

INTER**RIDGE** NEWS

Promoting international cooperation in ridge-crest studies



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Contents

From the Office	1
Letter from the Chairs	1
Coordinator Update	2
Education and Outreach Update	6
InterRidge Fellows	6
InterRidge Cruise Travel Bursaries	10
International Research	12
Battling through the thermal boundary layer: Deep sampling in ODP Hole 1256D during IODP Expedition 335. (<i>Teagle et al.</i>)	12
Oceanic and continental margin terranes at the Sundaland-Philippine Sea Plate collision boundary: Preserved evidence on northwestern Mindoro, Philippines. (<i>Yumul et al.</i>)	18
Keys to ancient Fe-Si formation: low-temperature hydrothermal oxide deposits along modern oceanic ridges. (<i>Zhibei et al.</i>)	21
Lead isotope composition variations in sulfides from hydrothermal fields of the Mid-Atlantic Ridge: high-precision MC-ICP-MS isotope data. (<i>Chernyshev et al.</i>)	24
Accelerator Mass Spectrometry to understand hot vents history and precipitation of seafloor sulfides. (<i>Roonwal et al.</i>)	27
Ocean Exploration at the Mid-Cayman Rise. (<i>German</i>)	30
Ultramafic hydrothermal systems on the Rainbow abyssal hill: a wide variety of active and fossil chemosynthetic habitats. (<i>Lartaud et al.</i>)	32
Moytirra: a newly discovered hydrothermal vent field on the mid-Atlantic Ridge between the Azores and Iceland. (<i>Wheeler et al.</i>)	37
New hydrothermal field on the Mid-Atlantic Ridge. (<i>Shilov et al.</i>)	40
Dredged samples from the ocean floor at Woodlark Basin provide evidence of hydrothermal fluid circulation and wall rock alteration. (<i>Visbiti</i>)	42
Hydrothermal activity in the Eastern Manus Back-arc Basin, Papua New Guinea, with focus on fluid geochemistry. (<i>Schaen</i>)	45
Hydrothermal exploration along the southern Central Indian Ridge. (<i>Okino</i>) . . .	46
Three new hydrothermal fields found at 13-14°S Mid-Atlantic Ridge. (<i>Tao et al.</i>) .	48
MoMar-Demo at Lucky Strike. A near-real time multidisciplinary observatory of hydrothermal processes and ecosystems at the Mid-Atlantic Ridge. (<i>Cannat et al.</i>) .	49
International study of larval dispersal and population connectivity at hydrothermal vents in the southern Mariana Trough. (<i>Beaulieu et al.</i>)	50
National News	54
Working Group Updates	70
Hydrothermal Energy and Ocean Carbon Cycling	70
Long Range Exploration	73
Mantle Imaging	73
Seafloor Mineralisation	73
Vent Ecology	74
Workshops and Conferences	76
IODP/ICDP Workshop: Geological carbon capture & storage in mafic and ultramafic rocks	76
Circum-Antarctic Ridges	77
Ocean Mantle Dynamics: From Spreading Center to Subduction Zone	78
Publications	79
Upcoming Events	80
Upcoming Cruises	82
InterRidge National Correspondents	84
InterRidge Steering Committee	85

**INTERRIDGE
NEWS**



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www.interridge.org

LAYOUT

Kate Davis

FOR CONTRIBUTORS

Please send all items for publication via email to the InterRidge Coordinator.

Text should be in Microsoft Word format. Figures should be sent in high resolution (minimum width of 1000 pixels, 2000 is preferable), in eps or tif format for optimal printing, although other formats are accepted.

**DEADLINE FOR INTERRIDGE NEWS
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Letter from the Chairs

Bramley Murton and Jon Copley



Figure 1:
RSS *James Cook* outside the National Oceanography Centre, Southampton, UK.

