

Towards planning of seafloor observatory programs for the MAR region

Proceedings of the II MoMAR Workshop

**Ricardo Serrão Santos, Javier Escartín, Ana Colaço
& Agnieszka Adamczewska (Eds)**



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Ricardo Serrão Santos, Javier Escartín, Ana Colaço & Agnieszka Adamczewska

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Towards planning of seafloor observatory programs for the MAR region

MOMAR

15 - 17 June
Horta - Azores, Portugal

workshop

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Towards planning of seafloor observatory programs for the MAR region

Proceedings of the II MoMAR Workshop

Horta 14-17 June 2002

InterRidge Monitoring and Observatories Working Group

CONVENERS:

*Ricardo Serrão Santos (DOP, University of
Azores, Portugal)*
Javier Escartín (IPGP/CNRS, France)

ASSOCIATED CONVENER

*Ana Colaço (DOP, University of the Azores,
Portugal)*

INTERRIDGE COORDINATOR

*Agnieszka Adamczewska (InterRidge,
Japan)*

WORKING GROUP MEMBERS:

<i>Javier Escartín (co-chair)</i>	<i>France</i>
<i>Ricardo Serrão Santos (co-chair)</i>	<i>Portugal</i>
<i>Christopher Fox</i>	<i>USA</i>
<i>Kyohiko Mitsuzawa</i>	<i>Japan</i>
<i>Pierre-Marie Sarradin</i>	<i>France</i>
<i>Adam Schultz</i>	<i>UK</i>
<i>Paul Snelgrove</i>	<i>USA</i>
<i>Paul Tyler</i>	<i>UK</i>

ORGANISATION:



CO-FUNDING:



II MoMAR Workshop
Horta (Azores, Portugal), 14-17 June 2002

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WORKSHOP PROGRAM

14 June 2002

18:00 II MoMAR Workshop registration and reception

15 June 2002

09:30 Introduction and goals of Workshop
Ricardo Serrão Santos (IMAR-DOP/UAç, Portugal) & Javier Escartín (IPGP/CNRS, France)

10:00 Biological issues
Daniel Desbruyères (IFREMER, France)

11:00 Hydrothermal issues
Chris German (Southampton Oceanography Center, UK)

14:30 Geological and geophysical issues
Wayne Crawford (IPGP/CNRS, France)

16:00 Ridge2K (USA) organization
Jim Cowen (U. Hawaii, USA)

17:00 Preparation of Working groups

16 June 2002

09:00 Biology Working Group (*David Dixon & Ana Colaço*)
Earth Sciences Working Group (*Wayne Crawford & Mathilde Cannat*)

10:00 Lucky Strike site Working Group (*Mathilde Cannat & Paul Tyler*)
Rainbow, Menez Gwen and MoMAR Working Group (*Yves Fouquet & Chris German*)

12:00 Summary of discussions and preparation of afternoon Working Groups

14:00 Data management Working Group (*Javier Escartín & Marcia Maia*)
Site management Working Group (*Daniel Desbruyères & James Cowen*)
Technological development Working Group (*Pierre-Marie Sarradin & António Pascoal*)

20:00 Dinner Reception

17 June 2002

09:00 Summary of discussion groups

10:30 General discussion: MoMAR organization after II MoMAR Workshop

11:30 Conclusion of II MoMAR Workshop

Towards planning of seafloor observatory programs for the MAR region

EXECUTIVE SUMMARY

INTRODUCTION

The I MoMAR (**M**onitoring the **M**id-Atlantic **R**idge) Workshop (Lisbon, Portugal, 28-31 October 1998) established the scientific basis for long-term observations and monitoring of active processes at the crest of the slow-spreading Mid-Atlantic Ridge. The MoMAR area, located south of the Azores Islands, was identified as the preferred site for the concentration of multidisciplinary studies over a long period of time, as required to understand the active processes (magmatic, tectonic, hydrothermal, biological, biochemical, microbial) and their casual links taking place at active mid-ocean ridge hydrothermal systems. The Lucky Strike vent field was also recognized as the favoured target for small-scale studies, as required for the study of biological and hydrothermal processes. The ultimate goal of the I MoMAR Workshop was to foster international cooperation, and to establish a structure to steer and coordinate efforts towards the implementation of MoMAR projects, and the organization of an II MoMAR Workshop in 2000 to present results of MoMAR-related projects and further discuss the future of this international effort.

In the years following the I MoMAR Workshop, scientific cruises and projects have been carried out in the MoMAR area, and additional projects are planned in the near future (see Poster Abstracts). However, just a few of the long-term or observatory-type experiments outlined in the I MoMAR Workshop have been implemented (i.e., deployment of autonomous underwater hydrophones – see poster abstracts by BAZIN et al., DZIAK et al.; Biological sampling and observation time-series at *LabHorta* - COLAÇO et al.). It has also been recognized, based both on recent technological developments and the better scientific knowledge of the different MoMAR sites, that a coordinated action to monitor the Mid-Atlantic Ridge is possible, requiring a more organized structure than previously available.

The InterRidge Monitoring and Observatories Working Group organized II MoMAR Workshop. The goals of this meeting were: 1) to establish a realistic short (< 5 years) and long-term (> 5 years) plan of experiments to monitor the Mid-Atlantic Ridge at the MoMAR area; 2) to have a better definition of the geographical scope and targets of the MoMAR project; 3) to establish the basis for the data and site management associated with MoMAR projects, and 4) to decide on the follow-up structure of MoMAR. This II Workshop is convened at the same time as two Letters of Intention for European projects (See Appendix IV) have been submitted to the VI European Framework Science Program for future consideration. In addition, a more specific Vent-Sites Management Workshop took place immediately after the II MoMAR Workshop (see supplement 4 of *Arquipélago*).

The first day (15 June) of the Workshop was dedicated to summary talks on different scientific disciplines (biology, hydrothermalism, geology and geophysics) and on the planning and philosophy of the Ridge2000 Integrated Sites, followed by short discussions. These sessions were intended to provide a common basis of understanding of the needs, scientific goals, and limitations for each discipline, required to establish effective interdisciplinary projects. The second day (16 June) was dedicated to three series of discussions by Working Groups. At the request of the biological community, two disciplinary groups (Biology and Earth Sciences Working Groups) were established to briefly outline their goals. These were followed by discussions on site projects and planning (*Lucky Strike Working Group* and *Rainbow, Menez Gwen and larger MoMAR area Working Group*). The afternoon was dedicated to more general discussions on management and future requirements for the implementation of MoMAR (*Data Management Working Group*, *MoMAR site Management Working Group*, and *Technology Development Working Group*). The morning of the last day (17 June) was dedicated to presentation of results of the different Working Groups, and the discussion of the follow-up structure for MoMAR.

1. WORKING GROUPS: RECOMMENDATIONS & RESULTS

1.1. INTRODUCTION

Discussions of Working Groups (WG) were organized around 3 axes: 1) brief thematic discussions on Biology and Earth Sciences; 2) plans and approach to study the Lucky Strike site, and those of Menez Gwen, Rainbow and the larger MoMAR area; and 3) focused discussions on Data Management, Site Management, and Technology Development. These were followed by a general session, with the presentation of the results of these Working Groups, and follow-up structure of MoMAR.

1.2. BIOLOGY WORKING GROUP

Introduction

Chairpersons: David Dixon & Ana Colaço

Deep-sea hydrothermal vent biology has received scientific interest and attention since their discovery, the result being better knowledge about vent organisms and ecosystems on a range of biological scales (*viz.* sub cellular, physiological, whole animal and ecological) than about almost any other biological component in the marine environment. With the exception of coral atolls, deep-sea vents are also a unique example of a biological community that is intimately linked to subsurface geological processes. Given this dependence on the underlying geology and the vent chemistry, vent biota has been assumed to be isolated from processes elsewhere in the ocean, while other marine ecosystems are dependant on photosynthesis as an energy source. However, the recent demonstration that photosynthesis is important to maintain mid-Atlantic Ridge macrofaunal populations living on the (DIXON *et al.* 2002), forces a review of hydrothermal vents. These ecosystems can thus be used to test hypotheses on community structure and function, as well as carbon and biogeochemical cycling. These aspects would be difficult to study

elsewhere in the deep-sea due to lack of knowledge of the biota, and the extended time-scales that prevail due to low temperatures and scarcity of food supply.

By virtue of their well-studied nature, the higher energetic state, and their relatively low biodiversity, the Atlantic hydrothermal vent environment is a tractable microcosm in which to study a range of processes with wider oceanic/global importance (i.e., carbon cycling and flux, hydrothermal flux and ocean mineral budgets, link between chemosynthetic and photosynthetic ecosystems, vent ecosystem impact due to release of heavy metals and radionuclides...). In addition to these fundamental aspects, the study of the hydrothermal vent ecosystem provides invaluable opportunities to understand the working of hydrothermal systems, and to generate advances in instrumentation and technology, biotechnology, pollution control and bioremediation. These extreme environments also offer a way to increase our understanding of the potential for life on other planets.

Background

The Mid-Atlantic Ridge *sensu lato* is a major source of energy and mineral flux into the surrounding ocean. As hydrothermal vent systems (HTVs) are placed in an oligotrophic region, hydrothermal fluxes are likely to significantly impact biogeochemical cycling and carbon flux. At the same time, HTVs are dependant on photosynthesis. It is thus necessary a multidisciplinary approach to understand the interactions between the biosphere and the fluxes (hydrothermal, pelagic). This requires the study of temporal variations within the ecosystem (e.g., competition, recruitment, larval dynamics...), the link between fluxes and deeper-seated geological processes (seismicity, magmatism), and the seasonal fluctuations in carbon production and energy fluxes. Sampling is therefore required at scales ranging from the cm to the segment-scale, so as to include all venting processes that are biologically important.

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Required techniques/installations:

1) *Long term data gathering*: sensors for *in situ* measurements and new strategies for data collection and processing.

2) *Acoustically retrievable cages*: Now restricted to vent mussels and epifauna, allow sequential recovery year-round. Should be developed for use in microbiology, biotechnology (i.e., control of substrates to overcome laboratory isolation and culturing), and recovery of additional species.

3) *LabHorta*: Facilities to maintain HTV samples in aquariums and/or high pressure for molecular, biochemical, physiological and behavioural studies, in proximity to the hydrothermal vent area.

4) *PLASMA*: A planktonic larval sampler for molecular analysis, plus sediment traps, allow studies of larval dispersal/community dynamics, and should be extended to DNA analysis *in situ*, (e.g. studies on larval dispersal/transport, response to environmental changes). Rainbow may be a test bed as flow-patterns are well documented.

5) *ROV & AUVs*: ROVs (Remote Operated Vehicles) and AUVs (Autonomous Underwater Vehicles) are an important tool for the development of MoMAR - related activities. IFREMER (France) and SOC (UK, from mid 2003) capabilities can be complemented with US ROVs and AUVs.

Identified biological studies of interest, to be developed within MoMAR:

Shell growth: Shell growth rings can provide records of hydrothermal activity (i.e., metal accumulation) and temperature changes (i.e., aragonite/calcite ratios, isotopes) both locally and across a vent field.

Fish/crustacean populations: Fish and crustaceans are a major component of the transport of HTV activity products (energy, minerals, and toxicants) between the vents and the ocean, and require quantitative approach to follow population changes and migration (e.g., "smart" tagging).

Organic carbon production, particulate and dissolved organic fluxes: Quantification of production and flux discharge from vents and vent communities of both abiotic and biotic sources, including the distribution of particulate and dissolved organic matter (requires development of detection/recording techniques).

Mapping and quantification of diffusive venting: Diffuse vents are an important component of the total heat flux, and may support biological corridors allowing the propagation of specimens.

Ecotoxicology: Toxic effect of metals on mussels and other organisms, including the role of symbiotic bacteria.

Results can be very useful for education and the general public, and outreach activities should be incorporated in all projects. Potential relay of real-time images to schools and colleges can be a powerful educational tool and provide a societal impact of ridge-related activities.

1.3. EARTH SCIENCES WORKING GROUP

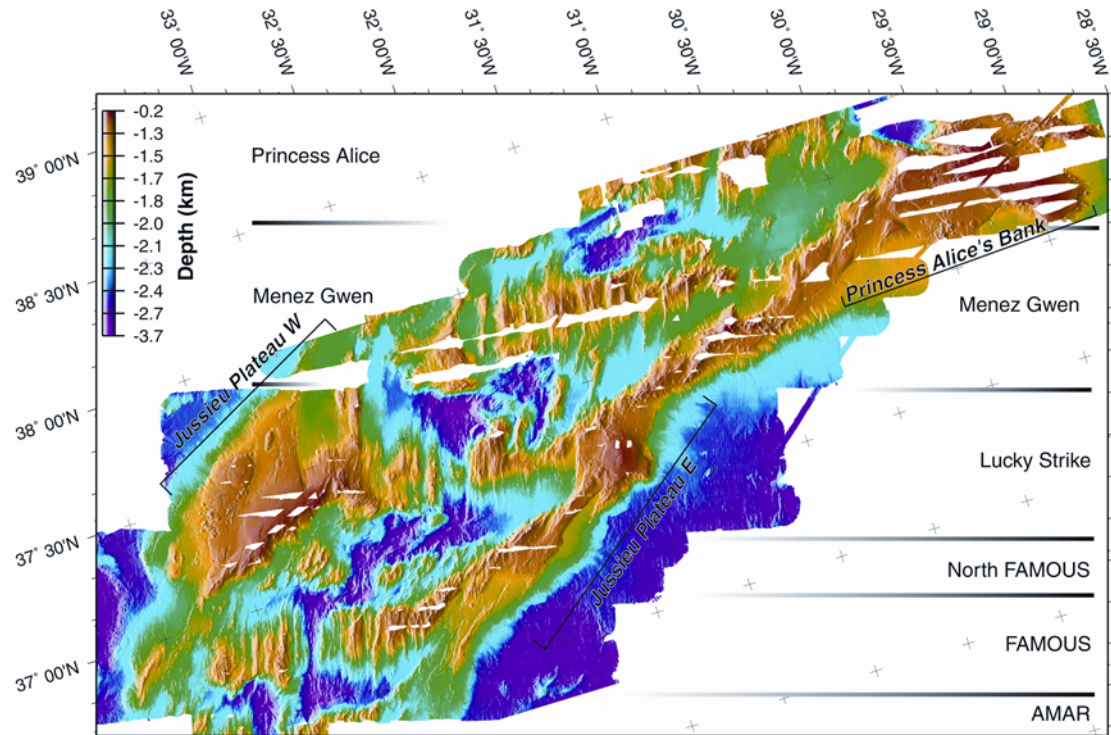


Fig. 1. Multibeam bathymetry map (Simrad EM12) from the Sudacores cruise (N/O ATALANTE, France; PI: Mathilde Cannat, CNRS, France). (ESCARTIN et al. 2001)

Chairpersons: Wayne Crawford & Mathilde Cannat

To understand the driving mechanisms of hydrothermal circulation it is necessary to characterize the sources of heat that drive the system, the structure of the crust that hosts it, and the active magmatic and tectonic processes that may affect hydrothermal flow and, ultimately the ecosystems associated to vents at the seafloor. To characterize fully these hydrothermal systems in depth, we need to constrain or characterize the following processes:

- Distribution of possible heat sources and fluid paths in the shallow lithosphere
- Distribution of seismic activity (tectonic, magmatic and hydrothermal activity monitoring)
- Seafloor deformation

- Quantification of heat fluxes and their spatial distribution

All these aspects can be studied with existing technology and means, and include:

Active seismic experiments: Refraction and reflection seismics constrain the velocity structure of the lithosphere, both at large (segment-scale) and small-scales (vent-field scale). This information is useful to identify possible heat sources, the porosity structure susceptible of hosting hydrothermal fluids, and is required to accurately locate microseismic events.

Passive seismic experiments: Installation of an ocean-bottom seismometer network around a vent field, to locate seismic events, and correlate these with changes in hydrothermal fluid circulation. The aperture of the array may depend on the size of the hydrothermal cell associated with

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individual vents. This will complement the Autonomous Hydrophone Array data at a larger scale that will be available till the end of 2006.

Geodesy: Installation of benchmarks to perform repeated gravity - and pressure measurements required to constrain vertical movements of the crust. The use of these benchmarks may be expanded to tilt meters, acoustic extensometers, or other techniques, in due time, as these experiments are programmed or new techniques are available.

Heat flux: Establish the general thermal state of the area, quantify flux at vents, including diffuse discharges (i.e., acoustic scintillometry), and obtain temperature records at several vents and over long periods of time that may be related to tectonic and/or magmatic events as inferred from microseismic activity.

Microbathymetry & magnetics: High-resolution bathymetric and magnetic surveys with AUVs or ROVs can provide both the precise tectonic setting of individual vent fields, and the location of demagnetized areas associated with hydrothermal discharges.

These experiments are required to fully characterize the Lucky Strike area in order to establish and interpret the results of long-term or continuous observations, and can be further complemented with additional geological and geophysical experiments (i.e., electromagnetics, high-resolution geological and geochemical sampling, etc). All or a subset of these experiments are required, but at a later time, at other hydrothermal vent fields (Menez Gwen, Rainbow), as a basis of comparison between sites, or to prepare future projects (i.e., ODP drill proposal at Rainbow).

1.4. LUCKY STRIKE WORKING GROUP

Chairpersons: Mathilde Cannat & Paul Tyler

The goal of this working group was to outline the scientific and technological priorities for multidisciplinary long-term monitoring of the Lucky Strike vent field. Given the short time allotted for this discussion (1 hour 1/2), and the

absence of expertise (mainly in the hydrothermal fluid field) and key people to develop and carry out specific experiments, it was not possible to agree on a precise implementation plan for the Lucky Strike experiments. It was recognized that a specific "Lucky Strike" planning meeting is required in the near future (as soon as fall or winter 2002) to produce a detailed implementation plan.

The basic design of the Lucky Strike experiment, however, was clearly defined and agreed upon during the discussions:

- It should aim at understanding the evolution of vents ecosystems, from processes that control hydrothermal venting (dynamics of hydrothermal cells, link with volcano-magmatic and tectonic activity), to processes that control the small scale distribution of animals at individual vents. One particular issue would be to constrain the budget of organic carbon at and near vent sites. Organic carbon input has been partially quantified but the export of organic carbon and its affect on the surrounding deep sea is unconstrained. The time scale of a monitoring experiment should be of approximately 5 years, but with a view of continuing monitoring at Lucky Strike over at least a decade.
- Long-term monitoring should be planned pragmatically, using existing technology for the first stages of the experiment, and developing reliable tools (i.e., thermal probes, seismometers) required for the long-term (i.e., chemical probes). Although technology is available, it may be necessary to obtain instruments dedicated for long periods of time, as required in monitoring.
- The first stages can be planned for completion before 2005-2006, involving the preliminary deployment of instruments at the seafloor for continuous monitoring, and performing repeated measurements at specific locations. Key aspects to monitor are:

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- Seismicity (seismometers)
- Vertical movements of the seafloor (gravimeters and pressure gages)
- Vent fluid temperature and chemistry (thermal and chemical probes)
- Fluxes of particles (sediment traps and current meters)
- Distribution macrofauna at Tour Eiffel vent field (optical images, photomosaics, and microbathymetry)

The discussion addressed the following issues:

The scale of the experiment: depending on the processes to be monitored, experiments should be designed encompassing the segment scale, the scale of the Lucky Strike central volcano, the scale of the vent field, and the scale of individual vents. Biological monitoring can be performed realistically only at the scale of a single vent (e.g., Tour Eiffel), hydrothermal monitoring at the scale of the several vents or the vent field, and geophysical observations can range from the vent field to the segment scale

The choice of sites and the specific locations within individual sites for long-term monitoring. This choice should be as educated as possible, based in all the available data from Lucky Strike, and requirements of the different disciplines and projects (Fig. 2). One of the main goals of the “Lucky Strike meeting” would then be to present all the available data and set the basis for future experiments.

