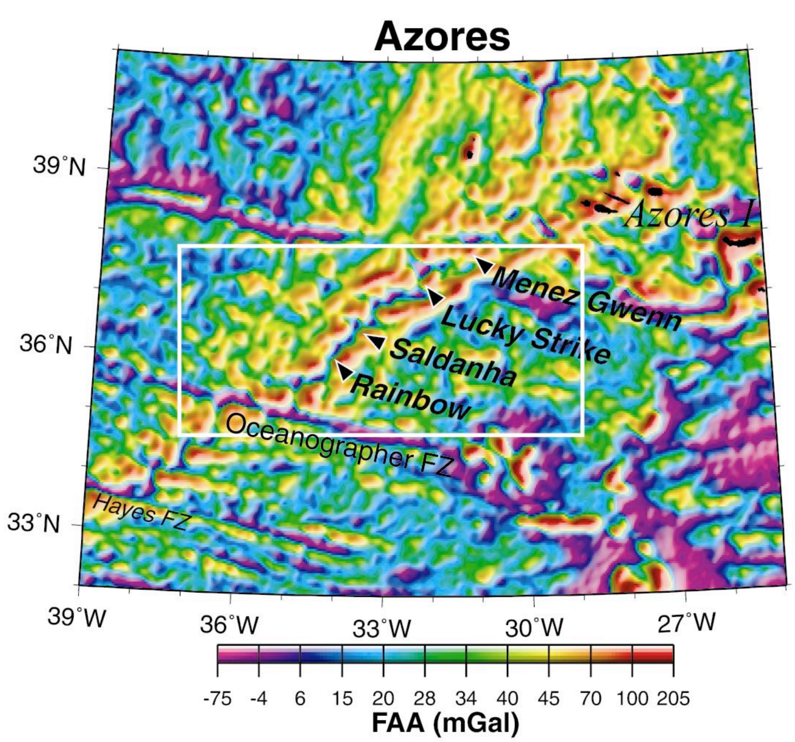
Long-Term Monitoring of the Mid-Atlantic Ridge

Proceedings of the III MOMAR Workshop

7-9 April 2005
Lisbon, Portugal

Convenors

Fernando Barriga	**Universidade de Lisboa, Portugal**
Ana Colaço	**University of the Azores, Portugal**
Javier Escartin	**CNRS, Paris, France**
Emilie Hooft	**University of Oregon, USA**
Susan Humphris	**Woods Hole Oceanographic Institution, USA**
Nadine Le Bris	**IFREMER, France**
Celia Lee	**Universidade de Lisboa, Portugal**
Nuno Lourenço	**University of Algarve, Portugal**
Frank Wenzhofer	**Max Planck Institute for Marine Microbiology, Germany**



INTRODUCTION

The third in a series of workshops to define the objectives of the **Mo**nitoring the **M**id-**A**tlantic **R**idge (MOMAR) project was convened at the Museu de Ciêcia in Lisbon, Portugal, on 7-9 April 2005 with approximately 80 scientists from 12 countries participating. MOMAR brings together researchers from the international scientific community to plan a long-term monitoring program on the Mid-Atlantic Ridge in a region south of the Azores. With an emphasis on real-time data retrieval, MOMAR plans to combine long-term monitoring of geological, physico-chemical, and biological activity at hydrothermal vents with broader-scale monitoring of tectonic, volcanic and hydrothermal processes at the ridge axis. These studies will lead to a comprehensive, interdisciplinary understanding of temporal changes in, and linkages among magmatic, tectonic, seismic, hydrothermal, and biological activity at this slow-spreading plate boundary, enabling the development of quantitative, whole-system models of the inter-linked array of mid-ocean ridge processes.

The I MOMAR workshop (Lisbon, 1998) established the scientific basis for long-term observations and monitoring. The key questions identified at that meeting were:

- How does the slow-spreading MOR environment - seismicity, volcanism, hydrothermalism, and the distribution and characteristics of biological populations - change with time?
- How do these changes affect heat and mass transfer to, and the biological productivity of, the overlying ocean?
- What are the components and space/time extent of the subseafloor biosphere?

The MOMAR area (36-39°N) was chosen as the preferred site for concentrated, long-term, multidisciplinary studies, with the Lucky Strike segment and vent field selected as the favored target for small-scale studies of hydrothermal and biological processes.

The II MOMAR workshop (Horta, Azores, 2002) had a more technical emphasis with the goals of the meeting to establish technical goals and experimental plans, to better define the geographical scope and targets, to establish criteria for data and site management, and to decide upon the follow-up activities. In addition, it provided the opportunity to update the participants on the cruises and projects that had been carried out since the 1998 meeting, and plan and coordinate additional projects. This effort resulted in two EU-funded projects: the MOMARNET Research and Training Network, and the EXOCET/D technology development program, encompassing a broad scientific community interested in MoMAR-related science. On-going efforts at the EU level are in place to establish a network of cabled seafloor observatories that will include the MOMAR area (ESONET project).

Additional impetus has also developed at the level of some national programs. In particular, the French funding agency (CNRS) has identified observatory science at MOMAR as one of its main goals. A MOMAR France Committee has been in place since late 2004, and fieldwork programs in the MOMAR area are financed from summer

2005 through summer 2007. Portugal is also making strong efforts for research in this area, and an ROV capable of reaching the Lucky Strike vent field is under construction and will be located in the Azores.

In March 2004, the US Ridge 20000 Program provided an additional impetus for US involvement through its Mid-Atlantic Ridge Workshop held in Providence, RI. At that meeting, the US community reached a consensus on a single region for focused studies, extending from the Oceanographer Fracture Zone (at 35°N) to the Lucky Strike hydrothermal vent field to be proposed as a Ridge 2000 Integrated Study Site. One key criterion for the selection of this site was its inclusion of both a basalt-hosted (Lucky Strike) and a peridotite-hosted (Rainbow) hydrothermal vent site. The Oceanographer Transform was incorporated because a large offset fracture zone is an important component for experiments designed to understand the relationships between mantle flow patterns and crustal thickness variations in the morphological evolution of this slow-spreading ridge. The enhancement of collaborative research and funding arising from co-location of the Ridge 2000 and MOMAR sites was also considered very beneficial.

As interest in MOMAR science has accelerated at international (EU-funded program) and national levels (France, US, and Portugal), a III MOMAR workshop was deemed necessary to engage a large number of individual scientists in combining efforts and resources to plan and coordinate projects and fieldwork in the MOMAR region. The objectives of the III MOMAR meeting (Lisbon, 2005) were to (i) continue the planning process for long-term monitoring while also taking into account and coordinate the additional goals of the EU programs and a Ridge 2000 Integrated Study Site, (ii) design experiments to conduct both in the short-term (~3 years) and in the long-term when a cable or buoy to provide power and data transmission might be in place (i.e., ORION, ESONET), and (iii) develop implementation plans to move these studies forward.

The first morning of the Workshop was dedicated to a summary of current knowledge of the MOMAR, followed by reports from the funding agencies and national science initiatives. In the afternoon, the overarching scientific questions developed at the I and II MOMAR meetings for each component of MOMAR (segment-scale monitoring, vent-scale monitoring, event detection and response, and regional/comparative studies) were reiterated. The concept of a code of conduct – or responsible research practices – at hydrothermal vent sites was also discussed, partly in response to existing proposals to establish Marine Protected Areas in the MOMAR region.

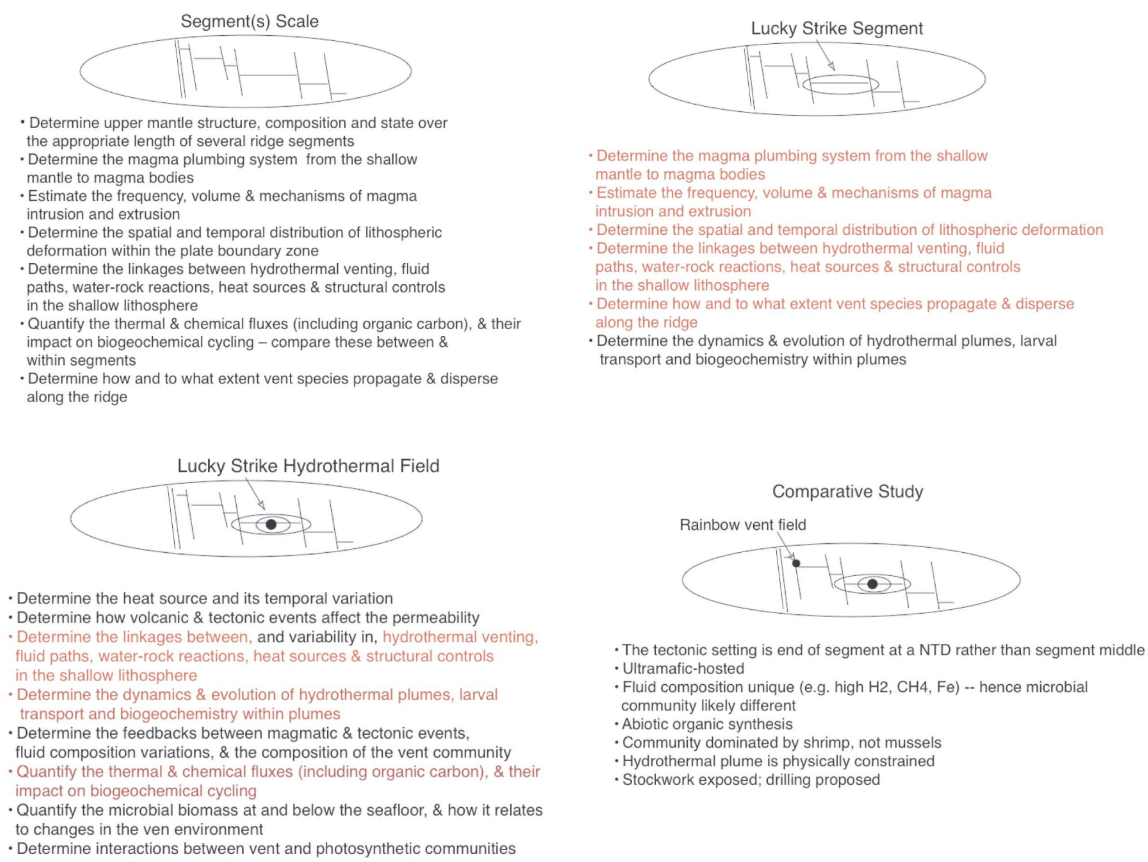
Based on group discussions, three working groups were formed: a Multi-Segment Group, a Lucky Strike Vent Monitoring Group, and a Rainbow Vent Field Group. The charge to all three groups on the first day was to:

- Reaffirm specific scientific questions to be addressed within the temporal/spatial scales under consideration.
- Begin to define the general types of experiments needed.

At the beginning of the second day, the scientific objectives were reorganized into a nested series of three spatial scales for the MOMAR area, similar to the nested bulls-eye model that has been defined for Ridge 2000 Integrated Study Sites:

- the multi-segment scale, extending over several segments and 1-300 kilometers,
- the single-segment scale (a few tens of kilometers), centered on the Lucky Strike field,
- the vent field scale of no more than 1-2 km centered on one or several closely spaced vents.

Whenever possible, studies at the vent field scale should be co-located in the Lucky Strike field, but it is recognized that comparative studies will be required at other sites (mostly co-located at Rainbow). In the figure below, scientific objectives that apply at more than one of these scales are highlighted in red.



For the second day, the composition of the three working groups changed only slightly. The morning sessions considered the experimental approach, with the specific charge to consider the:

- Designs for type experiments
- Timeline of execution (plans for the first 5 years as well as 5-15 year outlook)
- Technology requirements.

The results were presented in the early afternoon before the groups continued their sessions, this time focusing on implementation strategies and, more specifically, on:

- Prioritization of experiments
- Opportunities and strategies for collaborative efforts
- Code of conduct considerations and implementation
- Data management
- Coordination and oversight of field and data management programs
- Next steps.

On Day 3, each working group summarized its deliberations – these are presented in the following reports. Finally there was a general discussion concerning broad issues of organization and communication.

1. **MOMAR Steering Committee**: there was a clear consensus that a committee is needed. This should be a relatively small (6-7 members) international committee under the auspices of InterRidge. Membership will be determined in the next few weeks.

   Tasks of the steering committee might include:
    1. Overseeing science activities in the MPAs.
    2. Facilitating science planning, and stimulating coordinated, interdisciplinary research through, for example, publicizing letters of intent that very generally describe the science that individual researchers are interested in doing in the MOMAR area.
    3. Coordinating science activities: managing site activities with particular focus on avoiding mutual interference among experiments; publicizing locations of navigational benchmarks and long-term deployments; providing information on cruises; publicizing "added-value" requests, such as piggy-back sea time and sample requests. This effort needs to be initiated in 2005 to include cruises planned for next summer.
    4. Coordinating data and samples management: developing standards; encouraging and facilitating development of the capacity to manage large datasets; ensuring that data are widely available through an appropriate GIS (or other) framework.

2. **Communications**: considerable effort needs to be put into communications, not only within the MOMAR community, but also with other observatory efforts in Europe, Canada and the USA, and with the funding agencies. The Steering Committee needs to become involved in the EU initiative on a Network of Excellence as there may be funding available for infrastructure as part of the ESONET (European Seafloor Observatory Network). In the USA, funding opportunities exist through the OOI (Ocean Observatories Initiative).

3. **Planning Workshops:** in order to build a sufficiently large and diverse community of researchers to implement multi-segment studies, especially those designed to determine crustal and mantle structure, a workshop (similar to that used for implementation of the multi-national MELT experiment on the East Pacific Rise) will be required. An IODP -Ridge 2000 workshop on Drilling related to InterRidge

objectives (planned for spring 2006) may provide an opportunity, through an added day for MOMAR discussions, for a timely and cost-effective workshop. This co-location fits well with the role for ocean drilling that is embodied in the Multi-Segment and Rainbow Working Group objectives.

4. **Web Presence:** a MOMAR website (http://www.momar.org) that is linked to the InterRidge website, is currently managed as a community service by Javier Escartin. It contains background data and information that may be useful for preparation of proposals. Additional information should be relayed to the community via a listserver set up for MOMAR-interested scientists, and an alert system should be implemented for new information and events. In addition, a database of MOMAR-interested scientists that includes their disciplines would be helpful as collaborations are sought to implement experiments within the MOMAR region.

WORKING GROUP REPORTS

I. Multi-Segment Working Group

One of the central goals of the ridge science community is to understand the causal links among magmatic, tectonic, hydrothermal, and biological activities at the ridge crest. Some processes, such as mantle flow, extend significantly beyond a single segment; others occur within individual segments but vary significantly between segments. In addition, off-axis studies are critical to understand larger-scale temporal variability of segment-scale processes and to obtain samples of the lower crust and mantle that are only exposed by faulting at and beyond the rift valley walls.

The major scientific goals for multi-segment studies in the MOMAR area are focused around four principal themes:

Theme 1: Understanding regional mantle flow beneath and around the MOMAR region

Theme 2: Understanding the detailed geology, geophysics, hydrology and biogeography of a wide "plate boundary region" (This implies mapping/surveys of parameters including lithology, alteration, sediment, structure, flora/fauna, at scales comparable to those of current AUV surveys)

Theme 3: Assessment and comparative studies of whole-segment crustal structure and its evolution through time (~10 Ma?)

Theme 4: Detection of hydrothermal and volcanic events with selective short-term (rapid) response to determine their nature.

In designing an implementation plan, the Working Group began with the basic assumption that an adequate, uniform background dataset exists for the entire MOMAR region. Key components of such a dataset include, bathymetry, gravity, magnetics, and hydrothermal and biological inventories. To the extent that this assumption is incorrect, remedial surveys should be carried out as soon as possible.

The four principal themes are broken down into seven science objectives, each of which has its own implementation plan. In some cases, specific experiments and surveys address more than one science objective.

1. Determine upper mantle structure, composition, and state over the appropriate scale-length of several ridge segments (Themes 1 and 3)

- What is the pattern of regional upper mantle flow (including beneath the Azores hot spot)?
- What are the effects of fracture zones and non-transform offsets on patterns of mantle flow?
- Is there buoyant upwelling beneath individual segments? If so, how is it distributed?

Methodology and Implementation

(i) Complete additional swath bathymetry + geophysical surveys out to the plume/non-plume transition (Theme 1) – note that some datasets already exist.
(ii) Generate 3D geodynamic models that can be used interactively in the design of seismic and electromagnetic experiments (Theme 1).
(iii) Conduct a wide-aperture (multi-segment), regional mantle imaging (seismic and magnetotelluric) study (this implies deployment for a period $\geq$ 1 year) (Theme 1).
(iv) Sample crustal and upper mantle rocks along off-axis isochrons and flow-lines using dredges and shallow penetration (IODP) drill holes (Theme 1).
(v) Compare crustal and upper mantle structure between segments and over time by conducting seismic refraction/3D seismic reflection and controlled-source electromagnetic experiments) (Theme 3).

2. Determine the magma plumbing system from the shallow mantle to magma bodies (Themes 1, 2 and 3)

- What are the pathways of melt migration?
- How does the magma plumbing system vary along the multiple segments in the MOMAR area?

Methodology and Implementation

(i) Image the sub-lithospheric magma plumbing system at $\leq$ 1 km resolution through seismic refraction/3D seismic reflection, CSEM and compliance experiments (Theme 1).

(ii) Conduct high-resolution, near bottom gravimetry, magnetics, (+ sidescan, bathymetry, sniffer, video, flow cytometry, CTD) using AUVs (Theme 2).

(ii) Determine the distribution of different rock types (e.g. primitive and differentiated gabbros, and dunite versus peridotite) along isochrons and flow-lines (Themes 2 and 3).

3. Estimate the frequency, volume & mechanisms of magma intrusion and extrusion in the axial region (Themes 2 and 4)

Methodology and Implementation

(i) Map, date and drill axial volcanic systems and off-axis dikes to determine timing of magmatic events (Theme 2).

(ii) Monitor seismicity over multiple segments in real-time, over multiple years, to determine frequency of magmatic/tectonic events (Theme 4).

(iii) Conduct repeated detailed bathymetric and 3D seismic surveys to quantify flow volumes and other seafloor morphology changes (Theme 4).

(iv) Prepare for rapid response geodetic measurements (continuous deformation) (Theme 4).

4. Determine the spatial and temporal distribution of lithospheric deformation within the plate boundary zone (Themes 2 and 4)

Methodology and Implementation

(i) Conduct high-resolution bathymetry, sidescan, and potential field (gravity, etc.) mapping (Theme 2).

(ii) Conduct real-time, regional, multi-segment monitoring of seismicity over multiple years to determine the distribution of magmatic/tectonic events (Theme 4).

(iii) Monitor temporal and spatial variations in strain over a complete segment (Theme 4).

(iv) Monitor deformation at the scale of one or more individual vent fields (Theme 4).

5. Determine the linkages between hydrothermal venting, fluid paths, water-rock reactions, heat sources & structural controls in the lithosphere (Themes 2 and 4)

Methodology and Implementation

(i) Sample the lower crust and mantle off-axis using surface sampling and drilling (Theme 2).

(ii) Monitor seismicity over a decadal-scale *with sufficiently high-resolution* (tens of meters scale) to monitor events in progress, to permit relative event relocation, and to determine source mechanisms (Theme 4).

(iii) Determine the distribution of hydrothermal activity within the MOMAR region (Themes 2 and 4).

(iii) Determine hydrothermal fluid temperatures and compositions, measure heat flow, and conduct electromagnetic experiments to determine fluid flow paths for representative vents (Themes 2 and 4).

(iv) Conduct drilling of an extinct hydrothermal system to determine its subsurface anatomy and investigate water-rock reactions (Themes 2 and 4).

(v) Integrate the results of all these surveys and experiments to determine linkages.

6. **Monitor fluid chemistry and vent biology, and their response to tectonic, volcanic and oceanographic forcing functions (Themes 2 and 4)**
   - How do these interactions and responses vary within and between segments?
   - What variations occur within different parts of the hydrothermal system (e.g, recharge zones, shallow, deep, etc.)?
   - How do ecosystems respond to changes in fluid flow regime, temperature, and composition?

Methodology and Implementation

(i) Conduct AUV-borne surveys for multiple parameters, including bathymetry, gravity and magnetics, optical (and thermal?) imaging, thermal/salinity measurements, flow-cytometry, and DNA chip technology.

(ii) Determine distribution and nature of diffuse flow (including geochemistry, physical measurements, microbial sampling and incubation) to an 'appropriate' distance off-axis.

(iii) Map sediment distribution and heat flow to an 'appropriate' distance off-axis, and assess microbial activity using chemical and biological sensors.

(iv) Conduct heat flow measurements on a ~1-10 m scale around active high-temperature and diffuse vents and recharge zones.

(v) Conduct ultra-high-resolution, time-series measurements of active vents (temperature/salinity, fluxes) very near (< 1 m) the seafloor.

7. **Determine the extent and mechanisms by which vent and non-vent species (including sub-seafloor biosphere) propagate & disperse along the ridge (Themes 2 and 4)**
   - What are the current and tidal flow patterns in the MOMAR area?
   - What hydrothermal and biological signals are there in the water masses on a regional scale?

Methodology and Implementation

(i) Conduct a comprehensive inventory of species (supplementing sample collection by appropriate techniques, including AUV-borne imaging for macro-fauna and also subsurface sampling for micro-organisms).

(ii) Lagrangian and Eulerian flow measurement/monitoring.

II. Lucky Strike Vent-Scale Monitoring Working Group

In previous MOMAR meetings, the decision was made that the vent field on the summit of the Lucky Strike Seamount (37°17'N) should be the focus of the vent scale monitoring activities. The major scientific objectives of this experiment are to:

- Determine the variation in time and space of the Lucky Strike hydrothermal system, its subsurface geometry, and its response to external events (i.e., earthquakes or volcanic eruptions).

- Estimate the thermo-chemical budget and its temporal variation for the Lucky Strike hydrothermal site.
- Quantify the microbial biomass at and below the seafloor, and how it relates to changes in the vent environment.
- Determine how vent communities evolve & adapt to the extreme hydrothermal environment.
- Investigate interactions between vent, non-vent benthic, and water column fauna.

Given the interdisciplinary nature of these questions, a useful approach in formulating experiments for a hydrothermal vent site is to consider that the fluid is the linkage between the geology/geophysics and the ecosystem. From a geology/geophysics perspective, the more detailed questions that lead to experiments become:

(i) How do volcanic and tectonic events affect the permeability of the system, and how does this impact the nature of the venting and its biological communities?

(ii) How does the heat source drive the system, and how does it vary in space and time?

(iii) How do water-rock reactions evolve and influence the composition of the hydrothermal fluids?

From the biological perspective, the more detailed questions become:

(i) How does the compositional variability of fluids both in space and time influence the composition of the vent and subsurface community?

(ii) What are the interactions between vent community and the other components of the marine biosphere (e.g. deep-sea, photosynthetic community, etc.)?

(iii) What are the temporal and spatial scales of the biological response to perturbations caused by magmatic and tectonic events?

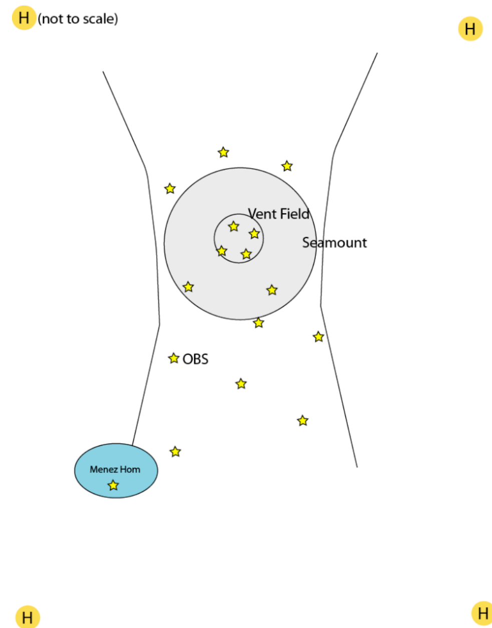
(iv) What are the major mechanisms for larval dispersal and recruitment?

These two sets of questions can then be coupled by obtaining a more complete estimate of the heat budget at a single vent field, as well as a more complete biological survey.

The spatial and temporal scales of observations required to address the overall objectives are highly variable. Spatial scales of significance include those that permit determination of the convection cell geometry (probably segment scale at Lucky Strike), the vent field scale to determine hydrothermal budgets (350 m or less at Lucky Strike), and the individual vent scale to examine geology-chemistry-biology interactions. Temporal scales include assessing the long-term record of magmatic, tectonic, and hydrothermal activity (this requires off-axis observations), monitoring to measure temporal variability of the hydrothermal site (likely 5-10 years), and the ability to respond to short-term perturbations, such as volcanic events, earthquakes, hydrothermal cracking events, etc. (on the timescales of hours to a few weeks). Establishing an observatory at the Lucky Strike vent field will allow long-term monitoring of change, as opposed to summer-only site visits, and near real-time detection of, and rapid response to, short-term perturbation events.

