_0.pdf) identified several regions of the world's oceans that, for many ridge-related scientific disciplines, it would be important to explore thoroughly and on a large scale. One of the key regions is the Southern Mid-Atlantic Ridge (SMAR) including its Equatorial Fracture Zones (Devey et al., IR News, 2010). The science drivers for SMAR exploration range from those of biodiversity and the links in terms of gene flow between the Southern Ocean and the Arctic, questions of the interplay between magmatism and tectonics during slow spreading and the physical oceanography of ocean mixing above the rough slowspreading bathymetry. The SMART WG aims are:

1. To collate and combine information already available from recent and older cruises to establish a thorough "State of the art" of Southern MAR studies. For this work active participation of scientists from many countries working toward this common goal is essential - a core strength of InterRidge.
2. To provide focus for the international coordination of further South Atlantic exploration, specifically aiming to identify and then fill gaps in our knowledge of this relatively unexplored region. We will convene a workshop to produce a project plan of how to

explore the SMAR thoroughly in the next 5-10 years, defining and prioritizing goals, and identifying cruises needed.

3. In a larger framework, the South Atlantic Basin as a whole is an important yet relatively little-explored ocean region. We expect the SMART WG to provide a seed to establish basin-scale studies within the framework of bodies such as SCOR. This could spearhead international efforts to use the Atlantic Basin as a test-bed for collection and synthesis of, for example, the phylogeographic history of chemosynthetic faunas (vent and seep) from the Arctic to the Antarctic and to study gene flow. These efforts, in collaboration with mapping, physical oceanographic studies, studies of reproductive biology & larval distributions, and modelling efforts would make important contributions to science and to the management of resources associated with chemosynthetic ecosystems.

A workshop will be held to formulate project plans for the continued exploration of the SMAR. This will likely include discussing how we intensify the exploration at high southern latitudes (as far south as the Bouvet Triple Junction at 55°S). This may require pooling of several national polar capabilities and a review of the state of autonomous underwater vehicle capability to explore these particularly extreme regions, a further area prioritized

for future internationally-coordinated exploration at the LREWG Workshop. Furthermore the workshop will be tasked with determining if any target areas in the SMAR region warrant the mounting of time-series and/or constant monitoring activities

which, due to its remoteness, are probably only realizable as part of an internationally coordinated effort and, hence, entirely the kind of activity at which InterRidge excels.

Vent Ecology

Chairs – Stephane Hourdez (Sta.Biol. Roscoff, France) and Yoshihiro Fujiwara (JAMSTEC, Japan)

Deep-sea Mining

The pilot Solwara 1 project could start operations in 2012. The vent biology community is closely watching this world-first and worries about the consequences. Helen Rosenbaum wrote a very nice and comprehensive report on the subject, including economics and biology. This report can be downloaded from <http://stoplynas.org/wp-content/uploads/2011/11/Out-Of-Our-Depth.pdf>. Another article more generally about mining the ocean floor in the Pacific can be accessed at: <http://www.deepseaminingoutofourdepth.org/>

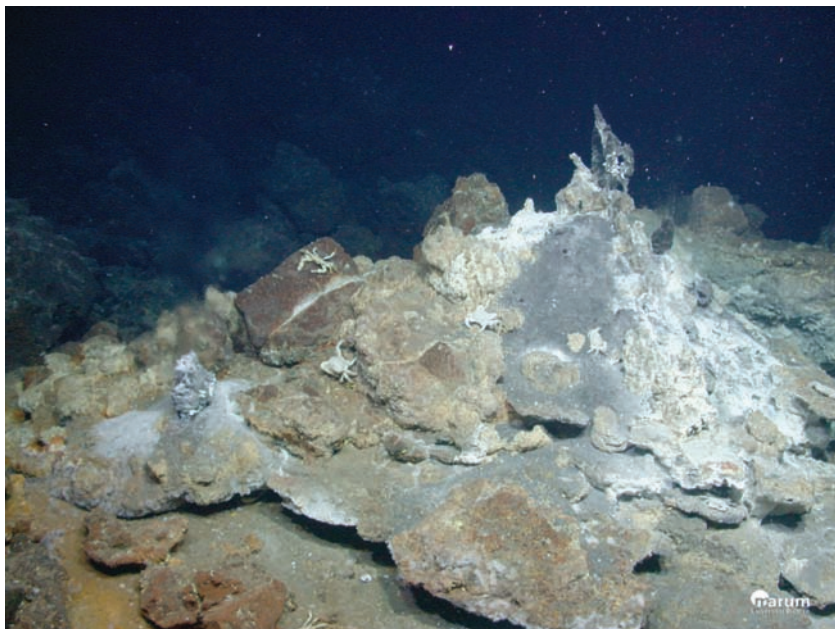
High-throughput

The high-throughput page has nicely grown over the years. To have a look at the list of projects, go to <http://www.interridge.org/highthroughput>, and if you would like to add to the list, go to <http://www.interridge.org/node/add/highthroughput>.

Meetings

The CAREX Conference on Life in Extreme Environments was held in Dublin, Ireland on 18-20 October 2011. It was an important event on the European and international scenes, providing the opportunity to discuss and present the state of the art and the latest developments on research on life in extreme environments, and vent biology plays an important role in CAREX. For more details, see <http://www.carex-eu.org/activities/carex-conference-on-life-in-extreme-environments.html>

The 13th International Deep-Sea Biology Symposium will be held in Wellington, New Zealand 3-7 December 2012. Held every 3 years, this general deep-sea meeting includes presentations on hydrothermal vents. For more details, see <http://www.confer.co.nz/dsbs2012/>



Newly discovered Bubbles vent site (Mid-Atlantic Ridge). Menez MAR cruise (Chief Scientist N. Dubilier, Sept-Oct 2010), copyright Marum-Universität Bremen.