One issue that arose was the choice of locations for temperature probes so as to have temporal records of fluid-temperature that are significative of the hydrothermal processes at the scale of the whole vent field. A task prior to the next meeting would be to reprocess existing temperature records (1-year) to better understand correlations within individual sites and among several sites, and determine the limitations associated with time-series temperature records.

In addition to this thermal study, results from Electro Magnetic (EM) experiments and deep-tow magnetic survey could also prove

fundamental when deciding the location of stations for monitoring.

The design of the biology component of the experiment. The biological monitoring should be focused first on the “Tour Eiffel” site, which should be fully imaged optically and at repeated occasions, and equipped with temperature probes, flux meters, sediment traps and current meters; all these parameters are required to better constrain the fluxes associated with this particular vent.

Restricted sampling is required during the length of the monitoring. Only limited sampling for very specific experiments may be allowed, such as the limited sampling of mussel shells to identify events recorded by the growth bands (i.e., earthquakes, changes in fluid temperature, etc).

In addition to this site-scale component, there should be a segment-scale effort to monitor particles and water fluxes, with special emphasis on the fluxes of organic carbon.

Preparation of Lucky Strike monitoring. Several experiments should take place prior to installation of long-term monitoring instruments and implementation of experiments involving repeated measurements over the long term. In particular, the identified cruises that should take place before 2005:

- *Crustal seismic structure:* a seismic refraction and reflection cruise is necessary to constrain crustal velocities at the scale of the segment and the volcano, required to accurately locate and monitor active microseismicity.
- *Geodetic benchmarks and measurements:* A cruise to install bench marks is required so that they can be reoccupied to perform long-term geodetic measurements.
- *Thermal state of the lithosphere:* The present-day, general thermal state of the oceanic lithosphere requires a dedicated heat flow experiment that can provide the base for other studies involving heat flux and transfer from the crust into the ocean.

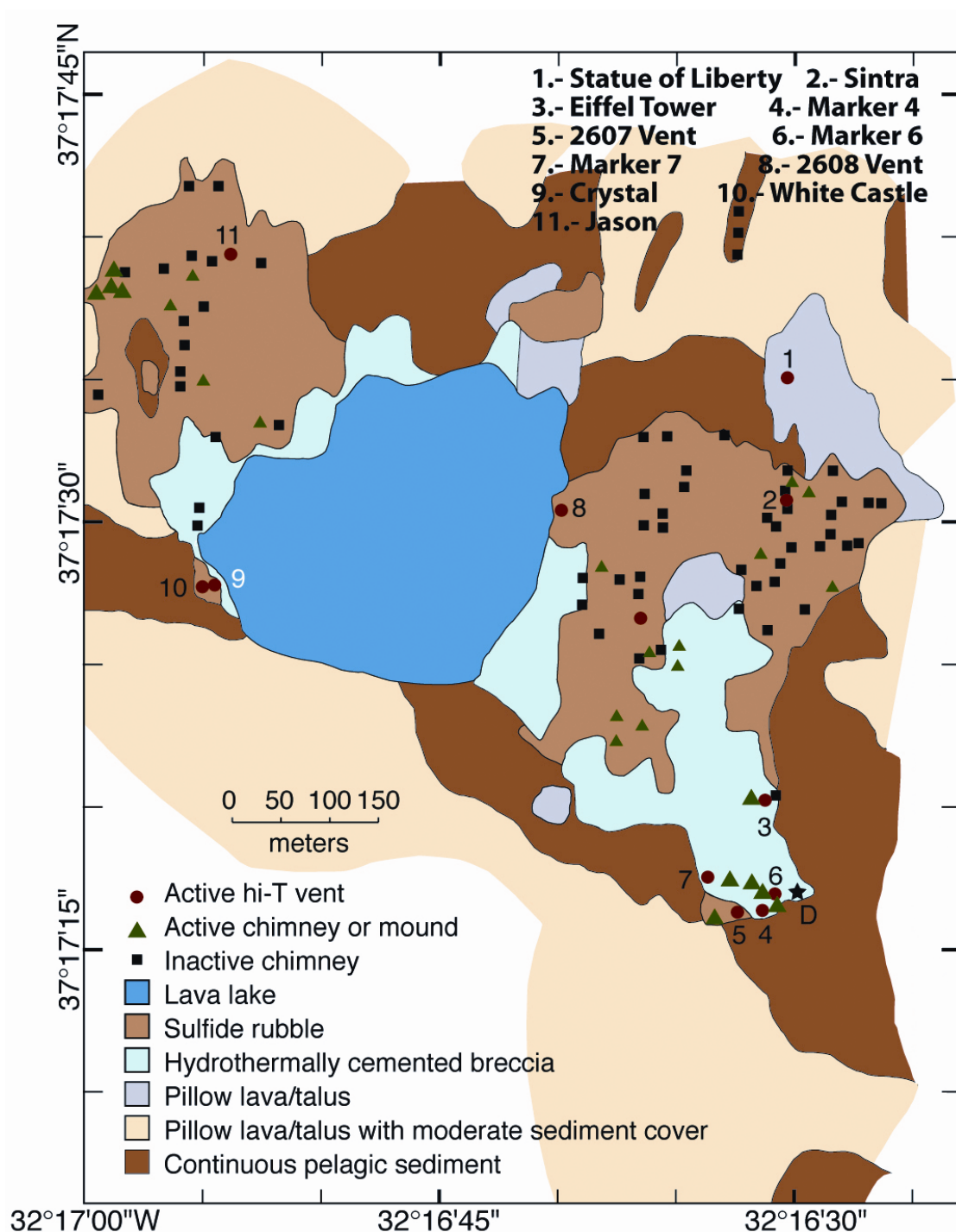


Fig. 2. Geological map from the LUSTRE'96 cruise (RV KNORR, USA, PIs: Dan Fornari & Susan Humphries, WHOI). (HUMPHRIS et al. 2002)

Experiments requiring installation of benchmarks and instruments at the seafloor may have an impact and produce disturbances in the ecosystem. It is clear that management and coordination is required, since the early stages of the Lucky Strike experiments. These aspects should be reviewed in a more specific 'Lucky Strike' meeting.

- *Future technological requirements.* Basic technological requirements to be developed include:

AUVs

Optical and acoustic imaging to monitor biological processes

Buoys and acoustic telemetry and navigation systems

Due to the lack of time, not much time was devoted to go in detail over the specific requirements for these technological developments.

- *Drilling.* In the long-term, drilling of the Lucky Strike vent field may be proposed to understand the construction of the hydrothermal slabs that cover large areas of the field, its influence on hydrothermal circulation, and the presence and nature of a deep biosphere. In addition to the scientific objectives outlined, there was a brief discussion of the important site management that such an experiment will have (i.e., possible modification of hydrothermal flow and system, impact on ecosystems in nearby vent sites, etc). These issues should be addressed when preparing drilling proposals at Lucky Strike or elsewhere.

1.5. MENEZ GWEN, RAINBOW, AND LARGER MOMAR AREA WORKING GROUP

Introduction - why study several hydrothermal sites?

Chairpersons: Yves Fouquet & Chris German

Known data on hydrothermal systems in the Azores domain demonstrates that the Azores are not only a logistical interesting site to work, but is also one of the most attractive sites in the world

to study the geodiversity of styles and types of venting. These vents can be studied in terms of depth variation, composition of the basement rocks, styles of volcanic activity, and tectonic versus volcanic control. In addition, as we are on a slow spreading ridge some of the time variations will be slow (several hundreds of years or more), the study of several hydrothermal sites at different evolutive stages provides an alternative way to study time-variation and evolution of hydrothermal fields.

The discussion was divided in three parts:

1. Rainbow, Saldanha & Menez Gwen area: Work to be done on existing sites
2. North of Menez Gwen: Exploration for hydrothermal activity
3. From the ridge to the islands

Part 1 - Rainbow to Menez Gwen area: Work to be done on existing sites

What is done, what we do know?

These three sites, together with Lucky Strike, have been the object of several projects during the last decade which have provided an important wealth of information. These projects are: MARFLUX (1993-1997), AMORES (1997-2000) and VENTOX (2000-2003), and Portuguese FCT funded projects AMAR (1997-2000) and SEHAMA (2002-2004). The data sets resulting from these projects include, among others, bathymetric maps, side scan sonar images, detailed plume mapping and several biological and geological diving operations during which animals, rock samples and hydrothermal fluids were collected and detailed video and photographic coverage was made.

What we need to do

One important project for the future will be drilling operations. All the three high temperature hydrothermal sites have specific characteristics that need subsurface investigation. At Rainbow we need to know the depth of serpentinization, the downward extension of sulphide mineralization replacing the ultramafic rocks, the relation between fluids, minerals, and bacteria at

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depth and processes and conditions of the synthesis of abiotic organic compounds. At Lucky Strike strong evidence exists for deep bacterial communities and subsurface sulphide mineralization under the silica slab formation blanketing the vent field. At Menez Gwen the boiling and the absence of metals at the surface both in fluids and precipitates opens the possibility that most metals are precipitated as sulphide in a deep stockwork mineralization. Importantly, this may also be the case at all other vent-sites that may occur, north of Menez Gwen.

What is missing?

a) Drilling operations

To improve the drilling proposal it is now necessary to complete detailed geophysical investigations at the scale of the vent field. Near bottom magnetic survey was recently done at Rainbow and partly at Lucky Strike. We recommend for the two larger fields (Rainbow and Lucky Strike) high-resolution seismic surveys, electromagnetic investigations, and gravimetric measurements. The aim of these experiments would be to constrain the vertical geometry of the hydrothermal system, the thickness of the massive sulphide and the extension of the alteration zone, the depth of serpentinization the possible occurrence of subsurface gabbroic intrusions. This is a very important step to determine the best strategy for drilling operations. After drilling, it will be important to monitor some of the holes using corking facilities as a contribution to the MoMAR monitoring of the vent field. The extension of microbial communities at depth will be an important objective of the 3D studies of the various types of hydrothermal fields. Data that will be helpful for all sites is a combination of high resolution bathymetry and sonar imagery.

b) Monitoring vents

For this we considered two types of operations: time series sampling at the sites and long-term continuous monitoring of vents.

To achieve either of these objectives we must be sure that we have already identified all the key sites of venting within each active field. For

Menez Gwen, Lucky Strike & Rainbow this basic mapping is complete. Comparable studies will be completed at Saldanha during ROV Victor dives in summer 2002. Time series operations have already started on Menez Gwen, Lucky Strike and Rainbow. This has to be continued in the future. For the moment there is no major variation in the fluid compositions on a period of 4 years. Comparatively on the EPR vents having a low salinity fluid similar to Menez Gwen have changed their composition to brine within a few months.

Temperature has been monitored at several sites iwithin the Lucky Strike vent field, during one year. This monitoring was successful at sites at $T > 200^{\circ}\text{C}$. Interpretation of the data is complex, and to date it is not possible with the limited available data to discriminate between local variations and more regional variations that are of significance for the hydrodynamics of the hydrothermal system. This type of interpretations will require a combination of these data with that of other experiments, such as the continuous monitoring of microseismicity on the area. At the satellite vent-sites it will not be necessary to conduct the same detailed microseismicity experiments proposed for LS site. Rather, these studies will be designed much more simply, just to DETECT tectonic activity at, and close to, these vent-sites – but not to determine its precise LOCATION, at depth.

c) Hydrothermal fluxes from the seafloor

In the short term, a basic level of monitoring could be initiated at all non-Lucky Strike sites using already available technologies. Put simply, each vent-site could be monitored continuously for temperature of the vent-fluids, co-registered with basic microseismics to detect when any change occurs. That continuous record could then be combined with episodic sampling of actual vent-fluid compositions during visits of a manned submersible and/or ROV – once per year in summer dive window. An advantage of this approach is that all known vents at Rainbow emit a common fluid composition – i.e. it is easy to be sure that what we monitor at one or more vents is representative of ALL venting at this site.

Similarly, Menez Gwen site is very small and so all vents can be monitored – much more easily here than at the more complex Lucky Strike site.

To measure flux at any site it would also be ideal to install long-term continuous flow meters – perhaps possible using acoustic techniques? At Rainbow this can also be complemented by installing a long-term, large-scale array of current meters with profiling CTDs and sediment traps/samplers – see later – to measure the integrated flux from the entire vent-site as recorded in the well-organized hydrothermal plume. This approach has already been demonstrated over 12 months – see THURNHERR et al. 2002 – which, when combined with at-vent-site monitoring as described above will provide important new information about variations in flux from the Earth to the Oceans.

In principle the same approach may also be applicable at the Lucky Strike and Menez Gwen sites but, before that could start, more detailed 3-dimensional plume/physical oceanography investigations would be required at those sites.

d) Biology

An important approach to long-term monitoring at these satellite vent-sites will be to consider how the vent ecosystem/community interacts with the wider biosphere – notably photosynthesis.

A first approach to this will be to determine fluxes – notably C-org - from above, settling from the upper water column to the seafloor at the vent-site. This can be achieved by the deployment of sequentially-sampling sediment traps in the water column immediately above the water-depth of hydrothermal plumes at all sites. Similarly, it will be possible to register fluxes away from the vent-sites by placing in situ samplers – e.g. PLASMA – and sediment traps within current meter arrays stationed down-wind from each vent-site. An additional experiment at Rainbow would be to place two arrays across the rift-valley: one at the vent-site, the other at the Saldanha site. We already know that the Rainbow hydrothermal plume can be traced all the way to the Saldanha site. The approach suggested here would allow us – for the first time anywhere in

the world – to measure flux/communication from one vent-site to the next, along the ridge axis.

A second important emphasis will be to investigate the detailed biodiversity at each of the sites and also to understand how their populations are maintained – i.e. knowledge of biomass and production.

While we have explored and characterized geophysically to a basic level the different sites, it appears that knowledge of the full biodiversity of each site has not been established yet. This characterization will require more ROV or submersible studies at these sites. To understand how the system functions, a useful start has been made by the VENTOX program, which uses acoustically-released cages that can be deployed by submersible. We recommend this to be applied to all sites. During one visit per year, the ROV/sub can deploy a suite of four sets of cages on acoustic releases. These can then be collected seasonally from a surface ship under poorer weather – once every three months – and any variations observed on that low-resolution time-scale can be interpreted in the context of: continuous satellite records of surface ocean colour/productivity; hi-resolution sediment-trap fluxes; continuous seafloor vent-temperature and seismic records; continuous export records from current meter/sampler/trap arrays and once-yearly seafloor interventions using submersible/ROV.

At present, the cage sampling technique described above is limited to recovery of sessile organisms, such as mussels. Over the lifetime of MoMAR we expect to move to increasingly sophisticated work using the same generic infrastructure – acoustically released structures – to host more complex biological experiments.

Part 2 - Additional hydrothermal explorations

Justification

Objectives - Why do we need to continue exploration north of Menez Gwen?

Our work to date in the MoMAR region has witnessed a change in both styles of hydrothermal venting and associated ecosystems, which reflect

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the varying geological setting at these sites, at decreasing pressure. It is of interest therefore to continue our investigation to the very shallowest depths/pressures observed within and among the Azores archipelago. Our motivation here is not purely curiosity-driven. It also has profound societal relevance.

Geological hazards.

Evidence for past explosive volcanism has already been established at Menez Gwen and, possibly, at Lucky Strike. At shallower depths (to as little as 400m below sea level) the potential is that explosive volcanism may become increasingly common at the ridge-axis - exactly where it passes closest to the Azores islands themselves. Thus an improved understanding of both the controls and the episodicity/evolution of such processes would also be extremely powerful in terms of risk assessment on behalf of the Azorean population.

Environmental toxicity.

The VENTOX programme has already begun an assessment to which toxins from the Menez Gwen vent-site may be coupled with the wider fisheries food-chain south of the Azores. As we approach the islands more closely, any still-shallower hydrothermal fields, which we discover, will be likely to be ever more closely coupled to the overlying upper-ocean photosynthetic life-cycle. Light and heating from the sun are typically assumed to penetrate to ca.200m water depth. Thus, plumes emitted from a shallow vent-site are most probably mixed upward into this upper ocean zone.

Evolutionary studies/biodiversity.

Previously, it has been shown that at decreasing depth there is increasing invasion of local seabed fauna into the known vent-site communities, in the order Rainbow, Lucky Strike, Menez Gwen. It is interesting to question, therefore, whether vent-specific fauna may be displaced so effectively that they are completely absent from the shallowest ridge-crest amongst the Azores islands. If so, this shallow section of the ridge may act as a genetic barrier which isolates the

vent-faunal communities south of the Azores from those to the north (there are no vent-communities yet identified anywhere between the Azores and Iceland) rendering these two distinct ridge-sections as genetically isolated biogeographic provinces. If so, this will make the Azores area an important next local in which to investigate evolution within marine organisms in general. For that reason, exploration should also continue north of the Azores until depths comparable to Lucky Strike/Rainbow are reached at the Kurchatov Fracture Zone.

Ease of instrumentation.

Finally, from an entirely pragmatic perspective, any shallow vent-site located close to the Azores islands would be much more easy to connect (both economically and logistically) to a fibre-optic cable feeding to land providing real-time information from instrumentation at the seafloor to the University of the Azores and, via Internet Access, the international community beyond.

Implementation

Exploration north of Menez Gwen can be considered in two parts - a) on-axis exploration north of Menez Gwen from 38-ca.40 degrees North (a natural termination might be the Kurchatov Fracture Zone); b) exploration around the Azores islands.

We consider each in turn, below.

On-axis exploration.

The implementation plan for this component of the work is quite straightforward and can follow that used with such success over the past decade from 36-38N. Swath bathymetry for this area was already collected (SIMRAD EM12) during the FAZAR programme. The next component of baseline study required is 100% sidescan sonar coverage of this area using low-frequency deep-tow sidescan. An obvious choice would be the TOBI vehicle equipped with *in situ* sensors to obtain co-registered information on hydrothermal plume distributions and images of the seafloor useful for determining the volcano-tectonic settings of those hydrothermal "hot-spots". As well as the optical sensors, which have proven to

be so useful previously, at depths where Fe-rich plumes are formed, novel *in situ* chemical sensors should also be added.

Experience at Steinaholl (300m deep vent-site near Iceland) has revealed plumes rich in methane, hydrogen and manganese. SOC already has an *in situ* Mn sensor available for such work. More recently, *in situ* H₂ and CH₄ sensors have also become commercially available and were used at Menez Hom site on the ROV VICTOR. The latter sensor has been limited to depths less than 1000m, to-date, which has limited their usefulness for deep-ocean exploration. Nevertheless, they may be ideal, off-the-shelf, for this particular field-area. Another observation at Steinaholl - also observed above at least one seamount of the Azores region, is the release of free gas bubbles from shallow sites of venting. Free gas has been observed directly from the manned submersible NAUTILE, bubbling from the Menez Gwen site (YVES FOUQUET, pers. comm.). Elsewhere, both in the Azores and south of Iceland a 38kHz "fish finder" sonar system has been used. The advent of multi-beam swath-mapping versions of this "fish-finder" sonar technology could also provide a very efficient means of exploration for new sites of venting along-axis.

Further studies could be carried out based on the study of the distribution and nature of seismic activity, and on the survey of the area with deep-towed instruments such as TOBI. The hydrophone array deployed has already revealed important seismic activity at the Lucky Strike segment (March 2001) which may be of magmatic origin. Study of these areas could be combined with CTD systems, higher-resolution geophysical systems, and geochemical sniffers and other. Newly discovered hydrothermal sites would serve as a basis of comparison with those being monitored within the MoMAR project.

Off-axis exploration among the Azores islands. Similar exploratory studies could be carried out off-axis, among the nearby Islands and seamounts, using the same techniques as proposed above for the axial surveys. These

studies would require, however, additional geophysical surveying (bathymetry primarily) that is not available to date. Possible additional projects could include systematic coring of sediments (ca. 1 cm) to map metalliferous enrichments, as used successfully in the past along the flanks of the EPR. Finally, specific hydrothermal sites could be investigated using AUVs, ROVs, or other.

Locating Additional Sites of Venting, 36-38°N.