Experimental Approach

The experimental approach to the vent-scale studies at Lucky Strike is divided into two phases: the short-term experiments that can be accomplished without an observatory, and that will form the background scientific basis for a cabled and/or buoy observatory; and the long-term goals when a real-time presence is possible.

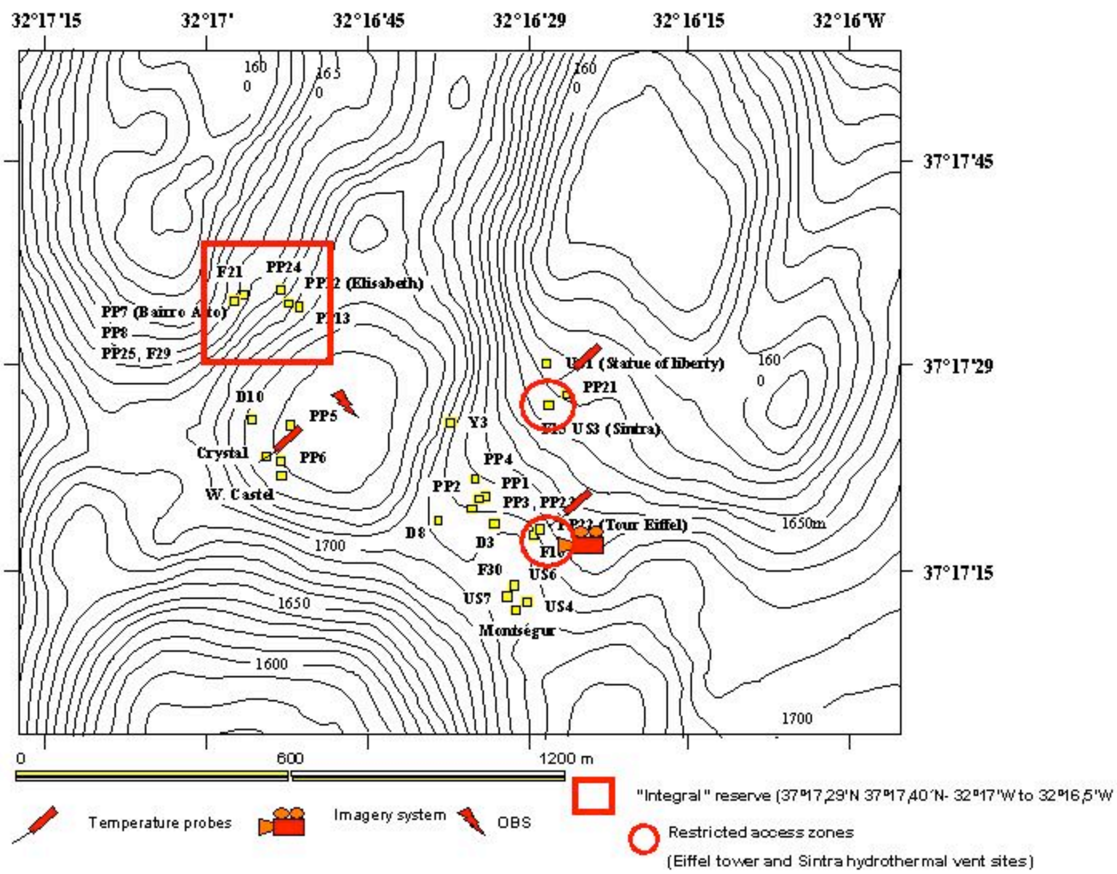


Schematic diagram (not to scale) of the OBS and hydrophone arrays for the Lucky Strike monitoring experiment.

The highest priorities for the first phase are (i) to couple a passive seismic exprtiment with vent temperature monitoring, similar to the one recently conducted at the TAG hydrothermal field and other EPR sites, and (ii) to complete and update the site survey work (i.e. microbathymetry and biological basemaps). The short-term experimental approach for work at Lucky Strike includes:

- Deployment of a nested array of OBS's (stars) from the vent field to the southern end of the segment to (i) monitor seismic activity (and to link with comparative studies at Menez Hom), and (ii) conduct an active seismic experiment to determine the heat source for the vent field (this part of the project is scheduled for completion in summer 2005 by the SISMOMAR project – CNRS/France funded).
- Begin long-term geodetic work: this will be initiated in 2005 and fully implemented in 2006 for monitoring in subsequent years by the GRAVILUCK cruise – CNRS/France funded).
- Hydroacoustic monitoring (H in circle) of the Lucky Strike and neighboring segments to provide some context for interpreting events at Lucky Strike. A network of hydrophones around the MOMAR area will be deployed in summer 2005 (funded by Portugal and France, in cooperation with NOAA) to complement the northern North Atlantic hydrophone array, and substitute for it after its decommission in 2006.
- Deployment of autonomous temperature probes at selected vents (including high and low temperature, focused and diffuse flow) to permit relations between microseismicity and changes in hydrogeology to be detected.
- High resolution imaging (both bathymetry and photography) of the vent field to map geology and distribution of biological communities.
- Time-series measurements of vent fluid chemistry.

- Drill through the hydrothermally cemented breccia to investigate subsurface microbiology – this is currently possible using the BGS drill (if adaptations to prevent pollution of samples are implemented).
- Map the hydrothermal plumes to assess the heat flux.
- Instrument the water column with current meters, sediment traps, etc. to determine the physical oceanographic regime, and the biogenic input from the overlying water column.
- Deploy colonization cages for macro-biology.
- Possible testing of an ASSEM node for energy supply and data transmission.



In the long-term, energy and data transmission in real-time is envisaged using a cable (i.e. ESONET) and/or buoy system (i.e. ORION). With a power source, the ability to respond to events and to do adaptive sampling are gained. Some of the monitoring efforts listed above will transition to the observatory to provide near-real time data. These include:

- Linking the OBS and hydrophone arrays to the real-time network.
- Installation of chemical sensors to monitor vent fluid chemistry in real-time.

In addition, other capabilities to be added include:

- An AUV docked at a node or on a mooring, equipped with chemical and microbiological sensors that can be used in a rapid response mode.
- Continuous real-time video imaging of selected biological communities to determine their interactions and temporal variability.
- The ability to pump large volumes of water that will be valuable for many *in situ* chemical analyzers and for collection of particulate matter.
- Installation of "CORK like" instrumentation in one of the drillholes for measurements of permeability, temperature, microbiology, etc.

However there will also be a number of technical challenges that will need to be addressed for long-term monitoring in a vent environment:

1. *Navigation* – a high-resolution map and benchmarks that are visited during every research program conducted at Lucky Strike will be critical to orderly organization of the research efforts in this relatively small area. In addition, it may be important to deploy one permanent transponder at the site.
2. *AUV programming and navigation* – significant advances in AUV manipulations and navigation are underway that will result in vehicles with different capabilities; e.g. those that conduct underway geophysics versus those that land on the seafloor and conduct an operation (e.g. pump water).
3. *Biofouling or chemical degradation* – keeping instruments clean and operational in the vent environment is a large challenge. However, with power available, it may be possible to develop mechanical devices for defouling (e.g. lens "windshield washers", rotating sensors, blowing valves, etc.).

Collaborative Efforts and Strategy

1. Considerable efforts are already going into other observatory efforts (NEPTUNE, MARS, VENUS, etc.), so there will be some cross-over in terms of technological development and testing. It will be important for MOMAR to collaborate with these other efforts to promote the technical and sensor development that will be necessary in the next few years.
2. An international oversight committee will be needed for MOMAR that should be under the auspices of InterRidge to coordinate operations. It might also be appropriate for this committee to produce a MOMAR Science Plan.
3. An ROV capable of reaching the Lucky Strike vent field is under construction in Portugal and will be stationed in the Azores. This will provide an excellent opportunity for rapid response to Lucky Strike events. However, AUVs are a critical component of the plans for the Lucky Strike observatory because:
   -- an on-site AUV can respond in hours rather than days to an event
   -- an AUV response is cheaper than a ship-based response, which means that responses can be launched to smaller events, without the risk that there may be nothing to detect.
4. Potential sources of funding include:

- The ESF's Network of Excellence does not normally provide funding for research, but can provide support for infrastructure. US institutions are permitted to be part of a Network (at no cost). It will be very important to have a MOMAR "hero" who pushes this program in the European funding agencies. The ESONET proposal will be submitted at the end of 2005, which will include a request of funding for MOMAR observatory infrastructure and instrumentation.
- US funding might be possible through either ORION (the observatory program) or through Ridge2000 (if MOMAR becomes designated as an Integrated Study Site).

5. Data management will be a critical issue – there needs to be the capacity for managing large datasets, and ensuring data is available through a GIS framework.
6. Research efforts will have to be closely coordinated to comply with the MPA regulations. Sintra and Tour Eiffel vents are designated as restricted access zones, and vents in the NW corner of the vent field are part of an integral reserve.

III. Rainbow Vent Field Working Group

The highest priority site for comparative studies in the MOMAR project is the Rainbow vent field (36º13.8'N) at 2270-2320 m water depth because it is distinctly different from Lucky Strike in its geotectonic setting, substrate, fluid and hydrothermal deposit composition, and biological communities. Discovered in 1997, the Rainbow vent field is located at the end of a segment at a non-transform discontinuity. The area of hydrothermal activity is located on the western slope of an ultramafic ridge and covers an area of ~300 m (East-West) by ~100 m (North-South). The western part is tectonized with some diffuse fluid flow, and there is little macrofauna in this region. The central part of the field contains an active fault with tall, highly active black smokers aligned along it. Shrimp are abundant and there are also some mussels. The eastern portion is extremely active hydrothermally but the chimneys are small (< 1 m tall).

The seawater-peridotite reactions at Rainbow result in hydrothermal fluids with distinct characteristics. The fluids are high in hydrogen and methane, but low in hydrogen sulfide. They are also enriched in Fe (more than twenty times the concentration at Lucky Strike) and contain high concentrations of Cd, Zn, Ag, Mn and Co. The fluid composition does not vary spatially, suggesting a common source. Conditions at the site also may result in the abiogenic production of organic compounds, including short-chain hydrocarbons. Microbially, the system is dominated by methanogens and, surprisingly, there appear to be few methanotrophs. The macrofauna are dominated by shrimp – unlike Lucky Strike that is dominated by mussels. The heat source driving the hydrothermal convection is unknown but perhaps may be derived from heat along the deep lithosphere (up to 20 km depth), from magmatic intrusions, or perhaps in part from the heat of serpentinization. Hence, Rainbow provides a sharp contrast in geotectonic setting, substrate, fluid composition and biological communities to Lucky Strike

Experimental Approach

Rather than a continuous monitoring experimental approach at the Rainbow vent field, research will be centered around an east-west transect of four drillholes that have been proposed for IODP, and will include baseline survey work and time-series experiments. This will provide the opportunity for InterRidge and Ridge 2000 to collaborate with IODP. Apart from drilling itself, the research plan includes studies of geophysics, geology, petrology, fluid chemistry, magnetics, and the deep biosphere, and time-series studies that will include downhole instrumentation. Based on the results from these studies, Rainbow should be re-evaluated in 5-7 years as a potential long-term monitoring site.

The plan for research activities at Rainbow involves the following:

- A series of cruises to provide the site survey data for the proposed IODP drilling. These will include high-resolution (1 m) bathymetric mapping of the entire Rainbow Ridge (most likely using an AUV), near-bottom magnetics, sonar, and imaging of the vent field, detailed sampling of basement rocks, hydrothermal fluids and deposits, microbiology, and macrofauna.
- Deployment of OBSs around Rainbow, and temperature probes in both high-temperature and diffuse fluid flow sites for about a year. Active and passive seismic experiments, coupled with the temperature data, would determine the crustal structure, and geologic and tectonic setting of the Rainbow region, the nature of the heat source, and variability in the subseafloor fluid circulation.
- Further characterization of the chemistry of hydrothermal fluids, both spatially and temporally, especially as it relates to the organic compounds and the high concentrations of H_2, CH_4, Fe, etc., found within the fluid.
- Detailed experiments to determine the linkages between the microorganisms, macrofauna, and fluids both on the surfaces of the chimneys and hydrothermal deposits and within the

- Deployment of incubation experiments to measure microbial and macrofauna colonization rates and factors that influence their diversity.
- A long-term heat flux study (that starts pre-drilling and continues post-drilling) using hydrographic moorings and water column profilers.
- IODP drilling of a transect of holes, with full characterization of the petrology and geochemistry of the cores, downhole logging, and a complete microbiological component.
- Deployment of a CORK in one or more bore holes for both short-term and long-term, post-drilling geophysical, geochemical and microbiological experiments.

Timeline of Execution

2005-2007	2008-2009	2010-2011
Pre-drilling cruises*: Site survey and high resolution mapping using near-bottom sonar and imaging, time series observations of fluid, rock, microbiology, macrofauna; electromagnetic and seismic experiments, deploy and recover OBSs and HOBOs; long-term heat flux study using moorings and water column profilers	IODP drilling (Fouquet): Concurrent vent temperature measurements; time series measurements; deploy CORK experiments	Post-drilling cruises: Continue time series sampling and observations, and CORK experiments; deploy and recover OBS and HOBOS

*Should (and partially will) occur regardless of drilling operations.
Equipment necessary to conduct these experiments is largely available off the shelf at this time.

Oversight

An oversight committee for activities at Rainbow, which should fall under the auspices of InterRidge, will be necessary to address the following issues:

- Data and sample management
- Cruise planning as it relates to managing site activities, deployment of instrumentation, possible interference with other experiments/instrumentation, etc.
- Issues arising from the designation of a Rainbow marine protected area, and adherence to a code of conduct

For issues related to the MPA, the oversight committee should also have members representing other conservation and management bodies (e.g., International Seabed Authority, WWF, etc.). Since the Rainbow vent field is a very small site, MPA spatial zonation models for other hydrothermal sites (e.g. Lucky Strike, Endeavour) may not be appropriate. Clearly, there will be a need for some flexibility, and the designation of sample and non-intervention zones may not be compatible within the scientific activities. A conservational approach to the use of the site would guarantee its long-term availability for science, especially for monitoring and comparative studies. Thus, the most appropriate model would be to have the entire site managed by the oversight committee. Detailed requests for samples and site operations would be submitted to that committee for approval prior to any cruise, and an inventory of samples collected would be provided after the

APPENDIX I

International MoMAR Implementation Workshop

Lisbon, Portugal, 7-9 April 2005

<u>Agenda:</u>

Day 1

08:45 Registration
09:30 Welcome
10:00 coffee break
10:15 *Background Summary on the MoMAR Area* (Javier Escartín & Gretchen Früh-Green)
11:15 *European and National Initiatives*
  European Initiatives:
    ESONET (Miguel Miranda)
    EXOCET (Pierre-Marie Sarradin)
  National Initiatives:
    France - MoMAR (Mathilde Cannat)
    Portugal (Fernando Barriga & Ricardo Santos)
    US – R2K (Chuck Fisher)
12:15 lunch
13:30 *Summarize Overarching Science Questions* (Susan Humphris)
14:10 *Introduction to code of conduct* (Colin Devey)
14:30 Discussion to ensure that we all agree.
  Division into Working Groups:
    1. Regional scale problems
    2. Lucky Strike
    3. Rainbow
14:45 Working Groups
  Charge I: Examine how the science questions are best addressed at the temporal and spatial scales appropriate for each group.
15:45 Posters and coffee break
16:00 Discussion in Working Groups of Charge I continues.
17:00 Wrap Up 1st Day
  Summary of Group Discussions and General Discussion.
18:00 End of 1st day
19:00 Ice-breaker and Posters

Day 2

09:00 Introduction
09:10 *EU Funding Agency* (Gilles Ollier)
09:30 Working Groups
  Charge II. Experimental Design
10:15 Posters & coffee break
11:00 Working Groups continue with Charge II
12:30 lunch
14:00 Morning Wrap Up
  Summary of Group Discussions and General Discussion.
14:45 Working Groups

Organizing international collaborations; technology requirements; infrastructure needs; code of conduct.

15:45 Posters & coffee break

16:30 Working Groups continue with charge III.

18:00 End of 2nd day

Evening: A dinner

Day 3

9:30 Wrap Up 2nd Day

Summary of Group Discussions and General Discussion.

10:00 Posters & coffee break

10:45 *Final Discussion*:

1. Summarize: where we are and what we agreed to.
2. Broad issues: organizing international collaborations; maintaining good communication; country specific issues; level of coordination and management needed.

12:30 End of the meeting

APPENDIX II

LIST OF PARTICIPANTS – International MOMAR implementation workshop April 05

Almeida, Ana Catarina
acatt6@hotmail.com
+351 289800 900
University of Algarve
Portugal

Almeida, Armando
aalmeida@fc.ul.pt
FCUL
Lisbon University
Portugal

Alves,Tiago
talves@ncmr.gr
302291076358
Hellenic Centre of Marine Research
Greece

Bach, Wolfgang
wbach@whoi.edu
508 289 2523
Woods Hole Oceanographic Institution
United States

Barriga, Fernando
fbarriga@fc.ul.pt
+351 217500066
University of Lisbon
Portugal

Bebianno, Maria João
mbebian@ualg.pt
+351 289800995
University of Algarve
Portugal

Biscoito, Manuel
manuel.biscoito@cm-funchal.pt
+351 291700360
Museu Municipal do Funchal (Historia Natural)
Portugal

Blackman, Donna
dblackman@ucsd.edu
(858) 534-8813
Scripps Institution of Oceanography
United States

Bohnenstiehl, DelWayne
del@ldeo.columbia.edu
845-365-8382
Lamont-Doherty Earth Observatory of Columbia
United States

buck@ldeo.columbia.edu
845-365-8592
Lamont-Doherty Earth Observatory
United States

Cambon-Bonavita, Marie Anne
macambon@ifremer.fr
+33 298224756
Ifremer
France

Canales, Juan Pablo
jpcanales@whoi.edu
508/289-2893
Woods Hole Oceanographic Institute
United States

Cannat, Mathilde
cannat@ipgp.jussieu.fr
+33 1 44275192
Institut de Physique du Globe de Paris
France

Carlut, Julie
jcarlut@geologie.ens.fr
France

Charlou, Jean Luc
charlou@ifremer.fr
+33 298224262
IFREMER
France

Christie, David
dchristie@coas.oregonstate.edu
5417375205
Oregon State University
United States

Cochran, James R.
jrc@ldeo.columbia.edu
845-359-8396
Lamont-Doherty Earth Observatory
United States

Colaço, Ana
acolaco@notes.horta.uac.pt
+351 292200436
IMAR-DOP-University of the Azores
Portugal

Collins, John
jcollins@whoi.edu
508-289-2733
Woods Hole Oceanographic Institution

Company, Rui
rcompany@ualg.pt
+351 289800900
University of Algarve
Portugal

Cosson, Richard
richard.cosson@univ-nantes.fr
+33 251125669
Université de Nantes-CNRS
France

Costa, Isabel
icosta@fc.ul.pt
+351 212064667
University of Lisbon
Portugal

Cravo, Alexandra
acravo@ualg.pt
+351 289800995
University of Algarve
Portugal

Dando, Paul
oss109@bangor.ac.uk
01248 382904
University of Wales-Bangor
United Kingdom

Desbruyères, Daniel
Daniel.Desbruyeres@ifremer.fr
+33 298224301
IFREMER
France

Devey, Colin
cdevey@ifm-geomar.de
+49 4316002257
InterRidge
Germany

Dias, Agata
ascdias@fc.ul.pt
+351 217500066
University of Lisbon
Portugal

Dick, Henry
hdick@whoi.edu
508-289-2590
Woods Hole Oceanographic Institution
United States

Dixon, David
drd@soc.soton.ac.uk
+44 752633244

Dyment, Jérôme
jdy@ipgp.jussieu.fr
+33 144272821
IPGP
France

Dzhatieva, Zalina
zald@soc.soton.ac.uk
+44 2380596573
Southampton Oceanography Centre
United Kingdom

Dziak, Robert
robert.p.dziak@noaa.gov
541/867-0175
Oregon State University/NOAA
United States

Escartin, Javier
escartin@ipgp.jussieu.fr
+33 144274601
Institut de Physique du Globe
France

Felicia, Helena
hfelicia@ualg.pt
+351 289800900
University of Algarve
Portugal

Fisher, Chuck
cfisher@psu.edu
814/865-3365
Penn State
United States

Fontaine, Fabrice
fontaine@ocean.washington.edu
206 543 8956
University of Washington
United States

Fouquet, Yves
fouquet@ifremer.fr
+33 298224254
IFREMER
France

Freitag, Katja
coordinator@interridge.org
+49 4316002133
InterRidge
Germany

Früh-Green, Gretchen
frueh-green@erdw.ethz.ch
1 632 3794

Garcia, Rafael
rafa@eia.udg.es
+34 972419812
University of Girona
Spain

German, Chris
cge@soc.soton.ac.uk
+44 2380596542
Southampton Oceanography Centre
United Kingdom

Gloter, Alexander
gloter@lps.u-psud.fr
+33 169155371
U. Paris Sud
France

Gomes, Tania
a18390@ualg.pt
+351 289800900
University of Algarve
Portugal

Goslin, Jean
goslin@univ-brest.fr
+33 298498714
CNRS/University of Brest
France

Holden**,** James
jholden@microbio.umass.edu
413-577-1742
University of Massachusetts
United States

Holm, Nils
nils.holm@geo.su.se
+46 8164743
Dep of Geology and Geochemistry
Sweden

Hooft, Emilie
emilie@uoregon.edu
541-346-4762
University of Oregon
United States

Humphris, Susan
shumphris@whoi.edu
508-289-3451
Woods Hole Oceanographic Institution
United States

Kadar, Eniko
enikokadar@notes.horta.uac.pt
+351 292200417

Kim, Bong-Chae
bckim@kordi.re.kr
82-31-400-6117
Korea Ocean Research & Development Institute
Korea

Le Bris, Nadine
nlebris@ifremer.fr
+33 298224085
IFREMER
France

Lourenço, Nuno
nuno.lourenco@fc.ul.pt
+351 217500978
University of Algarve
Portugal

Luis, Joaquim
jluis@ualg.pt
+351 289800995
University of Algarve
Portugal

Marques, Ana Filipa
afamarques@fc.ul.pt
+351 917407607
University of Lisbon
Portugal

Martins, Inês
imartins@notes.horta.uac.pt
+351 292200400
IMAR-DOP-University of the Azores
Portugal

Matias, Luis
lmatias@fc.ul.pt
+351 217500812
University of Lisbon
Portugal

Matsumoto, Haruyoshi
haru.matsumoto@noaa.gov
541-867-0176
Hatfield Marine Science Center
United States

Mestre, Nélia
neliamestre@gmail.com
+351 962913162
Portugal

Miranda, Miguel
jmmiranda@fc.ul.pt
+351 217500809
University of Lisbon

Neumann, Christian
christian.neumann@wwf.de
+49 4216584628
WWF Germany
Germany

Neves, Maria
mcneves@ualg.pt
+351 289800938
University of Algarve
Portugal

Nordstrom, Patricia
pxn105@psu.edu
814-865-7434
Penn State
United States

Ollier, Gilles
European Commission
Belgium

Pascoal, Antonio
antonio@isr.ist.utl.pt
+351-21-8418081
Instituto Superior Tecnico
Portugal

Pinto, Álvaro
Alvaro.pinto@fc.ul.pt
Lisbon University
Portugal

Porson, Roland
France

Queiroz, Gabriela
gq@notes.uac.pt
+351 296650147
Azores University
Portugal

Ramirez-Llodra, Eva
ezr@soc.soton.ac.uk
+44 2380596446
Southampton Oceanography Centre
United Kingdom

Rommevaux-Jestin, Céline
rommevau@ipgp.jussieu.fr
+33 144277723
CNRS/IPGP
France

Sarradin, Pierre Marie
pierre.marie.sarradin@ifremer.fr
+33 298224672

Sarrazin, Jozée
jozee.sarrazin@ifremer.fr
+33 298224329
IFREMER
France

Schultz, Adam
adam@coas.oregonstate.edu
541-737-9832
Oregon State University
United States

Seama, Nobukazu
seama@kobe-u.ac.jp
+81 788035798
Kobe University
Japan

Searle, Roger
r.c.searle@durham.ac.uk
+44 1913342307
University of Durham
United Kingdom

Seher, Tim
tseher@web.de
Germany

Serafim, Angela
aserafim@ualg.pt
+351 289800900
University of Algarve
Portugal

Serrão-Santos, Ricardo
ricardo@notes.horta.uac.pt
+351 292200400
IMAR-DOP-University of the Azores
Portugal

Sievert, Stefan
ssievert@whoi.edu
508-2892305
Woods Hole Oceanographic Institution
United States

Simão, Nuno
University of Lisbon
Portugal

Solomon, Ezeh
parastatal_info_ng@yahoo.com

Thurnherr, Andreas
ant@ldeo.columbia.edu
(845) 365-8816
Lamont-Doherty Earth Observatory
United States

Toomey, Douglas R
drt@newberry.uoregon.edu
541-346-5576
University of Oregon
United States

Wenzhoefer, Frank
fwenzhoe@mpi-bremen.de
+49 4212028836
Max Planck Institute for marine Microbiology
Germany

Yang, Ting
freemanty@yahoo.com
(401)-74-6828
University of Rhode Island
United States

Zbinden, Magali
magali.zbinden@snv.jussieu.fr
+33 144273502
Université Pierre et Marie Curie
France

APPENDIX III

ABSTRACT INDEX & ABSTRACTS
(From meeting Information Package)

Contents

Metal accumulation in the shells of Bathymodiolus azoricus

Almeida, A.[1], A. Cravo[1] & M. J. Bebianno[1]

[1]University of Algarve, CIMA, Faculty of Marine and Environmental Sciences, Campus de Gambelas, 8000-139 Faro, PORTUGAL, acravo@ualg.pt, +351289800900 (telephone), +351289818353 (fax)

The mussels Bathymodiolus azoricus from the hydrothermal fields on the Azores Triple Junction survive in an environment with high metal levels. Shells can be a potential reservoir for metals due to their capacity to remove bioavailable metals from the environment. The aim of the this work was to determine the potential of B. azoricus shells as an indicator for metal bioavailability at Menez Gwen, Lucky Strike and Rainbow hydrothermal vent fields.