The 5th International Symposium on Chemosynthesis-Based Ecosystems will be held in Victoria, BC, Canada on 18-23 August 2013. Initially Hydrothermal Vent Biology Symposium, the scope has expanded to all chemosynthesis-based ecosystems to now include cold seeps, whale falls, sunken wood, and sulfidic caves. This meeting, held every 4 years, is the main focused symposium for the vent biology community. Registration is expected to begin November 2012. For more details, see: <http://www.neptunecanada.ca/cbe5/>

Books

Elanor Bell (editor) and part of the CAREX community produced a book entitled “Life at Extremes: Environments, organisms and strategies for survival” that came out in March 2012 (CABI publishing ISBN-13: 978 1 84593 814 7). This book offers a transversal view of various extreme environments, including hydrothermal vents. (See the Publications section of this volume).

Workshops and Conferences



VentBase 2012 Workshop

National University of Ireland, Galway, 10-12 April 2012

Convenors: Patrick Collins, Bob Kennedy, Jens Carlsson

VentBase is a forum for scientists, commercial enterprises and both governmental and non-governmental bodies involved or interested in assessing the environmental impact of mining seafloor massive sulfides (SMS) deposits in the deep-sea. VentBase uses themed breakout sessions to allow stakeholders in the deep-sea to engage with each other in an informal, yet productive, manner. A primary goal of VentBase is the production of a best practice documents that can inform stakeholders and highlight the most up to date methodologies, both current and soon to be available.

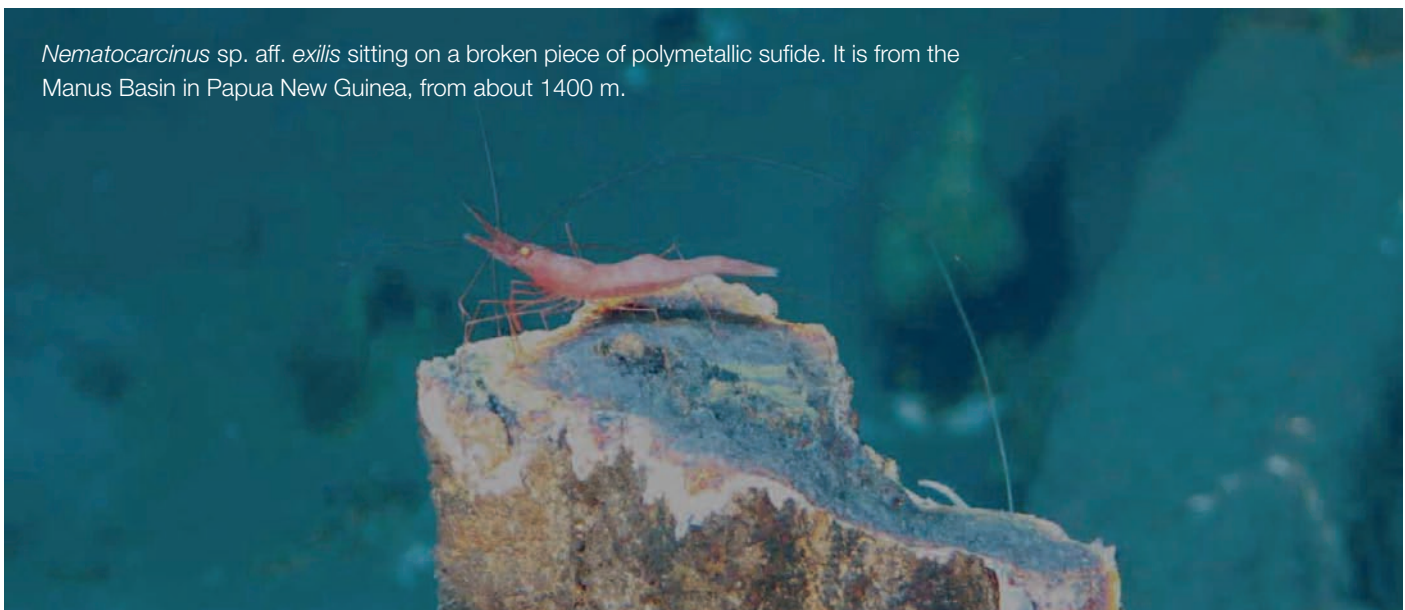
The VentBase 2012 workshop had the primary aim of standardizing methods used for assessing the ecological impacts of commercial mineral extraction at seafloor massive sulfides (SMS) deposits. The workshop was supported by InterRidge, INDEEP and the International Seabed Authority (ISA). Thirty-two experts on marine science (biodiversity, oceanography, ecology, etc) from twelve countries convened from 10-12 April 2012.