It is also important to determine the distribution of hydrothermal sites between 36°N and 38°N, where several signals of hydrothermal plumes have been discovered, and have not been linked to known to date hydrothermal fields (i.e., the "Menez Hom" site). The possible presence of additional vent fields among the already known ones within the MOMAR area can play a critical role in the migration of vent fauna. These studies will also help determine the presence of diffuse and lower temperature hydrothermal activity (i.e., Lost City, MAR at 29°N). These investigations will require prospecting for hydrothermal signals in areas where these were found in the past, in combination with near-bottom surveys for identification of sites and their nature i.e., ROV or AUV surveys). The ultimate goal recommended is to identify the totality of hydrothermal fields on the area, in addition of the already known ones, and establish their nature.

1.6. DATA MANAGEMENT WORKING GROUP

Chairpersons: Javier Escartín & Marcia Maia

Data management is recognized as an important part of the MoMAR program both in the preparation phase expected to develop in short-term (<5 years), and during future long-term and/or observatory experiments. It is also recognized that data management should include aspects of dissemination of MoMAR - related data to scientist within and out of the MoMAR community, to education, and to the general public.

1.6.1. Preparation of Projects and Implementation of MoMAR

Immediate action

The preparation of multiple, multidisciplinary proposals targeting the MoMAR area in general or specific sites in particular (i.e., Lucky Strike), requires that a minimum amount of basic data are made available immediately to all the scientific community via a web page (i.e., free download with proper referencing instructions).

The WG identified a set of critical data and datasets that are already published and/or available from individual scientists:

Bathymetry grids: Compilation of regional grids (data synthesis), ship multibeam data surveys, and deep-tow bathymetry surveys. These data are useful as a background to any project in the area and for planning purposes.

Acoustic backscatter images: High-resolution side-scan sonar data (TOBI, DSL-120) for identification of morphological structures and detailed tectonic setting of the area.

Geological maps: Detailed geological maps of Lucky Strike, Menez Gwen, Rainbow and Saldanha, with location of vents and geological formations.

Table of vent site information: Tabulated information of vent sites, including the location (even if not accurate), name, temperature of water venting, and type of hydrothermal outflow (black smokers, diffuse flow, shimmering water).

Epicentre locations: Location of seismic activity (and magnitude/focal mechanism if available) at or near the ridge axis recorded by the SIVISA (Sistema de Vigilância Sismológica dos Açores) array. Results of the US Autonomous Hydrophones (south of the Azores) are already available. The Autonomous Hydrophone Array for the Atlantic will be installed till 2006, and data is available on-line as it is processed at: <http://autochart.pmel.noaa.gov:1776/autochart/Ge tPosit.html>

This data can be posted on the MoMAR web page (link through the InterRidge web pages), and include in each case information regarding proper referencing and use of the data.

Longer term

Actions such as coordinated instrumentation of a site will require that the scientific partners have current information from the area of study. This will be probably required at the level of individual site or sites within a hydrothermal field. As it is not feasible to compile these data in a systematic manner, this synthesis should be one of the tasks proposed by a future MoMAR steering committee. This can be achieved by:

- Synthesis provided by scientists that have carried out experiments and/or are familiar with the site(s)
- Data and background review meetings targeting all the scientific partners involved in the experiments and implementation of MoMAR.

1.6.2. Data generated in the context of MoMAR

As in the case of preliminary MoMAR data, it is also recognized that a minimum amount of data availability can be enforced immediately, and that the archival, management, and distribution of MoMAR data, requiring both infrastructure and personnel, is a complex and longer-term action.

Immediate action

A clear limitation at the present time is the lack of detailed information regarding cruises and experiments in the MoMAR area. These information include the identification of scientists responsible for specific cruises, experiments or holding specimens, the location of sampling sites or stations (biological, instruments, etc), and the complete set of experiments performed in an area. The Working Group thus recommends that *all cruise reports* are made available to the scientific community via a web site. The working Group would also encourage that Principal Investigators (PIs) of cruise reports written in a language other than English include a short 1-page summary with basic information of the cruise.

The Working Group recognizes the concerns of the community regarding a) the limitations of the quality of the data and information in cruise reports, prior to proper processing, and b) the

possibility of misuse of some data by other scientists. However, cruise reports provide an important part of the information requested by scientists, and the benefits that will come out of sharing cruise report information clearly outweigh the risks of misuse of the data.

This effort, on the long term, should be part of the tasks of experiment coordination and follow-up of site experiments as identified by the *Site management Working Group*.

Finally, a reference database is recognized as a potentially useful tool to mine existing data and results. The reference list within the I MoMAR Workshop (see report and InterRidge web pages) should then be updated, and if possible include the electronic versions of the latest papers. All the participants of the II MoMAR Workshop, as well as the larger community should provide this information.

Long-term action

The MoMAR Steering Committee or an ad-hoc group with this specific mandate should define a clear data policy accepted by all the scientific partners within MoMAR. We recognize that there are issues regarding implementation of this data policy at the present time, and that the situation may change depending on the level of funding and the origin of these funds. As MoMAR is a long-term project, with observations spread over several years, data should be made available as a service to the community, in the same manner as is done in other observatories. Some basic requirements recognized by the Working Group should be considered by a MoMAR data policy to be developed in the future:

Centralization and storage of data: Data should be gathered in a specific site to avoid dissemination and eventual loss of data.

Basic data formats and metafiles: Protocols regarding the types of data strings and the specific formats should be developed with the goal of setting up an archive for future use. Precise metadata information will be also necessary to allow for the proper use of the data.

Immediate data availability: The long-term and/or observatory-type observations require that a minimum amount of basic monitoring and environmental data that are useful to a wide scientific community should be made available without restrictions. The two basic parameters that should be freely distributed are the temperature time-series recorded at monitored hydrothermal sites, and the location of seismicity or microseismicity to the community at large.

Limited period for proprietary data: Some data could be held for the use of individual PIs, but both raw and processed data should be made available to the wider scientific community after a predetermined period of time. The length of this period of time, and the conditions of use of the data should be discussed within a detailed data policy, and incorporating particular cases when needed. To insure that the data is indeed available to the community, it should be centralized in a MoMAR database, rather than being held by individual scientists and released upon request.

Protocols for preservation of biological samples: Biological and geological specimens of potential interest for other scientists (i.e., microbiologists) should be preserved using predetermined protocols that will insure their future use.

Reference collection for biological research: A basic collection for scientific use should be made available to the community. It should include part of the specimens preserved for future use as stated in the item above.

Legal concerns: Data policy should include aspects regarding property of samples, genetic material, and biological material generated from collected samples, and other legal issues that may issue from the use of the samples for commercial use (i.e. genetic engineering, DNA patents). These aspects are particularly critical for microbiology studies.

Data policies/databases should be coordinated with those developed by other organizations, in particular Ridge 2000, ODP and the UNESCO-COI.

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1.6.3. Hosting and coordination of data, information, etc.

There is a clear need, at a medium and long term to have both facilities and at least one person dedicated to maintain databases and do the work of compilation, synthesis, quality check required for MoMAR. The Department of Oceanography and Fisheries (University of the Azores, Portugal) or other institutions based in Horta, would be natural host of these database facilities

The immediate actions proposed above can be achieved with a minimum amount of work coordinated by the InterRidge Working Group in Long-Term Monitoring and Observatories, and the basic data and information can be made available using existing web pages dedicated to MoMAR.

1.6.4. Data dissemination and outreach

Data management should have an active role in the dissemination and outreach to scientist outside the ridge and hydrothermal community, and include education and the general public. These efforts are not sufficiently developed in Europe, but have a huge potential both to increase the societal impact of the MoMAR generated science, and to promote MoMAR projects in funding and science management institutions.

Link with established organizations: Organizations such as museums, cultural and educational institutions, and government agencies have well-established programs and set-ups to reach the general public. MoMAR will collaborate with these organizations as a means of indirect outreach to the general public, providing basic scientific information, visual support from hydrothermal sites, or collaborate with these institutions in setting up these actions.

Web site: A MoMAR website should include a data/scientific domain, and an education and general public domain. This could include presentations and scientific information tailored for use in classrooms (courses, graphics, etc), reports of MoMAR activities (cruise and experiments web pages with real-time

information), and general background information on the scientific goals and actions of the MoMAR project.

Links with education: An important societal return is the use of scientific results generated by MoMAR in the educational system. In addition to making available documents that could be freely used in classrooms as course material, MoMAR should set-up cruise and MoMAR project oriented web pages tailored for use in classrooms, and investigate the possibility of involvement of teachers (and eventually senior students) in scientific projects or cruises. These actions are promoted and developed in the US Ridge community through several national and private programs, and have proven extremely successful.

1.7. MOMAR SITE MANAGEMENT WORKING GROUP

Chairpersons: Daniel Desbruyères & James Cowen

It is recognized that site management requires a well-organized committee structure, established in the shortest delay possible, to have active coordination of efforts during the initial phases of MoMAR and when the first long-term experiments are developed and implemented. Given the lack of time, the Working Group focused the discussions on aspects that the Site Management Committee should take action on, and that should be part of its mandate.

1.7.1. Important policy issues

Portuguese EEZ: Lucky Strike and Menez Gwen are located in Portuguese EEZ, thus requiring clearance requests for cruises (process based on International Law of the sea). The process of clearance should provide reasonable treatment and permission granting.

Marine Protected Area: Several MoMAR sites (Lucky Strike, Menez Gwen), are likely to be located in newly-established Marine Protected Areas, with restrictions associates with their

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status (issues were dealt in follow-up Vent Management Workshop). PIs must operate within the restrictions imposed by MPA policy.

MoMAR restricted areas: It is also recognized that additional restrictions may be required to insure proper implementation of MoMAR experiments, such as definition of ‘work’ vs. ‘control’ areas where no or limited sampling is allowed. These areas should be defined based on existing and planned experiments.

Site Management Committee mandate:

- Advise PIs providing clear guidance for permit process, and interact with Portuguese authorities to insure that MoMAR - related projects are properly coordinated.
- Help PIs plan individual projects, and coordinate different projects, within the context of both the MPA and MoMAR regulations and restrictions, and promoting non-intrusive techniques for long-term observations

1.7.2. Planning and organization of the MoMAR project

In order to plan and organize the MoMAR project in the long term, the Site Management Committee should act at several stages through out the preparation and implementation of projects:

Pre-proposals: The Committee should solicit, collect, disseminate proposals, and be proactive in the solicitation of proposals when required, to insure an adequate progression of experiments and monitoring. Part of this task should include the evaluation of potential/realized impacts, safety, and scientific aspects with regard to the MoMAR Science Plan.

Track planning of and actual cruises: The Committee should track the location, duration, deployment of instruments, experiments, and all activities at MoMAR sites, in order to provide effective coordination. This should be done in close association with the development of databases and centralization of information. A

centralized, detailed ‘map’ of observatory sites with equipment location, experiments, markers, protected and restricted areas clearly marked and available on internet should be available to both the Committee and all PIs. The Committee must establish a procedure to solicit information from PIs, update maps, and provide information via internet.

PI responsibilities: PIs should:

- Provide pre-proposals to the Committee, including sections on ‘Impact on Environment’ and ‘Relevance to the MoMAR project’.
- Provide timely information on cruises, operations, location of instrumentation and duration of deployments, etc. Submittal of cruise reports to the Committee may be one of the procedures to insure that the required information for coordination of projects is passed to the Committee.

1.7.3. MoMAR: Integration and outreach

In order for MoMAR to develop, the cooperation with National and International bodies should be worked out, including the search for funds from all possible sources, and a strong educational outreach through media, museums, public aquaria, schools, and other.

1.7.4. Requirements and responsibilities of PIs

Requirements and responsibilities of PIs working within the MoMAR framework should be clearly established, and compliance followed-up by the Committee, and should include

- Submittal of pre-proposals
- Prompt submittal of cruise, equipment and/or experiment data
- Data and metadata sharing (see *Data Management Working Group*)

These should be clearly specified in a “Code of Good Conduct” to be followed by all PIs working in the area, and including some basic measures to enforce the basic requirements listed.

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1.7.5. MoMAR Committee structure

The Working Group recommends that a MoMAR committee is established as soon as possible after the Workshop, composed by 5-9 members (and an additional staff person). This committee should be established based on both national representation, and a disciplinary balance.

This structure will need some basic funding to allow for a staff person, travel money for the committee members, and for outreach activities.

1.8. TECHNOLOGY DEVELOPMENT WORKING GROUP

Chairpersons: Pierre-Marie Sarradin & António Pascoal

The objective of this working group was to identify and recommended a strategy in technological developments needed to achieve the MoMAR proposed scientific objectives. These objectives are gathering segment scale studies and on site experiments at least two time scales:

- 0 to 5 years and the beginning of the MoMAR project,
- 5 to 10 years corresponding to a second step in data acquisition.

The strategy presented below corresponds to these two time scales and is not going through a detailed equipment list.

0 to 5 years

The first phase will be based on an approach combining repeated cruises (surface or submersible) on the studied sites and using of readily available technology. Some of the required technology has been already used (e.g. OBS) in vent fields and needs to be refitted for long-term deployments. Development must focus on the standardisation of the hardware, the reduction of size and cost of instruments, and the improvement of reliability.

An important need stressed in the first MoMAR meeting in 1998, and that is still

required at the present time, is that of both chemical and biological sensors available for long term deployment in hydrothermal fields. Only a limited number of sensors are available or have been adapted to environmental studies in hydrothermal fields; autonomous temperature probes are the only ones readily available for long term monitoring. Other sensors (pH, flow meters, methane, sulphide) or in situ analysers are available for short term studies (cruise-based operations) and must be adapted for operation at longer periods of time (year or longer). The time series approach must also be combined with a discrete sampling strategy also to be developed.



Fig. 3. *In situ* analysis using Alchemist manipulated by the ROV Victor, Atos cruise 2001, Lucky Strike. Photo © IFREMER

Biological studies at the site scale require non-invasive observational techniques, such as video imagery, and associated scaling methods (e.g., lasers). Long-term deployment of optical sensors is not possible due to the precipitation of material over the optical surfaces. In addition, lighting requires large amounts of energy for long-term deployments. Development of long-term optical observational techniques should be a second priority in technology development within MoMAR.

Finally, the possibility of deployment of several moorings, and the intensive use of ROVs or AUVs, opens the possibility to adapt existing instruments for deployment in these platforms at little cost.



Fig. 4. Monitoring of temperature over a clump of mussels, ATOS cruise 2001, Lucky Strike. Photo © IFREMER

5 to 10 years

The approach used in MoMAR will be that of ‘watching’ through the acquisition of time-series images/data. This approach does not require real-time data transmission from the seafloor, although some minimum communication to control and validate the correct functioning of on-bottom and moored instruments is desirable.

The development of benthic observatories or networks such as ASSEM and GEOSTAR could potentially be used to increase the working potential of MoMAR studies in the future, by means of energy supply, data acquisition and transmission from and to the seafloor. The use of existing technology in the first phase of MoMAR could be used as a basis to develop an observatory-type site through a connected network in the studied region.

The Working Group also recognizes that there are on-going efforts in technology development in different countries and seafloor observatory projects. The InterRidge Monitoring and Observatories Working Group should facilitate the flow of information so that instruments, data formats, etc are transferable and/or standardized.

Recommendations for technological development

- Need to work on existing reliable technology to adapt it for long-term deployment.
- Need to develop reliable chemical and biological sensors and imaging techniques for long-term deployment in hydrothermal fields.
- Use existing MoMAR projects in the short-term to eventually establish an integrated observatory based on existing technology and instruments.

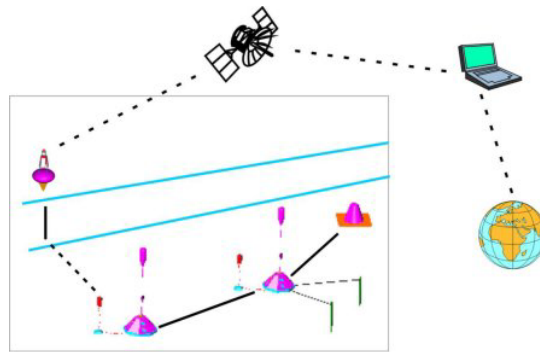


Fig. 5. Principle of the ASSEM observatory. (Array of Sensors for long term SEabed Monitoring of geohazards). © IFREMER

1.9. FOLLOW-UP OF MoMAR

1.9.1 Role of MoMAR

The follow-up structure of MoMAR requires a strong steering capability, as it must coordinate and manage all MoMAR - related projects, and be at the same time proactive to promote and instigate required projects when clear lacks and needs are identified. Coordination of projects is necessarily based on enforcement of a ‘code of good conduct’, on the availability of information of on-going cruises and experiments, and the flow

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and distribution of data and information. All these aspects should be assumed by PIs and enforced by the Committee so insure the efficient coordination of MoMAR. Finally, MoMAR is one of several observatory- or long-term observation sites developing (i.e., Ridge2K Integrated Sites Program, NEPTUNE, etc), so the Committee should effectively link with other international and national programs and sites, and be proactive in promoting outreach activities.

1.8.2 MoMAR committee

As MoMAR should have effective steering capability, it should be composed of a reduced (6-9) number of committed and available members, and representing a balance both of disciplines and of the main national active partners (this is an international and not an exclusively European Union effort). The Committee will act upon guidelines established by the MoMAR scientific community (Science Plan, Implementation Plan, 'Code of Conduct', etc.); will actively and promptly inform the community (i.e., web-based information) and consult the larger scientific community when required (email, Workshops or Meetings).

The Convenors of the Workshop will consult different national partners and attendees of the Workshop, and will propose a list of Possible Committee Members for comments and discussion by the beginning of 2003.

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APPENDIX I - WORKING PAPERS

BIOLOGICAL ASPECTS WORKING PAPER: HOW TO STUDY THE ECOSYSTEM DYNAMICS AT A DECADAL SCALE?

DANIEL DESBRUYÈRES



DESBRUYÈRES, D. 2002. Biological aspects working paper: How to study the ecosystem dynamics at a decadal scale? Pp. 21-25 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

To understand, on a *slow spreading* Ridge, the *linkages* between hydrothermal ecosystem *diversity* and *dynamics* and the complex of hydro-geological system that sustains them.

Daniel Desbruyères (e-mail: daniel.desbruyeres@ifremer.fr), Centre de Brest de l'Ifremer BP 70, 29280 Plouzané, France

INTRODUCTION

All previous studies of temporal and spatial changes in mid-ocean ridge (MOR) vent communities have been conducted on fast-spreading or intermediate spreading ridges (e.g. 9°N/EPR (SHANK et al. 1998), 13°N/EPR (DESBRUYÈRES 1998), CoAxial segment Juan de Fuca Ridge (TUNNICLIFFE et al. 1997)). In these ridges, catastrophic events (e.g. dyke injections) are rather frequent as compared to slow spreading ridges and cause disturbance events that are key structuring forces for the ecosystems. The studies following these large catastrophic disturbances investigate the re-establishment and development of associated communities focusing on colonization processes and population successions. The interest of monitoring the vent ecosystem on a slow spreading ridge is rather different and can not rely on the unlikely hope to witness such an large scale event; it must be focused on pseudo-steady stage communities and their links to micro-events and variations in hydrothermal fluxes (DZIAK & JOHNSON 2002).

INTERESTS OF THE AZORES TRIPLE JUNCTION AREA ESTABLISHING A LONG-TERM MONITORING

Since 1993, the ATJ studied area has been the focus of several American, French, Portuguese and EU funded cruises/programmes. The geological-geophysical background of the area is well constrained, and most of the general characteristics of the communities were yet described. It is almost ideally located for logistics allowing short transit time for deployment and retrieval of moorings / tools, and the installation of a cable can be envisaged. Moreover the biological diversity of communities and ecological patterns (VAN DOVER 1995; VAN DOVER et al. 1996) (DESBRUYÈRES et al. 2000; DESBRUYÈRES et al. 2001) from Rainbow (2300m / ultramafic) to Menez Gwen (800m / basaltic) allow comparative strategy between vent fields. All our thought and planning processes must consider this unique opportunity of comparative strategy.