With this aim Sr, Mg, Fe, Mn, Zn, Cu, Cd and Ag were determined in the shells of B. azoricus from the three hydrothermal vent fields, Menez Gwen, Lucky Strike and Rainbow. Also in order to evaluate the effect of weight, metal concentrations were analysed individually in shells after an adequate cleaning procedure that includes the removal of the periostracum.

From the studied metals, Sr in particular and Mg were consistently higher, one to two orders of magnitude, than the rest of the metals at the three hydrothermal vents. These metals are considered major elements, associated with the mineralogy of shells, the most important in the substitution of calcium in the shell matrix ($CaCO_3$). From the other metals Fe showed the highest concentrations followed by Mn and Zn while Cu, Cd and Ag in particular were present in much lower concentration, which can reflect the composition in metals of the vent fluids. Only at Lucky Strike hydrothermal field, Mn and Zn concentrations in the shells showed variation with weight; therefore comparisons of this vent field population with other sites were only reliable between similar shell ranges. Comparisons between mussel shells from the three vent fields populations revealed that Mg concentration was highest in Menez Gwen, while Sr and Cu were at Lucky Strike and Fe, Mn and Cd at Rainbow hydrothermal field. Relatively to Zn no significant differences were found between the three populations.

The highest differentiation between populations concerning the metal concentrations in the shells of B. azoricus was found for Mn. The mean concentration of this metal was maximum at Rainbow, five times higher than at Menez Gwen. Relatively to other metals the differences between the three populations were not striking. These data may suggest that the shells of B. azoricus can be only considered a good indicator of Mn, nevertheless the magnitude of the metal concentrations found in mussel shells from hydrothermal vents were not particularly different from those reported in shells of other bivalves either from “clean” coastal areas or metal contaminated areas.

Surveying the Flanks of the Mid-Atlantic Ridge

Alves, Tiago M. [1;2], T. Cunha[3], S. Bouriak[4], A. Volkonskaya[4], J.H. Monteiro[1], M. Ivanov[4] and TTR12-Leg 5 Scientific Party

[1] Departamento de Geologia Marinha, INETI -National Institute for Engineering, Technology and Innovation, Lisbon, Portugal.
[2] Department of Geology and Geophysics, Hellenic Centre of Marine Research, Anavissos, Greece.
[3] Department of Earth Sciences, University of Oxford, United Kingdom.
[4] Geology Faculty, Moscow State University, Russia.

Mid-ocean ridges are relevant to marine research as areas where underwater volcanic and hydrothermal processes are associated with the formation of mineral deposits. Ridge axes are key zones for the investigation of sea-floor spreading processes while adjacent sedimentary basins comprise information on older stages of ocean development. Recognising these facts, and based on the knowledge that scarce information has so far been acquired in the sedimentary basins adjacent to the Azores Islands, Leg 5 of UNESCO's TTR (Training-Through-Research) 12 cruise gathered new seismic reflection, sediment core and OKEAN (9.5 kHz) sidescan sonar data. The acquired information was used to characterise the seismic stratigraphy and structure of the region southeast of the Azores Islands (36^0N), providing constraints on the tectono-sedimentary evolution of deep-ocean basins located on the flanks of slow spreading ridges. TTR12-Leg 5 also allowed the collection of significant biological and sea-floor samples in areas where the Mid-Atlantic Ridge (MAR), adjacent abyssal hills and major seamounts have an important control on oceanographic and seabed processes.

South of the Azores, thick sedimentary sequences (>1.0 s two-way travel time) correlated with units in the Madeira Abyssal Plain (ODP Sites 950-952) overlay an irregular basement generated by a combination of volcanic and tectonic processes. Similarly to the Madeira Abyssal Plain, three main Cenozoic depositional events are recognised and signed by distinct seismic megasequences. The moderate deformation of the sedimentary units and the structural fabric of the underlying oceanic crust shown on seismic and sidescan data suggest the existence of a complex tectonic setting: prominent abyssal hills west of 30^0W change into a segmented oceanic crust denoting an extensional/transtensional tectonic regime east of the latter meridian. Such change may reflect the increasing importance of MAR-related processes (i.e. volcanism, hydrothermalism) in shaping the sea-floor topography towards the MAR and Azores hotspot.

We consider that the significance of the seamount-related volcanism in the depositional history of the study area should be further investigated, particularly due to the similar seismic-stratigraphic character between units in the Madeira Abyssal Plain and those observed on seismic data. In addition, comprehensive seismic, well, geochemical and geophysical information on the study area should help constraining the events that led to the formation of the Azores Plateau and adjacent seamount groups.

Subseafloor Hydrothermal Mineralization and Bioglyph Mineralogy

An, W., Zhimin Cao,& Jianbin Zheng

College of Marine Geosciences, Ocean University of China, Qingdao, 266003

Abstract: Based upon biology, mineralogy, biogeochemistry, element and isotope geochemistry, hydrothermal sulfide samples from 9-10°N of East Pacific Rise (EPR) were studied. Focusing on the evolvement features of bioglyph minerals (mineralized organism) and element and isotope geochemistry, the objective of this study is to reveal the mechanism, organism records and biogeochemical processes of subseafloor hydrothermal mineralization, the role of organisms in hydrothermal mineralization process, and patterns of fluid evolvement and biological activities. Prelimimary studies showed the existence of typical mid-ocean ridge sulfide minerals assemblage, with nearly 85% chalcopyrite, and followed by pyrite, sphalerite, bornite and alphachalcocite, with anhydrite and barite as gangue minerals. Hand specimen showed evident mineral zonation (Fig. 1). Euhedral to subhedral chalcopyrites appearing as disseminated to massive sulfides are mainly distributed in the inner side of the funnel, some chalcopyrites appear as unmixing bands (Fig.2) or emulsion texture with sphalerites. Due to late Cu enrichment metasomatism, there are chalcopyrite-borite-alphachalcocite or chalcopyrite-borite zones. Besides the outcrops as unmixing bands with chalcopyrites, sphalerites also appear as anhedral or euhedral crystals intergrowthing with chalcopyrites and pyrites. Coarse-grained euhedral pyrites are found intergrowthing with the gangue minerals, and most fine-grained rounded pyrites are only left as remnants-borders. Besides, there are also some fungus-shaped (Fig. 3) and biological mineralized (Fig. 4) pyrites. Gangue minerals including gypsums (columnar, nemaline and radiated assemblages) and barites are distributed along the outside belt.

Electron microprobe analysis for chalcopyrites showed that they have relatively high Cu/Fe and S/Fe ratios compared with that from mid-ocean ridges. Contents of trace elements in chalcopyrites, sphalerites and pyrites from different mineralization stages changed evidently.
The deep, subseafloor biosphere around black smokers have a big impact on the hydrothermal ore-forming processes, and a lot of hydrothermal vent biota had been discovered around EPR 9-10°N. Pyrites formed from biological mineralization provided a chance to the further study of the impact of biota on the regional mineralization processes.

Studies showed that temperatures of hydrothermal fluids had three-stage evolution (low-high-low) and mineralization stages could be devided into three stages, accordingly. The first stage is characterized with chalcopyrite-sphalerite-gypsum assemblage, the second stage is a relatively high temperature stage, characterized with sphalerite-chalcopyrite assemblage (exsolution texture indicated a temperature up to 400□), and a last low temperature stage with bornite- alphachalcocite-chalcopyrite assemblage). Locations of black smokers Around EPR 9-10°N are relatively shallow to the axial magma chamber (<1.7km), and this resulted in the unsteady of the hydrothermal temperature and chemical composition, which, in turn, controlled mineral assemblages of the sulfides. In all, the regional volcanic-hydrothermal-structural active system is the main agent of the ore-forming process, and biological activity had taken a part in the mineralization process.

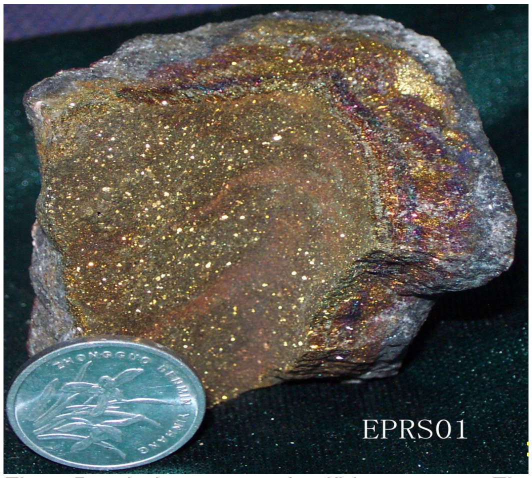


Fig. 1 Banded structure of sulfide ore

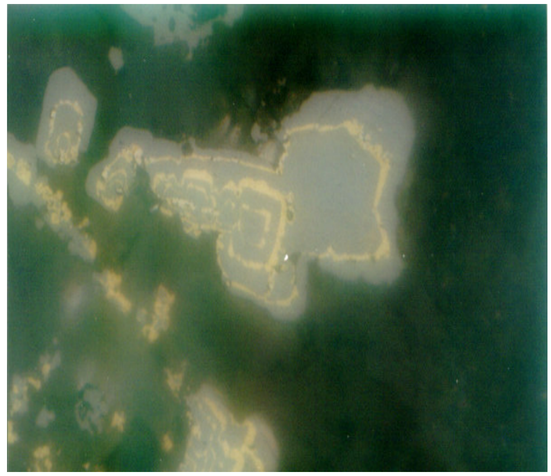


Fig.2 Unmixing Chalcopyrite bands from Sphalerite

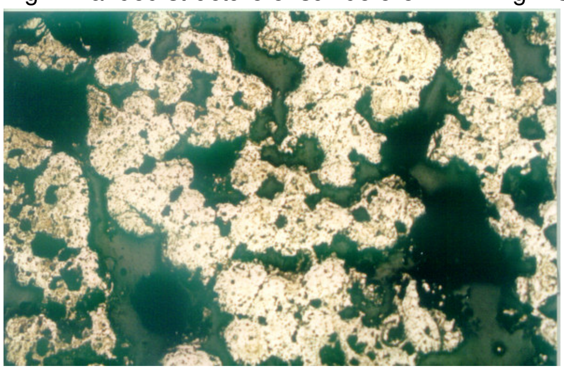


Fig. 3 Fungus-shaped pyrites

Fig. 4 Pyrites formed from biological mineralization

Key words: Organism relict mineralization 1, Hydrothermal mineralization 2, Hydrothermal vent biomass 3, Hydrothermal fluids 4.

Water-rock reactions, magnetite and hydrogen production during serpentinization: results from ODP Site 1274

Bach, Wolfgang[1], Holger Paulick[2], Benoit Ildefonse[3], Susan E. Humphris[1]

[1]Wolfgang Bach, Dept. of Marine Chemistry and Geochemistry, WHOI, MS#8, Woods Hole, MA02543, USA, wbach@whoi.edu, 508-289-2523, 508-457-2183
[2]Holger Paulick, Mineralogisch-Petrographisches Institut, Universität Bonn, Bonn, Germany
[3]Benoit Ildefonse, Laboratoire de Tectonophysique, Université Montpellier II, Montpellier, France
[4]Susan Humphris, Dept. of Geology and Geophyscis, WHOI, Woods Hole, MA02543, USA

Serpentinization at mid-ocean ridges profoundly influences lithospheric rheology, magnetic anomalies, gravity and seismic structure, deep-sea microbial ecosystems, and ocean-lithosphere exchange budgets. Despite a renewed interest in serpentinization of the seafloor, the underlying peridotite-water reactions are very poorly constrained. Here we propose a sequence of serpentinization reactions that reconciles petrographic observations with mass balance and physical properties constraints.

We have investigated the textural and mineral chemical evolution of retrograde serpentinization of harzburgite and dunite drilled during Ocean Drilling Program Leg 209 at Site 1274 on the Mid-Atlantic Ridge 15º39'N. Thin section petrography of variably serpentinized harzburgites and dunites from Hole 1274A reveals a simple sequence of reactions: Serpentinization of olivine and development of a typical mesh texture with serpentine mesh rims followed by replacement of olivine mesh centers by serpentine and brucite. The serpentine mesh rims on relic olivine are devoid of magnetite. Conversely, domains in the rock that are completely serpentinized show abundant magnetite, either in stringers or patches or in late magnetite and chrysotile+magnetite veins.

We propose that the textural, mineral chemical and bulk physical property evolution during serpentinization reflects a sequence of serpentinization reactions that start with low fluid flux (quasi-isochemical) serpentinization of olivine to serpentine and ferroan brucite. Later-stage serpentinization is more open-system and invokes formation of magnetite, primarily by the break-down of ferroan brucite. This reaction step requires transfer of silica, which likely relates to the serpentinization of orthopyroxene. This reaction step also requires a source of acidity and a sink for dissolved Mg, which could both be provided by the reaction of olivine mesh cores to serpen-tine and magnesian brucite. Serpentinization of orthopyroxene is slower than that of olivine and the Fe/Mg ratios are preserved. A simple model that invokes linear rates of olivine serpentiniza-tion and a power-law increase in the magnetite-forming reaction yields an excellent fit of the observed covariation of grain density and magnetite susceptibility. Our results suggest that magnetite formation peaks when >60-70% of the peridotite are serpentinized.

By mass-balancing these reactions, we derive the following net reaction:
$34Mg_{1.8}Fe_{0.2}SiO_4 + 6Mg_{0.9}Fe_{0.1}SiO_3 + 52H_2O =$
$18Mg_{2.85}Fe_{0.15}Si_2O_5(OH)_4 + 2Mg_{2.7}Fe_{0.3}Si_2O_5(OH)_4 + 11Mg_{0.9}Fe_{0.1}(OH)_2 + 1Fe_3O_4 + 1H_2$
Accordingly, 55 kg of harzburgite may produce 1 mole of H_2. At a water-to-rock mass ratio of 1, this corresponds to ~20 mM H_2, similar to H_2(aq) concentrations measured in vent fluids from axial serpentinite-hosted systems.

The reaction pathways proposed here are not representative for all serpentinization systems. In fact, vent fluid compositions suggest that there is a strong variability in pH, aH_2(aq), $aSiO_2$(aq), etc. that must reflect differences in the conditions of water-peridotite interactions. The reaction sequences are primarily a function of temperature and fluid flux. An improved understanding of serpentinization will be required to further our understanding of its role in terrestrial and deep-sea serpentinite-hosted geochemical and microbiological systems of the modern and ancient Earth.

Importance of Monitoring Volcano-Scale Earthquake Processes within a Seafloor Observatory Framework at the Lucky Strike Seamount

Bohnenstiehl, DelWayne R. [1] *and Maya Tolstoy*[1]

[1]Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964, USA; del@ldeo.columbia.edu; +845-365-8382 (phone); +845-365-8156 (FAX)

Earthquakes represent fundamental physical perturbations to the mid-ocean ridge environment, which can be used to track many important lithospheric processes. As such, seismic monitoring provides a critical tool for studying the dynamics of this system. Here we express our interest in deploying a nested ocean-bottom seismic (OBS) array within the Lucky Strike region of the Mid-Atlantic Ridge, centered near 37° 17' N, 32° 17' W. This passive monitoring effort would permit the study of magmatic and hydrothermal processes within the central seamount's hydrothermal field, while yielding the first long-term (2+ yr) micro-seismic image at the scale of a slow-spreading volcanic system. The collection and analysis of these data would form an important component of the MOMAR initiative, which includes several already scheduled experiments within the Lucky Strike Segment during the next two years. It is our hope that strong international collaborations will yield an extensive geological and geophysical context for the interpretation of earthquake data and provide coincident geodetic, hydrothermal and biological time-series measurements.
To facilitate collaboration and maximize the impact of these data, we anticipate that a hypocentral catalog could be prepared and made openly available to MOMAR investigators as the data are processed. In addition to standard location techniques and focal mechanism determinations, we would implement the double-difference (DD) relocation procedure of Waldhauser and Ellsworth [2000] to remove model errors and improve relative hypocentral precision. This inversion makes use of both relative and absolute phase picks, allowing us to relocate all earthquakes within the study area. Such analysis has the potential to resolve individual fault structures and hydrothermal pathways, providing an unprecedented look at tectonic, magmatic and hydrothermal processes within the slow-spreading environment.

The goals of our analysis would be to characterize and better understand the patterns of intra-segment and volcano-scale seismicity. Quantitative analysis of hypocentral data, when merged with active-source seismic constraints to be collected in 2005 and existing multi-resolution morphologic data, would provide a comprehensive four-dimensional view of a slow-spreading volcanic system. Through close collaboration, we would like to examine the co-variability of earthquake properties with respect to along-axis changes in crustal structure, fault development and magma supply. Our analysis would likely focus on the statistical properties of the earthquake populations, allowing us to highlight temporal and spatial variability in the scaling and dynamics of the system that can be linked to active physical processes within the seamount. Waveform data also would be made readily available to facilitate a wide range of other studies.

Relocated hypocentral information would provide a mechanism for tracking the depth and extent of the hydrothermal cracking front, and place important constraints on fluid source regions, hydrothermal pathways and heat fluxes. Specifically, the source regions and hydrothermal pathways associated with geochemically distinct vents within and just outside the summit area could be investigated. Our nested approach, however, will not only provide a record of micro-seismicity within the upper hydrothermal system, but also yield an unprecedented look at the larger-scale coupling between the hydrothermal and volcanic systems. In the coming years, existing plans call for the deployment of bottom pressure sensors, gravity benchmarks for repeat surveys, temperature sensors, micro-biological colonization boxes, long-term in situ chemical and biological analyzers, and camera and video equipment. This creates an important opportunity for studying the manifestations of volcano-scale processes, which can be tracked using seismicity, on the hydrothermal systems within the seamount's summit region.

Magmatic controls on fault offset at slow-spreading mid-ocean ridges

Buck, W. Roger[1], Luc L. Lavier[2], and Alexei N. B. Poliakov[3]*

[1]Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA; beck@ldeo.columbia.edu, tel. 845-365-8592, fax 845-365-8179.
[2] Jackson School of Geosciences, Institute of Geophysics, University of Texas, Austin TX 78759, USA
[3]Royal Bank of Canada, 71 Queen Victoria Street, London EC4V 4DE, UK

More faults are formed at spreading centers that at all other tectonic environments on Earth. The spacing, offset and dip direction of mid-ocean ridge normal faults show great variability. Along the ends of some slow spreading ridge segments fault offsets appear to be tens of kilometers while along most parts of slow-spreading ridges the maximum fault offset is less than a kilometer. Slow spreading ridge faults, and the related axial valley, can form due to stretching axial lithosphere in response to horizontal extensional stresses. We simulate ridge faulting using a numerical approach that allows fault formation and offset as well as magmatic accommodation of plate separation. Model faults form spontaneously in response to specified strain weakening in an extending viscoelastic-plastic ridge structure. We assume a ridge lithospheric structure that results in an axial valley of similar size to those mapped. Large differences in the model stretching fault offsets can result from variations in the fraction, M, of plate separation accommodated by magmatic intrusions. For M=0.9 fault offsets can be a few hundred meters, while for M=0.5 the model fault offset is unlimited. The models also require particular rates of brittle layer weakening with strain, but temporal variations in magma supply are not required to produce large offset faults. We speculate about how great differences in magma supply rate for the center versus distal ends of segments may arise when most magma supplied to a segment passes through a central magma chamber.

Microbial diversity in marine extreme environments

Cambon-Bonavita M. A.[1], Godfroy A.[1] , Geslin C.[2], Le Romancer M.[2], Prieur D.[2], Querellou J.[1]

[1] UMR6197, Ifremer centre de Brest, DEEP-LM2E, BP 70 29280 Plouzané
[2] UMR6197, IUEM, Place N Copernic, 29280 Plouzané

Deep sea hydrothermal vents and various deep subsurface environments have been studied by our team using both cultivation techniques and molecular approaches. Cultivation techniques, mainly focused on thermophily in deep sea hydrothermal vent, have led to the characterisation of a numbers of new genera and species involved in various geo-biochemical cycles. Our team have also isolated virus and genetic elements from several deep sea hydrothermal vents. More recently, mesophilic and psychrophilic cultures have been undertaken on deep subsurface and European margin environments.

Molecular approaches have been used to describe the microbial and virus diversity associated with hydrothermal samples (chimney, invertebrates), deep subsurface sediments, enrichment cultures.
In MoMAR project, we intend to work on various aspects of microbial ecology of MoMAR area deep sea hydrothermal vents environments including : (1) The study of chemosynthetic microflora using both genomic and cultural approaches, to better understand their role and their interactions with minerals and invertebrates. (2) The development of new culture methods in order to approach as closely as possible the conditions of natural habitats with emphasis on cultivation of microbial communities and correlated with an in situ approach using autonomous instrumented colonisation devices. (3) The study and diversity of viruses and plasmids of thermophiles from deep sea vents. And (4) the investigation of the deep subseafloor (IODP program), by studying microbial communities in terms of phylogeny and metabolism to understand their implication in sediment evolution and transformation.

Seismic structure of the TAG segment, Mid-Atlantic Ridge 26°N

Canales, J. Pablo, R. Reves-Sohn, & Susan Humphris

Department of Geology and Geophysics, Woods Hole Oceanographic Institution, 360 Woods Hole Rd., Woods Hole MA 02543 USA

Tectonic control is thought to play a prominent role in the evolution of long-lived hydrothermal systems at slow-spreading mid-ocean ridges. In 2003 we conducted an active-source seismic experiment in the TAG segment and hydrothermal mound (Mid-Atlantic Ridge, 26°N) to understand the relationship between long-lived hydrothermal activity, faulting, and the presence of crustal magma reservoirs. Two-dimensional travel-time tomography reveals that the TAG hydrothermal mound sits on a crustal section of unusually high seismic velocities. This crustal anomaly extends for ~15 km along the axis of the segment, and ~5 km across the eastern valley wall, and it is characterized by seismic velocities typical of lower crustal rocks at depths as shallow as ~1 km below the seafloor. No low seismic velocities indicative of hot rock or magma reservoirs are found immediately beneath the hydrothermal mound. In contrast, relatively low seismic velocities are found at ~2-3 km depth along the western side of the valley floor beneath the neovolcanic zone, a few km west of the TAG mound. These observations indicate that the long-lived TAG hydrothermal mound sits on a body of lower crustal rocks that has been uplifted and exposed along the eastern valley wall by asymmetric tectonic extension. Our results suggest that long-lived faults can act as pathways and focus hydrothermal fluids away from their heat source for long periods of time.

Annual spawning of the hydrothermal vent mussel, *Bathymodiolus azoricus*, under controlled aquarium conditions at atmospheric pressure.

Colaço A. [1], I. Martins[1], M. Laranjo[1], L. Pires[1], C. Leal[1], C. Prieto[1], V. Costa[1]; H. Lopes[1]; D. Rosa[1], P. R. Dando[2], R. Serrão-Santos[1]*

[1]IMAR- Department of Oceanography and Fisheries. University of Azores, Cais de Sta Cruz, 9901-862 Horta Portugal.
[2]School of Ocean Sciences, University of Wales-Bangor, Menai Bridge LL59 5AB, UK
*To whom correspondence should be addressed.
E-mail: *acolaco@notes.horta.uac.pt*

Dense macrofaunal communities of modioliform mussels are a major component of many hydrothermal vent and cold seep ecosystems. The hydrothermal vent mussel *Bathymodiolus azoricus*, that dominates hydrothermal vent communities near the Azores Triple Junction, can be maintained in aquaria at atmospheric pressure. Cages containing these mussels were placed over diffuse vent outlets and recovered at different times. Cages recovered in January 2003 contained spawning mussels while those recovered in July, August and November 2001 and in April 2003 did not. Mussels collected post-spawning in April 2003 spawned in the aquaria in January 2004. Young mussels recruited to the cages in April 2003. The data indicate single annual periods of spawning and juvenile recruitment for *B. azoricus*.