These past 12 months have, again, proved to be extremely exciting and rewarding for the InterRidge community. It is clear, looking through the pages of this year's InterRidge News, that there has been a significant step-change in the discovery and investigation of new hydrothermal sites and their mineral deposits. While this reflects the growing economic interest in hydrothermal resources (see Chunhui Tao's paper), it is also a testament to the collaborative nature of our research and the sharing and development of new technologies. Particularly exciting to me is the new discovery of a large polymetallic sulphide deposit (the Peterburgskoye field - reported here by Shilov et al.) located 16 km off-axis on the Mid-Atlantic Ridge. My excitement reflects the fact that this is an extinct hydrothermal site, yet was discovered by remote geophysical sensing using electrical potential anomalies detected during a geoelectrical survey. It has always been hard to reconcile the apparent difference between the frequency and flux of high-temperature hydrothermal vents with theoretical models for the cooling of new oceanic crust that suggest hydrothermal flow should be far more common than we have found. One explanation is that there are far more dead and diffuse vents sites than those we know. But finding them, in the absence of water column plumes, is not an easy task. So this new discovery and the method used to find it marks a new era in assessing the impact of past hydrothermal activity at all spreading systems. That said, we are also finding an increasing number of active venting systems with new and unexpected vent biology. I am especially delighted to welcome our Irish colleagues into the InterRidge family. They have arrived on the scene with a great flourish, having located the first high-temperature hydrothermal field north of the Azores (the Moytirra field, reported here by Andy Wheeler et al.). Chris German's report also highlights the continuing and steep learning curve we are on with NOAA's Ocean Exploration cruise returning to the Mid-Cayman Spreading Centre vent fields in

the Caribbean and making the remarkable find of both live tube-worms and vent shrimps thriving together. As a former ophiolite geologist (having spent many happy years studying the Troodos Ophiolite in Cyprus), I am also delighted to see a renewed focus on these uplifted fragments of oceanic crust (see Yumul's paper). A recent visit with undergraduates back to Troodos reminded me how fabulous the outcrops are and the unparalleled opportunities these exposures provide to understanding the more inaccessible parts of the ocean crust.

As we approach the third decade of InterRidge, our collective efforts to coordinate and develop ridge-crest research through international collaboration and capacity building is of increasing importance. At a national level, the logistic, technological and financial burden of ridge crest science is significantly offset by international collaboration. Through InterRidge, such multi-nation efforts can be brought to bear on focused scientific areas, thereby greatly enhancing the scientific value of any individual nation's research effort. Ridge-crest science also inspires and motivates the next generation of Earth scientists. Towards these objectives, InterRidge continues to develop new research-led Working Groups, sponsors meetings that report the most contemporary scientific topics and supports a growing programme of opportunities for the educational development of early career scientists from across the globe (see Coordinator's report).

With increasing demands for resources worldwide, the economic potential of mid-ocean ridge mineral deposits is expanding rapidly. There have already been two applications to the United Nations' International Seabed Authority (ISA) for polymetallic sulphide exploration licenses (one along the Southwest Indian Ridge and another along the Mid-Atlantic Ridge). Yet, as host to these abundant natural resources, ridge crests also host fragile and unique chemosynthetic ecosystems. Inevitably, resource exploration will target sites of active and inactive hydrothermal venting, with implications for the potential disturbance to their ecosystems. In response, InterRidge continues to engage with governmental policy makers, legislators, non-government organisations (NGO's) and industry to offer advice based on the views of our community. Our experience to date is that these bodies are keen to work with us. A recent example was the ISA's request to InterRidge to consult our community to help identify the most scientifically and culturally 'valuable' hydrothermal vent sites. The results of that consultation are published on the InterRidge website and reflects the diversity of opinion and strength of feeling amongst us. InterRidge aims to continue to consult our community and hence supply valued scientific advice to help stakeholders make informed decisions about potential anthropogenic impacts and sustainability. With the growing and potentially competing interests on mid-ocean ridges, it is imperative that InterRidge expands this role. With this, and the emerging 'big' scientific questions in mind, we will set out a road map for future InterRidge activity during the 'Third Decadal Plan 2014-2023' meeting in San Francisco this December (2011). Please visit the IR web site to have your say on the forum - we all need to express our views to make this a success.