WHICH FACTORS ARE TRIGGERING THE ECOSYSTEM DYNAMICS?

The diversity and functioning of vent communities are intimately linked to hydro-geological processes that determine the distribution and patterns of venting. The present stage (diversity and functioning) of the community results from a long history of interactions between hydrothermal fluxes and biological processes (dispersal, colonization, competition, population dynamics, adaptations, population genetics). It is important to remember that, even in a steady stage of hydrothermal fluxes, the communities do evolve under biological processes. The monitoring of hydrothermal fluxes and event detection (disturbance) must be therefore associated with a study of the patterns of biological interactions. Moreover, a determining part of the life cycles of the vent organisms takes place off the vent fields either in the water column or at the benthic boundary layer. Their links with pelagic material have been underscored [e.g. (POND et al. 1997 & POND et al. 2000)] stressing the importance of monitoring pelagic fluxes within and outside the active fields to understand the mechanisms of dispersal and life cycles. The knowledge of the general circulation within the axial valley is also crucial to understand community dispersal (MULLINEAUX 1995).

THE INEVITABLE REQUIREMENT

If we aim to understand how the vent system function by monitoring them, we must assume that the disturbance that we bring doing so, is kept negligible as compared to phenomena under investigation. Most of the time, this preliminary assumption is not verified and it becomes very difficult to deduce what is attributable to natural variations of the ecosystem and what is directly coming from the anthropogenic impact on (TUNNICLIFFE 1990 & MULLINEAUX et al. 1998a). In particular, most of the strategies presently used for taxonomy, diversity studies, population dynamics, physiology and population genetics (i.e. most of the present strategies used by

biologists) require important manipulations of the system (including heavy sampling), which could be deleterious to the ecosystem and (for sure) is not compatible with the multiyear observation strategy.

The research community could resolve this conflict (1) by embracing the concept of deep-sea hydrothermal vent reserves (2) developing remote, non destructive (*non-invasive*) and environmentally "friendly" techniques (biological) monitoring (3) choosing nearby sites for sampling where those who need to manipulate and sample the system could work with a voluntary action to avoid adverse impacts and optimise sampling by coordination, exchanges of samples and information between scientists. *We really need an integrated programme with a steering committee in charge of coordination of the at-sea work.*

WHICH RESEARCH?

Biodiversity: Population dynamics (including growth rates, mortality), successions (competition for space and resource) and diversity as related to hydrothermal flux temporal patterns.

Reproduction: life cycles, colonization and dispersal - propagules, inter annual variations and seasonal patterns as related to hydrothermal / pelagic fluxes (need the extensive mapping of vent settings on the studied segments -Rainbow to Menez Gwen).

Biodiversity of microbial communities: Microbial activity / diversity, successions (including sub-surface) as related to hydrothermal fluxes (+ events) and temporal patterns.

Bio-geochemical interactions between organisms and environment: temporal variations

Food Web: Which variation within temporal sequence (if existing)?

Eco-physiology: Which links between organism physiology and hydrothermal flux variation - which response to major events (e.g. variation in toxicity of fluids). Variations within symbiotic systems with chemical patterns in venting.

WHAT ARE THE PARAMETERS? WHAT ARE THE AVAILABLE TECHNIQUES IN THE 5-10 UPCOMING YEARS? WHAT ARE THE STRATEGIES?

The biological studies of natural vent ecosystem require (1) the knowledge of short and long term variations in environmental conditions at the scale of organisms and populations (2) an assessment of pelagic, hydrothermal, and biological fluxes (at the scale of vent sites/fields) - and fluxes between vent fields (3) information on community distribution (density, biomass, diversity, behaviour / activity...). These information could be recorded (a) during (frequent) cruises with access to the site by manned submersibles or ROV (mostly during summer in the case of MAR / ATJ) or (b) by continuous recording.

Continuous recording

If techniques for environmental parameters monitoring (temperature, flow rates, pH, sulphide, oxygen, methane, iron...) could be sensibly expected to be available on shelf within the next five years using existing or new sensors, nevertheless their present life span and drift as well as mineral / bacterial fouling probably would force frequent supplying of an observatory at vent ecosystem. The present colorimetric techniques used on submersible to monitor chemical parameters (LE BRIS et al. 2000, LE BRIS et al. 2001, JOHNSON et al. 1986a, JOHNSON et al. 1986b & JOHNSON et al. 1988), must be customized for long term measurements. Current meters (Anderaa and ADCP), CTD, TBD (stand-alone devices to monitor turbidity), thermistor

chains could be easily customized to monitor the hydrothermal plume.

Conversely, almost no sensors are available for the study of biodiversity and functioning of the benthic communities (we don't know how to force living organisms through an optical fiber) with the exception of still cameras (digital) or video imagery (JUNIPER et al. 1998 & SARRAZIN & JUNIPER 1998). They are usually used associated with submersible but can be also disposed on the bottom as autonomous devices. The test made by TYLER et al. (1999) during the MARVEL / PICO cruises demonstrated the interest and limitations of this technique due to power failures and mineral fouling on lenses. The questions of resolution (biodiversity), quantification (densities, biomass) and representativeness of the set of frames or video footage remain to be explored and solve. The scientific storage management and processing of huge quantities of information coming from months of observation is not also a trivial issue.

Discrete experimental study of the ecosystem

If sampling of natural population is accepted, most of the existing techniques for the study of dynamics of vent biology consist of experimental devices moored on the bottom and retrieved during surface or submersible cruises.

COMPLEMENTARY STUDIES: "IN SITU SIMULATED" EXPERIMENTS

The proximity of the Biological laboratory (*LabHorta*) in the island of Faial allows long-term experiments on living samples using pressurized aquaria and regulated media.

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Table I
Available techniques for biological studies

Name	Objective	References
Sediment traps (sequential)	POM fluxes (pelagic / hydrothermal) - post larval stages	KHRIPOUNOFF & ALBÉRIC 1991, KHRIPOUNOFF et al. 2000 & KHRIPOUNOFF et al. 2001
PLASMA	Plankton pump	DIXON & DIXON 1998
Colonisation experiments (soft and hard substrates)	To study the variation of recruitment with time inside and outside vent area	MULLINEAUX & MANAHAN 1998, MULLINEAUX et al. 1998b & 2000, DESBRUYÈRES et al. 1980 & TAYLOR et al. 1999
Retrievable cages	To access to hydrothermal vent fauna long after the end of a dive cruise	DIXON et al. 2001
Vent caps / diverse culture media	Sampling / culture - microbiology	TAYLOR et al. 1999 & REYSENBACH et al. 2000
Marking and recapture experiments - sclerochronology	Growth / behaviour studies	

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THE ICHTHYOLOGY OF THE MAR HYDROTHERMAL VENTS AND THE MOMAR INITIATIVE

MANUEL J. BISCOITO, ARMANDO J. ALMEIDA & RICARDO S. SANTOS



BISCOITO, M.J., A.J. ALMEIDA & R.S. SANTOS. 2002. The ichthyology of the MAR hydrothermal vents and the MoMAR initiative. P. 26 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Since the discovery of Lucky Strike in 1993, scientists from the above mentioned laboratories have been studying the ichthyology of the hydrothermal vents and surroundings.

There was limited knowledge not only on the species living inside the active areas, the so-called “vent endemics”, but also on the bathyal species inhabiting the periphery of the vent fields, some of which are entering the active sites for feeding.

During these last 9 years, studies on this field have been mainly qualitative. Six «vent endemic» species (possibly 7) and nearly 50 bathyal species have been recorded from the active fields in MAR, the vast majority of their identifications having been based on video records or photographs from several research cruises, using the deep submersibles NAUTILE and ROV VICTOR (IFREMER, France) and ALVIN and ROV JASON (WHOI, USA).

We consider important to:

- Continue improving knowledge (updating inventory and studying the biology of particular species)
- To quantify the ichthyofauna
- Study the behaviour of species
- To assess temporal variation

What can be done within the framework of MoMAR?

Taking advantage of existing software (Adelie[®]) we intend to assess the distribution of the fish species in space and time and try to quantify it. To do this we hope to use both historical data and data from new cruises.

Tagging specimens, using both conventional and electronic tags (e.g. using AUDOS and developing new techniques) is another important way to assess distribution and to analyze behaviour of the species. This research is very relevant in terms of a monitoring programme, which should be put in practice in the MoMAR area, with particular interest for the management of the future Marine Protected Area. This may well lead to the installation of three to five fixed transponders.

Manuel J. Biscoito, IMAR - Faculdade de Ciências da Universidade de Lisboa - Laboratório Marítimo da Guia, Cascais, Portugal; Armando J. Almeida, IMAR - Museu Municipal do Funchal (História Natural) & Estação de Biologia Marinha do Funchal, Madeira, Portugal; Ricardo S. Santos (e-mail: ricardo@notes.horta.uac.pt), IMAR - Departamento de Oceanografia e Pescas - Universidade dos Açores, Horta, Portugal.

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APPENDIX II – LIST OF PARTICIPANTS

Note: Entries in italics correspond to those that registered but did not attend the Workshop

- ADAMCZEWSKA, AGNIESZKA
e-mail: intridge@ori.u-tokyo.ac.jp
InterRidge Coordinator, Ocean Research Institute,
1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639,
Japan. Tel: +81 3 5351 6820; Fax: +81 3 5351
6530
- ALMEIDA, ARMANDO J.
e-mail: aalmeida@fc.ul.pt
Laboratorio Maritimo da Guia, Universidade de
Lisboa, Estrada do Guincho, 2750 Cascais,
Portugal. Tel: +351 214 869 833; Fax: +351 214
869 720
- ANDRADE, JOSÉ M. G.
e-mail: jandrade@icbas.up.pt
Fisiologia Geral, Instituto de Ciências Biomédicas
de Abel Salazar Laboratório de Fisiologia Instituto
de Ciências Biomédicas de Abel Salazar Lg Prof.
Abel Salazar, 2, 4099-003 Porto, Portugal Tel:
+351 22 2062264, Fax: +351 22 2062232
- BALLU, VALÉRIE
e-mail: ballu@ipgp.jussieu.fr
Laboratoire de Gravimétrie et Géodynamique,
Institut de Physique du Globe de Paris, P.O. Box
89, 4 Place Jussieu, 75252 Paris Cédex 05, France.
Tel: +33 1 44 27 33 45; Fax: +33 1 44 27 73 40
- BARRIGA, FERNANDO J.A.S.
e-mail: F.Barriga@fc.ul.pt
Departamento de Geologia, Faculdade de Ciências,
Universidade de Lisboa, Edifício C2, Piso 5, 1749-
016 Campo Grande, Lisboa, Portugal. Tel: +351
217500000 ext 22516 Fax: +351 217 599 380
- BAZIN, SARA
e-mail: bazin@ipgp.jussieu.fr
Laboratoire de Geosciences Marines, IPGP -
Université Pierre et Marie Curie Case 110, 4 place
Jussieu, 75252 Paris Cédex 05, France.
- BENTO, RITA S. M.
e-mail: ritasanmiguel@yahoo.com
University of Azores, Rua da Mãe de Deus, 9501-
801 Ponta Delgada, Portugal. Tel: +351 917 784
050
- BISCOITO, MANUEL J.
e-mail: manuel.biscoito@mail.cm-funchal.pt
Estação de Biologia Marinha do Funchal, Museu
Municipal do Funchal (Historia Natural), Cais do
Carvão - Promenade da Orla Maritima do Funchal
Gorgulho, 9000-107 Funchal, Madeira, Portugal.
Tel: +351 291 700360; Fax: +351 291 766339
- CADIOU, JEAN-FRANÇOIS
e-mail: jfcadiou@ifremer.fr
Underwater Systems Department - IFREMER,
Center de Toulon - La Seyne Zone Portuaire de
Bregailon B.P. 330-83507 La Seyne-sur-mer.
Cedex, France
- CANNAT, MATHILDE
e-mail: cannat@ccr.jussieu.fr
Laboratoire de Geosciences Marines, IPGP -
Université Pierre et Marie Curie Case 110, 4 place
Jussieu, 75252 Paris Cédex 05, France. Tel: +33 1
44 27 51 92; Fax: +33 1 44 27 39 11
- CARDIGOS, FREDERICO
e-mail: frederico@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411
- GONZALÉZ, ANTÓNIO G. C.*
e-mail: acheca@ugr.es
Estratigrafia e Paleontologia, Facultad de Ciências,
Universidade de Granada, Av. Fuentenueva,s/n
18071, Spain. Tel: +34 958 243201; Fax: +34 958
248 528
- COLAÇO, ANA
e-mail: acolaco@notes.horta.uac.pt
IMAR - University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Sta
Cruz, Horta, Azores 9901-862, Portugal. Tel: +351
292 200 436; Fax: +351 29 220 411
- COMPANY, RUI
e-mail: rcompany@ualg.pt
CIMA, Laboratory of Ecotoxicology and
Environmental Chemistry, FCMA, University of
Algarve, Campus de Gambelas, 8000-870 Faro,
Portugal. Tel: +351 289 800 100 Fax: +351 289
818 353
- COSTA, RAQUEL P.*
e-mail: raquel.costa@fc.ul.pt
Dep. Geologia of Lisbon University, CREMINER,
R. Bernardino Costa , 40, 3º Lisboa 1200, Portugal.
Tel: +351 217 500 064
- COSTA, VALENTINA
e-mail: valentina@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411

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- COWEN, JAMES P.
e-mail: jcowen@soest.hawaii.edu
Department of Oceanography, School of Ocean & Earth Science & Technology, University of Hawaii, 1000 Pope Road, Honolulu HI 96822, USA. Tel: +1 808 956 7124; Fax: +1 808 956 9225
- CRAWFORD, WAYNE C.
e-mail: crawford@ipgp.jussieu.fr
Laboratoire de Geosciences Marines, IPGP - Université Pierre et Marie Curie Case 110, 4 place Jussieu, 75252 Paris Cédex 05, France.
- DA CUNHA, MARINA R.
e-mail: mcunha@bio.ua.pt
Departamento de Biologia, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal. Tel: +351 234 370 785; Fax: +351 234 426 408
- DANDO, PAUL R.
e-mail: oss109@bangor.ac.uk
School of Ocean Sciences, University of Wales-Bangor, Menai Bridge, Isle of Anglesey, LL59 5EY, UK. Tel: + 44 1248 382 904; Fax: + 44 1248 382 620
- DESBRUYERES, DANIEL
e-mail: ddesbruy@ifremer.fr
Département de l'Environnement Profond, Direction des Recherches Océaniques, IFREMER Centre de Brest, B.P. 70, 29280 Plouzané Cédex, France. Tel: +33 2 98 22 43 01; Fax: +33 2 98 22 45 47 / +33 2 98 22 46 53
- DIXON, DAVID R.
e-mail: drd@mail.soc.soton.ac.uk
Head of Molecular Genetics, George Deacon Division for Ocean Processes Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, UK. Tel: +44 1703 596 014; Fax: +44 1703 596 247
- DUENNEBIER, FRED K.
e-mail: fred@soest.hawaii.edu
Hawaii Institute of Geophysics, University of Hawaii at Manoa, 2525 Correa Road, Honolulu HI 96822, USA. Tel: +1 808 956 4779; Fax: +1 808 957 5154
- DZIAK, ROBERT P.
e-mail: dziak@pmel.noaa.gov
Oregon State University, Hatfield Marine Science Center, 2115 SE OSU Drive, Newport, Oregon, 97365, USA. Tel: +1-541-867-0175; Fax: +1-541-867-3907
- EINARSSON, PÁLL
e-mail: palli@raunvis.hi.is
Science Institute, University of Iceland, Hofsvallagata 53, 107 Reykjavik, Iceland. Tel: +354 525 4816; Fax: +354 552 1346
- ESCARTÍN, JAVIER E.
e-mail: escartin@ipgp.jussieu.fr
Laboratoire de Geosciences Marines, IPGP, Université Pierre et Marie Curie, Case 89, 4 place Jussieu, 75252 Paris Cédex 05, France. Tel: + 33 1 4427 4601; Fax: + 33 1 4427 3911
- FERRAZ, ROGÉRIO R.
e-mail: ferraz@notes.horta.uac.pt
University of the Azores, Department of Oceanography and Fisheries (DOP), Cais de Santa Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200 400; Fax: +351 292 200 411
- FERREIRA, PEDRO
e-mail: pedro.ferreira@igm.pt
Departamento de Geologia Marinha / Instituto Geologico e Mineiro, Instituto Geologico e Mineiro Estrada da Portela. Zambujal, Apartado 7586, 2720 Alfragide, Portugal. Tel: +351 214 705 400; Fax: +351 214 719 018
- FOUQUET, YVES
e-mail: fouquet@ifremer.fr
Département de Géosciences Marines, Direction des Recherches Océaniques, IFREMER Centre de Brest, B.P. 70, 29280 Plouzané Cédex, France. Tel: +33 2 98 22 42 54; Fax: +33 2 98 22 45 70
- FOX, CHRISTOPHER G.
e-mail: fox@pmel.noaa.gov
NOAA/PMEL/VENTS Program, 2115 S.E. OSU Drive, Newport OR 97365, USA. Tel: +1 541 867 0276; Fax: +1 541 867 3907
- GAILL, FRANÇOISE
e-mail: francoise.gaill@snv.jussieu.fr
Laboratoire de Biologie Marine, CNRS UPR 7622, Université Pierre et Marie Curie (Paris 6), 7 Quai Saint-Bernard, F-75252 Paris Cédex 05, France. Tel: +33 1 44 27 30 63; Fax: +33 1 44 27 52 50
- GAUTHERON, CECILE
e-mail: gauthero@ipgp.jussieu.fr
IPGP laboratoire de Geochimie et Cosmochimie, T14-15 3eme etage, 4 place Jussieu, Paris 75005, France. Tel: +33 144 274 805; Fax: +33 144 273 752

II MoMAR Workshop
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GENTE, PASCAL

e-mail: gente@univ-brest.fr
Institut Universitaire Européen de la Mer, UMR
6538 "Domaines Océaniques", Place Nicolas
Copernic, 29280 Plouzané, France. Tel: +33 2 98
49 87 18; Fax: +33 2 98 49 87 60

GERMAN, CHRISTOPHER R.

e-mail: cge@soc.soton.ac.uk
Challenger Division for Seafloor Processes,
Southampton Oceanography Centre, European
Way, Empress Dock, Southampton, SO14 3ZH,
UK. Tel: +44 2380 596542; Fax: +44 2380 596554

GLOWKA, LYLE

e-mail: lglowka@csi.com
Biodiversity Strategies International, Agnesstrasse
41, 53225 Bonn, Germany. Tel: +49 284 797 921

GUENTER, ASCH

e-mail: asch@gfz-potsdam.de
GeoForschungsZentrum Potsdam 14473 Potsdam
Telegrafenberg, Germany. Tel: +49 331 288 1214;
Fax: +49 331 288 1266

HASSLER, DEBORAH R.

e-mail: dhassler@psu.edu
RIDGE 2000, 208 Mueller Lab, Dept of Biology,
Penn State University, State Collge, PA 16802,
USA Tel: +1 814-863-6604; Fax: +1 814-865-4364

JAKOBSEN, KIRSTEN

e-mail: rebikoff@web.de
Foundation Rebikoff-Niggeler, Rocha Vermelha,
Praia do Almoxarife, 9900 Horta, Açores,
Portugal. Tel: +351 292 949 505; Fax: +351 292
949 563

KADAR, ENIKO

e-mail: Enikokadar@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411

LANGMUIR, CHARLES H.

e-mail: langmuir@eps.harvard.edu
Department of Earth and Planetary Sciences,
Harvard University, Oxford Street 20, Cambridge,
MA 02138, USA. Tel: +1 845 365 8657

LOPES, HUMBERTO

e-mail: hlopes@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411

LOURENÇO, NUNO

e-mail: nlouren@ualg.pt
FCMA - University of Algarve, Campus de
Gambelas, 8000 Faro, Portugal.