IODP and MOMAR –unrealized opportunities

David Christie[1]

[1]College of Oceanic and Atmospheric Sciences, Oregon State University, 104 COAS Admin. Bldg. Corvallis OR 97331-5503. dchristie@coas.oregonstate.edu. 541-737-5205

The potential for IODP to contribute to an improved understanding of the composition, structure, and evolution of the ocean lithosphere is enormous and has been enunciated in planning documents since ocean drilling began. Yet, the number of active "ocean crust" proposals in the IODP system at the present time is very small, and the great majority of these are focused on a single class of problem -- seafloor exposure of gabbroic and peridotite sections that form where extensional tectonics dominates accretionary style rather than magmatic intrusion/extrusion. The reasons for this limited engagement in by the "crustal community" in IODP are unclear, but they may reflect a misperception that IODP (and ODP before it) is focused two end-member objectives that are not yet achievable – so-called "zero-age" drilling and drilling to the MOHO. As we plan for MOMAR, we should clearly enunciate the scientific motivation for an active partnership of IODP with InterRidge and the national "ridge" programs. MOMAR scientists should become aware of the opportunities that IODP offers and work together to ensure that relevant proposals are written and carried through the approval process.

IODP incorporates many of the most effective tools for direct scientific sampling of deep seafloor environments and (I)ODP has, in fact, had a number of successful projects within and close to the axial valley of the Mid-Atlantic Ridge. Deep-sea drilling is the only tool for direct sampling of hard rock, consolidated sediment and fluids at significant depth below the seafloor, and the resulting drillholes also provide a valuable access for short- and long-term sub-seafloor monitoring. IODP tools can and should be effectively combined with those available from conventional surface ships and from submersible vehicles. Only through an effective combination of drilling, surface ship, submersible and seafloor instrumentation resources can we maximize the scientific return from MOMAR.

Much of the motivation for drilling into the ocean crust is embedded in two of the three main themes of the IODP Initial Science Plan, "The Deep Biosphere and the Sub seafloor Ocean" and "Solid Earth Cycles and Geodynamics", and especially under the key initiatives "Deep Biosphere" and "21st Century Mohole". Although, at first glance, these titles seem to allow little room for drilling relevant to MOMAR, there is a clearly expressed need for a clearly defined scientific strategy that incorporates a mandate for a broad range of crustal drilling projects. It is up to the community to define those projects and to create the proposal pressure that will make them a reality. To date, such proposals have not been forthcoming. The reasons for this lack of response are unclear, but at some level it means that the community has not recognized that there is a wealth of critical scientific problems that can be addressed with current technology. One goal of this workshop should be to identify opportunities for true collaboration between IODP, with InterRidge and the national "ridge" programs.

Examples of Scientific Questions/problems for IODP at MOMAR
These examples are from the JOI/USSSP workshop report "Opportunities in Geochemistry for Post-2003 Ocean Drilling".

Lithosphere Structure and Aging.
- How extensively do fluids penetrate and react with ocean crust and mantle?
- Is seismic Layer 2a equivalent to the pillow lava section of the ocean crust? Does the relationship change as seafloor age increases away from the spreading axis?

Hydrothermal Exchanges.
- How deeply do seawater-derived fluids penetrate into the oceanic lithosphere and what are the thermal consequences of this hydrothermalism?
- What are the nature and extent of geochemical reactions that transform wall rock and fluid compositions along fluid pathways?
- How does fluid circulation evolve as porosity, tectonic stress and sediment burial change as the lithosphere moves away from the spreading axis?

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

Deep Biosphere.

- How do the species compositions and abundances of microbial communities evolve as porosity and thermal structure change laterally and with depth?
- What are the thermal and physiochemical boundaries to the distribution of individual microbes and communities?

The examples above are all focused on recovered rock samples. But there are numerous scientific problems that can potentially be addressed using boreholes as resources. They include:

- Sampling of fluid for hydrogeological and geochemical studies
- In situ monitoring of fluids and microbial populations in CORKed boreholes
- Seismic monitoring of magmatic and hydrothermal processes using borehole seismometers
- Hole-to-hole geophysical experiments to determine crustal properties
- Monitoring of deformation using downhole instruments

MOMARnet: MOnitoring deep sea floor hydrothermal environments on the Mid Atlantic Ridge: A Marie Curie Research Training Network funded by the European Commission

Cannat, Mathilde[1], Ricardo Santos[2], J.M. Miranda[3], Nils Holm[4], Nicole Dubilier[5], Paolo Favali[6], Chris German[7], Adam Schultz[8], Paul Dando[9], Rafael Garcia[10], Frank Dehairs[11], Pascal Tarits[12], Françoise Gaill[13], Nadine Le Bris[14]

[1]Laboratoire de Géosciences Marines, C.N.R.S-Institut de Physique du Globe de Paris
4 place Jussieu, 75252 Paris Cedex 05, France. cannat@ipgp.jussieu.fr. (33) 01 44275192. (33) 01 44 27 99 69
[2]Instituto do Mar. Dept. of Oceanography and Fisheries & U. Açores. Horta Portugal.
[3] Centro de Geofisica Universidade de Lisboa Portugal
[4] Dept. of Geology and Geochemistry, Stockholm University Sweden
[5] Max Plank Intitute for Marine Microbiology, Bremen Germany
[6] Instituto Nazionale di Geofisica e Vulcanologia, Roma Italy
[7] Southampton Oceanography Center UK
[8] Dept. of Earth Sciences, Cardiff University UK
[9] University of Wales Bangor UK
[10] Institute of Informatics and Applications, University of Girona Spain
[11]Analytical and Environmental Chemistry, Vrije Universiteit Brussel Belgium
[12]Institut Universitaire Européen de la Mer, Un. de Bretagne Occidentale, Brest France
[13]UMR Systématique, Adaptation & Evolution, U. Pierre et Marie Curie, Paris France
[14]Institut Français de Recherche pour l'Exploitation de la Mer, Brest France

The MOMARnet Marie Curie Research Training Network (coordinator: M. Cannat) aims at strengthening the European approach to deep seafloor observatory science and technology, by reinforcing the links between 14 laboratories in 8 european countries, by training a multidiciplinary group of young researchers, and by producing new science and preparing for new seagoing cruises and seafloor experiments. MOMARnet science will contribute to the implementation of the MOMAR (« MOnitoring the Mid-Atlantic Ridge ») international project of setting up a multidiciplinary sea-floor observatory for monitoring hydrothermal vent environments along the Mid-Atlantic ridge close to the Azores archipelago.

MOMARnet is funded for 4 years (starting from sept 2004) and has two broad research targets: Understanding the dynamics of slow-spreading ridge hydrothermal vents and their plumbing system (depth of seawater circulation, heat sources, feedback between volcanic, hydrothermal and seismic events).Understanding deep-seafloor hydrothermal ecosystems, including their distribution, role and variety of organisms, life cycles, effects of changes in the hydrothermal outflow (temperature, flowrate, chemistry, etc.)

MOMARnet research is organized into seven linked work packages and addresses scales ranging from regional (a few hundred kilometers along the ridge axis), to the scale of vent organisms (centimeter-scale and beyond). The seven work packages comprise fifteen specific research tasks carried out by the young researchers hired by the network. These young researchers are mostly of pre-doc level. Their training plan aims at providing them with an excellent background in their respective area of expertise, and with a solid awareness of the scientific issues and specific operational needs of the other disciplines involved in deep-seafloor monitoring research.
The network's web site (http://www.momarnet.org) is meant to become an instrument for the coordination of research, training (description and schedule of training courses, relevant seminars in the contractors institutes), and dissemination. The site is linked to other deep seafloor observatories web sites internationally.

Axis-parallel depth and gravity profiles: implications for intra-segment crustal thickness variations and near-axis tectonic processes

Cochran, James R.[1]

[1]Lamont Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964 USA, jrc@ldeo.columbia.edu, (845) 365-8396 (v), (845) 365-8179 (f)

Axial depths within a ridge segment generally increase regularly along the axis away from an intrasegment minimum. These along-axis depth variations are widely assumed to be an isostatic response to along-axis intrasegment variations in crustal thickness, particularly in the Atlantic where MBA gravity lows are consistently found at the shallowest portion of segments, leading to the widespread use of gravity anomalies as a proxy for along-axis crustal thickness variations. However, Neumann and Forsyth [1993] have argued that the ridge axis cannot be locally compensated because the axial valley is a dynamic feature. Also several studies at the fast-spreading East Pacific Ride have suggested that axial depth, gravity anomalies and crustal thickness variations are not necessarily related. To the extent that along-axis depth variations reflect crustal thickness variations, they should persist onto the ridge flanks as the isostatic expression of the changes in crustal thickness. Similarly MBA gravity anomalies resulting from crustal thickness variations should continue onto the ridge flanks.

We examined ridge-parallel depth and gravity variations, both on-axis and at various distance from the axis, at the 12°-15°N area of the EPR, several segments of the SEIR characterized by axial highs, and at the MAR from 31°S to 34°S. The areas on the EPR and SEIR were chosen because they have large along-axis depth variations. The MAR region includes the "Plume" segment with the largest known axial MBA gravity anomaly. We picked the ridge axis location at 1' (1.853 km) intervals in these data sets and generated flow lines through the ridge axis locations. The bathymetry and gravity grids were sampled at 1 km intervals along the flow lines. The bathymetry profiles were then filtered using several techniques to remove the abyssal hill relief and were used to construct ridge parallel profiles at various distances from the axis. Similar conclusions were reached from analysis of filtered and unfiltered data.

Along-axis depth variations at intermediate- and fast-spreading ridges do not extend out onto the ridge flank. Within segments where there is significant relief along the axis, axis-parallel profiles on the ridge flanks are either nearly flat or have a steady long-wavelength regional gradient across the segment. Profiles across the axis demonstrate that changes in axial depth result from variations in the form and relief of the axial morphology. This is particularly clear at intermediate spreading ridges where there is greater along-axis depth variation, but can also be seen at 13°N-15°N portion of the EPR where there is significant along-axis depth variation. At a few segments on the SEIR, a small (100 m) along-axis off-axis bathymetric high is found along the same flow line as the much larger axial bathymetric high.

Along-axis depth and MBA gravity profiles at the slow-spreading MAR show a close correlation, as has been noted by many investigators. However, he characteristic humped axial morphology does not usually extend off-axis. The interior of segments on the ridge flanks is shallower than the ridge discontinuities, but the shallowest off-axis depths are not in the center of the segment but rather near the ends. The center of the segment, the location of the shallowest axial depth, is several hundred meters deeper than near the segment ends. This appears to be the result of tectonic processes near the segment ends, which form segment-bounding ridges parallel to the axis. These ridges are most prominent on the "inside corners", but are usually present at both on both sides of the axis.
At the 33°S "Plume" segment on the southern MAR, the off-axis MBA profiles have the same shape as the axial profile, although with slightly smaller amplitude. At shorter segments, the off-axis gravity anomalies do not show a coherent pattern. It thus appears that, at short segments, tectonic activity as the crust is transported up and out of the rift valley may disrupt the crustal thickness distribution established at the ridge axis. At longer segments, disruption by faulting is limited to the segment ends leaving the gravity pattern in the center of the segment intact.

Deployment of a Deep-Water, Acoustically-Link, Moored Buoy Observatory System on the Nootka Fault, off Vancouver Island

Collins, J.[1], D. Frye[1], L. Freitag[1], M. Grund[1], J. Ware[1], R. Detrick[1], R. Johnson[2] M. Lilley[2], W. Wilcock[2], A. LaBonte[3], K. Brown[3], J. Delaney[2]

[1] Woods Hole Oceanographic Institution, Woods Hole, MA
[2] University of Washington, Seattle, WA
[3] Scripps Institution of Oceanography, UCSD, La Jolla, CA

We have developed an acoustically-linked moored buoy system that uses high-speed acoustic modems for two-way communication between instruments on the seafloor, or in the water column, and a surface buoy. An Iridium satellite link on the buoy telemeters data to shore several times a day and can be used in conjunction with the two-way acoustic link to send commands to instruments at the observatory. This system is ideally suited for a variety of applications where data telemetry requirements are relatively modest, but real-time or near real-time data are required. A conventional discus buoy (2.7m diameter) is equipped with dual Iridium transceivers, two acoustic modems, a Linux-based system controller, and a solar power system with a three-month alkaline battery backup. Up to 15 remote nodes on the mooring or on the seafloor can be polled several times a day and the data passed back to shore via the Iridium satellite link. Total demonstrated throughput has been 1 Mbyte per day, and can be much higher. An initial 2 month test deployment in Nov. 2003 off the U.S. east coast verified the operation of the acoustic and Iridium data links, as well as the control, power and mooring systems. Acoustic data rates of up to 5300 b/s have been achieved in 2700m of water at slant ranges of just under 3 km using modest transmit power (<10 W). The Iridium connection has been used to remotely reconfigure various aspects of the data collection system as well as transfer large quantities of data. In May 2004 this system was deployed for one year at a seep site off Vancouver Island where the Nootka fault crosses the toe of the accretionary prism in order to monitor fluid expulsion along the fault, and to examine the links between seismic deformation and episodic flow. The Nootka observatory is equipped with a suite of meteorological sensors on the buoy, an in-line current meter on the mooring, an Ocean Bottom Seismometer, and two additional seafloor nodes, one of which is equipped with sensors for monitoring the seep site, including temperature, fluid resistivity, heat flow, and an optical flow meter. The data from these sensors are collected on shore automatically and displayed on a web page in near real time (http://fathom2.whoi.edu/). Initial results from this prototype observatory will be shown based on data telemetered to shore in near-real time.

Short-term effects of essential (Zn) and non-essential metals (Ag and Hg) on the antioxidant defence system of Bathymodiolus azoricus

Company, R.,[1] A. Serafim[1], M. J. Bebianno[1], R. Cosson[2], A. Fiala-Médioni[3] & B. Shillito[4]

[1]University of Algarve, CIMA, Faculty of Marine and Environmental Sciences, Campus de Gambelas, 8000-139 Faro, PORTUGAL, rcompany@ualg.pt, +351289800900 (telephone), +351289818353 (fax)
[2]University of Nantes, Laboratory of Marine Biology, ISOMER, BP 92208, F-44322 Nantes, FRANCE
[3]University P.M. Curie, Observatoire Océanologique, BP 44, 66651 Banyuls sur Mer, FRANCE
[4]University of Paris, Marine Biology Group, Centre National de la Recherche Scientifique (CNRS), FRANCE

The deep-sea hydrothermal mussel, Bathymodiolus azoricus, can survive near the emission of metal rich vent fluids, of both essential and non-essential metals, but the specific adaptations they possess to deal with such high concentrations remain largely unknown. Metals are known to increase reactive oxygen species (ROS) production in bivalves and consequently may interfere with antioxidant enzyme protection. The effects of metals on antioxidant enzymatic system and cellular damages (lipid peroxidation – LPO) in B. azoricus are still largely unknown.

Therefore, the aim of this work was study the short term effects of one essential (Zn) and two non-essential metals (Ag and Hg) on superoxide dismutase (SOD), catalase (CAT), total glutathione peroxidases (Total GPx), selenium dependent glutathione peroxidases (Se-GPx) and LPO in deep-sea hydrothermal mussels.

Mussels were collected in Menez-Gwen vent field in Summer 2001 during the ATOS cruise and exposed separately to Zn (1000 $\mu g\ l^{-1}$), Ag (25 $\mu g\ l^{-1}$) and Hg (25 $\mu g\ l^{-1}$) in a pressurized tank (IPOCAMP) at 85 bar for 12 and 24 hours. Gills and mantle were dissected and antioxidant enzymes determined by UV/Vis spectrophotometric assays.

Results show that these metals have different effects on antioxidant parameters. The essential metal Zn had little effect in the gills, increasing the activity of mitochondrial SOD activity in this tissue, while in the mantle Zn inhibited SOD, CAT, total GPx and Se-GPx. However, no LPO was induced in both tissues, suggesting that this species can tolerate a large range of Zn concentrations. Ag increased significantly the activity of cytosolic SOD in the gills, while an inhibitory effect on Total GPx was observed in this tissue. In the mantle, the exposure to Ag inhibited significantly mitochondrial SOD, whereas Total GPx activity increased significantly in Ag-exposed mussels. LPO occurred in the mantle after Ag exposure, probably due to a reduced capacity to scavenge superoxide radicals by SOD inhibition.

Finally, Hg had no effects on both antioxidant enzymes and LPO in both tissues of B. azoricus, suggesting that environmental mercury concentrations are particularly high. Nevertheless, Hg concentration (25 $\mu g\ l^{-1}$) used in this experiment may be excessive compared to what these mussels are naturally exposed in Menez-Gwen, or the short time of exposure (24h) was not enough to induce antioxidant defences responses or LPO damages in B. azoricus.

Acknowledgements: This study was supported by an FCT Ph.D. Grant (SFRH/904/2000) and the European Project VENTOX (EVK3 CT1999-00003).

Vent mussel shells as recorders of environmental change

Dando, P. R., Clarke, L. J., Kennedy, H., Libertinova, L. and Richardson. C. R.

School of Ocean Sciences, University of Wales Bangor, Menai Bridge, Isle of Anglesey, LL59 5AB, U.K. E-mail: oss109@bangor.ac.uk, tel.: + 44 12548 382904 fax.: +44 1248 382620

The incremental shell growth of molluscs allows time series reconstruction of shell growth rate and ambient environmental conditions, the latter via geochemical proxies.. The vent mussel Bathymodiolus azoricus dominates the fauna at MAR vents south of the Azores and the mussels contain a mixture of both sulphide- and methane-oxidising bacteria within the same bacteriocytes in their gills (Fiala-Medioni et al., 2002). Of these MAR sites Menez Gwen is located at 850 m water depth enabling recovery of live animals that subsequently can be maintained in aquaria under different conditions, e.g. with or without sulphide and/or methane. Any shell growth that occurs under these well constrained laboratory conditions can be used to robustly validate growth rates and geochemical proxies. For field-derived validation, mussels have also been relocated into cages, placed at or near active venting sites and the cages recovered periodically using acoustic releases (Dixon et al., 2001), thereby resulting in a shell time-series based on the same cohort of mussels. Both the laboratory and field-based data will be used to examine the periodicity and cause of shell banding (c.f. Richardson, 2001), as well the validation of the geochemical proxies, such as $\delta^{18}O$ and Mg/Ca for temperature, elemental ratios (e.g. Mn/Ca) in the shell that likely reflect changes in the water chemistry around the mussels habitat, as well as the $\delta^{13}C$ in the shell organic matrix as a proxy for nutritional changes. In this way it will be possible to use Bathymodiolus azoricus shells as novel chronometers of biological and chemical change. The project would benefit greatly from access to other hydrothermal vent mollusc shells that are associated with some environmental constraint e.g. temperature at the collection site, and we would welcome contact with anyone holding such material. This project is being undertaken within the EU Marie Curie Research Training Network MOMARnet programme.

Dixon D. R., P. R. Dando, R. S. Santos, J. P.Gwynn (2001), Retrievable cages open up new era in deep-sea vent research. InterRidge News, 10, 21-23.

Fiala-Medioni A., Z. P. McKiness, P. Dando, J. Boulegue, A. Mariott, A. M. Alayse-Danet, J. J. Robinson and C. M. Cavanaugh (2002), Ultrastructural, biochemical, and immunological characterization of two populations of the mytilid mussel Bathymodiolus azoricus from the Mid-Atlantic Ridge: evidence for a dual symbiosis. Mar Biol 141, 1035-1043.

Richardson, C. A., (2001) Molluscs as archives of environmental change. Annu. Rev. Oceanog. Mar Biol. 39, 103-164.

MoMAR-FR : a coordinated national approach to the international MoMAR (Monitoring the MidAtlantic Ridge) project

Desbruyères, D.[1], M. Cannat [2], R. Bally[3], P. Cochonat[1], C. Deplus[3], Y. Fouquet[1], F. Gaill[4], P.M. Sarradin[1], and P. Tarits[5]

[1]Ifremer (Daniel.Desbruyeres@ifremer.fr)
[2] Institut de Physique du Globe de Paris, CNRSUMR 7097 (cannat@ipgp.jussieu.fr),
[3] CNRSINSU (christine.deplus@cnrsdir.fr),
[4] Université de Paris VI, CNRS (francoise.gaill@snv.jussieu.fr),
[5] Université de Brest (tarits@univbrest.fr)

In this presentation, we provide an update on the national coordination of the french contribution to MoMAR, under the auspices of Ifremer and CNRS-INSU. This contribution was elaborated in the course of two open workshops, held in Roscoff and Paris in 2003 and 2004. It focuses on two priority objectives: setting up an IODP drillhole observatory at the ultramafic-hosted Rainbow hydrothermal site, and setting up a multiscale observatory of hydrothermal processes and related ecosystems in the Lucky Strike ridge segment. Specific actions planned at both sites will be outlined to serve as a basis for discussions at the MoMAR Lisbon meeting. The authors of this contribution are members of the MoMAR-FR Steering Committee, set up jointly by CNRS-INSU and by Ifremer in June 2004.

Low temperature hydrothermal Manganese crust from Saldanha field, Mid-Atlantic Ridge

Dias, Ágata A. [1], Raul C. G. S. Jorge[1,2], Fernando J. A. S. Barriga[1,2]

[1]CREMINER Faculdade de Ciências, Universidade de Lisboa, Portugal
E-mail: agata.dias@fc.ul.pt; telephone: +351 21 7500000; fax: +351 21 750 0064
[2] Dep. Geologia Faculdade de Ciências, Universidade de Lisboa, Portugal

The Saldanha hydrothermal field is located at the top of a serpentinized massif (Mount Saldanha, MS) at a non-transform offset (NTO5) along the Mid-Atlantic Ridge (MAR), south of the Azores. It is one of the rare known sites in the world where evidence of low-temperature hydrothermal activity has been provided by direct observation of fluids venting through small orifices in the ocean floor sedimentary cover. These fluids spread over a surveyed area of approximately 400m^2. Maximum fluid temperature measured in situ was 9ºC, whereas the adjacent seawater was only 2ºC (Barriga et al., 2003). However, mineralogical and geochemical data of MS hydrothermal sediments implies that fluids have higher temperatures than 9ºC (Dias and Barriga, 2005). Geology of Saldanha field is characterized by a heterogeneous melange of gabbros, volcanic rocks, serpentinized and steatitized (talcshist) ultramafic rocks, and hydrothermal sediments.

Manganese oxides occur mainly in the form of black crusts at the top of the hydrothermal sediments, as well as disseminated in sediments or incrusting foraminiferous tests. Manganese crusts form a millimetric cap poked by millimetric and centimetric holes interpreted as micro-chimneys. Microscopic observations of these crusts show alternate thin layers of acicular Mn oxides with massive cryptocrystalline Mn oxides. X-ray diffraction (XRD) patterns indicate a mixed birnesite/todorokite composition. However, high Mg and low Fe, Ca, Na, and K contents of these Mn oxides (microprobe data) suggests a predominant birnesite composition. Associated with these oxides, an uncommon, prismatic transparent mineral was observed. Electron microprobe analyses for this mineral show MnO and MgO averages of 22.6 wt.% and 41.6 wt.%, respectively, resembling manganobrucite composition. The small size and scarcity of the crystals precluded an XRD investigation.Disseminated Mn oxides occur isolated or in clusters within the sediments and present characteristic botryoidal textures that often show internal zonation. XRD diffraction data indicate the presence of vernardite. Microprobe data of this Mn phase also revealed high Mg contents. Similar Mn oxide structures found in sediments afar from the hydrothermal discharge zones show lower Mg and higher Fe contents, although they also reveal low concentrations in other elements.

Mn oxides textures collective suggest that these minerals grow in open spaces within the sediments cover. These Mn phases precipitate in the upper part of the hydrothermal system where extensive mixing between discharge hydrothermal fluid and unmodified seawater occurs. This fact could be responsible for the high Mg contents in the Mn oxides and in Mg-brucite composition, especially in the discharge zone.

Barriga F. J. A. S., Almeida A., Biscoito M., Colaço A., Company R., Costa R., Costa V., Cruz V., Dias Á., Ferreira P., Gadanho M., Iyer S., Kadar E., Lopes C., Lourenço N., Marques A., Martins V., Pinto Á., Relvas J., Rohais S., Segonzac M., and Serafim M. (2003) Seahma-1 Cruise Report. In Creminer (ed. FCT). Faculty of Sciences University of Lisbon.