The workshop conducted three simultaneous breakout sessions. Documents from each of the Breakout sessions have been submitted to the legal technical council of the ISA. The

Environment Impact Assessment session, chaired by Bob Kennedy, discussed the conceptual recommendations for EIA at SMS deposits with suggested amendments for the ISA document (ISBA/16/LTC/7, 2010). The Oceanographic and Geography group, chaired by Peter Croot, also proposed amendments to the ISA document (ISBA/16/LTC/7, 2010) from an oceanographic and geological perspective. The Sampling Methods session, chaired by Patrick Collins, submitted a document outlining sampling guidelines for biological survey at SMS's. The guidelines outline methods for appropriate survey design, state of the art molecular approaches for assessing geneflow and connectivity, plankton/larval sampling, macrofaunal studies, video/photographic time series and statistical approaches.

VentBase realised the need for international collaboration and made progress in the standardisation of methodologies used for EIA at deep-sea SMS deposits. Subsequent collaborations resulting from the workshop have led to the writing of two peer-reviewed manuscripts: an EIA primer for SMS deposits and sampling guidelines for biological survey at SMS deposits. A follow up VentBase workshop is planned for 2013.

Nematocarcinus sp. aff. *exilis* sitting on a broken piece of polymetallic sulfide. It is from the Manus Basin in Papua New Guinea, from about 1400 m.



The metal potential of a slow-spreading ridge segment

GEOMAR, Kiel, Germany, 19-20 April 2012

Convenor: Sven Petersen; Report by John Jamieson, Univ. of Ottawa, Canada

This workshop, hosted by GEOMAR, brought together scientists with backgrounds in geology, geophysics, modeling and engineering, but who all had an interest in hydrothermal mineralisation processes at slow-spreading ridges. Thirty-three participants from 8 countries attended the workshop. The goal of the workshop was to develop a framework for an integrated study of the metal content of a slow-spreading ridge segment with a multi-disciplinary approach that combines geological and geophysical studies and uses the latest technological advances in marine surveying.

The proposed study relies on the use of multiple surveying platforms and techniques, including rock sample and fluid collection,

visual reconnaissance, ship and AUV-based high-resolution mapping, and geophysical surveys along and across the spreading axis. The goal is to produce various high-resolution geological and geophysical surveys of an entire ridge segment in order to calculate the full metal budget of a ridge segment and its variability with time. The integration of these various sources of information will be used to constrain the proportion of metals transported to the seafloor by hydrothermal fluids along the length of a ridge that are either deposited as massive sulfides, or dispersed over a wider area by the hydrothermal plume, or dissolved back into seawater. The area chosen for this study is the TAG segment on the Mid-Atlantic Ridge that hosts known active and inactive hydrothermal systems.

MarVeL Workshop catalyzes new international collaborations for studies of connectivity between deep-sea vents

Okinawa Institute of Science and Technology, 10-11 May 2012

Convenors: Stace Beaulieu, Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA (stace@whoi.edu)

Satoshi Mitarai, Okinawa Institute of Science and Technology, Onna, Okinawa 904-0495 JAPAN (satoshi@oist.jp)

Hiromi Watanabe, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Kanagawa 237-0061 JAPAN (hwatanabe@jamstec.go.jp)

Despite three decades of research on deep-sea hydrothermal vents, larval dispersal and population connectivity between these discrete and extreme habitats remain poorly understood. Connectivity, which occurs on time scales of one to several generations, is what ultimately drives the biogeography of the species endemic to hydrothermal vents. Understanding connectivity between vents requires expertise from multiple disciplines, including biology, physical oceanography and the geo-sciences. The **Mariana Vent Larvae (MarVeL) Workshop: International Study of Connectivity Between Hydrothermal Vents** was held 10-11 May 2012 in Okinawa, Japan, at the Okinawa Institute of Science and Technology (OIST) (<http://marvelworkshop.who.edu>). The workshop was convened by Stace Beaulieu (WHOI), Satoshi Mitarai (OIST) and Hiromi Watanabe (JAMSTEC) and funded by the U.S. National Science Foundation (NSF Grant #1157556) and OIST. Two main objectives of the workshop were to: 1) Share state-of-the-art methods and data for studies of larval dispersal and population connectivity of deep-sea vent fauna in regions currently

being investigated by U.S., Japanese and other PIs, and 2) Develop a coordinated research plan to study connectivity between hydrothermal vents in the western Pacific, specifically considering the Mariana arc and back-arc.

Workshop participants were recruited by the conveners, with the aim to balance disciplinary interests and nationalities, and special consideration was given to early career researchers including postdocs and students. The workshop had a total of 35 participants (18 Japan, 14 U.S., 2 Canada, 1 France) and an additional 5 participants via EVO web conferencing (2 U.S., 1 Japan, 1 France, 1 Korea). This total of 40 participants included 13 postdocs and students who received training and guidance for effective collaboration with researchers from diverse backgrounds (Fig.1). One of the postdocs, S. Arellano, said, "It was really valuable to meet the many other researchers from around the U.S., France, Canada and Japan. The small workshop setting gave me a chance to talk to many researchers in a way that I wouldn't be able to if we

were at a larger conference” (Fig.2). This was especially true for non-native English speaking students to be involved in international activity. In addition, the opening introduction to OIST by R. Baughman, Provost, showed that our workshop played a role in building marine science capacity in Okinawa.