MACHADO, JORGE P.

e-mail: jmachado@icbas.up.pt
Instituto de Ciências Biomédicas Abel Salazar,
Departamento de Produção Aquática, Lg Prof. Abel
Salazar, 2, 4099-003 Porto, Portugal. Tel: +351 222
062 294; Fax: +351 222 062 232

MADUREIRA, PEDRO

e-mail: pedro@uevora.pt
Department of Geosciences - University of Évora,
Universidade de Évora - Apartado 94, 7002-554
Évora Codex, Portugal Tel: +351 266 745 300,
Fax: +351 266 744 971

MAIA, MARCIA

e-mail: marcia@univ-brest.fr
Institut Universitaire Européen de la Mer, UMR
6538 "Domaines Océaniques", Place Nicolas
Copernic, 29280 Plouzané, France. Tex: +33 298
016 170; Fax: +33 298 016 620

MARQUES, FILIPE A.

e-mail: afam@fc.ul.pt
CREMINER, Dep. Geologia, Fac. de Ciências da
Universidade de Lisboa, Faculdade de Ciências,
Edif. C2, Piso 5, Lisboa 1749-016 Campo Grande,
Portugal. Tel: +351 91 7407607; Fax: +351 217
500 064

MARTINS, ANA

e-mail: amartins@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411

MARTINS, HELEN R.

e-mail: hmartins@horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411

MARTINS, INÊS

e-mail: imartins@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411

MATA, JOÃO

e-mail: jmata@fc.ul.pt
Departamento de Geologia / Centro de Geologia
Universidade Lisboa, Faculdade de Ciências,
Universidade de Lisboa, Campo Grande, C2 - 5º
Piso, 1749-016 Lisboa, Portugal. Tel: +351 217
500 077

Towards planning of seafloor observatory programs for the MAR region

- MATIAS, LUÍS
e-mail: lmatias@fc.ul.pt
Centro de Geofísica da Universidade de Lisboa,
Edifício C8, 1749-016 Campo Grande, Lisboa,
Portugal. Tel: 217 500 812; Fax: 217 500 977
- MELLO, SIDNEY
e-mail: smello@igeo.uff.br
Dept. de Geologia/LAGEMAR-UFF, Av. Litorânea
s/n., Gragoatá, Niterói, RJ, 24210-340, Brazil. Tel:
+55 021 719 4241; Fax: +55 021 719 4241
- MENEZES, GUI
e-mail: gui@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411
- MESTRE, NÉLIA
e-mail: neliamestre@hotmail.com
Universidade do Algarve, Faculdade de Ciências
do Mar e do Ambiente, Rua António Morais Silva
nº5 cave, 2810-021 Feijó, Portugal.
- MÉVEL, CATHERINE
e-mail: mevel@ccr.jussieu.fr
Laboratoire de Geosciences Marines, IPGP -
Université Pierre et Marie Curie, Case 110, 4 place
Jussieu, 75252 Paris cedex 05, France. Tel: +33
144 275 193; Fax: +33 144 273 911
- MIRANDA, MIGUEL A.
e-mail: jmiranda@fc.ul.pt
Instituto de Ciências da Terra e do Espaço, Centro
de Geofísica, Universidade de Lisboa, Rua da
Escola Politécnica 58, 1250 Lisboa, Portugal. Tel:
+351 213 921 864; Fax: +351 213 953 327
- MONTEIRO, HIPÓLITO
e-mail: hipolito.monteiro@igm.pt
Departamento de Geologia Marinha / Instituto
Geológico e Mineiro, Instituto Geológico e Mineiro
Estrada da Portela. Zambujal, Apartado 7586, 2720
Alfragide, Portugal. Tel: +351 214 705 400; Fax:
+351 214 719 018
- MOREIRA, MANUEL A.
e-mail: moreira@ipgp.jussieu.fr
Laboratoire de Géochimie et Cosmochimie, IPGP
T14-15, 3eme etage 4 place Jussieu 75252 Paris
cedex 05, France. Tel: +33 144 274 805; Fax: +33
144 273 752
- OLIVEIRA, PAULO
e-mail: pjcro@isr.ist.utl.pt
Instituto Superior Tecnico / Instituto de Sistemas e
Robotica, Torre Norte, 8 andar Av. Rovisco Pais, 1,
1049-001, Lisbon, Portugal. Tel: +351 218 418
053; Fax: +351 218 418 291
- PACHECO, JOSÉ
e-mail: jp@notes.uac.pt
Departamento de Geociências da Universidade dos
Açores, Departamento de Geociências da
Universidade dos Açores, Complexo Científico,
Rua da Mãe de Deus, 9501-801 Ponta Delgada,
Portugal. Tel: +351 296 650 143; Fax: +351 296
650 141
- PASCOAL, ANTÓNIO
e-mail: antonio@isr.ist.utl.pt
Institute for Systems and Robotics, IST-Torre
Norte Av. Rovisco Pais, 1, 1049-001 Lisboa,
Portugal. Tel: +351 218 418 051; Fax: +351 218
418 291
- PEREIRA, FERNANDO L.
e-mail: flp@fe.up.pt
Institute of Systems and Robotics - University of
Porto, Portugal. Tel: +351 225 081 857, Fax: + 351
225 081 443
- PORTEIRO, FILIPE
e-mail: filipe@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411
- QUEIROZ, GABRIELA
e-mail: gq@notes.uac.pt
Departamento de Geociências da Universidade dos
Açores, Universidade dos Açores, Rua da Mãe de
Deus, 9501-801 Ponta Delgada, Portugal. Tel:
+351 296 650 140; Fax: +351 296 653 141
- RAMIREZ-LLODRA, EVA
e-mail: eramirez_llodra@hotmail.com
Southampton Oceanography Centre, SOES
Southampton Oceanography Centre European way
SO14 3 ZH, Southampton, UK. Tel: +442 380 592
557; Fax: +442 380 593 059
- RIDAO, PERE
e-mail: pere@eia.udg.es
Electronics, Computer, Engineering and
Automation, Escola Politecnica Superior, Avd.
Lluís Santalo s/n, CP 17071, Girona, Spain. Tel:
+34 972 418 879; Fax: +34 972 418 098
- ROMMEVAUX-JESTIN, CÉLINE
e-mail: rommevau@ipgp.jussieu.fr
Laboratoire de Geosciences Marines, IPGP -
Université Pierre et Marie Curie, Case 110, 4 place
Jussieu, 75252 Paris cedex 05, France. Tel: +33
144 277 723; Fax: +33 144 273 911

II MoMAR Workshop
Horta (Azores, Portugal), 14-17 June 2002

- RUIVO, MÁRIO
e-mail: cointersec.presid@fct.mct.pt
Intersectorial Oceanographic Commission -
Avenida Infante Santo, 42 - 4º, PT-1200 Lisboa,
Portugal. Tel: +351 213 904 330; Fax: +351 213
952 212
- SANTOS, RICARDO S.
e-mail: ricardo@notes.horta.uac.pt
University of the Azores, Department of
Oceanography and Fisheries (DOP), Cais de Santa
Cruz, 9901-862 Horta, Portugal. Tel: +351 292 200
400; Fax: +351 292 200 411
- SARRADIN, PIERRE-MARIE
e-mail: pmsarrad@ifremer.fr
Département de l'Environnement Profond,
Direction des Recherches Océaniques, IFREMER
Centre de Brest, B.P. 70, 29280 Plouzané Cédex,
France. Tel: +33 298 224 672; Fax: +33 298 224
547
- SCHULZE, ALBRECHT
e-mail: robert@gfz-potsdam.de
GeoForschungsZentrum Potsdam 14473 Potsdam
Telegrafenberg, Germany. Tel: +493 312 881 220;
Fax: +493 312 881 266
- SICHEL, SUSANNA
e-mail: Susanna@igeo.uff.br
Dept. Geology / Universidade Federal Fluminense
Brazil. Av. Bartolomeu Mitre 33/1301, Leblon
22431- 000 Rio de Janeiro, Brazil. Tel: +55 021
719 4241; Fax: +55 021 719 4241
- SILVA, PEDRO
Centro de Geofísica, Universidade de Lisboa, Rua
da Escola Politécnica, 58, 1250 Lisboa, Portugal
- SILVEIRA, GRAÇA M.
e-mail: gracams@fc.ul.pt
Centro de Geofísica da Universidade de Lisboa,
Rua da Escola Politécnica 58, 1250 LISBOA,
Portugal. Tel: +351 213 921 898
- SILVESTRE, CARLOS
e-mail: cjs@isr.ist.utl.pt
Instituto Superior Técnico / Instituto de Sistemas e
Robotica, Torre Norte, 8 andar Av. Rovisco Pais, 1
1049-001, Lisbon, Portugal. Tel: +351 218 418
052; Fax: +351 218 418 291
- STUDART, NEURE
e-mail: neure_maira@bol.com.br
Universidade Católica do Salvador - Brasil, R.
Príncipe Alberto de Mônaco, nº 18. Tel: +55 292
392 940
- TOLSTOY, MAYA
e-mail: tolstoy@ldeo.columbia.edu
Lamont-Doherty Earth Observatory, 61 Route 9W,
Palisades, NY 10964-8000, USA. Tel: +1 845 365
8791; Fax: +1 845 365 8179
- TYLER, PAUL A.
e-mail: pat8@soc.soton.ac.uk
Department of Oceanography, University of
Southampton, Southampton Oceanography Centre,
European Way, Empress Dock, Southampton,
SO14 3ZH, UK. Tel: +44 1703 592 557; Fax: +44
1703 593 059
- WEBB, SPAHR C.
e-mail: scw@ldeo.columbia.edu
Lamont Doherty Earth Observatory, Columbia
University, 61 Route 9W, Palisades, New York,
10964, USA. Tel: +1 845-365-8439; Fax: +1 845-
365-8150

Towards planning of seafloor observatory programs for the MAR region

APENDIX III - POSTER ABSTRACTS

THE GRAVILUCK PROJECT IN THE MOMAR FRAMEWORK

VALÉRIE BALLU, JÉRÔME AMMANN, SABINE ARNAULT, MATHILDE CANNAT, MARIE-HELEN CORMIER, CHRISTINE DEPLUS, MICHEL DIAMENT, JEROME DYMENT, JAVIER ESCARTÍN, PASCAL GENTE, PHILIPPE JOUSSET, MARCIA MAIA, LAURENT MÉTIVIER, I. PANET, MORGANE RAVILLY, GILLES REVERDIN, C. ROMMEVAUX, GLEN SASAGAWA & ISABELLA VELICOGNA.



BALLU, V., J. AMMANN, S. ARNAULT, M. CANNAT, M.H. CORMIER, C. DEPLUS, M. DIAMENT, J. DYMENT, J. ESCARTÍN, P. GENTE, P. JOUSSET, M. MAIA, L. MÉTIVIER, I. PANET, M. RAVILLY, G. REVERDIN, C. ROMMEVAUX, G. SASAGAWA & I. VELICOGNA. 2002. The GRAVILUCK project in the MOMAR framework. P. 33 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The poster presents the GRAVILUCK cruise project. This experiment is planned on the Lucky Strike segment, which is the target area of the MoMAR (Monitoring of the Mid-Atlantic Ridge) project to study the temporal evolution of a slow-spreading ridge segment. The MoMAR project is multi-disciplinary and we will be working at the border between marine geosciences, satellite geosciences and physical oceanography.

The primary purpose of this cruise is both to do a detailed gravity survey at a ridge segment and to study the dynamical processes that are active at this ridge. The detailed gravity survey aims at characterizing the shallow crustal structure and will be focused on a volcanic edifice and a 2D profile perpendicular to the spreading axis, using a land type gravity meter operated inside the submersible NAUTILE. For the second objective, we are going to deploy permanent benchmarks on the seafloor and collect gravity and pressure data on these benchmarks. This approach should allow us to better understand the current tectonics and the dynamics of the volcanic and hydrothermal systems involved. In addition, we plan on installing two pressure gauges on the seafloor for a one year recording. One of the gauges will be placed on the top of the active volcano and the other one outside the geodynamically active area for a reference time series. This differential measurement, together with satellite altimetry data, should help us analyze (and, if possible, remove) the oceanographic signal variability which hides the geophysical signal we are looking for.

As a side project, we will also use the pressure recording for satellite (gravity and altimetry) data calibration and interpretation. As part of the night program, we plan a dense geophysical survey of the segment (up to anomaly 3a) as well as the collection of physical oceanography data (CTD).

Valérie Ballu (e-mail: ballu@ipgp.jussieu.fr), Institut de Physique du Globe de Paris, Laboratoire de Gravimétrie et Géodynamique, Dép. Géophysique Spatiale et Planétaire UMR 7096 IPGP Case 89 4 place Jussieu 75252 Paris Cedex 05 France.

DEPLOYMENT OF NEW HYDROPHONE ARRAY NORTH OF THE AZORES FOR SEISMIC MONITORING OF THE RIDGE AND THE AZORES PLATEAU

SARA BAZIN, RITA BENTO, CHRIS FOX, JEAN GOSLIN, NUNO LOURENÇO, JOÃO LUÍS, LUÍS MATIAS, HARU MATSUMOTO, JULIE PERROT, PIERRE-FRANCK PISERCHIA & JEAN-YVES ROYER



BAZIN, S., R. BENTO, C. FOX, J. GOSLIN, N. LOURENCO, J. LUIS, L. MATIAS, H. MATSUMOTO, J. PERROT, P-F. PISERCHIA, J-Y. ROYER. 2002. Deployment of new hydrophone array north of the Azores for seismic monitoring of the ridge and the Azores Plateau. P. 34 *in* R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Six autonomous hydrophones were recently deployed during the SIRENA cruise (J. Goslin chief scientist, 17 May - 3 June 2002) on board French R/V LE SUROIT. The moorings are located on both flanks of the Mid Atlantic Ridge between the Azores and the Gibbs Fracture Zone. This new array will ideally complete the southern one deployed since January 1999 south of the Azores Plateau (SMITH *et al. in press*). The PMEL (NOAA's Pacific Marine Environmental Laboratory) instruments are deployed at about 1000 m depth and record T-phase energy which can propagate in the SOFAR (SOund Fixing And Ranging) channel with very little energy loss. The recordings will be used to monitor and accurately localize regional seismicity as well as whale migrations and other sources of noise (FOX *et al.* 2001). The southern array of moorings (15°-35°N) was able to lower the detection threshold of seismic events with a magnitude of completeness m_c of 3.0: the number of hydrophone-recorded earthquakes is 30 times larger than of those recorded by the global seismic network for a similar period. However the Azores Plateau intersects the SOFAR channel and creates a shadow zone. Therefore the early array was not able to monitor the seismicity located north of the Azores. The new array was designed to fill this gap and enable monitoring of the entire ridge axis. Our three main objectives are: 1- contribute to the understanding of accretion processes, 2- investigate ridge-hotspot interaction in the upper mantle, 3- better access seismic hazard in the Azores archipelago.

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Sara Bazin (e-mail: bazin@ipgp.jussieu.fr) Laboratoire de Géosciences Marines, Institut de Physique du Globe de Paris, 4 Place Jussieu, 75252 Cedex 05 Paris.

ON THE MODEL OF PERIOSTRACUM AND SHELL FORMATION IN
UNIONIDAE (MOLLUSCA: BIVALVIA)

ANTÓNIO G. CHECA



CHECA, A.G. 2002. On the model of periostracum and shell formation in *Unionidae*. P. 35 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The development of the periostracum, from its origin in the periostracal groove until beginning of mineralization at the shell edge, has been studied in three species of unionids. The periostracum consists of a thin outer layer and a thick inner layer, without traces of a third periostracal layer. The outer periostracal layer is the only one formed within the periostracal groove. Growth lines are formed when the outer periostracal layer forms localised folds at the exit of the periostracal groove. In some cases, both flanks of the fold stick together at their inner surface, forming loops. This occurred when growth stopped at the margin while the outer periostracum secretion continued. The excess of this layer contracted and folded at the exit of the periostracal groove (where the periostracum is thinner and weaker). Folds are later sealed at their base by the inner periostracum. The latter layer was secreted outside the periostracal groove, presumably by the internal surface of the outer mantle fold when this extended to the shell tip during mineralization episodes. Its obliquely banded nature and progressive thickening towards the shell edge confirm this. Distally, the periostracum curves back and aragonitic prisms initiate (as spheruliths) within the jelly inner periostracum. In transversal sections, prism growth lines plunge dorsally uninterruptedly across adjacent crystals and continue later into the boundaries between layers of nacreous tablets of the inner shell. This strongly suggests that the mantle causes mineralization when it adheres periodically to the inner surface of the shell growth margin.

António Checa (e-mail: acheca@ugr.es), Departamento de Estratigrafía y Paleontología, Universidad de Granada, 18071-Granada, Spain.

LABHORTA - A LAND-BASED LABORATORY FOR VENT STUDIES

ANA COLAÇO, RICARDO S. SANTOS &, VENTOX PARTY



COLAÇO, A., R.S. SANTOS & VENTOX PARTY. 2002. LABHORTA - a land-based laboratory for vent studies. P. 36 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. *Towards planning of seafloor observatory programs for the MAR region* (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The set up of a land-based laboratory at a research centre within the Azores archipelago, within close proximity to active deep-sea vent sites, which are able to be kept supplied with live animals from acoustically-retrievable cages, is a major conceptual and technical breakthrough in both vent and deep-sea research in general, particularly when combined, as is the case here, with the use of the extremely innovative IPOCAMP pressure vessel. The installation of land-based laboratory facilities (*LabHorta*) will allow *in vivo* studies to extend over a longer period than the cruise itself. The R/V ARQUIPÉLAGO of the IMAR-DOP/UAc, was used as a shuttle between the mother ships of the diving research cruises and the land-based laboratory. Biological material, equipment, scientists, were transferred by the "shuttle vessel" ARQUIPÉLAGO. This procedure permitted to open the time window by supplying material for biological research during selected periods.

Taken together these technological advances promise to significantly bring forward the *state of the art* relating to both the fundamental and applied aspects of vent research.

Ana Colaço (e-mail: acolaco@notes.horta.uac.pt), Ricardo S. Santos, IMAR- Department of Oceanography and Fisheries, University of the Azores, Horta, Portugal; VENTOX Party (Paul Dando - University of Wales-Bangor, UK; David Dixon - Southampton Oceanography Centre, UK; François Lallier, Didier Jolliver & Frank Zal - UMR 7127 CNRS-UPMC, France; Aline Fiala-Médioni - Observatoire Océanologique de Banyuls, France; Maria João Bebião - Universidade do Algarve, Portugal; Françoise Gaill & Bruce Shillito - UMR CNRS 7622 Biologie Cellulaire et Moléculaire du Développement, France; Pierre-Marie Sarradin & Daniel Desbruyères - Département Environnement Profond Centre de Brest de IFREMER, France; George Barbier & Anne Godfroy - Direction des ressources vivantes - Microbiologie et Biotechnologies des Extrémophiles (DRV/VP/MBE), France; Manuel Biscoito & Armando Almeida - Imar-MMF e IMAR-LMG, Portugal; Richard Cosson - Université de Nantes, France; Marc Laulier- Université de Le Man, France).

ANTIOXIDANT DEFENCE MECHANISMS IN THE HYDROTHERMAL VENT MUSSEL *Bathymodiolus azoricus* FROM THE MID-ATLANTIC RIDGE HYDROTHERMAL SYSTEMS

RUI COMPANY, ANGELA SERAFIM & MARIA J. BEBIANNO



COMPANY, R., A. SERAFIM & M.J. BEBIANNO. 2002. Antioxidant defence mechanisms in the hydrothermal vent mussel *Bathymodiolus azoricus* from Mid-Atlantic Ridge Hydrothermal Systems. P. 37 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Antioxidant defence mechanisms include several enzymes capable to remove oxyradicals as the superoxide anion radical (O_2^-), hydrogen peroxide (H_2O_2) and the hydroxyl radical (OH). The effectiveness of these antioxidant defence systems define the extent to which oxyradicals generation produces biological damage. Hydrothermal vent mussels live in a very specific environment with anomalous conditions for deep-sea environments, including high metal concentrations. Extensive mussel beds of the mytilid *Bathymodiolus azoricus* dominate the hydrothermal vent fauna in Azores Triple Junction (ATJ), located in the Mid-Atlantic Ridge. It is still unknown the existence and effectiveness of antioxidant defence mechanisms in these mussels.