Dias A. and Barriga F. (2005) Mineralogy and geochemistry of hydrothermal sediments from serpentinite-hosted Saldanha hydrothermal field (N36º34'; W33º26') at MAR. Marine Geology submitted.

The plutonic foundation of a 40 km long section of the Mid-Atlantic Ridge

Henry JB Dick[1], Maurice A. Tivey[1], and Brian E. Tucholke[1]

[1]Department of Geology & Geophysics, Woods Hole Oceanographic Institution, Woods Hole MA, 02543, USA; hdick@whoi.edu; 508-289-2590; fax 508-457-2183
[2]Second Author, department, institution affiliation, city, state, country
[3]Third Author, department, institution affiliation, city, state, country

The Kane megamullion is the exhumed footwall of a long lived (1.2 my) normal detachment fault exposing a section of the upper mantle and lower crust in an oceanic core complex that is readily accessible to survey, sampling, and eventual drilling. The fault surface is characterized by a set of low domes with smooth topography interrupted by a distinct series of linear ridges, corrugations, or mullions oriented parallel to the spreading flow-line direction. Detailed sampling and mapping of the detachment surface and of cross-cutting outward-facing fault scarps using the ROV Jason-2 and the autonomous underwater vehicle ABE in conjunction with extensive dredging was done on Cruise 180, Leg 2 of the RV Knorr in November and December 2004. We found that the lithology of the basement exposures correlates directly with the distribution of volcanics inferred from seafloor physiography on crust of the same age on the conjugate tectonic plate. In the north, serpentinized peridotite with little dunite and only minor largely evolved crosscutting gabbros are exposed, while the conjugate, volcanic crust has low elevation. In the south, large exposures of primitive gabbro and troctolite were found intercalated with diabase dikes, while the conjugate is elevated volcanic crust. Mantle peridotites dredged from this plutonic complex, unlike the peridotites to the north, contained abundant dunite. Dunite is formed by focused melt flow in the shallow mantle and its absence in peridotite suites and the lack of primitive gabbro to the north, suggest limited melt transport across the crust-mantle boundary there. The abundance of dunite and primitive troctolites to the south demonstrates the opposite. Thus, the plutonic foundation of the oceanic crust along a 40 km axis-parallel section is consistent with the intensity of magmatism inferred from elevation of the volcanic crust on the conjugate plate.

An unexpected finding is two major, orthogonal, high-angle normal faults have localized off-axis volcanism within the core complex, creating a curious T-shaped constructional volcano at their intersection at 45°19'W-23°35'N. One fault is an outward facing 700-m high scarp that runs N-S for ~45 km and intersects a second E-W fault at the southern edge of the transverse ridge flanking the Kane transform. The volcanic edifice is locally elevated up to ~300 m above the top of the footwall of the N-S fault, and it extends E-W ~5.5 km and at least 8 km to the south along the N-S fault. Locally faulted but otherwise intact pillow-lava flows were found on the west-facing flank of the edifice. Small amounts of fresh glass in a palagonite matrix are preserved; this is in contrast to the abundant pillow-basalt debris rafted on the detachment fault surface, and suggests that these lavas erupted more recently than the pillow debris scattered over the detachment surface. The two faults likely formed during unroofing and uplift of the lower crust and mantle at the paleo inside-corner high to form the northern portion of the Kane megamullion core complex, providing direct evidence for off-axis volcanism on the western side of the paleo inside-corner high.

Seasonal reproduction in the Atlantic vent mussel Bathymodiolus azoricus is linked to the timing of photosynthetic primary production.

Dixon, David R.[1], David M. Lowe[2], Peter I. Miller[2], Guillaume Villemin[1], R. Serrão-Santos[3], Linda R.J. Dixon[1,4]

[1]Southampton Oceanography Centre, Waterfront Campus, European Way, Southampton SO14 3ZH, UK.
[2]Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH.
[3]University of the Azores Department of Fisheries and Oceanography, Horta, Faial, Portugal
[4]Marine Biological Association, Citadel Hill, Plymouth PL1 2PB, UK.

Here we show evidence of seasonal reproduction in the vent mussel Bathymodiolus azoricus, a dominant member of the hydrothermal fauna of the Mid-Atlantic Ridge. This is the first time that seasonal reproduction has been described for any deep-sea vent organism, and was achieved using acoustically retrievable cages, which enabled us to extend the frequency and temporal range of sampling that was previously limited to the summer months. The main spawning peak takes place in late December and January and appears timed to take advantage of a winter bloom in surface water primary production, which serves as an important food source both for the adult mussels and their planktonic larvae. The reproductive cycle of the vent mussel closely mirrors that seen in its coastal relative, the blue mussel Mytilus edulis. This discovery demands a re-evaluation of the relative rôles of photosynthesis and chemosynthesis in the energy budgets of those vent species which possess a functional gut. Acoustically-operated cages provide a powerful new way for performing time-series studies in an environment that has previously been inaccessible for biological sampling during the winter months.

This research forms part of the BICEP core-strategic research programme of the Southampton Oceanography Centre, and was funded in part by EU funds: Framework 5 project (VENTOX) EVK3 CT-1999-00003.

MOMAR-DREAM : a cruise proposal on Rainbow hydrothermal site

Dyment, Jérôme[1]*, Françoise Gaill*[2]*, Yves Fouquet*[3] *and the MOMAR DREAM Scientific Team*

[1]CNRS UMR 7097 Laboratoire de Géosciences Marines, Institut de Physique du Globe de Paris, 4 place Jussieu, 75005 Paris, France; jdy@ipgp.jussieu.fr; 33 1 44 27 28 21; 33 1 44 27 99 69
[2]CNRS UMR 7138 Systématique Adaptation Evolution, Université Pierre et Marie Curie, 7 Quai Saint Bernard 75005 Paris France
[3]Laboratoire Géochimie/Métallogénie, Département Géosciences Marines, IFREMER Centre de Brest, B. P. 70, 29280 Plouzané cedex, France

Hydrothermal site Rainbow, one of the few known site with an ultramafic basement rock, is an exceptional target for the multidisciplinary study of hydrothermal phenomena. This site is characterized by the abundance of iron, an element which plays a major role in the active processes spanning from the site as a whole to the scale of molecules. Indeed iron plays an essential role to produce the strong magnetic anomalies discovered by cruise IRIS of R/V L'Atalante and ROV Victor in 2001; the wide variety of iron sulfurs collected at the site; the highest iron content measured on hydrothermal fluid in the whole North Atlantic Ocean; and a possible new type of symbiosis based on iron oxidation as proposed for shrimp Rimicaris exoculata. In addition, site Rainbow has been the focus of a drilling proposal, favorably reviewed by the international ocean drilling program ODP, which is going to be re-submitted to the new program IODP in April 2005. After several reconnaissance cruises, cruise MOMAR-**DREAM** has for objective to "**D**efine **R**ainbow by an **E**xploring **A**pproach (that is) **M**ultidisciplinary" (the acronym sounds quite better in French). The goals are, first, to study the role of iron in the geological, hydrological, and biological processes, and second, to systematically characterize the site to prepare for the drilling cruise. Beyond the requirement of a "zero state" for the repeated observations and in fine the site monitoring in the framework of the MOMAR project, the completion of an exhaustive inventory of the site biological populations is needed for the sake of preservation of a fragile environment. Therefore we propose to achieve a detailed and exhaustive mapping of the site (including geological, physical/chemical and ecological parameters); to collect rock, fluid, and biological samples; and finally to deploy colonization modules. These objectives can be achieved on the new submersible-carrier French ship R/V « Pourquoi pas? » and ROV Victor. The cruise is proposed for 2006 or 2007.

On preliminary results of the active electromagnetic survey of Saldanha hydrothermal venting field, MAR

Dzhatieva, Zalina [1], Martin Sinha[1], Fernando A. Monteiro Santos[2], Nuno Silva[2], Agata Dias[2], Filipa Marques[2], Simon Dean[1], Anna Maxey[1], Ed Morris[1], Michelle Ellis[1], Nadia Frerichs[1], Jamie McIntosh[1] and Alan Burchell[3]

[1] Southampton Oceanography Centre, School of Ocean and Earth Science, the University of Southampton, European Way, Southampton, SO14 3ZH, UK
E-mail: zald@soc.soton.ac.uk; telephone: +44 (0)23 8059 6573; fax: +44 (0)23 8059 3052
[2] University of Lisbon, Campo Grande, Ed. C8, Lisboa, Portugal
[3] Department of Earth Sciences, University of Durham, Durham, DH1 3LE, UK

The Saldanha hydrothermal field is located at the Mid Atlantic Ridge, south of Portugal's Azores Archipelago (N36º34'; W33º26'), between the Pico and the Oceanographer Fracture Zones. Major morphological elements in the study area include the FAMOUS and AMAR segments of non-transform offset and, also, the Saldanha seamount, located between them. Although Saldanha is located away from spreading centres there are both diffuse hydrothermal activity and focused discharges of clear fluid at the top of the mount. Hydrothermal fluid venting through the sedimentary cover of the seafloor has been directly observed over an area of approximately 400 m^2 and at depths between 2200 and 2220 m.

The lithotypes over the Saldanha seamount do not correspond to a typical oceanic crustal assemblage. The major lithologies include tectonic breccias dominated by serpentinites and volcanic breccias, pillow lavas and gabbros with a heterogeneous melange of gabbros, volcanic rocks, serpentinized and steatitized ultramafic rocks and sediments on the top of the mount.
Generally hydrothermal circulation systems have been considered to be associated with volcanic localities. The fact that, in the ocean-lithosphere interaction at Saldanha, recent magmatic activity appears to have played no direct role in driving hydrothermal venting makes this site of a particular interest of the study.

Within the context of MoMAR monitoring of active processes at the slow-spreading Mid-Atlantic Ridge we have carried out a unique survey covering a 10 km square grid centered on the Saldanha seamount in December 2004. Our main objective was to investigate the physical properties, and in particular the pore fluid properties in situ, within the upper few km of the seafloor beneath and around the vent site. Recent active source electromagnetic exploration (CSEM) of the MAR and other ridges have shown that the CSEM is a powerful tool for hydrothermal studies, including quantifying sub-sea-floor porosity and pore connectivity.

During the survey the active source DASI system transmitted a signal for frequency-domain sounding at frequencies of 0.25 and 1 Hz. Eight transmission lines were towed over an array of 18 seafloor electric field receivers. This survey geometry should provide us with 3D resistivity structure to a depth of about 3 km beneath the seafloor. In addition, we made, altogether, eleven coring and two dredging stations, and also collected a set of swath bathymetry, gravity and magnetic profiles across the ridge. The experimental data will be interpreted into constraints on geological structure, including distribution of fluid-filled fractures, at the Saldanha Massif by 1D and 2.5D forward modeling and inversion, and also geophysical effective medium modeling. By comparison of the results with those from volcanically hosted sites, we shall investigate whether the Saldanha vent site owes its existence to exothermal serpentinization reactions within a deep fracture network, extending downwards through the crust into the underlying mantle rocks.

This experiment was a joint research project carried out by the Southampton Oceanography Centre, University of Durham, UK and the University of Lisbon, Portugal.

Long-term Seismicity of the Northern Mid-Atlantic Ridge and MoMAR Area Observed Using Autonomous Hydrophone Arrays

Dziak, R. [1], J. Goslin[2], J. Haxel[1], H. Matsumoto[1], D. Bohnenstiehl[3], N. Lourenço[4]

[1]Oregon State University/NOAA, Newport, OR, U.S.A.
[2]UMR6538, IUEM, UBO, Technopole Brest Iroise, 29280 Plouzané, France
[3]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY., U.S.A.
[4]Centro de Investigaç□o Marinha e Ambiental, Universidade do Algarve, Faro, Portugal
Contact: robert.p.dziak@noaa.gov,

The seismicity of the North Atlantic Ocean has been recorded by two networks of autonomous hydrophones moored within the SOFAR channel on the flanks of the Mid-Atlantic Ridge (MAR). In February 1999, a consortium of U.S. investigators (NSF and NOAA) deployed a 6-element hydrophone array for long-term monitoring of MAR seismicity between 15□-35□N south of the Azores. In May 2002, an international collaboration of French, Portuguese, and U.S. researchers deployed a 6-element hydrophone array north of the Azores Plateau from 40□-50□N. The northern network (referred to as SIRENA) was recovered in September 2003. The low attenuation properties of the SOFAR channel for earthquake T-wave propagation results in a detection threshold reduction from a magnitude completeness level (M_c) of ~4.7 for MAR events recorded by the land-based seismic networks to M_c=3.0 using hydrophone arrays. From February 1999 to December 2002, 14,881 earthquakes were located along the MAR and throughout the Atlantic Ocean basin using hydrophone data, by comparison 6,182 earthquakes were located by land-based seismic (NEIC) networks.

Empirical Orthogonal Function (EOF) analysis was performed on the MAR hydrophone-recorded seismicity. The largest cluster of earthquake activity (first mode at 37.4%) along the MAR south of the Azores occurs on the ridge segment adjacent to the western Kane Transform, the first an ~140 event sequence that occurred from April to July 1999 and the second an ~100 event sequence that occurred from March to May 2002. The ridge segment at 31.5°N 40.5°W exhibits the second highest seismicity rates (mode of 9.8%) with an ~150 event sequence that lasted for 8 days beginning on 5 October 2000. The fourth mode at 6.9% was the 16-17 March 2001 Lucky Strike earthquake swarm which produced 147 events and was shown to be volcanogenic. The fifth mode was a small 17 event swarm that occurred on 12-13 December in 2002 at the 26.5°N ridge segment, just north of the TAG hydrothermal vent field. The final sixth mode occurs at 22°N, however this location is present in the first and third modes as well indicating the 22°N location is the site of pervasive, steady-state seismicity. The largest sequence north of the Azores (47.5% of the variance) was a 20 event sequence on 28 September 2002 located at 47.8°N 27.8°W. The ridge segment at 41.7°N 29°W exhibits the second highest seismicity rate (mode at 20.6%) with an 18 event sequence on 3 November 2002. MAR transform faults are conspicuous for their paucity of earthquakes, exhibiting infrequent seismicity that represents less than 5% of the mode of variability. This is in contrast to transforms on fast and intermediate-rate ridges that exhibit much higher rates of seismicity. Aseismic slip occurring in the presence of serpentinite has been proposed to explain the lack of MAR transform seismicity.

Evidence of recent magmatic activity was detected along the MAR on 16-17 March 2001, when a large earthquake swarm occurred at the Lucky Strike segment (37□N). The Lucky Strike segment is characterized by a broad rift valley (~12 km wide) and is dominated by the 8 km wide, 1 km high Lucky Strike Seamount which hosts a vigorous hydrothermal system and a lava lake Hydrophone data shows, (1) the Lucky Strike swarm began at 1528Z on March 16, continued for ~29 hrs and produced 128 earthquakes, (2) the onset of the swarm was accompanied by 30 minutes of broadband (>3 Hz) intrusion tremor, (3) half of the swarm earthquakes occurred in the first 1.5 hrs reaching a peak of 42 events/hr, thereafter rapidly declined to 5 events/hr, and (4) the swarm's event rate had a non-tectonic decay pattern indicating a volcanic origin. The episode also produced 33 teleseismic earthquakes making it the largest swarm at Lucky Strike in >25 yrs of seismic monitoring, and one of the largest ever recorded on the northern MAR. Submersible investigations of high-temperature vent fields at the summit of Lucky Strike Seamount 3 months after the swarm showed a significant increase in microbial activity and diffuse venting. We interpret the March 2001 Lucky Strike earthquake swarm as representing a magmatic/dike-emplacement episode that may have occurred without an eruption of lava on to the seafloor. This recent magmatic episode may be typical of volcanism along the MAR, where highly-focused pockets of magma produce sporadic intrusions into shallow ocean-crust creating long-lived, discrete volcanic structures and recharge pre-existing seafloor hydrothermal vents and ecosystems.

Temporal observation of the hydrothermal (eco)system on the Lucky Strike vent field

Escartin, J.[1], P.M. Sarradin[2], J. Sarrazin[2], C. Rommevaux Jestin[2] and the MoMARthyni project participants.

[1]IPGP, Paris, France.
[2]Ifremer DEEP, Brest, France

Hydrothermal fields along mid-ocean ridges are zones where processes deep seated in the crust and upper mantle interact with the water column, and sustain peculiar biological communities. Hydrothermal circulation, which is hosted by a porous crust and sustained by the transfer of heat towards the water column, shows important temporal variability, both as part of the "normal" evolution of the system or as a result of events such as earthquakes, volcanic events, or tides. The physical and chemical characteristics of vent emissions are the result of complex rock seawater interactions in the subsurface that forms high temperature hydrothermal fluids. These fluids can be subsequently modified by subseafloor and near surface mixing with background seawater leading to a variety of emitted fluids enriched in gases, metals and radionuclides. Deep-sea hydrothermal communities are dwelling in the interfacial zone where the hot and reduced hydrothermal fluid turbulently mixes with the cold and oxygenated seawater. This zone is highly reactive and produces mineral precipitation and large chemical gradients offering a complex variety of habitats for organisms. This fluctuating environment provides a periodical access to chemical species present both in the vent fluid and in seawater and required for chemolithoautotrophic bacterial primary production but also to potentially toxic species (e.g. heavy metals, radionuclides). The vent communities thriving on chemosynthesis are thus dependant on vent fluid supply for survival and growth. To understand the ecosystem dynamics and the links with the active hydrothermal processes require an integrated study of the whole hydrothermal system, together with the acquisition of time series of chemical, geophysical and biological variables.

We propose to initiate the implementation of an integrated deep sea observatory at the Lucky Strike hydrothermal vent field on the mid Atlantic ridge. The concerted and multidiciplinary strategy will allow the acquisition and integration of data at different spatial and temporal scales. The geophysical studies at the vent field scale will provide a global context to the ecological and microbiological projects performed at vent scales or smaller. Temperature will be used as a tracer of the temporal variability of the hydrothermal system at all the scales studied during the project and linked to other geochemical, geophysical and geological observables.

The main questions that we want to address are: What are the size and nature of hydrothermal systems at slow-spreading ridges? What is the correlation between hydrothermalism, geology, magnetic structure, and fine-scale tectonic structure of the seafloor? What is the correlation between the seafloor distribution of vents and their characteristics, associated ecosystems, and the effect of external environmental factors?

In the long term, through integration of data, we plan to study the system over a period of time of 5-10 years, so as to characterize the temporal evolution natural to the hydrothermal system, the feedback among active processes, the evolution of ecosystems ; determine the response of the system to extraordinary events such as a seismic crisis of possible magmatic origin that took place in early 2001 ; identify the biotic, abiotic or random factors that control the structure and dynamics of ecosystems at varying time-scales.

As plan of the MoMAR inititative, we plan to initiate coordinated field work in 2005 and 2007, with expected yearly fieldwork through 2012 for a first 5-yr phase of integrated studies.

Physical constraints on the dynamics and storage of brines in mid-ocean ridge hydrothermal systems

Fontaine, F.J.[1], W.S.D Wilcock[2] and M. Rabinowicz[3]

[1] University of Washington, School of Oceanography, Box 357940, Seattle, WA, 98195, USA; fontaine@ocean.washington.edu, tel.: (1) 206-543-8956, fax.: (1) 206 543 0275.
[2]University of Washington, School of Oceanography, Seattle, WA, USA
[3]UMR CNRS 5562,Toulouse, France.

Mid-ocean ridge hydrothermal systems are known to vent fluids with salinities substantially different from seawater. This is attributed to phase separation and the segregation of the resulting vapor and brine phases. Time series of vent temperature and salinity (chlorinity) show that some black-smoker vent fields have vented fluids with salinities well below seawater for over a decade. This raises important questions concerning chloride mass conservation and the fate of brines in these systems. One widely accepted model is that high-density brines formed during super-critical phase separation sink efficiently to the base of hydrothermal systems, leading to the development of a two-layer system in which a re-circulating brine layer underlies a single-pass seawater cell. However, there is no conclusive evidence for such a two-layer configuration or for the assumption that a brine layer will convect. In this study we first present theoretical arguments to constrain the dynamics of such a deep brine layer. From an analysis of brine properties in the two-phase area, we conclude that, if brines are stored in a layer at the base of high-temperature mid-ocean ridge hydrothermal systems they are unlikely to convect because phase separation will lead to a stable stratification. One consequence of this result is that the brine layer beneath black smoker systems has to be thin (< 10m) to match the high heat fluxes. However, estimates of the rate at which brines are accumulating in the crust below the Main Field on the Endeavour segment of the Juan de Fuca Ridge and below vents near 9^{o}50'N on the East Pacific Rise suggest that the brine layer is likely at least 100 meter thick. To resolve this apparent paradox we propose an alternative model which we support with both conceptual arguments and inferences from single-phase numerical models. It is generally believed that the pressure gradients in mid-ocean ridge hydrothermal systems are close to cold hydrostatic. At the high temperatures and pressures characteristic of the deeper parts of these systems brines with salinities as high as 20-30 wt% NaCl have densities around 800-900 kg/m^3 and will be buoyant in a cold-hydrostatic system. We argue that interfacial tensions between fluid and solid phases will likely favor the segregation of vapor into the main fractures and brine into the smaller fissures and backwaters. This allows the vapor to flow efficiently through the system and transport large heat fluxes while most of the porosity in the lower part of the system fills with brines that will rise only slowly because of their higher density and viscosity and the low permeability of brine filled fissures. Our numerical models suggest that brines that rise will reach a level of neutral buoyancy as they cool and enter high permeability regions in which the pressure gradients decrease.

Understanding peridotite-hosted hydrothermal systems: Insights from geochemical studies of the Lost City hydrothermal system (MAR, 30°N)

Früh-Green,Gretchen L.[1], Deborah S. Kelley[2], Adélie Delacour[1], Stefano M. Bernasconi[1], Giora Proskurowski[2], David A. Butterfield[2]

1Department of Earth Sciences, ETH-Zurich, Sonneggstrasse 5, CH-8092 Zurich, Switzerland, frueh-green@erdw.ethz.ch, tel. +41 1 632 3794, fax +41 1 632 1088
2University of Washington, School of Oceanography, Seattle, WA, USA

The Lost City Hydrothermal Field (LCHF) is a rare example of an active peridotite-hosted hydrothermal system, in which reactions between seawater and ultramafic rocks produce high alkaline (pH 9 to 11) fluids that are venting at 25 to 90°C and result in the formation of up to 60m tall carbonate-brucite structures. The fluids are enriched in hydrogen, methane and other hydrocarbons, and support dense microbial communities [Kelley et al., 2005]. Fractures and faults in the basement provide permeable pathways that control outflow at the main vent sites. In addition to the subvertical faults that channel flow to the largest vent structures, much of the subsurface flow is along subhorizontal surfaces and produces carbonate deposits parallel to the basement foliation and subparallel to gently west-dipping faults.

During an extensive, multidisciplinary field campaign in 2003, ten discrete active vent sites were sampled for co-registered fluids, rocks, and biota. Major element chemistries of the fluids show linear correlations of Mg concentrations with Ca, pH, SO_4 and carbonate alkalinity, and reflect mixing of seawater with high pH, zero-Mg and low sulfate end-member fluids. Sites that are venting at temperatures >65°C have the lowest sulfide concentrations. In the high pH (10-11) end-member fluids, carbonate alkalinity is low and carbonate ion (CO_3^{2-}) is the dominant form of dissolved inorganic carbon (DIC). This distinguishes the Lost City fluids significantly from black smoker environments and dictates that autotrophic organisms in the LCHF vents must be adapted to a low DIC, CO_2-poor and H_2-rich environment [Kelley et al., 2005]. End-member fluid compositions are characterized by enriched O-, H-, C-, and S- isotope compositions that reflect a variable influence of abiogenic processes in the basement and microbial activity at the vent sites. A co-variation of $\delta^{13}C$ (DIC) and sulfate concentrations in the fluids suggests active sulfate reduction in the vent structures and/or in the shallow serpentinite subsurface. Sulfur contents in bulk-rock serpentinites indicate addition of sulfur during serpentinization with S-isotope compositions close to seawater. Most of the sulfur is present as sulfate and the $\delta^{34}S$ values of extracted sulfides suggest that sulfide formation is linked to sulfate reduction. Sulfate reduction also likely contributes to variability in C-isotope compositions observed in DIC and in the carbonate minerals forming the structures. Carbon and oxygen isotope data of the vent structures provide further evidence for local methanogenesis as well as methane oxidation. Our studies indicate that mixing of seawater with hydrothermal end-member fluids that are rich in hydrogen and methane and poor in CO_2 and SO_4 is an important process in hydrothermal carbonate precipitation at Lost City. Our results are consistent with microbiological and organic geochemical studies, which document the presence of distinct methane and sulfur cycling microbial communities at the LCHF [Kelley et al., 2005]. Collectively, the isotopic compositions of the vents and basement rocks, measured fluid temperatures, and ^{14}C ages of the vents [Früh-Green et al., 2003], sediments and veins provide evidence that hydrothermal fluid flow and temperatures of ~100°-150°C have likely been sustained in the basement for many tens of thousands of years.