The workshop consisted of 8 sessions, with each geared towards linking disciplinary components of Earth systems (e.g. lithosphere-biosphere linkage). Goals for Day 1 included introductions, reviewing previous interdisciplinary studies of larval dispersal between hydrothermal vents, and starting to develop research questions to be addressed in the Mariana region. Goals for Day 2 included continuing review of previous studies, specifying research questions to be addressed in the Mariana region, considering Mariana vents in the context of a network of marine protected areas and planning fieldwork. To fulfil the objective of sharing state-of-the-art research, most sessions included two “keynote” presentations and brief “spotlight” talks with a balance of U.S. and Japanese speakers. Chart paper with a general question was posted at the end of each session for participants to respond to during the breaks. Many of the participants also displayed posters. Additional sharing

occurred during informal exchanges including excursions to Okinawa Churaumi Aquarium and Manzamo Cliff.

In the final session we discussed multiple funding opportunities within the U.S. (NSF, NOAA, private), Japan, France and Canada, and compiled a list of planned, proposed and potential cruise opportunities in the Mariana region. We discussed potential multi-disciplinary studies of connectivity between Mariana vents to include benthic and larval biology, geology and geochemistry, and oceanography. Much of this discussion involved differences among seamounts on the arc and vent sites along the back-arc. Discussion also included the larger spatial scale context of connectivity with Okinawa Trough and Izu-Bonin Arc vents. Our discussions generated momentum towards plans for research proposals that would involve international collaborations. Since the workshop, participants have submitted two Japanese cruise proposals that include larval collections near Mariana vents in 2013 and pre-proposals to the NSF Frontiers in Earth Systems Dynamics program and Schmidt Ocean Institute targeting shiptime in 2014/2015.

As a member of the InterRidge arc/back-arc Working Group, Watanabe will continue to engage other international colleagues in important discussions on connectivity between vents in these tectonic settings. The relationships between geological features of arc-backarc sequence and connectivity will provide useful knowledge to understand larval dispersal in the western Pacific vent fields. Additional outreach activities for the workshop included a news article at OIST (21 May 2012, “MarVeL Workshop Takes Aim at Cross-Ocean Connections,” <http://www.oist.jp/news-center/news>) and an interview by NHK (Japanese public television).



Figure 1: Group photo (co-conveners at centre, lower)



Figure 2: Co-convenor Hiromi Watanabe chats with Frederic Sinniger (specialist in high-throughput sequencing) and Eric Breuer (Science Coordinator for the Marianas Trench Marine National Monument).

Geodynamic processes and biochemical interactions at seafloor spreading ridges: A Symposium in tribute to Jean Francheteau and Summer School

GEOCEAN Symposium and Summer School, Brest, France, 27-31 August 2012

Convenors: Jean-Yves Royer (IUEM), Olivier Rouxel (Ifremer)

Report by: Stefan Lalonde (IUEM), Elisabeth Muller (Oxford Univ.), Bleuenn Gueguen (IUEM and Ifremer)



Participants at the GEOCEAN Symposium and Summer School.

In August 2012, an international cohort of over 100 young and established scientists assembled at the European Institute for Marine Studies (IUEM) and Ifremer in Brest. Drawing them together on the Brittany coast was a symposium in tribute to Jean Francheteau and a summer school focused on “Geodynamic processes and biochemical interactions at seafloor spreading ridges”, the first of several such meetings enabled by the recently successful Labex MER initiative, a 10 year “cluster of excellence” program that assembles top-ranked laboratories in the field of marine sciences in western France and ensures their future excellence in research and collaboration. The meeting was further made possible by additional support from the University of Brest, CNRS, Ifremer, the Region of Brittany, the General Council of Finistère and the Urban Community of Brest. Attendees represented a wide swath of scientific interests, including the kinematic and thermo-mechanical evolution of plates, geodynamic processes at seafloor spreading centers, the geochemistry of hydrothermal fluids and fluid-rock interaction, microbial biogeochemistry and ecosystems in extreme environments. An equally wide cross-section of career stages were represented, including senior and emeritus scientists intimately involved in the initial development of plate tectonic theory, mid- and early-career researchers leading the charge today, and young graduate students eager to make their mark. Uniting this diverse

group is the legacy their respective fields share in the study of seafloor spreading centers and the development of plate tectonic theory. No single individual represents this legacy better than Jean Francheteau, Professor at the University of Brest who passed away in July 2010 and to whom the symposium was dedicated.

The Symposium was organised in two day-long sessions on plate tectonics and processes at seafloor spreading centers, two fields in which Jean Francheteau made inspiring breakthroughs and discoveries. The welcome address by Jean-Yves Royer, Pascal Gente (Vice-President for research at the University of Brest) and Jean-François Stephan (Head of the Earth and Space Science Institute at CNRS) was complemented by a testimonial by Sarah Francheteau-Berman, Jean’s daughter, on how his family viewed and lived his scientific activities. Xavier Le Pichon and W. Jason Morgan recalled Francheteau’s contribution to finite plate reconstructions. Robert Ballard, Richard Hey, Claude Rangin and Thierry Juteau brought lively memories of Francheteau’s involvement in the frontier exploration of the mid-oceanic ridge system, from the FAMOUS expedition on the Mid-Atlantic Ridge to the exploration of the East Pacific Rise with submersibles that led to the discovery of hydrothermal smokers and deep-sea ecosystems. Pierre Choukroune, Claude Jaupart, Richard Gordon, Michel Diament,