The aim of this work was to determine the activity of the antioxidant enzymes, superoxide dismutase (SOD; EC 1.15.1.1), catalase (CAT; EC 1.11.1.6), selenium-dependent glutathione peroxidase (Se-GPX; EC 1.11.1.9), total glutathione peroxidase (GPX) in tissues of *B. azoricus* (gills and mantle) collected at Menez-Gwen (37° 51' N), Lucky Strike (37° 18' N) and Rainbow (36° 13' N) during the ATOS cruise. The seasonal variability of mussels from Menez-Gwen was also determined using organisms recovered periodically with acoustic release cages from July to September 2001.

Results indicate that as in coastal mussels population, hydrothermal vent mussels possess enzymatic protection against reactive oxygen species, considering the environmental specificity. The SOD enzymatic activity was significantly different between tissues in the three sites. A reduced CAT activity in the tissues analysed was observed, except for the Rainbow site individuals. No significant differences in GPX activity were observed between tissues, while Se-GPX activity was tissue dependent. Comparing hydrothermal vent sites, mussels from Menez-Gwen, Lucky Strike and Rainbow exhibits significantly different enzymatic activity of SOD, GPX and Se-GPX, which appears to be related to environmental characteristics, namely depth, temperature and heavy metal concentrations. The temporal variation resulting from the three cages recovered, indicate different tendencies for CAT and SOD enzymes. GPX and Se-GXP enzymes in both gills and mantle have a tendency to decline during cage recovery, from July to September.

Rui Company (e-mail: rcompany@ualg.pt), Angela Serafim & Maria J. Bebianno, CIMA, Laboratory of Ecotoxicology and Environmental Chemistry, FCMA, University of Algarve, Campus de Gambelas, 8000-870 Faro, Portugal.

SISMOMAR: SEISMIC STRUCTURE OF THE LUCKY STRIKE AREA

WAYNE CRAWFORD, MATHILDE CANNAT, JAVIER ESCARTÍN & SATISH SINGH



CRAWFORD, W., M. CANNAT, J. ESCARTÍN & S. SINGH. 2002. SISMOMAR: seismic structure of the Lucky Strike area. P. 38 *in* R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The SISMOMAR project has two goals:

1. to constrain the velocity structure of the lithosphere below the Lucky Strike vent field, and the correlation with the distribution of hydrothermal activity at the surface, and
2. to determine the segment scale structure of the lithosphere that hosts the hydrothermal plumbing system.

We plan to combine reflection, 3D refraction, and seafloor compliance measurements to determine the velocity structure of the lithosphere beneath the vent field throughout the crust and to image any magma lens that may be located beneath the field. We will focus on a 18x18km region centered at the center of the region. To image the entire crust within this region, we will combine shots to a dense array of OBSs within the region with shots to within the region to OBSs located ~40 km away from the region. We will also conduct a series of 2D surveys that will help to put the Lucky Strike venting into the context of the segment's magma budget and spreading history. Finally, we will conduct a brief 2D refraction/reflection study of a region believed to be "cold" hydrothermalism powered by serpentinization of peridotites at the southern end of the segment, to determine the depth to the peridotites. We have devised a series of OBS deployments and airgun lines that realizes these goals with a minimum amount of ship time and the equivalent of twice the # of OBS available, by deploying each OBS twice: once in a tight 3D array centered around the vent fields, and once in a larger 2D/3D array. We will explain first the requirements of a 3D survey within the focussed study area, then present the logistical plan for this survey.

Wayne Crawford (e-mail: crawford@ipgp.jussieu.fr), Institut de Physique du Globe de Paris, Case 89 4 place Jussieu 75252 Paris Cedex 05 France.

ACOUSTICALLY RETRIEVABLE CAGES OPEN UP DEEP-SEA VENTS TO TIME-SERIES STUDIES

DAVID R. DIXON, LINDA R.J. DIXON, DAVID M. LOWB & GUILLAUME VILLEMEN



DIXON D.R., L.R.J. DIXON, D.M. LOWB & G. VILLEMEN. 2002. Acoustically retrievable cages open up deep-sea vents to time-series studies. P. 39 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Acoustically retrievable cages offer an important new way to study temporal processes affecting deep-sea vent organisms. Previous constraints dictated by the timing of research cruises have meant that our knowledge of processes going on at deep-sea vents outside the summer weather window has been extremely limited. Sequential recovery of ROV-deployed cages containing vent mussels (*Bathymodiolus azoricus*) from hydrothermal vents located close to the Azores has now provided access to high quality research material into the winter months which has not only extended our knowledge of the way in which vent organisms cope with chronic, long-term environmental contamination but has also provided unexpected evidence for an annual reproductive cycle in this species. Previously it has been argued that vents are a seasonal due to their dependence on virtually unlimited, geochemical-based energy. However, in the case of *Bathymodiolus* it would seem that its larvae are produced in the spring to take advantage of a peak in primary production in the surface waters at that time. The detritus from this phytoplankton productivity burst acts as a source of food for the developing mussel larvae as they disperse between vents and is thus essential for the ongoing survival of this dominant vent species. This is the first time that such a dependence on photosynthetic pathways has been described for any deep-sea vent ecosystem, and overthrows previous vent dogma that has argued for trophic isolation (*viz.* the nuclear winter hypothesis). This link between the chemosynthetic and photosynthetic driven ecosystems here on earth has important implications for our understanding of the existence of life on other planets.

David R. Dixon (e-mail: drd@soc.soton.ac.uk), Linda R.J. Dixon, Southampton Oceanography Centre, Univ. Southampton & NERC Water front Campus, European Way, Southampton SO14 3ZH UK; David M. Lowb, Plymouth Marine Laboratory, UK, Guillaume Villemin, University of Paris, France.

ANALYSIS OF P- AND T-WAVE ARRIVALS RECORDED BY A MOORED HYDROPHONE ARRAY ALONG THE MID-ATLANTIC RIDGE (10°-35°N)

ROBERT DZIAK, HARU MATSUMOTO, JOE HAXEL, MATT FOWLER, DEBORAH SMITH, CHRIS FOX, DELWAYNE BOHNENSTIEHL & MAYA TOLSTOY



DZIAK, R., H. MATSUMOTO, J. HAXEL, M. FOWLER, D. SMITH, C. FOX, D. BOHNENSTIEHL & M. TOLSTOY. 2002. Analysis of P- and T-wave Arrivals Recorded by a Moored Hydrophone Array along the Mid-Atlantic Ridge (10°-35°N). P. 40-41 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

In February 1999, a consortium of U.S. investigators (NSF and NOAA) began long-term monitoring of Mid-Atlantic-Ridge (MAR) seismicity between 15°N and 35°N. The experiment uses six NOAA/PMEL autonomous hydrophones moored within the SOFAR channel on the MAR flanks. The hydrophones record the hydroacoustic tertiary phase or *T*-wave of oceanic earthquakes from throughout the Atlantic basin. The low attenuation properties of the SOFAR channel allow for a reduction in the detection threshold (cutoff Magnitude) of MAR earthquakes from $M_c=4.7$ of the land-based seismic networks to $M_c=3.0$ with the hydrophones (BOHNENSTIEHL et al. 2002). The improved detection capability of the hydrophones allows for a better view of the overall spatio-temporal patterns in MAR earthquakes (SMITH et al. *in press*).

To assess the waveform analysis capability of the hydrophones we present a preliminary examination of *P*- and *T*-wave arrivals recorded from both regional MAR earthquakes and teleseismic events. The hydrophones (8 bit data resolution) detect upper mantle *Pn* arrivals from regional MAR earthquakes at epicentral distances of 374-1771 km and from events as small as $m_b=3.6$. The *T*-waves of regional MAR events are also clearly recorded although the signals are significantly clipped when earthquakes are <400 km distant or $m_b>5$. A surprising result of the waveform analysis was the identification of *P*- arrivals from earthquakes outside the Atlantic Ocean basin. The hydrophones detected *P*-waves from global earthquakes with magnitudes from 5.8 to 8.3 at epicentral distances ranging from 29.6E to 167.2E. Examination of travel times suggests these teleseismic *P*-waves comprise the entire suite of body-wave arrivals from direct mantle *P*- to outer and inner core reflected/refracted phases. There is an apparent 2-second delay in expected *P*- arrival times consistent with acoustic conversion of the seismic phases at the seafloor interface and propagation to the hydrophone through the water-column.

The long-term goal of this study is to use the regional *P*- arrivals to estimate *Pn* velocity along the Mid-Atlantic-Ridge between 10° E and 35° N. The hydrophone arrays provide a unique opportunity to measure *Pn* velocities in the Atlantic Ocean upper mantle due to the difficulty in placing seismometers on the seafloor for an extended period of time. Additionally, the *P*- arrivals from global earthquakes could be used to estimate thickness of the core-mantle boundary. In May 2002, a joint French-U.S. experiment will deploy an additional 6 hydrophones between 40E-55EN along the Mid-Atlantic Ridge. Combination of these hydrophone data sets may provide an unprecedented view of the upper mantle beneath the entire northern MAR and the Azores Plateau.

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R. Dziak (e-mail: dziak@pmel.noaa.gov), H. Matsumoto, J. Haxel, M. Fowler, Oregon State University/NOAA, Hatfield Marine Science Center, Newport, OR 97365, U.S.A.; D. Smith, Woods Hole Oceanographic Institution, Woods Hole, MA; C. Fox & D. Bohnenstiehl, National Oceanic and Atmospheric Administration/ Pacific Marine Environmental Laboratory, Newport, OR 97365 USA; M. Tolstoy, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964 USA.

SEISMIC EXPRESSION OF PROCESSES ASSOCIATED WITH THE DIVERGENT PLATE BOUNDARY IN ICELAND

PÁLL EINARSSON



EINARSSON, P. 2002. Seismic expression of processes associated with the divergent plate boundary in Iceland. P. 42 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. *Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop)*. *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Greatly increased instrumental coverage of the volcanic rift zones of Iceland during the last three decades has provided numerous opportunities to observe seismic phenomena associated with plate divergence at this section of the Mid-Atlantic plate boundary. Both earthquakes and continuous tremor have been recorded. Magmatic processes accompanied by seismicity include the following:

1. Inflation of a magma chamber leads to strain in the surrounding crust, highest in the chamber roof. This strain may be high enough to cause earthquakes, particularly if the depth to the chamber is small. Fault plane solutions of the events are likely to be of the normal faulting type. Earthquakes of this type were recorded in Krafla 1975-1989 and the Hrómundartindur volcanic system 1994-1998.
2. Deflation of a magma chamber may similarly lead to earthquakes in the chamber roof, but the focal mechanisms will be characterized by reverse faulting. Earthquakes during deflation events of Krafla in 1975-6 and 1978, and Bárðarbunga 1974-1996, have been interpreted as deflation earthquakes.
3. Intrusion of a dyke is accompanied by high strain, particularly near the propagating dyke tip. Earthquakes caused by this process will therefore propagate in the crust, and the hypocenters reveal the location of the dyke tip as it changes with time. Propagating swarms are documented from Krafla 1975-1984 and Bárðarbunga 1996. Earthquake recording has been used very successfully at Krafla to trace the path and speed of lateral magmatic intrusions into the associated fissure swarm where extensive rifting subsequently took place. The propagation speed is highly variable within the range 0.5-1.2 m/s. Dyke propagation is also accompanied by continuous, spasmodic tremor of a broad frequency band. This intrusion tremor may be composed of frequent small earthquakes.
4. Solidification and cooling of a magma chamber leads to contraction of its volume and strain changes in its environment. Rapid cooling, e. g. associated with geothermal activity, may lead to earthquakes with irregular focal mechanisms, sometimes with a non-double-couple component, s. a. reported from the Hengill area in 1981 and 1991, and from Krafla in 1985 following the rifting activity there. Earthquakes surrounding an aseismic volume in the roots of the Torfajökull volcano can also be interpreted this way.
5. Volcanic eruptions are generally accompanied by eruption tremor, continuous vibrations with a narrow frequency band and even amplitude. In a broad sense the intensity of the tremor reflects the vigor of the eruption.

Páll Einarsson (e-mail: palli@rauvis.hi.is), Science Institute, University of Iceland, Hofsvallagata 53, 107 Reykjavík, Island.

METALLOTHIONEIN LEVELS IN FISHES FROM LUCKY STRIKE HYDROTHERMAL VENT

HELENA FELÍCIA, ANGELA SERAFIM, RUI COMPANYY & MARIA J. BEBIANNO



FELÍCIA, H., A. SERAFIM, R. COMPANYY & M.J. BEBIANNO. 2002. Metallothionein levels in fishes from Lucky Strike hydrothermal vent. P. 43 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Deep-sea hydrothermal vents are one of the most unusual habitats found on earth characterized by high temperature and enriched in potentially toxic chemical species (sulphide and heavy metals). The bathyal fish fauna surrounding the hydrothermal vent areas might penetrate these areas to feed on hydrothermal organisms or just stay on their vicinity.

The biological communities associated to hydrothermal vents can thrive on this toxic environment due to their ability to regulate intracellular metal levels by excretion or accumulation of metal ions in non-toxic forms. One of the main detoxification processes in fish is metal-binding by metallothioneins.

The aim of this work was to investigate the concentrations of metallothionein and total proteins at different subcellular levels in the liver, which have been shown to be a good metal accumulator. Two species were studied: the great lanternshark *Etmopterus princeps* and the ghost shark *Hydrolagus pallidus*, both collected from Lucky Strike hydrothermal vent field during VENTACO cruise with the R/V ARQUIPÉLAGO, in July 2001.

Metallothionein levels were determined by differential impulse polarography according to BEBIANNO & LANGSTON (1989) in fish livers, and total proteins quantified, in the same tissue, according to LOWRY et al. (1951), using bovine albumin as standard.

Metallothionein concentrations in *Etmopterus princeps* and *Hydrolagus pallidus* were $719,9 \pm 152,0 \mu\text{g g}^{-1}$ w.w. and $454,6 \pm 104,8 \mu\text{g g}^{-1}$ w.w., respectively. Total proteins were $19,3 \pm 5,2 \text{ mg g}^{-1}$ w.w. for *E. princeps* and $10,3 \pm 3,4 \text{ mg g}^{-1}$ w.w. for *H. pallidus*.

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H. Felícia (e-mail: hfelicia@ualg.pt), A. Serafim, Rui Company & Maria J. Bebianno, University of Algarve, Campus de Gambelas, F.C.M.A., 8000-810 Faro, Portugal.

CHEMICAL CHARACTERIZATION OF THE LUCKY STRIKE BASALTS

PEDRO FERREIRA, BRAMLEY MURTON & JOSÉ MUNHÁ



FERREIRA, P., B. MURTON & J. MUNHÁ. 2002. Chemical characterization of the Lucky Strike basalts. P. 44-45 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Since 1975 until present, evidence of a geochemical gradient towards the Azores Platform, related to mantle heterogeneities, has been described on a large spatial scale based on REE, LILE, HFSE and diverse radiogenic isotopes (SCHILLING, 1975; DOSSO et al. 1999) in Mid Atlantic Ridge between 31-45° N.

Studies of dredged and grabbed samples in the Lucky Strike Hydrothermal Field (37.35° N) have revealed that basalts separated only by few hundreds meters show different geochemical characteristics, based on major and trace elements obtained by XRF and ICP-MS.

Analytical data (whole rock composition) determined in fresh basalts revealed typical major element MORB's composition and constitute relatively primitive varieties with low TiO₂ contents (0,80-1,30%) and high #Mg (63-74), Al₂O₃ (15-22%), CaO (12-15,50%) and Al₂O₃/TiO₂ (12,5-24). The REE, some LILE and HFSE contents are represented in Figure 1 as a ratio to MORB-N typical compositions (normalising factors from SUN & MCDONOUGH 1989). Extreme enrichment in the more incompatible elements is emphasised and, based on all these data, three different groups of basalts having distinct geochemical signatures were established.

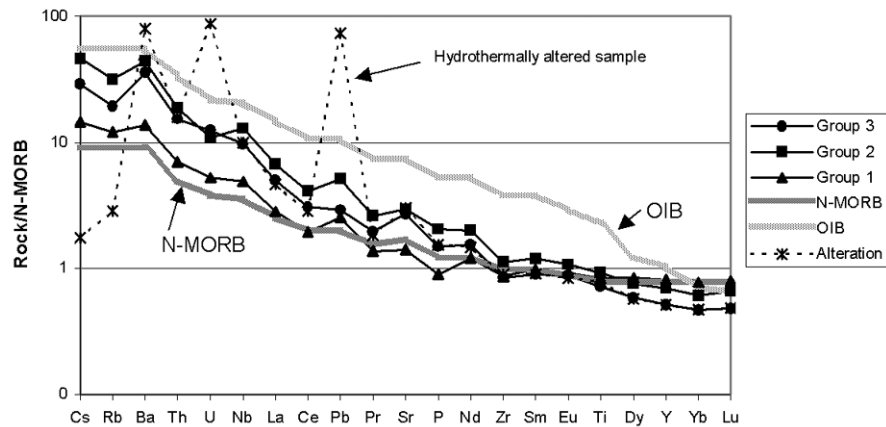


Fig. 1. N-MORB normalised compositions of representative Lucky Strike basalts. Normalising values from SUN & MCDONOUGH 1989.

The information obtained from the REE profiles, the ratios between incompatible elements with similar mineral K_d's during partial melting, the different elements' covariation and the data from Fig. 1 exclude fractional crystallisation and variable degrees of partial melting as the processes responsible for the existent geochemical variability. Mantle heterogeneities or

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mantle metassomatism must be considerate to explain variable degrees of enrichment as well as such small-scale geochemical variability in this area.

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Pedro Ferreira (e-mail: pedro.ferreira@igm.pt), Instituto Geológico e Mineiro, Alfragide, Portugal; Bramley Murton Southampton Oceanography Centre, U.K.; José Munhá, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal.

SUMMO/AÇORES. UNIFIED SYSTEM FOR THE GEOPHYSICAL MONITORING AND MODELLING OF THE AZORES REGION

JOÃO LUIS GASPAR, MIGUEL MIRANDA, LUISA SENOS, LUIS MATIAS, GRAÇA SILVEIRA & GABRIELA QUEIRÓS



GASPAR, J.L., M. MIRANDA, L. SENOS, L. MATIAS, G. SILVEIRA & G. QUEIRÓS. 2002. SUMMO/AÇORES. Unified System for the Geophysical Monitoring and Modelling of the Azores Region. Pp. 46-47 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

SUMMO/AÇORES is a project directed to the development of the Azores regional geophysical network that started in 1997 with the well-succeeded cooperation between the Azores University and the Meteorological Institute. The main objective of the project is to update and improve the existing geophysical networks creating a structure to serve the scientific community, the civil protection and the public in general.

The safety of populations exposed to geological risks such as earthquakes and volcanic eruptions obliged to the existence of monitoring networks based on independent techniques. In Portugal, this subject is particularly important for regions like the Azores, where earthquakes and volcanic eruptions are a permanent threat to all the inhabitants.

The different technologies of seismic monitoring associated with accurate GPS observations are basic tools to achieve such goals. All these primary geophysical techniques are powered by the possibility to use real-time or near-real-time raw data, an essential point when dealing with civil protection actions.