References:
Kelley, D.S. et al., (2005) A Serpentinite-Hosted Ecosystem: The Lost City Hydrothermal Field. Science, 307(5714), 1428-1434.
Früh-Green, G.L., et al., (2003) 30,000 years of hydrothermal activity at the Lost City vent field. Science, 301(5632):495-498.

Photo-mosaicing for environmental characterization: why is it so difficult?

Garcia R[1], J. Ferrer[1], R. Prados[1], M. Villanueva[1], and J. Escartin[2]

[1]Computer Vision and Robotics Group, University of Girona, Campus Montilivi, Edif. P-4, Girona, Spain, E-17003. E-mail: {rafa,jferrerp,rprados,miki}@eia.udg.es.
[2]Geosciences Marines. IPGP – CNRS. Paris, France. E-mail: escartin@ipgp.jussieu.fr.

Background
The ocean floor may provide a huge and rich amount of information when viewed from a camera. If images are systematically acquired and properly aligned, a composite image that combines the set of frames taken from the camera can be built. This composite image is known in the literature as *photo-mosaic*, and can be used as a visual map for undersea exploration and research. In order to construct ocean floor photo-mosaics, the individual images forming the mosaic are usually obtained by setting a camera on an underwater vehicle. The camera looks down and the acquired images cover a small area of the ocean floor. From a scientific viewpoint, photo-mosaics allow the geological analysis of the ocean floor structure, obtaining a global viewpoint of the interest site. At the same time, underwater photo-mosaics provide high-quality images of georeferenced areas for the study of biological communities. For this reason, development of algorithms for the automatic alignment of overlapping images of the ocean floor is desirable.

Difficulties building mosaics of the Mid-Atlantic Ridge
Building photo-mosaics of the Mid-Atlantic Ridge has to cope with a series of problems. First, photographic still cameras are frequently used in scientific surveys to get information from the ocean floor. However, the acquired images normally exhibit a low overlap, making the process of image alignment difficult. Additionally, artificial light sources tend to illuminate the scene in a non-uniform fashion. Therefore, application of image processing techniques to underwater imaging requires dealing first with this added problem. On the other hand, previous works in automatic construction of photo-mosaics have been limited to processing planar environments of small-sized areas ($<20\times20$m), while most of the regions of interest for the scientific community are spread over larger areas (>1 Km^2) with 3-dimentional (3D) relief. Moreover, even with small 3D terrain relief, a rigid motion of the light source and camera set (due to vehicle motion) creates a shift of the shadows induced in the scene. These shadows generate an apparent motion in the image sequence in the opposite direction to the real motion.

State of the art
In the last few years, video mosaics have been used as a low-cost sensor to estimate the position and orientation of underwater robots. In this case, a video camera carried by the underwater vehicle takes images of the ocean floor, and its position and orientation is computed by integrating the apparent motion of the images which form the mosaic. In this situation, consecutive images exhibit a large overlapping area, facilitating automatic estimation of motion. Although the algorithms and techniques developed by the Computer Vision and Robotics group of the University of Girona allow fully automatic motion estimation from video, as the video mosaic increases in size, a systematic bias is introduced in the alignment of the images which form the mosaic. Therefore, this cumulative error produces a drift in the estimation of the position of the images. However, development of tools to build photo-mosaics of the MOMAR area can take profit of the existence of acoustic transponder networks in some of the sites of interest (e.g. *Lucky Strike* area), solving the drawback of drift accumulation in video mosaicing techniques. On the other hand, new techniques are required to build mosaics from still images with a small overlap in an automatic way.

Methodology
We present a feature-based mosaicing method that we are developing for deep-sea underwater exploration using ROVs, AUVs and HOVs. The creation of the mosaic is accomplished in six stages: (1) image pre-filtering and feature selection; (2) detection of correspondences between consecutive images; (3) robust dominant motion estimation; (4) detection of non-consecutive overlapping images; (5) iterative global alignment; and (6) mosaic rendering. Once the mosaic has been created, an efficient solution is proposed to enable loading, viewing and editing large-scale photo-mosaics ($>150{,}000\times150{,}000$ pixels). The system is able to provide metric information using the knowledge of the intrinsic parameters of the camera while integrating the measurements of navigation data of the

vehicle. Moreover, this system will allow the analysis of the temporal evolution of both existing ecosystems and morphology of the underwater terrain with mosaics built from temporally successive surveys.
The experimental results on real images are shown both for coastal waters in Costa Brava (Spain) –where these techniques are being developed and tested– and to a small area of the Lucky Strike vent field. We plan to expand this technique to the LUSTRE'96 image dataset (>20,000 digital images), and make it available for other surveys of this type in this area or elsewhere.

Attended deliverables
Development and improvement of mosaicing techniques adapted to deep-sea underwater image surveys will allow us to construct mosaics of large areas of interest (i.e., hydrothermal vent fields), and the interfaces to allow scientists to visualize the mosaics and extract data from them. We plan to complete the mosaic of the LUSTRE'96 data over the Lucky Strike hydrothermal field, and make it available with a mosaic browser to the larger MOMAR scientific community. This project will also encompass and integrate future surveys in this and other areas.

Fig. 1. Video mosaic of the coastal water of Costa Brava (Spain). Image alignment has been computed using an affine model with 6 DOF. Notice the large overlap (>90%) between consecutive frames.

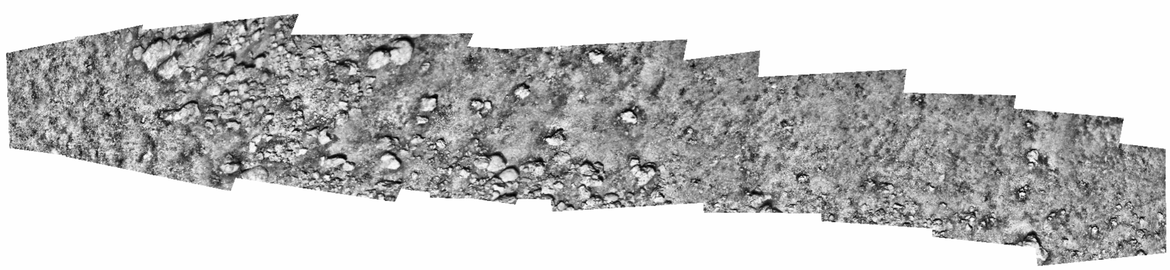


Fig. 2. Sample mosaic segment of LUSTRE'96 campaign (Mid-Atlantic Ridge). Image alignment has been computed using a projective model with 8 DOF. Notice the small overlap between images.

Mixed Iron Valences at Bacterial Surfaces From Hydrothermal Vents.

Gloter A [1], M .Zbinden, [2], F. Guyout[3], F. Gaill, [2], C. Colliex [1]

[1] Laboratoire de Physique des Solides. Universite Paris Sud UMR 8502 Orsay 91405 FRA
[2] Adaptations aux milieux extremes, UPMC, UMR 7138 7, quai Saint Bernard, Paris 75005 FRA.
[3] LMCP-IPGP 4 place Jussieu, Paris 75005 FRA

The atlantic shrimp *Rimicaris exoculata* seems to play an important role in iron dynamics at Atlantic hydrothermal sites. In this study, we have studied biomineralization associated to the epibionts of *Rimicaris exoculata*, collected at the Rainbow (Mid Atlantic Ridge) hydrothermal vent site. The structure, morphology and impurities distributions of the minerals were analyzed by Transmission electron microscopy and electron energy loss spectroscopy. The main minerals observed are clusters of two-lines ferrihydrite, found attached to the bacterial cells present in the gill chamber of the shrimp. EELS measurements at the Fe 2p excitation demonstrate that both 2+ and 3+ states are recorded from the ferrihydrite clusters. This anomalous behaviour of ferrihydrite might be related to its intimate mixing, at the nanometer scale, with Fe2+-bearing organic mater. The specific biomineralization mechanism might be a key to the stabilization of this phase.

Metallothioneins and metals in sponges from the genus Cinachyra from Monte Saldanha hydrothermal vent

Gomes, Tânia [1], Angela Serafim[1], Rui Company[1] & Maria João Bebianno[1]

[1]University of Algarve, CIMA, Faculty of Marine and Environmental Sciences, Campus de Gambelas, 8000-139 Faro, PORTUGAL, a18390@ualg.pt, +351289800900 (telephone), +351289818353 (fax)

Hydrothermal vents are one of the most extreme habitats of the deep sea, characterized by high pressure and temperature, as well as high concentrations of sulphides, methane and metals. Sponges are one of the filter feeders that can be found on these environments, although the information about these animals in hydrothermal vents is still scarce. The specialised adaptations which allow organisms to exploit vent habitats include the ability to regulate intracellular metal concentrations by excretion or accumulation of metal-ions in non-toxic forms. The presence of metallothioneins allows the detoxication of metals by metal-binding, protecting the cells from the toxic effects of the metals.

The aim of present study was to determine the metallothionein, total protein and metals concentrations presents (cadmium, copper and zinc) in the genus Cinachyra from Monte Saldanha hydrothermal vent and the relationship between them.

The specimens were collected in the Mid-Atlantic Ridge hydrothermal vent Monte Saldanha in 2001, and were frozen for preservation. After homogenisation of the sponges tissue, metallothionein levels were determined by differential pulse polarography according to Bebianno & Langston (1989), total proteins according to Lowry et al. (1951), and metals concentrations (cadmium, copper and zinc) in total and subcellular fractions of the tissue (pellet and heat-treated cytosol) by atomic absorption spectrophotometry.

The concentrations of metallothioneins and total proteins in the genus Cinachyra were 224,47 ± 75,04 µg/g dry weight and 10,74 ± 4,56 mg/g, respectively. Metal concentrations for cadmium ranged between 1,92 ± 0,35 and 3,32 ± 0,17 µg/g d.w. for total, 0,092 ± 0,008 and 0,739 ± 0,13 µg/g d.w. in the pellet, and 0,012 ± 0,002 and 0,590 ± 0,14 µg/g d.w. in the heat-treated cytosol fraction. For copper, the values ranged from 5,80 ± 0,76 and 28,28 ± 6,73 µg/g d.w. for total, 0,797 ± 0,19 and 14,10 ± 4,52 µg/g d.w. in the pellet, and 0,45 ± 0,041 and 6,61 ± 1,20 µg/g d.w. in the heat-treated cytosol fraction. And for zinc, the concentrations ranged from 222,49 ± 63,14 and 9027,12 ± 687,35µg/g d.w. for total, 130,79 ± 17,42 and 5221,45 ± 442,01 µg/g d. w. in the pellet, and 11,65 ± 2,87 and 2961,88 ± 503,97 µg/g d. w. in the heat-treated cytosol fraction.

The results indicate that these sponges possess significant metallothionein concentrations, and a high concentration of zinc, when compared with cadmium and copper. However, no significant relationships between metallothionein, total proteins and metals concentrations were found, suggesting that these proteins may not be the most important metal detoxification mechanisms in these hydrothermal vents animals.

Seismicity of the Mid-Atlantic Ridge at a regional scale: results from acoustic monitoring by two arrays of autonomous hydrophones

Goslin, J. [1], J. Perrot[1], J.-Y. Royer[1], C. Martin[1], R. Dziak[2], C. Fox[2], M. Fowler[2], J. Haxel[2], H. Matsumoto[2], N. Lourenço[3,4], J. Luis[3], S. Bazin[5] (the "SIRENA" Team)

UMR6538 "Domaines Océaniques", IUEM, UBO, Technopole Brest Iroise, 29280 Plouzané, France
Oregon State University/NOAA, Newport, OR, U.S.A.
Centro de Investigação Marinha e Ambiental, Universidade do Algarve, Faro, Portugal
Centro de Geofisica da Universidade de Lisboa, Portugal
Laboratoire de Géosciences Marines et Observatoire Volcanologique et Sismologique de la Guadeloupe, Institut de Physique du Globe de Paris, France
Contact: goslin@univ-brest.fr

The seismicity of the North Atlantic was recorded by two networks of hydrophones moored in the SOFAR channel, north and south of the Azores Plateau. The interpretation of the hydro-acoustic signals recorded during the first seven-month common period of operation of the two networks (1 June 2002 to 31 Dec. 2002) provides a unique data set on the spatial and time distributions of the numerous low-magnitude earthquakes which occurred along the Mid-Atlantic Ridge. More than 2000 events were localized along the MAR during this seven-month period between the Equator and 60°N, 480 of which are localized within the SIRENA network (40°20'N-50°30'N) and 721 within the wider-spread South Azores network (16°N-34°30'N).

The spatial distribution of the seismicity rate vs. latitude shows a remarkable first-order long-wavelength pattern: the seismicity rate is low when approaching the Azores and Iceland (reaching values as low as 10 events/d°), while it peaks to 70 events/d° in the vicinity of the Gibbs FZ. Moreover, the latitudinal distribution of the seismicity hints at an asymmetric influence of the Azores hotpot on the MAR. Finally, the spatial distribution of the seismicity anti-correlates well at long wavelengths with the zero-age depths along the MAR and correlates with the zero-age Mantle Bouguer (MBA) anomaly values and the Vs velocity anomalies at 100 km in the upper mantle. It is thus proposed that the seismicity level would be partly tied to the rheology and thickness of the brittle layer and be thus dependant on the thermal regime of the upper mantle. The seismicity distribution could then be used as an additional tool to characterize the along-ridge influence of the Azores and Iceland hotspots on the MAR slow-spreading center.

Even if a seven-month period can in no way be considered representative of the long-term temporal distribution of the seismicity, some preliminary results can nevertheless be derived from a qualitative appraisal of the temporal seismicity rate along two 3 degree-long sections of the ridge: 167 events were detected along an "high-activity" section of the ridge, between 46°N and 49°N, while only 21 events occurred along the "low-activity" 36°N - 39°N section. The seismicity of the 'high-activity' section appears characterized by higher-activity episodes, with more than 10 events occurring during five of the three-day periods - an additional hint for a tectonic origin of the sequences -. Conversely, the seismicity of "low-activity" section is more evenly distributed through time, a maximum of 4 events occurring within only one of the three-day periods.

Future work will shortly begin on this data set (which will soon be complemented by the localization of seismic events which occurred during the remaining 9 months of common operations of the two networks). A more comprehensive analysis of the space and time distributions of epicenters along the entire section of the MAR influenced by the Azores plume will be conducted. In addition, a more detailed analysis of the acoustic signals themselves will help and characterize the processes (tectonic or magmatic) which generate the event sequences observed along the MAR. Finally, we believe that our preliminary results fully justify the need for a long-term monitoring of the entire section of the MAR which undergoes at various degrees the influence of the Azores plume.
This work will strongly benefit from the recruitment of a PhD student, in the Work Package #1 of the Marie Curie Researh Training Network "MOMARNet". The recruitment is now completed and the PhD work should begin very shortly in Brest.

Characterization of Bathymodiolus azoricus symbiontic bacteria by 16 S rRNA cloning and FISH analysis.

Hoarau, Pascal and Maria João Bebianno

CIMA, Laboratory of Ecotoxicology and Environmental Chemistry, FCMA, University of Algarve, Campus de Gambelas, 8000-870 Faro, Portugal. Email phoarau@ualg.pt, tel: +351289800900, Fax: +351289818353

Symbioses between chemoautotrophic bacteria and marine invertebrates were first described approximatively 25 years ago from the Pacific hydrothermal vent giant tube worm Riftia pachyptila [Cavanaugh et al., 1981]. In mussels, two families of symbionts the thioautotrophic and the methanotrophic were described in the epidermal cells of gills [Distel et al., 1995; Fiala et al., 2002].

In the present work, two distinct sequences encoding for 16S rRNA genes of ≈ 1500 bp corresponding to 95% of the complete gene were cloned. Phyllogenetic analysis comparing both cloned sequences and those from a variety of reference bacteria demonstrate that the Bathymodiolus azoricus symbionts are derived from members of the gamma-subdivision of the Proteobacteria. The first sequence, named Ba1 (for Bathymodiolus azoricus 1), is clearly related to the thioautotrophic symbiotic bacteria (GenBank accession number: AY951931) and the second, Ba2, to the methanoautotrophic symbiotic bacteria (Genbank accession number: AY951932). Theses two sequences represent two new species closely related to the thioautotrophic MAR 1 (99 % of identity with Ba1) and to the methanoautotrophic MAR 2 (98 % of identity with Ba2) symbionts of Bathymodiolus puteoserpensis described by Distel et al. [1995].

To confirm the presence of these bacteria species in the gills of Bathymodiolus azoricus a fluorescent in situ hybridization was performed using both epifluorescent and confocal analyses with two set of probes specific of thioautotrophic and methanoautotrophic 16S rRNA bacteria. The result obtained are in agreement with the information already published about location of symbiontic bacteria and provide a new tool for location of a specific symbiont specie in Bathymodiolus azoricus.
The present molecular tool was further used for the localisation inside the symbiontic tissue of the interest mRNAs encoding for proteins involved in the detoxication processes.

Cavanaugh,-C.M.; Levering,-P.R.; Maki,-J.S.; Mitchell,-R.; Lidstrom,-M.E., 1981.Symbiosis of methylotrophic bacteria and deep-sea mussels. nature. vol. 325, no. 6102, pp. 346-347
Distel, -L.D.; Lee, -H. K.W.L; Cavanaugh -C.M., 1995. Intracellular coexistence of methano- and thioautotrophic bacteria in a hydrothermal vent mussel. Proc. Natl. Acad. Sci. vol. 92, pp. 9598-9602.
Fiala-Médioni A., McKiness Z.P., Dando P., Boulegue J., Mariotti A., Alayse-Danet A.M., Robinson J.J., Cavanaugh C.M., 2002. Ultrastructural, biochemical, and immunological characterization of two populations of the mytilid mussel Bathymodiolus azoricus from the Mid-Atlantic Ridge: evidence for a dual symbiosis. Marine Biology vol. 141, pp. 1035–1043

Spatial distribution and metabolic diversity of hyperthermophilic microorganisms in active hydrothermal sulfide deposits from the Endeavour segment, JdFR

Holden, James F. [1] *and Deborah S. Kelley*[2]

[1]Department of Microbiology, University of Massachusetts, N203 Morrill Science Center IV North, Amherst, MA USA 01003; jholden@microbio.umass.edu, (tel) 413-577-1742, (fax) 413-545-1578
[2]School of Oceanography, University of Washington, Seattle, WA USA

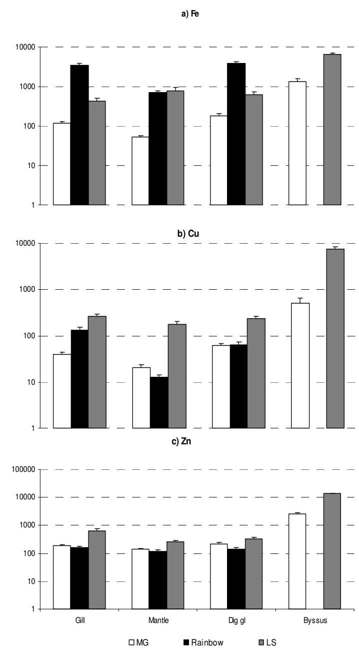
Six small active sulfide chimneys and an in situ incubator containing three growth chambers that had been deployed inside a large active sulfide structure for 9 months were collected from the Endeavour segment of the Juan de Fuca Ridge in 2004. Slurries were made from the soft porous marcasite-wurtzite-sphalerite interior region of the small sulfides and from the material deposited within the growth chambers using anoxic and reduced artificial seawater. These were used to inoculate anoxic media for hyperthermophilic microorganisms (optimal growth above 80°C) that used either organic carbon (i.e., heterotrophs) or CO_2 (i.e., autotrophs) for growth as well as mixtures of sulfur, poorly crystalline iron (mostly $Fe(OH)_3$), CO_2 and nitrate as potential terminal electron acceptors. They were then incubated at 95°C for up to 72 h. H_2 and CH_4 were measured from the headspace at various time points during incubation.

H_2 production was measured in heterotroph incubations from 5 of the 6 small sulfide chimneys. These had venting fluid temperatures of 204-305°C while the sixth chimney was venting 363°C fluids and was rich in anhydrite suggesting that its interior was too hot to support life. No heterotrophic growth was observed in the growth chamber incubations. In contrast, significant H_2 consumption was observed in autotroph incubations only in material from the two coolest growth chambers (1-204°C) and not in any of the small chimneys. Heterotrophic and autotrophic growth were observed in incubations containing a combination of 0.1% (w/v) elemental sulfur, 100 mM poorly crystalline iron and 20% (v/v) CO_2 as terminal electron acceptors but not in any incubations that also contained 10 mM KNO_3 suggesting that it inhibits growth at 95°C. No CH_4 was detected in any of the incubations. Pyrococcus spp. were cultured from each of the five heterotroph incubations that showed growth. These strains were capable of both elemental sulfur reduction and H_2 production. H_2 oxidizing iron reducers were grown from the two autotroph incubations that showed H_2 consumption. No methanogens or nitrate reducers could be cultured from any of the incubations. These preliminary data suggest that heterotrophs that grow at 95°C may be prevalent in small active sulfides, which are generally heavily colonized by macrofauna and may be the source of the organics for these hyperthermophiles in situ, while autotrophs are more prevalent in the interior of larger sulfides where very few animals are observed on their exterior. Furthermore, the prevalence of iron reducers over methanogens in the autotroph incubations suggests that the fluid chemistry within the structure favor the former metabolism. Using microbe-fluid chemistry relationships in anoxic aquatic sediments as a reference, the fluids in the growth chambers may have had reduction potentials and H_2 concentrations > - 330 mV and < 7 nM, respectively. The use of hyperthermophiles as a chemical tracer in vents is ideal since these organisms will not grow below 55°C in oxygenated fluids and are not generally found in background seawater that may contaminate a collected sample.

Tissue partitioning of micro-essential metals in the vent bivalve Bathymodiolus azoricus and associated organisms (endosymbiont bacteria and parasite polychaete) from geochemically distinct vents of the Mid-Atlantic Ridge

Kádár, Enikõ[1], Valentina Costa[2], Ricardo S. Santos[3] and Jonathan J. Powell[4]

[1,2,3]Department of Oceanography and Fisheries, University of Azores, Rua Cais de Santa Cruz, 9900 Horta, Portugal
[4]Department of Nutrition & Dietetics, Kings College London, 150 Stamford Street, London SE1 9NN, United Kingdom



Hydrothermal ecosystems are built on highly specialized organisms possessing effective adaptation mechanisms to tolerate elevated levels of toxic heavy metals typical at these extreme habitats (Desbruyeres et al., 2001; Kadar et al, 2005). Bioavailability and tissue compartmentalization of micro-essential metals (Cu, Zn, and Fe) is reported in the bivalve Bathimodiolus azoricus (von Cosel, 1999) from three geochemically distinct hydrothermal vents: Menez Gwen, Lucky Strike and Rainbow (Charlou, 2000). Additionally, in order to make inferences on the effect of biological interactions on the metal uptake, the bivalves' endosymbiont bacteria and commensal parasite Branchipolynoe seepensis (Jolivet, 2000) were analyzed for metal bioaccumulation. Micro-essential metal concentrations in byssus threads exceeded many-fold concentrations in gill and digestive gland, which in turn were consistently one order of magnitude above levels measured in mantle. Thus byssus thread is suggested to be the main route of metal excretion, and detoxification for micro-essential metals in the vent mussel. Inter-site comparison revealed highest Fe concentrations in tissues of mussels from Rainbow, whereas Zn and Cu in all tissues were highest in mussels from L. Strike, and which reflect metal concentrations in the water surrounding macro-invertebrates at each vent.

The omnipresence of the commensal parasite polichaete in gills of B. azoricus from Lucky Strike vent field is suggested to be an adaptation to the typically elevated Fe concentrations in the water column near mussel beds. Unprecedented Fe concentrations were measured in the digestive gland of mussels from Rainbow (4000 ppm) that were 3 times higher than levels in bivalves from polluted sites (Bustamante et al., 2000), and which call for further post-capture ecotoxicological investigations of potentially novel Fe-handling strategies.

We provide the first information on the bioaccumulation potential of hydrothermal organisms by calculation of concentration factors for the aforementioned metals in the bivalve host gills and also in its endosymbiont and/or parasites.