Emile Okal, Louis Géli and Yossi Mart presented syntheses on various topics illustrating the breadth of Francheteau's scientific interests in the origin of plate tectonics, heat-flux on the continents, current plate motion, intraplate volcanism, oceanic earthquakes and back-arc basins. The second day was devoted to seafloor spreading processes, including the ophiolite record of the generation and evolution of oceanic crust, volcanologic, geophysical and geochemical high-resolution observations from active ridges and deep-sea drilling efforts (Thierry Juteau, Mathilde Cannat, Alessio Sanfilippo, Michael Perfit, Catherine Mével, Anne Deschamps), as well as the dynamics of fast-spreading ridges and overlapping spreading centers (Jason Phipps-Morgan, Lars Ruepke, Richard Hey). A poster session concluded the symposium and covered various topics in line with the oral sessions: geophysical modelling of Earth's dynamics and transform faults, studies of hydrothermal sites in various environments, petro-geochemical investigations of deep-sea materials, and microbial ecology and interactions at hydrothermal sites and in deep cores. The symposium was very successful in bringing together several generations of scientists from the early days of mid-oceanic ridge exploration to the most up-to-date and state-of-the-art studies of seafloor spreading processes. In this respect, Jean Francheteau continued to play his role as a catalyst for gathering scientists from different fields. Session breaks and dinner at the Oceanopolis aquarium provided many opportunities for cross-field stimulating discussions.

After the two-day symposium, nearly 40 participants remained for the three-day summer school that followed. The summer school was divided into three themed sessions, one per day, where invited experts presented each theme through a combination of classroom lectures and interactive training sessions. On the first day and following a welcome and introduction by organizers Olivier Rouxel and Jean-Yves Royer, Debbie Milton provided an introduction and overview of InterRidge. Michael Perfit, Benoit Ildefonse and Wolfgang Bach then followed with lectures covering geodynamics and petro-geochemical processes at seafloor spreading ridges and flanks, complemented by hands-on exercises in geodynamic modelling (Anne Deschamps), core logging techniques (Louise Anderson) and petrological description (Wolfgang Bach, Benoit Ildefonse and Gilles Chazot). The second day, focusing on fluid-rock interactions and geochemistry of seafloor hydrothermal systems, featured presentations by Yves Fouquet, Margaret Tivey, Brian Glazer and Brandy Toner. Brian Glazer and Brandy Toner led training sessions on in-situ electrochemical analysis and the treatment of x-ray spectroscopic data, respectively, while Yves Fouquet, Olivier Rouxel and Jean-Alix Barrat directed sessions on seafloor mineral deposits and isotope geochemistry. The morning of the third and last day explored geobiological interactions in extreme environments through lectures by Stefan Lalonde, Olivier Rouxel, Anne Godfroy and Pierre-Marie Sarradin. The afternoon of the last day included a presentation on European funding opportunities for students and postdocs by Lucie Roa, but was largely set aside for what proved to be a lively round table discussion of the big picture scientific questions in each theme, along with the future research directions and methodological advances required to inform them.

Opinions and interests were as broad as the group of researchers represented, yet several key themes and ideas emerged as separate focus groups shared the results of their individual discussions in front of the entire summer school. The geodynamic and petro-geochemical discussion group highlighted current shortcomings in the integration of studies spanning disparate spatial and temporal scales. It was suggested that future investigations should better emphasize the consideration of both mineralogical data probing cm- to mm-scales and remote sensing data that can provide meter- to kilometer-scale geological context. The fluid-rock interaction and seafloor hydrothermal geochemistry discussion group pointed out a distinct lack of quantitative constraints on seafloor hydrogeology; further investigation of substrate permeability, reaction rates and fluid flows were identified as essential. Finally, the geobiology in extreme environments discussion group emphasized three main points: (1) that our current understanding of the deep biosphere is no longer limited by available methodology, but rather by a limited survey of potentially-important habitats; (2) symbiosis is hugely important at all scales in chemosynthetic ecosystems, however its investigation is hampered by current sampling technology, particularly with regards to maintaining in-situ temperatures and pressures during sampling, and (3) that linking organisms and their environment at the seafloor is essential and benefits greatly from in-situ measurement and a follow-the-energy approach.

Whether relating to the oceanic lithosphere, hydrothermal fluids or microbial ecology, several key themes proved universal among the diverse discussion group themes. First, the importance of in-situ measurement and observation was emphasized across disciplines. Framing observations and analyses in their geological, geochemical or biological in-situ context is a costly yet essential aspect of seafloor research that each of the focus groups emphasized independently. Related to context was the idea and importance of heterogeneity, and the difficulties inherent in defining it across disciplines. Also emphasized was the need for comprehensive and well-defined avenues of data sharing; the cost and effort involved in research at the seafloor warrants an open and lively exchange of data and samples. Lastly, it was recognized across disciplines that field work and the analysis of natural samples benefit significantly from complementary experiment or modeling efforts on land, and that tight coordination between such efforts represents an important but perhaps under-utilized avenue for facilitating discovery.

It is clear from the exit survey that the 2012 GEOCEAN symposium and summer school was a great success in the eyes of the participants. The organizers wish to thank the Labex MER program and external sponsors for their generous support, and Corinne Floc'h-Lazet, Dominique Gac and Aurélie François in particular for their personal assistance. Finally, a warm thank you is extended to the participants, who made for a symposium and summer school that we are certain would have made Jean Francheteau proud.