To fulfil these objectives we pretend to:

- consolidate the SIVISA (Sistema de Vigilância Sismológica dos Açores – Azores Seismological Surveillance System) through the real integration of all the Azores University and Meteorological Institute existing seismic monitoring facilities, into a unique, comprehensive system, with high operational standards, able to make available real-time high quality geophysical data through an open communication network;
- complement the SIVISA Network with Ocean Bottom Seismometers in order to cover the volcano-tectonic activity that take place in the Azores submarine geological structures;
- integrate of all the Azores GPS permanent stations in the same monitoring system, building a consistent database for multidisciplinary studies;
- develop an emergency national task force based on the existence of portable equipment to attend any seismic or volcanic crisis;
- combine geophysical and geodetic techniques to collect the most reliable and accurate information on geological risks;
- develop technical expertise to install, maintain and give support to all basic data providers, and to assure high information fluxes between providers and users, either professional or individual;
- implement of an efficient data dissemination system with specific access levels for researchers, civil protection authorities and general public;
- develop collaboration at all levels between public and private institutions, between state laboratories and research centres and between national and international observation networks;

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João Luis Gaspar, Gabriela Queirós, Centro de Vulcanologia da Universidade dos Açores, R. Mãe de Deus, 9501-801 Ponta Delgada, Portugal; Miguel Miranda, Luis Matias, Graça Silveira (e-mail: gracams@fc.ul.pt), Centro de Geofísica da Univerisdade de Lisboa, Edifício C8 Campo Grande, 1749-016 Lisboa, Portugal; Luisa Senos, Instituto de Meteorologia, Rua C ao Aeroporto, 1700 Lisboa, Portugal.

MONITORING HYDROTHERMAL ACTIVITY ON THE MID-ATLANTIC RIDGE

CHRISTOPHER R. GERMAN



GERMAN, C.R. 2002. Monitoring Hydrothermal Activity on the Mid-Atlantic Ridge. P. 48 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

To date, much of the hydrothermal perspective to long-term ridge-crest monitoring has focussed upon detailed instrumentation of individual chimneys and vents. Here, I argue for a more regional-scale investigation as part of an "Azores-centred" seafloor observatory initiative. There are two important issues that I believe are particularly note-worthy.

Among the Menez Gwen, Lucky Strike, Rainbow and Saldanha vents, 36-38°N, we have good examples of nearly every kind of venting yet discovered along the global ridge-crest, situated in close proximity. Menez Gwen and Lucky Strike host volcanically hosted venting ranging from shallow, clear, phase separated fluids to more conventional black-smoker fluids. The Saldanha site represents the newest form of venting recognised - driven by serpentinitisation of peridotites - which may be prevalent along ALL slow and ultra-slow ridges. Finally, Rainbow appears to represent a hybrid system venting high-temperature "black-smoker" type fluids that also reveal peculiarities characteristic of peridotite serpentinitisation. Importantly, this last site may be more relevant to studies of the origins of life than any other vent-site yet discovered along the global ridge-crest.

It is also important to consider what we hope to achieve from an observatory programme. I consider understanding how processes active within young ocean crust become manifest as hydrothermal flux across the seafloor to be an important issue still to be resolved. Further, I believe that the broad regional-scale approach is key to addressing this problem. Recent developments (e.g. JOHNSON et al. EOS, Feb.2002) have shown systematic ways to determine total, past and present, segment-scale hydrothermal flux - on a length scale comparable to seafloor (multibeam, sidescan) and subsurface (seismics, e-m) imaging. In addition, there are important processes for us to address. For example, recent "snap-shot" estimates have suggested integrated hydrothermal fluxes which cannot be sustained, according to geophysical theory, at Rainbow. Yet preliminary seafloor and sedimentary investigations have concluded that this site has been active, at current levels, for ca. 10kyr! Wherever direct observations and geophysics conflict, interesting work awaits...

Christopher R. German (e-mail: cge@soc.soton.ac.uk), Southampton Oceanography Centre, UK.

RIDGE 2000 BEGINS A NEW DECADE OF MID OCEAN RIDGE RESEARCH AND THE RIDGE 2000 STEERING COMMITTEE

DEBBIE HASSLER



HASSLER, D. 2002. RIDGE 2000 begins a new decade of Mid Ocean Ridge research and the RIDGE 2000 steering committee. Pp. 49-50 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

RIDGE 2000 is a new, (U.S.) National Science Foundation (NSF) sponsored research initiative. The program is community-based and promotes the interdisciplinary study of Earth's mid-ocean ridge system as an integrated whole, from its inception in the mantle to its manifestations in the biosphere and water column.

The science plan for Ridge 2000 aims at a comprehensive understanding of the relationships between the biological, geological, and chemical processes associated with plate spreading at mid-ocean ridges. This whole-system approach is integral to understanding how seafloor and sub-surface ecosystems are sustained by crustal accretion processes. An *Integrated Studies* theme will focus at specific geographic areas where detailed multidisciplinary studies will yield new insights into these processes. A *Time-Critical Studies* theme will focus on real-time detection and rapid response to volcanic and tectonic events at mid-ocean ridges.

The goal of the Time-Critical Studies program element is to understand the nature, frequency, distribution and geobiological impacts of magmatic and tectonic events along the global mid-ocean ridge system. This theme focuses on the immediate biological, chemical and geological consequences of active processes on the seafloor. Such processes generally occur as transient events and include volcanic eruptions and intrusions of magma at the ridge axis and faulting related to seafloor spreading.

The Integrated Studies theme of Ridge 2000 consists of focused, whole-system research of global mid-ocean ridge processes. This program component addresses the complex, interlinked array of processes that support life at and beneath the seafloor as a consequence of the flow of energy and material from Earth's mantle, through the volcanic and hydrothermal systems of the oceanic crust to the overlying ocean. Moreover, this part of the program recognizes that the complex linkages between life and planetary processes at mid-ocean ridges can only be understood through coordinated, time-series studies that span a broad range of disciplines. Thus, Integrated Studies will consist of multidisciplinary research that is focused on a small number of pre-selected "type" areas that are designed to characterize segments of the mid-ocean ridge system. The objective of Integrated Studies is to develop quantitative, whole-system models of a mid-ocean ridge system

The Integrated Studies theme will initially focus on three sites:

- 9°N segment of the East Pacific Rise;
- The Endeavour segment of the Juan de Fuca Ridge;
- The Central Lau Basin spreading centre.

A Ridge 2000 workshop will be held in early 2003 to select a mid Atlantic Ridge.

Ridge 2000 has held two major workshops since the first of the year: a Community Education workshop to provide background science information on the three Integrated Studies Sites, and an Implementation workshop to write implementation plans for each site. The papers presented at the Community Education workshop are available on the Ridge

Towards planning of seafloor observatory programs for the MAR region

2000 web site, as are the implementation plans, Endnote bibliographic files for the sites, and the Ridge 2000 data policy.

To join the RIDGE 2000 mailing list, for timetables, data, upcoming meetings and workshops, contacts and other information about the RIDGE 2000 program, see the RIDGE 2000 website at <http://www.ridge2000.bio.psu.edu/> or call 814-865-RIDG.

Debbie Hassler (e-mail: dhassler@psu.edu), RIDGE 2000/Penn State University, 208 Mueller Lab Penn State University Park, PA 16802 USA.

A TECTONIC MODEL FOR THE GENERATION OF THE SALDANHA MASSIF

NUNO LOURENÇO & SALDANHA TEAM



LOURENÇO, N. & SALDANHA TEAM. 2002. A tectonic model for the generation of the Saldanha Massif. Pp. 51 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The Saldanha Massif is a small dome shaped feature detached from the Famous segment western wall (at 36°33'54''N, 33°26'W) where diffuse hydrothermal degassing was observed during SALDANHA mission. We present an interpretation of high-resolution swath bathymetry, TOBI images and geologic observations from submersible dives to constrain its tectonic setting. The dome structure lies in a 32km² area of smooth topography where slopes range from 10° to 20°. This surface is corrugated by a series of low amplitude steps or ridges, which strike in the N103°-107°E direction, discordantly from the regional background of the NTO/Famous fabrics. Dives has allowed the validation of these corrugations as minor throw faults or serpentinitic ridges. The limits of this exposed section of mantle rocks are to the East, around 33°21' following a increase of roughness in the terrain resulting from volcanic processes and to the West, along a sharp NNW-SSE trending linear depression 70 to 150 m deep, which defines a structural limit between two geological domains. West of the depression, seafloor is dominated by different extrusive facies and no upper mantle rocks were observed, whereas to the east of this limit, the seafloor is covered by a tectonic melange with sampled rocks ranging from volcanic breccias, serpentinites, steatites, gabbros and spilitised pillow lava fragments. Similar morphological features have been observed elsewhere in the Atlantic and were interpreted as the result of large detachment faults activity in stages of stable amagmatic spreading. This model seems to be compatible with our observations. We interpret Saldanha Massif and related ultramafics as a direct consequence of pelicular tectonic exhumation, probably combined with sin-tectonic serpentinitisation effects.

Nuno Lourenço (e-mail: nlouren@ualg.pt), CIMA - Centro de Investigação Marinha e Ambiental da Universidade do Algarve) Faro, Portugal; Saldanha Team (A. Almeida, Laboratório Marítimo da Guia, Universidade de Lisboa, Portugal; M. Biscoito, Museu Municipal do Funchal, Madeira, Portugal; J.L. Charlou & Y. Fouquet, Département de Géosciences Marines, Direction des Recherches Océaniques, IFREMER, France; F. J. Barriga, A. Dias, R. Costa & A. Marques, CREMINER, Dep. Geologia, Fac. de Ciências da Universidade de Lisboa, Portugal; M. Miranda, P. Silva & L. M. Victor, Instituto de Ciências da Terra e do Espaço, Centro de Geofísica, Universidade de Lisboa, Portugal; F. Porteiro, Departamento de Oceanografia e Pescas, Universidade dos Açores, Portugal; G. Queiroz, Departamento de Geociências da Universidade dos Açores, Universidade dos Açores, Portugal).

MERCURY LEVELS IN ORGANISMS FROM MAR HYDROTHERMAL VENTS

INÊS MARTINS, VALENTINA COSTA, FILIPE PORTEIRO, ALEXANDRA CRAVO & RICARDO S. SANTOS



MARTINS, I., V. COSTA, F. PORTEIRO, A. CRAVO & R.S. SANTOS. 2002. Mercury levels in organisms from MAR hydrothermal vents. Pp. 52-53 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The Mid-Atlantic Ridge (MAR) hydrothermal vents fluids are characterised by high temperatures, high metal concentration, as well as high hydrogen sulphide content, related to interactions of the convective seawater circulation with basaltic rocks inside the ocean crust (ROUSEE et al. 1997). There is a potential for enhanced bioaccumulation of mercury (Hg) in biota from hydrothermal vents due to the exposure to hydrothermal fluids that is believed to contain high heavy metals concentration (MONTEIRO *et al.* 1998). Nevertheless, the biological communities at the vents can survive in this inhospitable environment owing to their ability to regulate intracellular metal levels by excretion or accumulation of metals ions in non-toxic forms (ROUSSE et al. 1997). The aim of this work was to determine the total and organic (MethylHg) Hg concentrations in organisms at hydrothermal vents of the Mid-Atlantic Ridge: Lucky Strike, Menez Gwen and Rainbow. The concentrations found were related to the size, the sex and the vent field where they were collected. The mussel *Bathymodiolus azoricus*, the amphipod *Eurythenes gryllus*, the shrimp *Rimicaris exoculata* and *Mirocaris fortunata*, the deep-sea crab *Chaceon affinis*, the chimera *Hydrolagus affinis* and *Hydrolagus pallidus*, the cut-throat eel *Synaphobranchus kaupi*, the bull-eyes *Epigonus telescopus* and the shark *Etmopterus princeps*, where collected for this study.

The mussel shells were removed and only the soft body was used for Hg study while the whole shrimps tissue were analysed. In crabs and fishes a sample of muscle was taken (dorsal muscle directly posterior to the operculum in fish). The samples were analysed using cold-vapour atomic absorption spectrometry. At Lucky Strike, the cut-throat eel *S. kaupi* and shark *E. princeps*, showed a positive relation between total Hg concentration and size while the mussels *B. azoricus* from Menez Gwen showed a negative one. For all species studied, there was no significant difference between total Hg concentration among sexes. The highest concentration was found in the shark tissues at Lucky Strike and the lowest in the shrimp *R. exoculata* tissues, at the Rainbow hydrothermal vent. The total Hg concentration in mussels was significantly different among hydrothermal vents, registering the highest concentrations at Menez Gwen. The organic fractions of Hg were greater than 80% of the total Hg.

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II MoMAR Workshop
Horta (Azores, Portugal), 14-17 June 2002

Bathymodiolus sp. from the Mid-Atlantic Ridge. *Biology of deep sea hydrothermal vents* 38 (2): 137-138.

Inês Martins (e-mail: imartins@horta.uac.pt), Valentina Costa, Filipe Porteiro, Ricardo S. Santos, IMAR, DOP-Department of Oceanography and Fishery of University of Azores, 9901-862 Horta, Azores, Portugal; Alexandra Cravo, UAlg-Universidade do Algarve: 8000-Faro, Portugal.

MASHA MULTI-SCALE APPROACH FOR SEISMOVULCANIC HAZARD IN THE AZORES

LUÍS M. MATIAS, GRAÇA M. SILVEIRA, NUNO A. DIAS, PATRÍCIA L. SILVA, JOÃO L. GASPAR, TERESA FERREIRA, CARLOS SILVA, MIGUEL M. MIRANDA & LUÍSA C. SENOS



MATIAS, L.M., G.M. SILVEIRA, N.A. DIAS, P.L. SILVA, J.L. GASPAR, T. FERREIRA, C. SILVA, M.M. MIRANDA & L.C. SENOS. 2002. MASHA Multi-scale approach for seismovulcanic hazard in the Azores. Pp. 54-55 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

MASHA is a project dedicated to study the processes that constrain and shape the volcanic and seismic hazard of the Azores area, using seismic and geochemical monitoring. The MASHA is structured as a multi-scale scientific approach to investigate the earth processes at: the *regional scale* – the Azores mantle plume and hot spot; the *mesoscale* – the crustal structure; and the *local scale* – the tectonic and volcanic structures that directly affect the island populations.

The first scale regards the study of the regional setting, mainly the anomalous lithosphere and asthenosphere structure of the Azores and its contribution to the episodic volcanic and seismic activity. The study will be conducted using data from two very broad band (VBB) seismic stations, complemented with island VBB stations installed under the umbrella of the Memorandum of Understanding-COSEA (COordinated Seismic Experiment in the Azores) plus data from CMLA already operating in S. Miguel. The large-scale network will provide tomographic images of the area with a resolution around 200 km.

The Mesoscale – 10's of km – regards crustal scale studies namely the seismic anisotropy, its correlation with crustal strain as well as its relationship with seismic and volcanic events. This study will be achieved by studying data acquired by short period and broadband seismic sensors.

The local scale – 1 km – regards the assessment of seismic and volcanic hazard, in the area of Faial, Pico and S. Jorge Islands. This area has been chosen due to its particular environment: 1) it is affected by a seismic crisis initiated in July 1998 with the source area well covered by seismic stations; 2) preliminary observations of geochemical parameters in Faial show a relationship between gas emanations and seismic activity. In order to correlate seismic and volcanic data acquired from independent sources, this project includes specific studies on seismicity pattern of the Faial crisis and a dedicated geochemical monitoring program in the Faial Island. The previous activities allowed the selection of the most sensible observation sites and the variables to be monitored.

The concurrence of: i) a operating pool of VBB instruments (COSEA Agreement); ii) the operation of a wide SP digital network since 1998; iii) the well constrained seismo-volcanic activity that occurs in the Faial channel; make this project a unique opportunity to study the multi-scale interaction between seismic and volcanic processes in the Azores. These conditions will not be easily met in the future.

We present some preliminary results obtained in the framework of the project.

Luis M. Matias, Graça M. Silveira (e-mail: gracams@fc.ul.pt), Nuno A. Dias, Patricia L. Silva, Miguel M. Miranda1, Centro de Geofísica da Universidade de Lisboa, Edifício C8 Campo Grande, 1749-016 Lisboa; Luis M. Matias, Patricia L. Silva, Miguel M. Miranda1,

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Departamento de Física da Univ. de Lisboa, Edifício C8 Campo Grande, 1749-016 LISBOA; Graça M. Silveira, Nuno A. Dias, Instituto Sup. de Engenharia de Lisboa, Rua Conselheiro Emídio Navarro, 1949-014 Lisboa; João L. Gaspar, Teresa Ferreira, Carlos Silva, Centro de Vulcanologia da Univ. dos Açores, R. Mãe de Deus, 9501-801 Ponta Delgada, Açores; Luisa C. Senos, Instituto de Meteorologia, Rua C ao Aeroporto, 1700 Lisboa.

DISTRIBUTION AND TEMPORAL EVOLUTION OF MACROFAUNA IN A HYDROTHERMAL EDIFICE - EIFFEL TOWER, IN THE LUCKY STRIKE HYDROTHERMAL VENT FIELD ON THE MID-ATLANTIC RIDGE

NÉLIA MESTRE, CRISTINA VEIGA-PIRES & DANIEL DESBRUYÈRES



MESTRE, N., C. VEIGA-PIRES & D. DESBRUYÈRES. 2002. Distribution and temporal evolution of macrofauna in a hydrothermal edifice - Eiffel Tower, in the Lucky Strike hydrothermal vent field on the Mid-Atlantic Ridge. P. 56 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The relationship between the distribution of biological assemblages, their proximity to the vent fluid exits (along the chemical gradient) and their evolution over time were studied. The work was based on imagery recorded with the manned submersible NAUTILE from three cruises (DIVA 2, 1994; MARVEL, 1997; PICO, 1998) and the ATOS cruise (2001) using the Remote Operated Vehicle – VICTOR 6000. The studied site was the Eiffel Tower active hydrothermal edifice, which is located south-eastward within the Lucky Strike hydrothermal vent field on the Mid-Atlantic Ridge. The fauna was identified from video images along with onboard laboratory observations and published data. The biological assemblages were considered in relation to faunal appearance and composition. Information on the environmental conditions was then incorporated in these data. Biological assemblages distribution is rather heterogeneous, but some relationships with the environmental conditions were observed. This edifice is covered with dense beds of mussels (*Bathymodiolus azoricus*) of different sizes. The most important abiotic factors that control the distribution of the organisms are the seawater dilution (i.e. temperature) and the composition of the fluids expelled from the vent exits. Regarding biotic factors, the most important seems to be the competition for space, either intra-specific (in the case of mussels), or inter-specific (e.g. mussels and shrimps). Comparing the distribution of the large and the small mussels, there is still doubt whether the small mussels are juveniles or adults with a low growth rate. In the first case (juveniles) it might be a strategy to avoid adult predation. In the second case the size would be related with nutritional facts (small mussels are less dependant on symbiosis with methanotrophic bacteria). In both cases, periodic migrations of mussels might also occur along the chemical gradient. With the temporal evolution study, it was observed that the small mussels are always in the periphery of the edifice. The surface covered by bacteria mats has increased during studied period along with a gradual decrease in the fluid flow and an important decrease of swarms of shrimps. It is hypothesized that the fluid circulation through the edifice has changed, and presents a more diffused flow than a focus venting (smoker). Nevertheless, the role of human perturbation cannot be discarded, since Eiffel Tower is the most visited and sampled edifice of the Azores Triple Junction area. Ecological succession of assemblages through time was not in evidence but cannot be discarded. The different assemblages cohabit the edifice at the same time and space.

Nélia Mestre (e-mail: neliamestre@hotmail.com), C. Veiga-Pires, Faculdade de Ciências do Mar e do Ambiente, Universidade do Algarve, Faro, Portugal; Daniel Desbruyères, Département Environnement Profond – IFRMER, Brest, France.

AN OVERVIEW ON NACRE FORMATION IN THE FRESHWATER CLAM,
Anodonta cygnea (L.) (MOLLUSCA: BILVALVIA)

GABRIELA MOURA, JOÃO COIMBRA & JORGE MACHADO



MOURA, G., J. COIMBRA & J. MACHADO. 2002. An overview on nacre formation in the freshwater clam, *Anodonta cygnea* (L.) (Mollusca: Bivalvia). P. 57 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

As usually accepted, the process of nacre formation in bivalves requires the combined action of the preformed nacre together with the bathing extrapallial fluid in which the crystals nucleate and grow. This fluid, on the other hand, depends on the mantle secretion and/or transport, namely from haemolymph, the circulating fluid of these animals.