	CF-gill			CF-bacteria	CF-polychaete
	L. Strike	M. Gwen	Rainbow	M. Gwen	L. Strike
Cu	3715,9	3549,9	1043,7	740,0	1974,9
Fe	1114,7	10036,2	16442,9	4312,8	2184,9
Zn	12579,3	43512,2	4739,8	3662,8	7005,8

References:
Bustamante, P, et al., 2000. Marine Pollution Bulletin 40, 688-696. Charlou, J. L., et al., 2000. Chemical Geology 171 (1-2): 49-75.
Desbruyeres D., et al., 2001. Deep-sea research Part I-Oceanographic research papers 48, 1325-1346.
Jolivet, D., et al., 2000. Journal of Marine Biological Association U.K., 80: 55-68.
Kádár, E., et al., 2005. Journal of Experimental Biology 208, 505-513
Von Cosel, et al.,1999. Veliger 42, 218-248.

Iron biogeochemical processes associated with symbiotic shrimps in deep-sea hydrothermal environments

Bris, N. Le [1], M. Zbinden[2,3], B. Shillito[2], P. Compère[3], F. Gaill[2]

[1]IFREMER Département Etude des Ecosystemes Profonds, BP 70, 29280 Plouzane, France, nlebris@ifremer.fr, +332 98 22 40 85, +33 2 98 22 47 57.
[2]UMR 7138 Adaptation aux Milieux Extremes, 7 Quai Saint Bernard, 75252 Paris cedex 05, France
[3]Institut de Zoologie, Université de Liège, 22 Quai Van Beneden, B-4020 Liege, Belgium

Iron redox cycling is a key biogeochemical process in many aquatic ecosystems. This process was recently pointed out as a significant energy pathway for chemoautotrophy at some deep-sea hydrothermal environments. Resulting of serpentinization processes, Rainbow fluids [Charlou et al., 2002, Douville et al., 2002] are particularly rich in iron and the question was raised of its potential biogeochemical importance to chemosynthetic biological communities at this site.

As for many of the known vent fields on the mid-Atlantic Ridge and Indian Ridge, the shrimp Rimicaris exoculata dominates the macrofauna of the Rainbow vent field. This species harbors a rich bacterial epibiosis in its gill chamber that was proposed to play a main role in sustaining shrimp swarms of up to several thousand of individuals per meter square [Polz et al., 1998; Gebruck et al., 2000]. The distribution and characteristics of iron oxyhydroxides and bacteria in the gill chamber, together with the chemical and thermal characteristics of the shrimp habitat, suggests that iron oxidation is microbially promoted in this micro-environment and lead us to propose that the certain epibiosis micro-habitat conditions would be favourable to neutrophilic iron oxidisers [Zbinden et al., 2004].

As part of the EC Marie Curie Research and Training Network MoMARNET, a PhD studentship in biogeochemistry/geobiology will be hosted at the French Institute for Marine Research IFREMER (DEEP) and the University of Paris 6 (CNRS-UMR7138 AMEX). It will focus on the development of a geochemical model on the basis of existing chemical and biological data from recent submersible research cruise on the mid-Atlantic Ridge. The aim of project is to quantify the energy budget and dynamics of the iron transformation in association with hydrothermal vent symbiotic shrimps, under the frame of an interdisciplinary collaboration.

Charlou, J.L., Donval, J.P., Fouquet, Y., Jean-Batiste, P. and Holm, N., 2002. Geochemistry of high H2 and CH4 vent fluids issuing from ultramafic rocks at the Rainbow hydrothermal field (36°14', MAR). Chemical Geology, 191(4): 345-359.
Douville, E. et al., 2002. The rainbow vent fluids (36°14'N, MAR): the influence of ultramafic rocks and phase separation on trace metal content in Mid-Atlantic Ridge hydrothermal fluids. Chemical Geology, 184(1-2): 37-48.
Gebruck, A.V., Southward, E.C., Kennedy, H. and Southward, A.J., 2000. Food source behaviour and distribution of hydrothermal vent shrimps at the mid-Atlantic Ridge. Journal of Marine Biological Association U.K., 80: 485-499.
Polz, M., Robinson, J., Cavanaugh, C. and Van Dover, C., 1998. Trophic ecology of massive shrimp aggregations at a mid-Atlantic Ridge hydrothermal vent site. Limnology and Oceanography, 43(7): 1631-1638.
Zbinden, M., Le Bris, N., Gaill, F. and Compère, P., 2004. Distribution of bacteria and associated minerals in the gill chamber of the vent shrimp Rimicaris exoculata and related biogeochemical processes. Marine Ecology Progress Series, 284: 237-251.

Ca-metasomatism at the Rainbow Vent Field: evidences from atypical lithotypes.

Marques, A.F.A [1], F.J.A.S. Barriga, and I.R. Costa

[1]CREMINER and Universidade de Lisboa, Faculdade de Ciências, Dep. Geologia, Edif. C6 Piso 4, 1749-016 Campo Grande, Lisboa, Portugal. afamarques@fc.ul.pt, +351 917407607
[2, 3]CREMINER and Universidade de Lisboa, Faculdade de Ciências, Dep. Geologia, Edif. C6 Piso 4, 1749-016 Campo Grande, Lisboa, Portugal.

Rainbow Vent Field is a serpentinite-rock hosted vent field, located the Mid-Atlantic Ridge (MAR) 36º14'N south of the Azores archipelago. There are still several unsolved questions concerning sub-seafloor processes occurring at the Rainbow Vent Field. Recent works (Lowell and Rona, 2002; Allen and Seyfried Jr., 2004) suggest that there may be a magmatic heat source at Rainbow and new geochemical evidences support these remarks, (Marques et al., submitted). The presence of a gabbroic-type body at depth should explain the unique physical and chemical features observed. During IRIS and SEAHMA cruises, atypical rocks were discovered including rodingitic material and metasomatized rocks. Petrographic observations on rodingitic-type rocks revealed non-pseudomorphic interpenetrating serpentine and chlorite aggregates, with rare bastite and garnet replaced extensively by aragonite. Large euhedral diopside grains are not in textural equilibrium with aragonite and overprint interpenetrating serpentine/chlorite aggregates, (Fig. 1a-b).

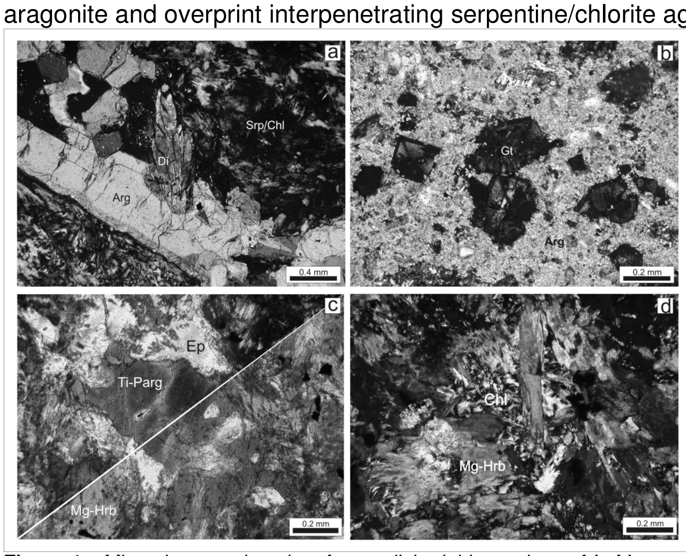


Figure 1 – Microphotographs taken from polished thin sections of **(a-b)** rodingitic material (IR-DR-01-L-01, SH1-PL5-96R) and **(c-d)** metasomatized rock (IR-DR-03-H) from the Rainbow Vent Field.

According to O'Hanley (1996), rodingites can occur within peridotites that underwent serpentinization. The observed assemblages are characteristic of rocks subjected to extensive rodingitization, despite of the protolith, in this case serpentinite. One sample of metasomatized rock was found exhibiting Ti-pargasite being replaced by Mg-hornblende, interstitial chlorite, epidote and rare vesuvianite (Fig.1 c-d). These metasomatized rocks are compatible with mineral assemblages produced during prograde metamorphism (deserpentinization) where metasomatic reaction zones occur with Ca-amphibole, chlorite and the absence of diopside and garnet, (O'Hanley, 1996). Ti-pargasite is indicative of high temperature conditions (temperature peak) followed by lower metamorphic grade assemblages (Mg-hornblende and chlorite). Although rare and atypical, these lithotypes suggest that Ca-metasomatic processes occur at the Rainbow vent field concurrent of the sub-seafloor sulfide mineralization processes. Ca metasomatism may be enhanced by the contact with a magmatic body that provides heat and promotes metasomatic changes.

Allen, D. and Seyfried Jr., W. E. (2004). "Serpentinization and heat generation: Constraints from Lost City and Rainbow hydrothermal systems." Geochimica et Cosmochimica Acta **67**: 1347-1354.
Lowell, R. P. and Rona, P. A. (2002). "Seafloor hydrothermal systems driven by the serpentinization of peridotite." Geophysical Research Letters **29**: 26-1, 26-4.
Marques, A. F. A., Barriga, F. J. A. S., Chavagnac, V. and Fouquet, Y. (2005). "Unraveling the formation of ore-deposits at the Rainbow vent site (36º14'N, 33º54'W; MAR): mineralogy, geochemistry and Nd isotope study." submitted.
O'Hanley, D. S. (1996). Serpentinites. Records of Tectonics and Petrological History. New York, Oxford University Press.

QUEphone: a sentry for hydroacoustic ridge events

Matsumoto, H.[1], R. P. Dziak[1], D. K. Mellinger[1] and C. Meinig[2]

[1]Cooperative Institute for Marine Resource, Oregon State University/National Oceanic and Atmospheric Administration, 2115 SE OSU Dr. Newport, Oregon, USA, 97365, Haru.Matsumoto@noaa.gov, 541-867-0272 (fax 3907)
[2]Pacific Marine Environmental Lab, Engineering Development Division, National Oceanic Atmospheric Administration, Seattle, WA, USA

A new type instrument to support the existing moored autonomous hydrophone arrays (AHA) including NSF and SIRENA arrays is discussed. The North Atlantic arrays have been successfully operated and maintained to monitor hydroacoustic events in the Mid-Atlantic Ridge and its sensitivity to low magnitude events has lead to a discovery of magmatic activities in Lucky Strike segment in Mid-Atlantic Ridge in 2001 [Dziak et al., 2004]. While the moored SOFAR channel AHA is robust and suited for a long-term hydroacoustic monitoring in remote areas, it is not real-time and requires cruises to service the array. As a result there is a delay up to six months after each turn-around cruise before the stored acoustic data are analyzed in the lab and the sources of hydroacoustic events are interpreted and identified. Although the cabled real-time seafloor observatories, e.g., Neptune, have advantages over the moored AHA for its bandwidth and power, installation schedule, location and logistics of maintenance are still yet to be determined [Chave et al., 2004]. A development of an intelligent hydroacoustic system: a **Qu**asi-**E**ulerian hydrophone (QUEphone) is under way at National Oceanic Atmospheric Administration and Oregon State University. The proposed instrument is a tether-free portable float with a single hydrophone which ascends or descends in the water column by its own internal buoyancy engine. In contrast to **ARGO** float, which drifts in mid-water to cover a large area [Roemmich et al., 2004], the QUEphone dives to the seafloor and stays in a relatively small area by anchoring itself on the seafloor with negative buoyancy. Once on the seafloor, an onboard low-power computer starts monitoring for hydroacoustic signal by running an intelligent event detection algorithm. Upon detecting significant number of seismic T-phases from ridge, perhaps accompanied by harmonic tremors, it ascends to the surface to transmit a small data file with its GPS location via satellite to a shore station. The instrument will be a semi-real-time and capable of repeating vertical trips 12 times or up to a year of continuous monitoring. Issues on detecting acoustic events at low false alarm rate and applications of this new technology to monitoring other geochemical properties are discussed.

Seasonal variations in the lipids composition of the hydrothermal vent mussel *Bathymodiolus azoricus* from Menez Gwen

Prieto C.[1] *; Margarida Monteiro*[2] *; Narcisa M. Bandarra*[2]*; Ana Colaço*[1]***

[1]IMAR - Centro da Universidade dos Açores- Cais de Sta. Cruz 9001-382 Horta, Azores, Portugal....
[2]IPIMAR- Instituto de Investigação das Pescas e do Mar - Av. Brasilia 1449-006 Lisboa, Portugal
* To whom correspondence shall be addressed acolaco@notes.horta.uac.pt

The mussel *Bathymodiolus azoricus* dominates communities associated with deep-sea hydrothermal vents from the Azores Triple Junction (ATJ). This species is known to harbour a dual symbiosis (thio- or methanotrophic bacteria) on its gill (Fiala et al. 2002), and use the symbionts for nutritional purposes (Colaço 2002, Pond et al. 1998). Nevertheless, this species has not lost the filter feeding capacity, and some pelagic material has been found on its gut (Colaço 2001, Le Pennec & Prieur 1984). The hydrothermal mussel *Bathymodiolus azoricus* collected in Menez Gwen hydrothermal vent field were examined for patterns of seasonal variations on the total lipids and lipids classes. There was an inverse relation of neutral and polar fractions with the season. Winter was the season with the highest neutral lipid percentage, but with the lowest polar lipid ones. The high neutral lipid content in the winter suggests that a significant part of the total lipids exists as energy reserves in this season. Seasonal variation of fatty acid profile of lipid classes, suggests that the major energy requirement in summer and winter were supplied by bacterial biomarkers 7 MUFAs fatty acids. Nevertheless, during spring the dominant fatty acids were 6 PUFAs .

Biogeography of deep-water chemosynthetic ecosystems - a key component of ChEss, a Census of Marine Life pilot project

Ramirez Llodra, Eva [1], Paul A. Tyler[2] and Christopher R. German[3]

[1] Southampton Oceanography Centre, European Way, SO14 3ZH Southampton, UK
Tel. +44 (0)2380 596446, Fax. +44 (0)2380 593052, E-mail: ezr@soc.soton.ac.uk
[2, 3] Southampton Oceanography Centre, European Way, SO14 3ZH Southampton, UK

ChEss (www.soc.soton.ac.uk/chess) is one of the ten pilot projects within the Census of Marine Life initiative (www.coml.org). The aim of ChEss is to determine the biogeography of deep-water chemosynthetically-driven ecosystems and to understand the processes driving them. The main objectives are to assess and explain the global diversity, distribution and abundance of species from chemosynthetic systems including hydrothermal vents, cold seeps, whale falls, sunken wood and oxygen minimum zones where they intersect the deep seafloor along certain ocean margins. ChEss follows two approaches: 1- development of a web-based relational database for all species from deep-water chemosynthetic ecosystems; 2- development of a long-term international field programme for the exploration for - and investigation of - novel chemosynthetically-driven communities at key locations on the seafloor. Finally, ChEss is also developing a strong outreach and education component.

ChEssBase (www.soc.soton.ac.uk/chess/database/database.html)
ChEssBase is a dynamic relational database available online since December 2004. The aim is to provide taxonomical, biological, ecological and distributional data for all species described from deep-water chemosynthetic ecosystems, as well as information on specific samples and collections. ChEssBase is in constant development and will be integrated with OBIS (Ocean Biogeographic Information System, www.iobis.org) during 2005.

Field Programme (www.soc.soton.ac.uk/chess/field.html)
Within a single programme, it is not practicable to investigate the full extent of the two domains (Mid-Ocean Ridges and Ocean Margins) where vents, cold-seeps, OMZs and large organic falls occur. Instead, the ChEss programme has chosen to select a limited number of key target areas where specific scientific questions most pertinent to biogeographic issues can be addressed. To assess the biogeography and biodiversity of chemosynthetic ecosystems it is essential that all the reducing systems be studied in combination. Furthermore, determining the evolutionary and ecological relationships amongst their fauna is crucial to understanding the processes that shape the distribution of species from chemosynthetic ecosystems at the global scale. Three top-priority regions of study have been selected for concerted ChEss research. The first represents a band of study areas spanning the breadth of the Equatorial Atlantic Ocean and adjacent seas. The second is focused in the exploration and study of the SE Pacific Ocean in the region where the East Chile Rise intersects the Peru-Chile Trench. The third will investigate chemosynthetic sites around New Zealand. ChEss has also identified a suite of additional areas, requiring a lesser degree of international coordination for progress to be achieved.

With the aim to promote international collaborations, avoid duplication of efforts and obtain the maximum return from the research being undertaken at both national and international levels, ChEss has established and is developing robust relationships with other programmes such as MoMAR, InterRidge and Ridge 2000.

Microorganisms/minerals interactions in oceanic hydrothermal environments: new methods for chemical and structural imaging.

Rommevaux-Jestin, Céline, Bénédicte Ménez, and Emmanuelle Gérard

CNRS – IPGP, UMR7047, Case 89, 4 Place Jussieu, 75252 PARIS Cedex 05, FRANCE; rommevaux@ipgp.jussieu.fr; tel : 33 1 44 27 77 23; Fax : 33 1 44 27 99 69

A large diversity of thermo and hyperthermophilic microorganisms (bacteria and archaea) is living around oceanic hydrothermal vents [e.g. Winn et al., 1986; Takai et al., 2001]. Most of the studies performed on this micro-fauna are based on microbial ecology, or fluid/microorganisms interaction. But we know actually that chemosynthetic prokaryotes are able to metabolize a large variety of metals (Fe, Au, As…) [Slobodkin et al., 2001; Holden and Adams, 2003], as well as sulfur or methane. These metals come from hydrothermal fluid, but also from crustal minerals, and it appears finally that life and minerals are inextricably linked and have to be studied jointly. Microbes are generally fixed on minerals through biofilms, and associated to cracks or specific crystallographic plans where they mobilize chemical species they need, thus weathering these minerals (for example on basalts) [Thorseth et al., 2003] but most of the processes remain unknown.

During the MoMARthyni cruise, we propose to i) identify the types of microorganisms found, ii) study the structure of communities as a function of mineral substrates, iii) evaluate how mineral crystallography and chemistry contribute to microorganisms metabolism by characterizing bioalteration patterns but also biominerals and fossilization process.

For this purpose, we plan to sample different oceanic substrates and associated sea water, following a gradient of influence from the hydrothermal fluid discharge zone, and simultaneously deposit colonization baskets containing different mineral substrates in order to establish the microbial preferences in term of mineralized environment. With the MoMAR observatory opportunity, we plan to leave these substrates for various period of time, in order to evaluate the influence of environmental variations, on micro-fauna and their interaction with minerals.

Characterization of these in situ experiments will rely on newly developed analytical protocols, aiming at imaging specifically microbes on mineral surfaces. These developments combine methods emerging from molecular biology (e.g; fluorescent staining, fluorescence in situ hybridization, immunogold detection) together with earth sciences analytical tools (i.e. electron and X-ray microprobes) and will be presented in detail.

Holden J.F. and Adams M.W.W. (2003), Microbe-metal interactions in marine hydrothermal environments, Current Opinion in Chemical Biology, 7, 160-165.
Slobodkin A., Campbell B., Cary S.C., Bonch-Osmolovskaya E. and Jeanthon Ch. (2001), Evidence for the presence of thermophilic Fe(III)-reducing microorganisms in deep-sea hydrothermal vents at 13°N (East Pacific Rise), FEMS Microbiology Ecology, 36, 235-243.
Takai K, Komatsu T., Inagaki K. and Horikoshi K. (2001), Distribution of archaea in black smoker chimney structure, Appl. Environ. Microbiol., 67, 3618-3629, doi: 10.1128/AEM.67.8.3618-3629.2001.
Thorseth I.H., Pedersen R.B. and Christie D.M. (2003), Microbial alteration of 0-30 Ma seafloor and sub-seafloor basaltic glasses from Australian Antarctic Discordance, Earth Planet. Sci. Lett., 215, 237-247.
Winn C.D., Karl D.M. and Massoth G.J. (1986), Microorganisms in deep-sea hydrothermal plumes, Nature, 320, 744-746.

EXtreme ecosystem studies in the deep OCEan: Technological Developments EXOCET/D

Sarradin, P.-M.[1], J. Sarrazin[1], E. Sauter[2], B. Shillito[3], C/ Waldmann[4], K. Olu[1], A. Colaco[5] and the Exocet/d consortium

[1] Ifremer, Brest, France
[2] AWI, Bremerhaven, Germany
[3] UMPC, Paris, France
[4] Univ. Bremen, Bremen, Germany
[5] IMAR, Horta, Portugal
http://w3.ifremer.fr/exocetd/

EXOCET/D is a three-year project starting in 2004 and funded by the European Commission (STREP, FP6-GOCE-CT-2003-505342).

The aim of EXOCET/D is the technological development of a specific instrumentation allowing the study of natural or accidentally perturbed ecosystems found in the deep ocean. These ecosystems are related to the emission of reduced fluids (cold seeps, hydrothermal vents), peculiar topographic structures (seamounts, deep corals), massive organic inputs (sunken woods) or to unpredictable events (pollution, earthquakes). Beside their insularity in the abyssal plain, the targeted ecosystems are characterized by patchy faunal distributions, unusual biological productivity, steep chemical and/or physical gradients, high perturbation levels and strong organism/habitat interactions at infra-metric scales. Their reduced size and unique biological composition and functioning make them difficult to study with conventional instrumentation and require the use of submersibles able to work at reduced scales on the seafloor as well as the development of autonomous instruments for long-term monitoring (seafloor observatories e.g. EU projects ASSEM and ESONET). In addition, the increasing anthropic pressure on these poorly known deep-sea ecosystems emphasises the need for a rapid development of technologies dedicated to their investigation. Several European countries are now purchasing or developing deep-sea underwater vehicles but their acquisition alone is not sufficient to realise effective integrated deep-sea studies. There is an urgent need for fast but long term stable multi-sensor instrumentation that can be either connected to autonomous seafloor observatories or deployed on underwater vehicles.

The general objective of this project is to develop, implement and test specific technologies aimed at exploring, describing and quantifying biodiversity in deep-sea fragmented habitats as well as at identifying links between community structure and environmental dynamics. Onboard experimental devices will complement the approach, enabling experiments on species physiology.

The achievement of the objectives will be attained by a constant collaboration between the technological teams in charge of the development, and the scientists in charge of instrument specifications and final validation. Collection of high resolution data is a crucial step forward to the understanding of factors influencing marine community structure and functioning at small spatial scales. Time- series studies are also essential to understand natural ecosystem dynamics. Cost efficient and reliable solutions will be found to make these instruments suitable for long term deployments on stationary deep-sea observatories or used as payload systems on underwater vehicles. The themes that will be addressed in EXOCET/D include : 3D video imagery and small scale reconstruction, long term video module, potential of acoustic imagery vs video imagery for ecosystem mapping in situ analysis of habitat chemical and physical components using in situ analyser and sensors (methane, flow) associated with water sampling, quantitative sampling of macro- and microorganisms, in vivo experiments in simulated in situ conditions; integration of multidisciplinary and multi scale data on a SIG software, instrument implementation on deep-submersibles sub-systems and scientific validation during demonstration actions, and final submersible cruise in 2006 (MoMARETO, hydrothermal vents, Mid Atlantic Ridge).

The Exocet/d consortium

Institute, Organisation	Person in charge	E-mail	Country
Ifremer	P.M. Sarradin	Pierre.Marie.Sarradin@ifremer.fr	Fr
AWI	E. Sauter	esauter.awi-bremerhaven.de	De
Instituto do Mar	R. Serrao Santos	ricardo@notes.horta.uac.pt	Pt
Instituto Superior Technico	A. Pascoal	antonio@isr.ist.utl.pt	Pt
UPMC	B. Shillito	Bruce.Shillito@snv.jussieu.fr	Fr
CNRS DR17	F. Zal	Zal@sb-roscoff.fr	Fr
Cardiff University	A. Schultz	adam@ocean.cf.ac.uk	UK
Heriot-Wat Univ.	D. Lane	D.M.Lane@hw.ac.uk	UK
Centro de Investigacao Technologica do Algarve	H. du Buf	dubuf@ualg;pt	Pt
Univ. Bremen	C. Waldmann	waldmann@marum.de	De
SeeByte Ltd	A. Cormack	Alastair.Cormack@seebyte.com	UK
Systea srl	L. Sanfilippo	Luca.Sanfilippo@systea.it	It
Capsum Gmbh	M. Masson	M.Masson@capsum.com	De

Spatial and temporal dynamics of hydrothermal communities colonizing the MoMAR zone located on the Azores Triple Junction

Sarrazin, J., P.M. Sarradin and the MoMARETO project participants

Ifremer-Deep, 29 280 Plouzané, France

There is world-wide recognition for the need of long term in situ monitoring of the marine environment. While the intertidal zone and coral reefs have retained much attention because of their accessibility and because their most common species make them well suited to manipulative experiments, technological limitations have delayed observational studies of community structure in the deep ocean. Only recently are we beginning to understand some of the dynamics of deep-sea communities. Even more important, most of the traditional techniques used to evaluate the influence of biological interactions are not yet applicable in subtidal or deep-sea habitats. As a result, our knowledge of the influence of biotic and abiotic factors in these ecosystems is extremely limited compared to shallower environments.