More information on these events can be found at <http://www.labexmer.eu/thematic-school>

Ridges and Hotspots around the Mascarene Islands

Bel Ombre, Mauritius, 3-7 Sept 2012

The Mascarene Islands and the neighbouring oceanic floor have been the goal of many scientific expeditions aimed at exploring the nearby mid-ocean ridges, the formation and erosion of the islands, and the ridge-hotspot interaction. The Rodrigues triple junction, located 900 km southeast of Rodrigues Island, is the place where the three contrasted Indian ridges meet and has been the focus of American, French, British, German and Japanese efforts. The geophysical, petrologic and hydrothermal peculiarities of the ultra slow-spreading Southwest Indian Ridge have attracted the attention of French, Japanese, and British scientists, and more recently American and Chinese scientists. The intermediate-spreading Southeast Indian Ridge has been the target of systematic geophysical and geochemical exploration led by American and French scientists, with specific attention given to the St Paul-Amsterdam plateau and its formation in relation to another hotspot. The slow-spreading Central Indian Ridge near Rodrigues Island has been the focus of ridge-hotspot interaction studies led by French, British, Japanese and American teams, whereas Russian and Indian, and more recently Korean teams have investigated the northern part of this ridge. The Rodrigues Ridge has been surveyed and sampled by British scientists, its eastern end by French, Japanese and American teams. La Réunion and its surrounding seafloor have been studied in some detail by five recent French scientific cruises.



Figure 1: Babu Mourya (left) and Sujith P.P., early-career scientists sponsored by InterRidge.

With regards to the considerable amount of data and knowledge generated by expeditions during the last 15 years, it therefore seemed timely to hold an international scientific meeting aiming to present results, exchange information and ideas, build collaborations and prepare new projects. Such goals fit well the objectives and the very essence of InterRidge.

Around 40 people from 11 countries met at Bel Ombre, on Mauritius's south coast for a 4-day conference. Sessions focused on the evolution of the islands and the delimitation of their EEZ, plate tectonics and hotspots, ridge-hotspot interactions, the Indian Ocean mantle, the Central Indian and Carlsberg ridges and their hydrothermalism. At the end there was discussion about future collaborations and new possibilities for research. A final day was spent visiting important geologic sites on the island and assessing the evidence for whether the western flank of Mauritius had suffered a catastrophic collapse in the past.

InterRidge sponsored two Indian scientists, enabling Babu Mourya and Sujith P.P. to attend (Fig. 1), and both presented posters on the mobilization of manganese along the Carlsberg Ridge. Mourya stated: "Attending the InterRidge conference was a great opportunity for me where I learned many new topics that are important for my research". We also thank the other co-organisers, CNRS-INSU and the Mauritius Institute of Oceanography for their support (Fig. 2).

The meeting was also dedicated to the memory of Kensaku Tamaki, a former InterRidge Chair, who led several cruises in the Western Indian Ocean in the last two decades and who made formative collaborations with the Mauritius Oceanographic Institute.



Figure 2: Sponsors at the opening ceremony of the conference.

Publications

Life at Extremes: Environments, Organisms and Strategies for Survival

Ed: Elanor Bell

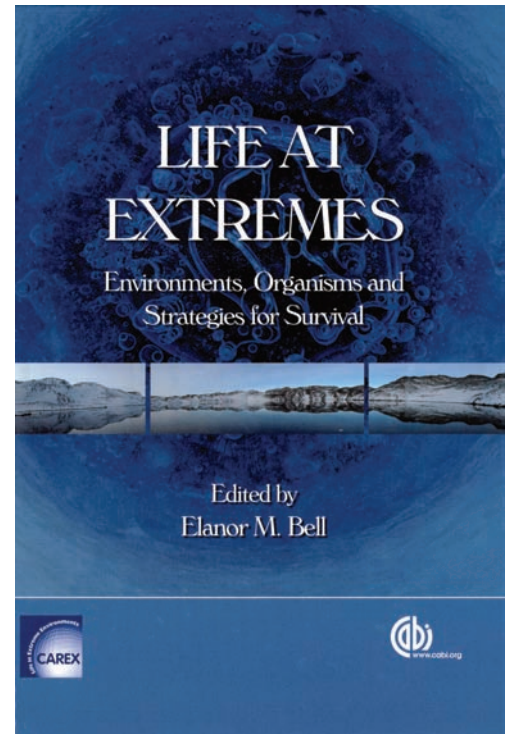
From arid deserts to icy poles, outer space to the depths of the sea, this exciting new work studies the remarkable life forms that have made these inhospitable environments their home. Covering not only micro-organisms, but also higher plants and animals such as worms, fish and polar plants, this book details the ecological, biological and biogeochemical challenges these organisms face and unifying themes between environments. Equally useful for the expert, student and casual scientific reader, this book also explores the impact of climate change, rapid seasonal changes and pollution on these extraordinary creatures.