Our recent work contributed to establish a periodicity for the calcium carbonate and organic matrix deposition in the nacreous layers of *Anodonta cygnea*, based on its composition and morphology but also on the compositional variations of the biological fluids. A specific structural organization of the organic matrix is necessary to induce the nucleation of the first calcium carbonate crystals and their growth in different directions forming resistant layers. In fact, a preferential order in the deposition of the organic compounds seems to occur with respect to the level of hydrophobicity and polarity: first chitin and insoluble proteins, then basic soluble proteins, and finally acidic soluble proteins and glycosaminoglycans.

In this model, glycosaminoglycans may function as relevant agents for the calcium ion transport and local aggregation. The subsequent enlargement of crystals seems to be determined by the higher levels of organic and inorganic material present in the biological fluids, which can in turn depend on external absorption, cellular synthesis or metabolic acidosis. In fact, our results indicate a relative increase for nacreous chitin in March followed by a minimum in April. The organic richness detected in April reflects the preparation of the organic matrix in order to initiate the biomineralization phenomenon. In this period a soluble protein, strongly basic, may establish the connection between the previously deposited insoluble matrix and the acidic soluble fraction. The maximum contents of proline and glycosaminoglycans, possibly indicating a proteoglycan, were reached in June, suggesting the presence of such an effective calcium transporter in the mineralization front, since this particular month corresponds to an intense calcium deposition period.

G. Moura, J. Coimbra & J. Machado (e-mail: jmachado@icbas.up.pt), Laboratório de Fisiologia Aplicada, Instituto de Ciências Biomédicas (ICBAS), Porto Portugal; J. Coimbra and Jorge Machado, Centro de Investigação Marítima e Ambiental (CIMAR), Porto, Portugal.

ALTERNATE SCIENTIFIC APPLICATIONS OF HYDROPHONE ARRAYS DEPLOYED AT MOMAR

SHARON L. NIEUKIRK, CHRIS G. FOX & RITA SAN MIGUEL BENTO



NIEUKIRK, S.L., C.G. FOX & R.S.M. BENTO. 2002. Alternate scientific applications of hydrophone arrays deployed at MoMAR. P. 58 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

Continuously recording hydrophones moored along the Mid-Atlantic Ridge (MAR) have provided valuable information on the seismicity of the ridge system. A six-element array deployed south of the Azores beginning in March 1999 has collected calibrated acoustic signals in the range 1-50 Hz in support of seismic studies and has been approved for four additional years of deployment. A new six-element array, deployed between the Azores and Gibbs Fracture Zone in June 2002 in a joint French-American program called SERENA, will provide continuous acoustic data in the 1-120 Hz frequency band. Both projects are driven by geophysical studies of the MAR and are intended to be extended for multiple years. Although deployed for seismic monitoring, these hydrophone-derived data sets are invaluable to other scientific studies as well. Large marine mammals, specifically blue whales, fin whales, humpback whales, and minke whale, vocalize in low frequencies and have been recorded by the MAR hydrophones. There are also many calls of unknown origin that have not been previously observed and variations on known calls. Marine mammalogists from the U.S. and Portugal are examining these data sets to determine the distribution, seasonality, and diurnal variability of these calls. The ability to determine the presence of cetacean species in these remote ocean areas is an invaluable windfall of the seismic monitoring effort. Another issue that is receiving increasing attention in global environmental policy is the increasing level of manmade noise in the ocean and its impact on marine life. The MAR hydrophones provide quantitative measurements of the contribution of manmade and natural noise to the Atlantic Ocean. One prominent example of manmade noise recorded on the southern hydrophone array is dominant sounds of distant seismic airgun profilers working around the margins of the Atlantic Ocean offshore Canada, Brazil, and West Africa. These signals can overwhelm natural signals at ranges of several thousand kilometres and are operated 24 hours/day for extended periods. Areas of intense seismic exploration in the North Sea and Gulf of Mexico are shadowed by bathymetry. Finally, U.S. tropical weather researchers are using the acoustic information to derived integrated energy estimates of tropical storms and hurricanes transiting the Atlantic. With an extended time series of calibrated acoustic recordings of seismic, biological, meteorological, and manmade noise, it becomes possible to construct a quantitative budget of ocean acoustic sources for the North Atlantic Ocean.

Sharon L Niekirk, Oregon State University, CIMRS, Newport, Oregon USA, Chris G. Fox (e-mail: fox@pmel.noaa.gov), NOAA, Pacific Marine Environmental Laboratory, Newport Oregon USA, Rita San Miguel Bento, Departamento de Biologia, Universidade dos Açores, Ponta Delgada, Portugal.

THE CHESSE PROGRAMME: BIOGEOGRAPHY OF CHEMOSYNTHETIC ECOSYSTEMS FOR THE CENSUS OF MARINE LIFE

EVA Z. RAMIREZ-LLODRA, PAUL A. TYLER & CHRISTOPHER R. GERMAN



RAMIREZ-LLODRA, E.Z., P.A. TYLER & C.R. GERMAN. 2002. The ChEss Programme: Biogeography of Chemosynthetic Ecosystems for the Census of Marine Life. P. 59 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The Census of Marine Life (CoML) initiative, formalised in 1997, is an international research programme aiming at assessing and explaining the diversity, distribution and abundance of marine organisms throughout the world's oceans. ChEss is a CoML project that will focus in deep-sea chemosynthetic ecosystems.

The main aim of ChEss is to improve our knowledge of the biogeography of chemosynthetically-driven ecosystems by promoting exploration in the more remote parts of the world's oceans, while at the same time determining the processes that affect the biogeography of vent and seep faunas. The ChEss office at Southampton Oceanography Centre (SOC) will be responsible for co-ordination, execution and delivery of the programme. An International Steering Committee will be created to organise the programme, ensure collaboration between participants and stimulate scientific innovation from a wider community. It is the intention of ChEss to work closely with InterRidge.

Eva Z. Ramirez-Llodra (e-mail: ezr@soc.soton.ac.uk), Paul A. Tyler & Christopher R. German, Southampton Oceanography Centre, European Way, SO14 3ZH Southampton, UK.

CONSTRAINTS ON THE EXISTENCE OF A SUBDUCTION PLATE BENEATH THE EQUATORIAL ATLANTIC

SUSANNA E. SICHEL, MARCIA MAIA, SÓNIA ESPERANÇA, ROGER HEKINIAN, THIERRY JUTEAU, ROBERT J. WALKER & MARIE F. HORAN



SICHEL, S.E., M. MAIA, S. ESPERANÇA, R. HEKINIAN, T. JUTEAU, J. WALKER & M.F. HORAN. 2002. Constraints on the existence of a subduction plate beneath the equatorial Atlantic. P. 60 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

St. Paul F.Z. (SPFZ) is a multiple transform fault system interrupted by several Intra-Transform Ridge (ITR) spreading centers.

Thirteen dives (5190m - 1000m) carried out with submersible NAUTILUS in Saint Paul T. F., revealed that the N flank is composed of mylonitic peridotites, with active faults. The S flank shows a thick cover of sediments and undeformed peridotites, indicating little or no tectonic activity. Intra-transform MAR segments are active but tectonics predominate over volcanism.

Abyssal peridotites were analyzed for Re, Pt, Os and Os isotopic composition (Os.i.c.). The results are consistent with the interpretation that these abyssal peridotites record a Re depletion event that is more typical of mantle that was separated from asthenosphere between 1Ga and 560Ma ago. Because the majority of the samples have gamma Os equal to below chondritic values they are unlikely to have originated simply by depletion of recent MORB-type mantle and are consistent with a source that preserves chemical characteristics of an older depletion event.

The existence of a cold upper mantle beneath the equatorial Mid-Atlantic Ridge (MAR) was first inferred from the analysis of ridge axis morphology and the petrology of both basalts and uplifted abyssal peridotites. Global upper mantle tomographic models show a significant increase in the velocities of seismic waves beneath the equatorial MAR, analogous to the pattern seen for some present day subduction zones. The existence of a fossil subduction in the Equatorial Atlantic is corroborated by paleo-reconstructions for the period between 460 and 300 Ma.

Melt inclusion analyses in plagioclase phenocryst at MAR show boninite composition. The presence of those Mg-SiO₂ rich melts is an additional line of evidence to support the hypothesis that part of the underlying oceanic mantle in the Equatorial Atlantic is a fossil slab.

Susanna E. Sichel (e-mail: susanna@igeo.uff.br), Dept. Geologia, LAGEMAR, UFF, Niterói, Brazil, Marcia Maia, T. Juteau, CNRS/UMR 6538, Plouzané, France; S. Esperança, J. Walker, Dept. of Geology, U. of Maryland, College Park, MD 20742, USA; R. Hekinian, IFREMER 29280, Plouzané, France; M. F. Horan, DTM-CIW, 5241 Broad Branch Rd., Washington, DC, USA.

MAGNETIC PROPERTIES FROM SALDANHA MASSIF BASALTS

PEDRO F. SILVA & SALDANHA TEAM



SILVA, P.F. & SALDANHA TEAM. 2002. Magnetic properties from Saldanha Massif basalts. P. 61 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop). *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

A study of the magnetic properties of a group of basalt samples, from Saldanha massif (Mid-Atlantic Ridge – MAR – 36° 33' 54" N, 33° 26' W), is presented here, and we try to interpret these properties in the framework of the tectono-magmatic evolution of this sector of the MAR. Most samples have low magnetic anisotropy and magnetic minerals of single domain grain size, typical of rapid cooling. The thermomagnetic study mostly points out two different susceptibility peaks. The high temperature one is related to mineralogical alteration due to heating. The low temperature peak allows the distinction between three different stages of low temperature oxidation: presence of titanomagnetite, titanomagnetite and titanomaghemite and exclusively of titanomaghemite. Based on established empirical relationships between Curie temperature and oxidation state, the latter is tentatively deduced for all samples. The spatial distribution of these properties is analyzed in terms of the structural position.

Pedro. F. Silva, Instituto Superior de Engenharia de Lisboa & Centro de Geofísica da Universidade de Lisboa, Lisboa, Portugal & Saldanha Team (A. Almeida, Laboratório Marítimo da Guia, Universidade de Lisboa, Portugal; M. Biscoito, Museu Municipal do Funchal, Madeira, Portugal; J.L. Charlou & Y. Fouquet, Département de Géosciences Marines, Direction des Recherches Océaniques, IFREMER, France; F. J. Barriga, A. Dias, R. Costa & A. Marques, CREMINER, Dep. Geologia, Fac. de Ciências da Universidade de Lisboa, Portugal; M. Miranda, P. Silva & L. M. Victor, Instituto de Ciências da Terra e do Espaço, Centro de Geofísica, Universidade de Lisboa, Portugal; F. Porteiro, Departamento de Oceanografia e Pescas, Universidade dos Açores, Portugal; G. Queiroz, Departamento de Geociências da Universidade dos Açores, Universidade dos Açores, Portugal).

COORDINATED SEISMIC EXPERIMENT IN THE AZORES (COSEA)

GRAÇA SILVEIRA, LUÍS MATIAS, SUZAN VAN DER LEE, ELEONORE STUTZMANN, JORGE M. MIRANDA, LUÍS M. VICTOR, JOÃO L. GASPAS, LUÍSA SENOS, SEAN SOLOMON, JEAN-PAUL MONTAGNER & DOMENICO GIARDINI



SILVEIRA, G., L. MATIAS, S. VAN DER LEE, E. STUTZMANN, J.M. MIRANDA, L.M. VICTOR, J.L. GASPAS, L. SENOS, S. SOLOMON, J.-P. MONTAGNER & D. GIARDINI. 2002. Coordinated seismic experiment in the Azores (COSEA). P. 62 in R.S. SANTOS, J. ESCARTÍN, A. COLAÇO & A. ADAMCZEWSKA (Eds). 2002. *Towards planning of seafloor observatory programs for the MAR region (Proceedings of the II MoMAR Workshop)*. *Arquipélago*. Life and Marine Sciences. Supplement 3: XII + 64 pp.

The Memorandum of Understanding COSEA is devoted to coordinate the efforts of Portuguese, French, American and Swiss scientific institutions for the deployment, operation and maintenance of a temporary broadband seismic experiment in the Azores Islands and for the collection, distribution and scientific exploitation of data.

In collaboration with other running projects, this experiment will highly contribute to the determination of the deep origin and structure of the Azores plume, the interaction between the Azores plume and the Mid-Atlantic Ridge and will also contribute the investigation of the structure and deep interactions of the plate boundaries between Eurasia, Africa and North America. Locally, the combination of the broadband data with the existing volcano and earthquake surveillance networks will enable the monitoring of the seismic and volcanic activity toward a better determination of hazard.

During 2001 a pool of eight very broadband seismic stations was installed in 8 of the 9 Azores islands by the teams involved in the Memorandum. Data are now being assembled after quality control and time correction. In this poster we present the array composition and configuration, as well as the organization of data.


Graça Silveira (e-mail: gracams@fc.ul.pt), Luis Matias, Jorge Miguel Miranda, Centro de Geofísica da Universidade de Lisboa, Edifício C8 Campo Grande, 1749-016 Lisboa; Suzan van der Lee, Domenico Giardini, Institute of Geophysics, ETH Honggerberg, CH-8046 Zurich; Eleonore Stutzmann, Jean-Paul Montagner, Institut de Physique du Globe de Paris, 4, place Jussieu, 75252 Paris Cedex 05; Sean Solomon, Depart. of Terrestrial Magnetism, Carnegie Inst. of Washington, 5241 Broad Branch RD. NW, Washington DC 20015; Luis Mendes Victor, Instituto Geofísico do Infante D. Luis, Rua da Escola Politécnica, 58, 1250 Lisboa; João Luis Gaspar, Centro de Vulcanologia da Univ. dos Açores, R. Mãe de Deus, 9501-801 Ponta Delgada, Açores; Luisa Senos, Instituto de Meteorologia, Rua C ao Aeroporto, 1700 Lisboa, Portugal.

II MoMAR Workshop
Horta (Azores, Portugal), 14-17 June 2002

APPENDIX IV – RELATED DOCUMENTS

An effort to coordinate scientists and projects around MoMAR was carried out at the end of 2001 and the beginning of 2002 within the European Union, as Europe-based scientists have been active in research programs and projects on the MoMAR area during the last two decades. In preparation of the VI European Framework Program, a MoMAR prospective meeting took place in Paris in February 2002, and two Expressions of Intention (EoI) were submitted 6 June 2002 to the European Union. Pending evaluation of the EoIs, full proposals to the EU will be in late 2002 or early 2003. All those willing to join one or both EoIs may contact the coordinators listed on the forms below.

A.1 Expression of Intention to the EU (VI FP) – Integrated Project MOMAR

	EUROPEAN COMMISSION	EXPRESSIONS OF INTEREST TO IDENTIFY RESEARCH ACTIONS READY FOR SPECIFIC PROGRAMME TOPICS AS A BASIS FOR THE PREPARATION OF WORK PROGRAMMES FOR THE 6 TH FRAMEWORK PROGRAMME FOR RESEARCH	EoI n°: (for Commission use only)
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ADMINISTRATIVE INFORMATION				
<i>Name of organisation submitting the EoI</i>	University of the Azores			
<i>Contact person details</i>	<i>Title (Dr, Prof ...)</i> Director	<i>Gender</i>	<input type="checkbox"/>	<input checked="" type="checkbox"/> M
	<i>Family Name</i> SERRÃO SANTOS	<i>First Name</i>	Ricardo	
<i>Address</i>	Department of Oceanography and Fisheries (DOP), University of the Azores PT- 9901-862 Horta (Azores), Portugal			
<i>Telephone No.</i>	+351.292200400	<i>Fax No.</i>	+351.292200411	
<i>E-mail</i>	ricardo@dop.horta.uac.pt			
<i>Title of the expression of interest</i>	Long Term Monitoring of the North Atlantic : An Observatory Approach			
<i>Acronym</i>	MOMAR			
<i>Sub-Thematic Priority¹ most relevant to your topic</i>	1.1.6.3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Other relevant Sub-Thematic Priorities²</i>	*****	*****	*****	*****
<i>Abstract (max. 10 lines)</i>	This project targets the Mid-Atlantic Ridge region near the Azores, with marine environments as diverse as mid-ocean ridge hydrothermal vents, seamounts, abyssal plains, and islands slopes. The objective is to monitor the complex and interacting biological, chemical, volcanic and tectonic processes in these environments over time, using the area as a natural laboratory for the study of a number of challenging scientific and technological issues in the fields of biology, chemistry, geology, geophysics, and physical oceanography. This project takes education purposes into account, and emphasizes issues such as ecosystems responses to environmental changes, life in extreme environments, and the sustainable management of resources. This concerted European effort is also meant to develop a European leadership in the challenging field of deep-sea monitoring technology. The research proposed for this IP would establish Europe as the key player in the challenging field of monitoring of deep-sea ecosystems.			
<i>I request that the information given in this form is not published³</i>	YES <input type="checkbox"/>			


Indicate only one sub-thematic priority number given in Annex 1, eg. 1.1.6.1.i or 1.1.1.ii.b or 2.3

² If appropriate, indicate one or more sub-thematic priority numbers given in Annex 1.

³ Unless you indicate "yes", the name of the organisation, contact person details, title and abstract of this expression of interest may be published by the Commission.

Towards planning of seafloor observatory programs for the MAR region

A.2 EXPRESSION OF INTENTION TO THE EU (VI FP) – NETWORK OF EXCELLENCE EURECO

	EUROPEAN COMMISSION	<i>EXPRESSIONS OF INTEREST TO IDENTIFY RESEARCH ACTIONS READY FOR SPECIFIC PROGRAMME TOPICS AS A BASIS FOR THE PREPARATION OF WORK PROGRAMMES FOR THE 6TH FRAMEWORK PROGRAMME FOR RESEARCH</i>	EoI n°: (for Commission use only)
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ADMINISTRATIVE INFORMATION			
<i>Name of organisation submitting the EoI</i>	UNIVERSITY PIERRE ET MARIE CURIE		
<i>Contact person details</i>	<i>Title (Dr, Prof ...)</i>	Research Director	<i>Gender</i> F <input type="checkbox"/>
	<i>Family Name</i>	GAILL	<i>First Name</i> Françoise
<i>Address</i>	Institut de Biologie Intégrative, UMR 7622 UPMC CNRS, University of Pierre et Marie Curie, 7 Quai Saint Bernard 75005 Paris		
<i>Telephone No.</i>	01 44 27 30 63	<i>Fax No.</i>	01 44 27 52 50
<i>E-mail</i>	francoise.gaill@snv.jussieu.fr		
<i>Title of the expression of interest (up to 10 words)</i>	EUROPEAN RIDGE ECOSYSTEMS		
<i>Acronym (up to 20 characters)</i>	EURECO		
<i>Sub-Thematic Priority⁴ most relevant to your topic</i>	1.1.6.3		
<i>Other relevant Sub-Thematic Priorities⁵</i>			
<i>Abstract (max. 10 lines)</i>	We propose a Network of Excellence to integrate and enhance European research on marine ecosystems along the ridge system where the European plate is generated, from the Mid-Atlantic Ridge at 36°N to the Gakkel ridge in the Arctic. Our objective is the understanding of the driving forces and key agents of marine ecosystems which utilize the natural resources of the deep Earth. Continuous mapping, sampling coverage, and long-term observation of ridge ecosystems, quantitative analyses of energy and element cycles, as well as ecological and genomic studies of key microbial and animal populations, will enhance our understanding of the evolution of the ridge ecosystems from deep structures to marine life and establish Europe as the international scientific leader in this field of deep-sea research.		
<i>I request that the information given in this form is not published⁶</i>		YES <input type="checkbox"/>	

⁴ Indicate only one sub-thematic priority number given in Annex 1, eg. 1.1.6.1.i or 1.1.

⁵ If appropriate, indicate one or more sub-thematic priority numbers given in Annex 1.

⁶ Unless you indicate "yes", the name of the organisation, contact person details, title and abstract of this expression of interest may be published by the Commission.



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