Particularly lacking in the study of abyssal benthic communities are time-series data. Regular visits to the deep-sea are prohibitively costly and ecologists have been slow to develop monitoring instruments to study community dynamics and patterns of succession in distant habitats. Time-series studies provide a means of studying organism growth, faunal succession, biological interactions and the response of species and communities to environmental changes. Thus, abiotic factors appear to have a strong impact on the spatial distribution and temporal dynamics of communities colonizing extreme environments such as hydrothermal vents. The links between the characteristics of the emitted fluid and the spatio-temporal distribution of hydrothermal communities are the result of both a nutritional dependence and also of the adaptation and tolerance of the organisms to the conditions of their habitat.

The main objective of the MoMARETO cruise is to study the spatial and temporal dynamics of hydrothermal communities colonizing the MoMAR zone, located on the Azores Triple Junction. The accomplishment of this objective relies on the implementation of a dedicated instrumentation that will be developed during the funded European EXOCET/D project (see oral presentation by Sarradin et al.). The final integration and validation phase of EXOCET/D will be done during the first leg of the cruise and is almost entirely funded by the European Commission (5 days of cruise/submersible).

The proposed approach for the second leg aims at studying the response of hydrothermal species to their environment and this, at two different temporal scales : a very short term response of the organisms to micro-variations of their milieu (hours-days) and a larger "observatory" type scale where the dynamics of faunal assemblages is linked to habitat variations (months-years). In addition, vent field scale geophysical studies will provide a global context to the different ecological, physiological and microbial projects. This integrated multidisciplinary approach, in which the different processes will be simultaneously observed, is crucial to the understanding of the entire (eco)system. It will take place during separate cruises in 2005 (SISMoMAR and EXOMAR) and 2006 (Graviluck) but in 2007, an integrated cruise is proposed (MoMARthyni, see poster by Escartin et al.). This data, reinforced by past studies within the area, will contribute to the establishment of a long-term observatory on the MoMAR zone.

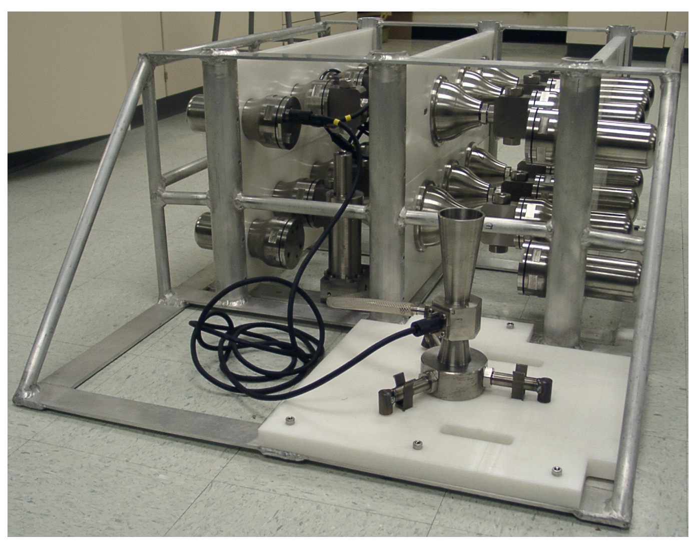
Isosampler – integrated monitoring, analysis and modeling of physical, chemical and microbiological processes at MOMAR

Schultz, Adam [1], Philip Taylor[2], and Michael Flynn[3]

[1]Adam Schultz, College of Oceanic and Atmospheric Sciences, Oregon State University, 104 COAS Admin Building, Corvallis, Oregon, USA, 97331-5503; adam@coas.oregonstate.edu; +1-541-737-9832; +1-541-737-9833
[2]Phil Taylor, School of Earth, Ocean and Planetary Sciences, Cardiff University, Cardiff, UK
[3]Michael Flynn, NASA Ames Research Center, Moffett Field, California, USA

Biogeochemical processes lie at the heart of Earth system science. The metabolic pathways of specially adapted organisms, their production of novel enzymes, and their genome allow us to trace evolutionary relationships back through the phylogenetic tree. This sheds new light on the origin of life on Earth, and points to the possibility that conditions suitable for anaerobic chemolithoautotrophic life may exist or have existed in the past elsewhere in the solar system. The intimate relationship between microbes and the rocks they inhabit is only recently becoming widely understood. Each microorganism influences the chemistry of its immediate environment, leading to changes in mineral deposition patterns, and to the composition of the resulting rock. The *isosampler* project goals are to provide a flexible instrumentation system capable of probing water-rock systems for chemolithoautotrophic biospheres, to identify the physical and chemical conditions that define these microhabitats and the details of the biogeochemical feedback loops that mediate them, and to culture and identify chemolithoautotrophic microbial communities. By carrying out gas-tight high pressure fluid sampling in sets of six or more 1-liter flow-through sample chambers, and by measuring the flow rates and temperatures of diffuse effluent, we can determine the advective heat flux density of vent fluids, the degree of sub-seafloor mixing between black smoker end-member fluids and seawater, and uncover mineralization and microbial processes as they are taking place. By maintaining the pressure of the sampled fluids dynamically, and by working towards regulating the chemical reaction kinetics, (obligate)barophilic chemolithoautotrophs can be characterized.

Under UK NERC, US NASA, EC FP6 and industrial support, we have produced three modular *isosampler* instruments, each operating as a set of individually-addressable, networked modules on a local area network, that will make possible simultaneous physical and chemical sampling and monitoring of hydrothermal and cold seep fluids, and the *in situ* and laboratory incubation of chemosynthetic microbes under high pressure, isobaric conditions. The has been designed with observatory operations in mind at Ridge-2K ISS sites, at proposed sites such as MOMAR, and within the scope of the ORION program. This *isosampler* design builds on the experience of ten years of *Medusa* instrument deployments (combined physical and chemical measurements) at ten vent fields around the world, including Lucky Strike and Menez Gwen within the MOMAR area. Several third-party sensors have been developed, and NASA support is pending to integrate these into *isosampler*. These include an *in situ* flow-through spectral chemistry system, a cavity ringdown $^{12}C/^{13}C$ system, and an intrinsic fluorescence instrument to target and discriminate between biological samples for automated sample collection.



Mid-ocean ridge axial volcanoes: The key to plate construction

Searle, R. C. [1] and Y. Niu[1]

Department of Earth Sciences, University of Durham, South Road, Durham, DH1 3LE, UK;
r.c.searle@durham.ac.uk; phone +44 191 334 2307; fax +44 191 334 2301

The oceanic lithosphere is created at mid-ocean ridges by intrusion and extrusion of mantle-derived melt, constructing abundant volcanoes and a variety of lava flow types. Many, but not all, of these form Axial Volcanic Ridges. These eruptive units record the conditions at which their parental magmas melted, evolved and were emplaced, and provide a window into the deeper crust and mantle. Much is known about the time-averaged processes of magma genesis and crustal formation, but very little about their rates - vital for determining fluxes of melt and heat, and for understanding melting and melt delivery processes and how they vary with time. Numerous observations document episodicity of magma genesis, volcanism and crustal accretion, but we do not know the time scales involved in the various processes. While the morphology of axial volcanoes has been well studies, the time scales of their construction and evolution are very poorly known. Together with colleagues elsewhere we are proposing new approaches to studying the architecture, stratigraphy and temporal evolution of axial volcanoes to address these questions.

Polycyclic Aromatic Hydrocarbons and Antioxidant Responses in the Hydrothermal Mussel Bathymodiolus azoricus

Serafim, Angela[1], Rui Company[1], Belisandra Lopes & Maria João Bebianno[1]

[1] University of Algarve, CIMA, Faculty of Marine and Environmental Sciences, Campus de Gambelas, Faro, PORTUGAL, aserafim@ualg.pt, +351289800900 (telephone), +351289818353 (fax)

Sources of polycyclic aromatic hydrocarbons (PAHs) in hydrothermal vent systems include microbial processing of organic matter in sediments and inorganic hydrolysis of mafic crustal rocks among others. PAHs are known to increase reactive oxygen species (ROS) and therefore interfere with antioxidant enzyme activities in coastal mussels from contaminated areas. In MAR vent fields, hydrothermal mussel Bathymodiolus azoricus are considered the dominant species and no information exists on PAHs concentrations and their effects on the antioxidant defence system in these organisms.

B. azoricus were collected from Menez-Gwen, Lucky Strike and Rainbow during SEAHMA cruise in 2002. PAHs in the whole soft tissues of B. azoricus were determined using HPLC-UV. Antioxidant enzymes (SOD, CAT, TGPx and Se-GPx) and lipid peroxidation (LPO) were determined in the gills and mantle of B. azoricus using spectrophotometric assays.

Results show that B. azoricus from Lucky Strike and Rainbow have significantly higher total PAHs concentrations compared to Menez-Gwen. Moreover, these mussels exhibited mainly low MW PAHs (2 to 3 rings) (>60% in Menez-Gwen and >90% in Lucky Strike and Rainbow) contrarily to what is observed in Mytilus galloprovincialis from contaminated coastal areas. This could result from the high solubility of the smaller PAHs in hot hydrothermal fluids and consequently higher bioavailability to be incorporated in vent organisms. However, only high MW PAHs, Benzo(b)fluoranthene and Benzo(g,h,i)perylene were related to SOD and GPx activities in both tissues. No significant relations were observed between PAHs and CAT activity or LPO. This suggests that high MW PAHs with 5 to 6 rings accumulated in B. azoricus tissues enhance the production of superoxide radicals and consequently SOD increased to detoxify this radical giving rise to hydrogen peroxide. This oxyradical, on the other hand is mainly detoxified by GPx rather than CAT. Antioxidant defence system seems to be efficient against PAHs mediated ROS since LPO remains unchanged.

Acknowledgements: This study was supported by an FCT Grant (SFRH/BPD/8407/2002) and the SEAHMA Project (PDCTM/P/MAR/15281/1999).

Microbiology and biogeochemistry of autotrophic microbes in the subsurface at hydrothermal vents: the potential importance of the reductive tricarboxylic acid cycle for autotrophic carbon fixation

Sievert, Stefan M.[1], Michael Hügler[2], Craig Taylor[2], Carl Wirsen[2], and Roger Summons[3]

[1]Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA, ssievert@whoi.edu, 508-2892305, 508-4572134
[2] Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
[3] Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, 02139

At present, our knowledge about the organisms responsible for inorganic carbon fixation at hydrothermal vents is inadequate, despite the fact that these organisms form the basis of these ecosystems. Available information indicates that microbial symbionts and free-living Thiomicrospira spp. are important in the surface portion of hydrothermal vents. Bacteria belonging to the epsilon subdivision of the proteobacteria (epsilon-proteobacteria) have been identified as a major, if not dominant component of microbial communities in deep-sea hydrothermal vents, ranging from black smoker chimney walls and associations with invertebrates to the shallow subsurface. Given the prevalence of epsilon-proteobacteria at hydrothermal systems, and the fact that cultivated representatives are autotrophic, it is likely that these organisms contribute significantly to primary organic matter production at hydrothermal vents. Recently, others and we have obtained evidence that autotrophic epsilon-proteobacteria are using the reductive TCA (rTCA) cycle for autotrophic carbon fixation. In addition, various other autotrophic and extremophilic microorganisms potentially occurring at hydrothermal vents use the rTCA cycle. These data suggest that autotrophic carbon fixation through the rTCA cycle might be more significant for carbon production at hydrothermal vents than previously thought. This seems especially relevant for the subsurface portion heretofore unconsidered in the overall organic matter production at deep-sea hydrothermal vent sites. We have previously identified a novel sulfur-oxidizing epsilon-proteobacterium that may form an important component of a shallow subsurface biosphere and that uses the rTCA cycle for carbon fixation. This organism excretes filamentous sulfur (0.5 µm wide and 20-500 µm long) as a product of its metabolism that is morphologically and chemically similar to the “snowblower” material observed after hydrothermal vent eruptions. We are pursuing integrated geochemical and biological studies to better define the potential importance of this novel metabolic process as a contributory factor of the subseafloor biosphere.

Local earthquakes on the Endeavour Segment of the Juan de Fuca Ridge: First seismic results from the Keck Seismic/Hydrothermal Observatory

Wilcock, W.S [1], A.H. Barclay[1], P.R. McGill[2], D.S. Stakes[2], T.M. Ramirez[2], D.R. Toomey[3], D.T. Durant[3], E.E. Hooft[3], T.L. Mulder[4], and J.P. Ristau[4]

[1]University of Washington, School of Oceanography, Box 357940, Seattle, WA 98115, USA
[2]Monteray Bay Aquarium Research Institute, 7700 Sandholt Rd. Moss Landing, CA 95039, USA
[3]University of Oregon, Dept. of Geological Sciences, Eugene, OR 97403, USA
[4]Geological Survey of Canada, Pacific Geoscience Centre, Box 6000, Sidney, BC V8L 4B2 Canada

The W.M. Keck Foundation is supporting a five-year program to conduct prototype seafloor observatory experiments to monitor the relationships between episodic deformation, fluid venting and microbial productivity on the Endeavour segment of the Juan de Fuca Ridge and at the intersection of the Nootka fault and the Cascadia subduction zone. At the Endeavour, the experiment is sited near the central portion of the segment in a region where the spreading axis is characterized by a 100-m-deep, 500-m-wide axial valley that hosts five high-temperature hydrothermal vent fields spaced 2-3 km apart. The objectives of the experiment are to monitor local and regional seismicity around the vent fields in conjunction with the deployment of sensors and samplers to monitor temporal variations in the physical, chemical and ultimately microbial characteristics of the hydrothermal fluids. The Endeavour seismic network was installed in the summer of 2003 with the ROV ROPOS and comprises seven GEOSense three-component short-period corehole seismometers and one buried Guralp CMG-1T broadband seismometer. Five of the seven short-period seismometers were inserted in horizontal coreholes drilled into seafloor basalts; two were deployed in concrete monuments on the ridge flanks. It is the first seismic network on a mid-ocean ridge in which the sensors are deployed with an ROV beneath the seafloor in order to ensure good coupling and minimize the effects of current-generated noise. In August 2004, we used the ROV Tiburon to service the Endeavour seismic network and recover the first year of data. In addition, we installed a second broadband and three short period seismometers on the Nootka fault and a third broadband seismometer on the Explorer plate. The Endeavour seismic network performed well with all eight instruments recording high-quality data. A preliminary inspection of the data reveals many examples of local, regional and teleseismic earthquakes. One striking characteristic of the local earthquake records is the high fidelity of the shear wave records. The preliminary analysis of the local earthquake data will be performed as part of an undergraduate research apprenticeship class taught this fall at the University of Washington's Friday Harbor Laboratories.

Upper mantle structure beneath the Azores hotspot from finite frequency Seismic tomography

Yang, T.[1]*, Yang Shen*[2] *and Shu-Huei Hung*[3]

[1]Graduate School of Oceanography, University of Rhode Island, South Ferry Road, Narragansett, RI 02882, USA; email: ty@waves.gso.uri.edu; phone: 1-401-874-6828; fax: 1-401-874-6848
[2]Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882, USA
[3]Department of Geoscience, National Taiwan University, Taipei, Taiwan

The Azores archipelago represents one of the classic hotspots that interact with the mid-ocean ridges and/or the triple junctions. While geochemical studies and a variety of geophysical observables have provided clear evidence for the influence of the mantle plume on the formation of the plateau, the seismic structure beneath Azores has never been imaged directly at regional and local scales. Here we construct the first high-resolution seismic velocity models of the mantle structure beneath the hotspot from teleseismic body waves recorded by 5 portable seismic stations on the Azores islands. Unlike in conventional tomography based on ray theory, the three-dimensional sensitivity kernels of body wave travel times are used to account for waves front healing, scattering, and other diffraction effects of realistic seismic waves. Our results from 175 P-wave relative traveltimes show a pronounced low velocity anomaly in the shallow mantle (~100 km depth) along the Azores islands. The low velocity anomaly becomes elongated in the NE-SW direction at greater depth (100-200 km). From 250 km to at least 400 km depth, the model shows a columnar low-velocity anomaly northeast of Terceira. These results are consistent with geochemical observations and provide seismic evidence for the proposed mantle plume-ridge interaction model, in which the plume conduit bends towards Azores triple junctions, supplying melt preferentially to southeast along a lateral sublithospheric channel. This model can also explain several puzzling questions regarding the formation of the Azores plateau and the evolution of the triple junctions such as the asymmetry of the influence of the mantle plume on south and north of Azores, the triple junction jump and the age distribution of the Azores Islands.

Bacteria and associated minerals in the gill chamber and gut of the vent shrimp Rimicaris exoculata and related biogeochemical processes

Zbinden, M.[1], M.A. Cambon-Bonavita[2], N. Le Bris[3], P. Compère[4], F. Gaill[1]

[1] UMR 7138 Systématique, Adaptation et Evolution, 7 Quai Saint Bernard, Bat A, 4ème étage, 75252 Paris cedex 05, France. Email : magali.zbinden@snv.jussieu.fr. Tel / Fax : 33 1 44 27 35 02 / 52 50
[2] Laboratoire de Microbiologie des Environnements Extrêmes, UMR6197, IFREMER Centre de Brest, BP 70, 29280 Plouzané, France
[3] Département Etude des Ecosystèmes Profonds, IFREMER Centre de Brest, BP 70, 29280 Plouzané, France
[4] Département des Sciences de la Vie, Institut de Zoologie, Université de Liège, 22 Quai Van Beneden, B-4020 Liège, Belgium

The shrimp Rimicaris exoculata dominates the megafauna of some mid-Atlantic Ridge hydrothermal vent fields. This species harbors a rich bacterial epibiosis inside its gill chamber. At the Rainbow vent field, the epibionts are associated with iron oxide deposits. Investigation of both bacteria and minerals by scanning electron microscopy (SEM) and X-ray microanalysis (EDX) shows the occurrence of three distinct compartments in the gill chamber (Zbinden et al., 2004): (1) the lower pre-branchial chamber, housing bacteria, but devoid of minerals, (2) the "true" branchial chamber that contains the gills and remains free of both bacteria and minerals, and (3) the upper pre-branchial chamber housing the main ectosymbiotic bacterial community and associated mineral deposits. According to our chemical and temperature data, abiotic iron oxidation appears to be kinetically inhibited in the environment of the shrimps and this would explain the lack of iron oxide deposits in the first two areas. We propose that, in the third area, iron oxidation is microbially promoted. The discrepancy between the spatial distribution of bacteria and minerals suggests that different bacterial metabolisms are involved in the two compartments. A possible explanation lies in the modification of physico-chemical conditions downstream of the gills, that would reduce the oxygen content and favor the development of bacterial iron-oxidizers in this Fe^{II}–rich environment. This would be unusual for hydrothermal ecosystems, where most previously described symbioses rely on sulphide or methane as an energy source.

A potential role of such iron-oxidizing symbionts in the shrimp diet is suggested. R. exoculata was indeed proposed to graze either on bacteria living on the surface of the chimney (Van Dover et al., 1988), or on its epibiotic bacteria (Gebruk et al., 2000). It has also been suggested that an autotrophic bacterial population living in the shrimp's gut might serve as a nutritional source (Polz et al. 1998). Phylogenetic analyses of the gut microbial population (Zbinden & Cambon-Bonavita 2003) shows that the diversity in the shrimp gut is very low compared to that of the surrounding medium and composed only 3 major groups: ε-Proteobacteria (48,8%), Entomoplasmatales (23,3%) and representatives of the phylum Deferribacteres (26,6%). Furthermore, the presence of groups which are not found in the external medium (Spiroplasma sp. and Geovibrio sp.) suggests the existence of a local microflora. The occurrence of iron-oxidizing bacteria in the gill chamber, and of Deferribacterales (most of which are iron-reducing) in the gut could reveal an iron cycle at the scale of the organism.

Gebruk A., Southward E., Kennedy H. and Southward A. (2000). Food sources, behaviour, and distribution of hydrothermal vent shrimp at the Mid-Atlantic Ridge. J. Biol. Assoc. U.K, 80, pp.485-499.
Polz M., Robinson J., Cavanaugh C. and Van Dover C. (1998). Trophic ecology of massive shrimp aggregations at a mid-Atlantic Ridge hydrothermal vent site. Limnol. Oceanogr., 43(7), pp.1631-1638.
Van Dover C., Fry B., Grassle J., Humphris S. and Rona P. (1988). Feeding biology of the shrimp Rimicaris exoculata at hydrothermal vents on the Mid-Atlantic Ridge. Mar. Biol., 98, pp.209-216.
Zbinden M. and Cambon-Bonavita M.-A. (2003). Occurence of Deferribacterales and Entomoplasmatales in the deep-sea shrimp Rimicaris exoculata gut. FEMS Microbiol. Ecol., 46, pp.23-30.
Zbinden M., Le Bris N., Gaill F. and Compère P. (2004). Distribution of bacteria and associated minerals in the gill chamber of the vent shrimp Rimicaris exoculata and related biogeochemical processes. Mar. Ecol. Prog. Ser., 284, pp.237-251.

In situ measurements of O_2, H_2S, and temperature at mussel beds from the Logatchev hydrothermal vent field

Zielinski, F. [1], F. Wenzhöfer[2], C. Borowski[3], and N. Dubilier[1]

[1]Department of Molecular Ecology – Symbiosis Group, Max Planck Institute for Marine Microbiology, Celsiustr. 1, 28359 Bremen, Germany; fzielins@mpi-bremen.de; Phone: 0049 421 2029 944; Fax: 0049 421 2028 580
[2]Department of Biogeochemistry – Microbial Habitat Group, Max Planck Institute for Marine Microbiology, Bremen, Germany
[3]Department of Biogeochemistry – Biogeochemistry Group, Max Planck Institute for Marine Microbiology, Bremen, Germany

Mussels of the genus Bathymodiolus (Bivalvia: Mytilidae) commonly described from hydrothermal vents at mid-ocean ridges live in dual symbiosis with sulfide- and methane-oxidizing bacteria. Both bacterial endosymbionts reside within the host's gill tissue, inside distinct bacteriocytes. Whereas much effort has been made to characterize the phylogenetical and physiological nature of both the bacteria and the host, only a few studies have attempted to investigate the biogeochemical conditions at sites where these mussels occur, most of which have not used in situ measuring techniques. The need for in situ biogeochemical surveys is, however, obvious: Hydrothermal vent fields are typically located at great depths and it can, therefore, take hours before discrete water samples are recovered and further processed on board the research vessel, hours in which multiple and complex redox processes can occur. Such samples may have little to do with the conditions that the mussels experience at the vents, and biogeochemical parameters should be measured in situ to gain a better understanding of how fluid gradients influence the mussel symbiosis.

Bathymodiolus azoricus and B. puteoserpentis are the dominant macrofaunal species at hydrothermal vent fields along the Mid-Atlantic Ridge. In January/February 2004 we visited the Logatchev vent field at 14°45’N with the research vessel Meteor and the ROV Quest. To study the diversity, biomass, distribution, and the activity of endosymbiotic bacteria in B. puteoserpentis in relation to biogeochemical gradients, we conducted in situ measurements of dissolved oxygen, dissolved H_2S, and temperature using Clark type O_2 microsensors, amperometric H_2S microsensors, and a Pt100 temperature sensor. During four ROV dives, each of which explored the vent site for approximately 6 hours, data were sampled with a resolution of one second, thus collecting datasets of around 22.000 single data points per parameter measured. The data clearly showed an increase in temperature and dissolved H_2S concentrations at sites where the mussels occurred whereas dissolved oxygen concentrations decreased, suggesting diffuse venting at these sites. Dissolved H_2S concentrations increased from 0 in the surrounding seawater to 20 - 30 µM just above the mussel beds while dissolved O_2 concentrations decreased from 170 µM in the surrounding seawater to 160 - 150 µM above the mussel beds. At all mussel sites, the temperature fluctuated noticeably, with temperatures ranging between 2.9°C and 7.5°C within minutes, above background values of 2.6°C. As temperature increased, higher sulfide and lower oxygen concentrations were measured. At the rim of a smoking crater where no fauna was observed, the temperature was much higher with a maximum measured at 27.5°C corresponding to concentrations of dissolved H_2S as high as 200 µM. At temperatures of 10°C and higher, O_2 concentrations dropped to zero.

These results show that the Bathymodiolus mussels have simultaneous access to both sulfide and oxygen indicating that the symbionts can oxidize sulfide with environmental oxygen. We are currently examining mussels from these sites to investigate if gradients in vent fluids influence the biomass and activity of the symbionts. These studies also show that changes in temperature are correlated to changes in O_2 and H_2S at the mussel beds. This indicates that temperature loggers, that can record temperatures for up to 1 year, could be used as valid indicators of fluctuations in fluid gradients over longer time periods. Such long term measurements may be more representative of the energy flow from the vent fluids to the mussels than those that can be recorded during a single dive.