Hardcover: 496 pages

Publisher: Cabi Publishing

ISBN-10: 1845938143

ISBN-13: 978-1845938147



Advances in Earthquake Prediction: Research and Risk Mitigation

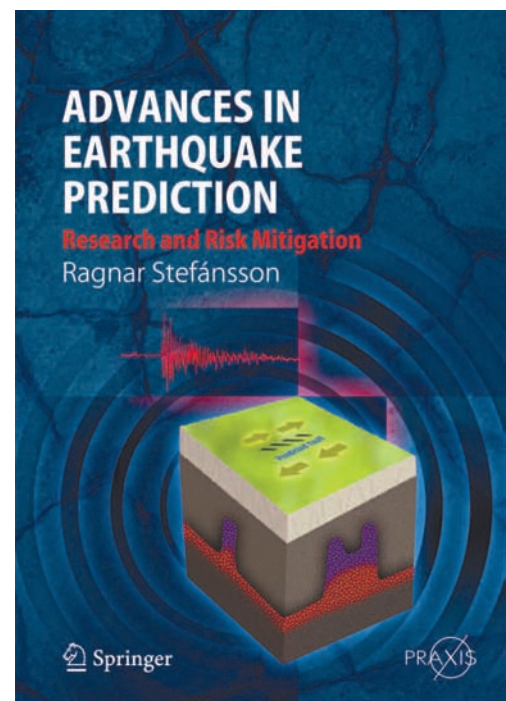
R. Stefansson

This book describes some significant results of earthquake prediction research in the South Iceland Seismic Zone (SISZ). For almost 20 years this earthquake-prone area has been a test site where scientists from a number of European countries have participated in various projects. These research projects adopted a multidisciplinary approach that explored the physics of processes leading up to large earthquakes.

Hardcover: 300 pages

Publisher: Springer

ISBN 978-3-540-47569-9



Upcoming Events



Dec. 01, 2012 Endeavour Hydrothermal Systems, San Francisco, USA

Dec. 02, 2012 CORK Connections@IODP 1027, San Francisco, USA



Dec. 03-07, 2012 13th International Deep-Sea Biology Symposium, Wellington, New Zealand



Dec. 03-07, 2012 AGU Fall Meeting, San Francisco, USA with two InterRidge-sponsored sessions:
Fast Moving Research at Slow Spreading Ridges
Deep Seafloor Biosphere

Jan. 28-31, 2013 IMBER IMBIZIO III, Goa, India

May 15-17, 2013 The Scotia Arc, Granada, Spain



Aug. 18-23, 2013 5th International Symposium on Chemosynthesis-Based Ecosystems, Victoria, BC, Canada

Also in 2013:



Aug. 16-17, 2013 InterRidge Steering Committee, Victoria, BC, Canada
TBD Hydrothermal Energy and Ocean Carbon Cycles, SCOR/IR WG, European venue

Visit the InterRidge website for Upcoming Event listings:

<http://www.interridge.org/events>

| Country | Dates | PI | Ship | Cruise ID/Location | Research Objectives |
|-----------|----------------|----------------|-----------------------|-------------------------------|---|
| Australia | Nov-Dec 2012 | B. Cohen | R/V Southern Surveyor | Tasmanid Seamounts | Volvanic, tectonic and carbonate record |
| Canada | April-May 2013 | | | Endeavour | Wiring the Abyss maintenance cruise |
| France | Jan 2013 | M. Maia | R/V L'Atalante | COLMEIA | |
| France | 2013 | | | BIOBAZ CENTRALE | |
| France | 2013 | | | OCEANOGRAPFLUX | |
| France | 2013 | | | ODEMAR | |
| France | 2013 | | | MOMAR 2013 | |
| France | 2013 | | | HYDROBSMOMAR | |
| France | 2013 | | | SISMOSMOOTH | |
| Germany | Nov-2012 | | R/V Poseidon 442 | Red Sea | |
| Germany | Mar 2013 | G. Bohrmann | | Sandwich Plate | |
| Germany | Nov 2013 | V. Schlindwein | | Indian sector, Southern Ocean | Geophysics, physical oceanography, HAFOS, SWEAP. |
| Germany | Early 2014 | | R/V Merian | MAR North Pond | Hydrological, microbiological and geochemical observatory studies of a young ridge flank. |
| Germany | June 2014 | A. Boetius | | AURORA, 83N Gakkel Ridge | Will use a new hybrid ROV/AUV system developed by WHOI for under-ice diving in collaboration with C. German (WHOI). |
| Japan | Jan-Mar 2013 | | R/V Yokosuka | Indian Triple Junction | Twenty dives of Shinkai 6500 are planned to clarify the characteristics of geology, geochemistry and ecosystem around the hydrogen-rich Kaiei hydrothermal site and two newly discovered hydrothermal sites in the Central Indian Ridge Segment 15/16 (Nakamura et al., 2012, PLoS ONE). We also plan to conduct crust and upper mantle imaging around the triple junction by OBSs and OBEMs. |

| | | | | | |
|-------------|-------------------|-----------------------|--------------|-------------------------------|--|
| New Zealand | Oct 2012 | R. Wysockanski | R/V Tangaroa | Kermadec Arc and Havre Trough | 1) Acquire multichannel seismic reflection data on Kermadec arc ridges, including a pseudo-3-dimensional experiment on Brothers Volcano; 2) Collect multibeam echo-sounder data – including the entire water column - over seamounts and rifts; 3) Collect rock and biological specimens from Havre Trough rifts. The data will be used to develop models for the formation of the Kermadec arc and rifting of the Havre Trough, and to assess the biota of deep rifts. |
| UK | Dec 2012-Jan 2013 | P. Tyler | JC080 | Southern Ocean | To test hypotheses relating to hydrothermal emissions and associated chemosynthetic faunas on the Mid-Cayman Rise. This is the deepest known seafloor spreading centre and is located in a poorly ventilated and geographically isolated deep ocean basin. It specifically targets a region identified as a priority for investigation by the International Census of Marine Life to advance the understanding of global vent biogeography. In addition, its unique samples will provide resources for the wider marine biotechnology and microbial metagenomics research communities. |
| UK | Feb 2013 | J. Copley | JC082 | Cayman Rise | To investigate the effects of hydrothermal circulation on both the geophysics and oceanography in the Panama Basin. |
| UK | Early 2014 | R. Hobbs | | Costa Rica Ridge | |
| USA | May 2013 | C. German | R/V Atlantis | Bermuda to St Petersburg FL | |
| USA | 2013 | C. German; J. Moffett | | South EPR | Investigating biogeochemical cycling in the South EPR hydrothermal plume (as well as Peru upwelling). |
| USA | 2013 | C. German | R/V Falkor | Mid Cayman Rise | |
| USA | 1 Jan 2013 | D. Wiens | R/V Oceanus | Mariana Trough | Mantle serpentinisation and water cycling through the Mariana Trench and forearc. |
| USA | Jun-Sep 2013 | D. Toomey | R/V Oceanus | Cascadia Initiative | Support for the Cascadia Initiative Expedition Team |

Updated Oct. 2012

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The InterRidge Office is moving!

From January 1st 2013, it will be based at Peking University, Beijing, China



John Chen (Chair) and



Jiabiao Li (Co-Chair) will be leading InterRidge over the next three years and the InterRidge community wishes them every success.

Principal Members

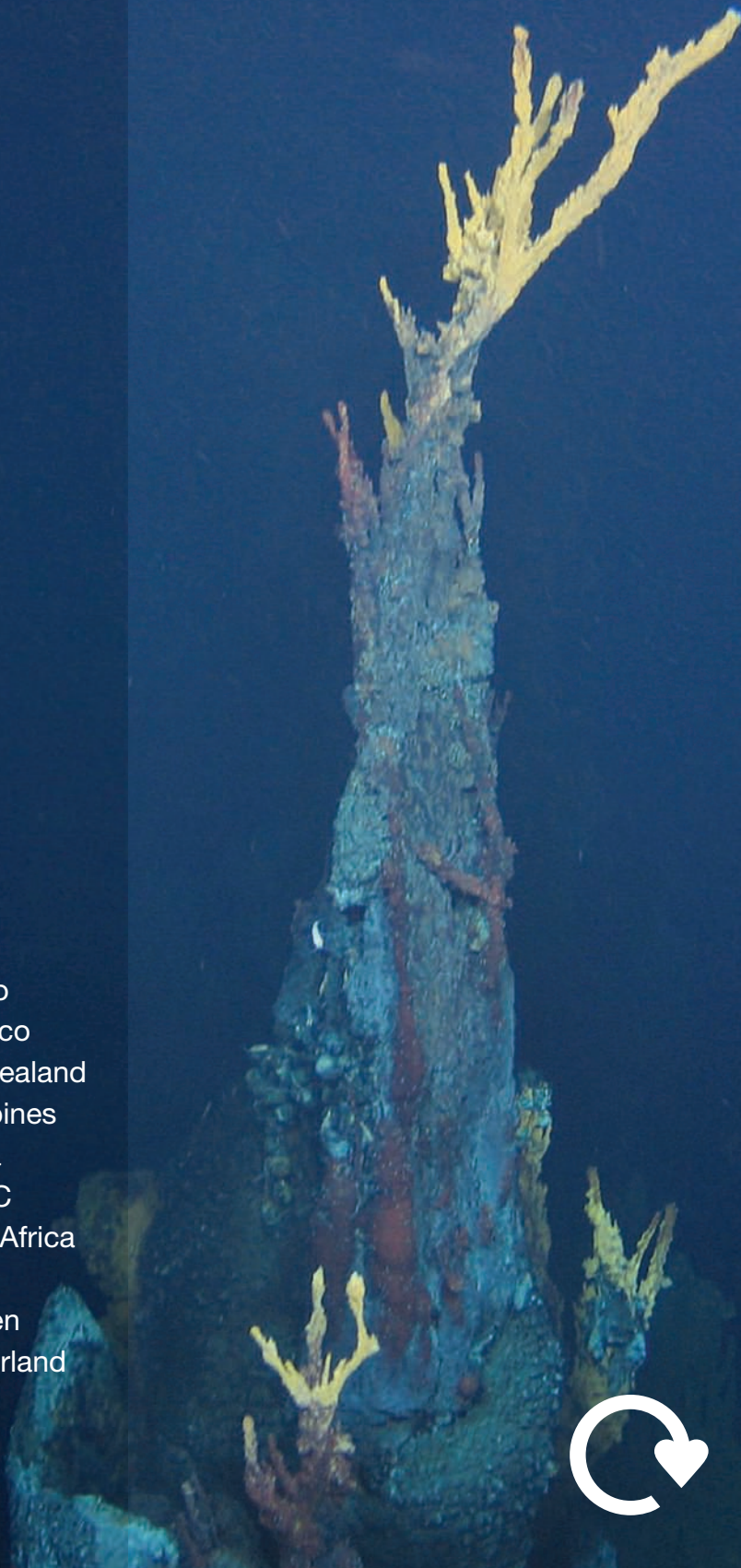
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Cover: Biota at 'Marsh Towers', E9 vent field, East Scotia Ridge, depth ~2600 m; image taken by *Isis* ROV during RRS *James Cook* Voyage 42, January 2010. Acknowl: NERC ChEsSo Consortium.

Back Cover: 'Jabberwocky' chimney, '49.65 deg E' vent field, SW Indian Ridge, depth ~2800 m; image taken by *Kiel6000* ROV during RRS *James Cook* Voyage 67, November 2011. Acknowl: University of Southampton.