Coordinator Update

Debbie Milton

During 2011, the InterRidge Office has continued to support individual InterRidge members as well as its Working Groups and other international meetings. It has been engaged in new outreach opportunities, namely the launch of the InterRidge Cruise Travel Bursaries and multilingual translations of the education and outreach areas of the website. We are also in discussion with GRID-Arendal, with whom we signed a Letter of Agreement in 2010, to produce a joint UNEP-InterRidge atlas of chemosynthetic environments for policy makers. Earlier in the year, a team at GRID-Arendal developed a Google Ocean “bubble” for InterRidge.

Kensaku Tamaki (1948-2011)



It was with great sadness that we learnt of the sudden death of Dr. Kensaku Tamaki, Professor at Tokyo University and former InterRidge Chair, on April 6 (Japan Time) at the age of 62 during his stay in New York.

Prof. Tamaki started his career at the Geological Survey of Japan, and made great contributions to the understanding of the backarc rift

system around Japan. He served as co-chief scientist on the ODP Leg 127 in the Japan Sea. After he moved to the Ocean Research Institute, University of Tokyo in 1986, he led several research cruises to world mid-ocean ridges. He coordinated the French-UK-Japan FUJI cruise (R/V *Marion Dufresne*, 1997) to the Southwest Indian Ridge, which was known as an ideal multinational collaborative cruise under the umbrella of InterRidge. He served as Chair of InterRidge from 2000 to 2003 and was very involved in writing the current IR science plan "InterRidge - The Next Decade". Kensaku moved to the Frontier Research Center for Energy and Resources, University of Tokyo in 2004 and recently focused on hydrothermal vent and deposit exploration. He was a pioneering researcher of mid-ocean ridge processes and hydrothermal activity in Japan and had led the Japanese ridge research community for many years. We shall always remember him, his gentle smile and his excellent contribution to the IR community.

(Obituary received from Kyoko Okino, Japanese National Correspondent for InterRidge. The memorial address by his wife, Ms. Kuni Tamaki, can be read at: <http://ofgs.ori.u-tokyo.ac.jp/~okino/TamakiMemorial>).

Membership

InterRidge has sustained a solid membership base, with ~2500 individual members representing 62 countries and regions. We try to maintain an updated list, so please email the IR Office or log on to

your online account if your contact details have changed. A bi-weekly newsletter continues to be sent to the “interridge-mail” list, this being the best way to announce news and events, and job postings are sent out to the ~190 people on the “interridge-classifieds” list.

Steering Committee

The IR Steering Committee (StComm) was held in Hangzhou, China in October 2011 (after this volume was sent to press). The report of this meeting will be posted at:

<http://www.interridge.org/stcom/reports>. Both UK representatives - Tim Henstock and Alex Rogers - have rotated off the StComm this year, and we thank them for their past involvement and support. We welcome Richard Hobbs as the UK National Correspondent. Invited guests included Georgy Cherkashov (Russia), Jiancai Jin (COMRA) and Sam Smith (Nautilus Minerals).

National Correspondents

One way in which news of ridge-crest research and outreach activities is disseminated is through the National News section of this volume. We rely on our system of National Correspondents to write in to the IR Office with updates. Last year, the IR office reported many unrepresented countries and that remains the case. Please consider if you could be the correspondent for one of the countries below, and if so, please write in to the IR office. The duties are not onerous – an annual report is required, and the advantages are that you can network with both national and international colleagues.

Countries needing a National Correspondent	
Argentina	Malaysia
Bangladesh	Maldives
Belgium	Monaco
Canada	Myanmar
Colombia	Nepal
Cuba	Netherlands
Cyprus	New Caledonia
Czech Republic	Pakistan
Denmark	Papua New Guinea
Ecuador	Peru
Egypt	Poland
Greece	Slovenia
Indonesia	Turkey
Iran	Ukraine
Israel	Venezuela
Jamaica	Vietnam

Welcome to three new National Correspondents



Dr. Andy Wheeler (Ireland) was Chief Scientist on the Irish/UK VENTuRE survey that discovered the Moytirra hydrothermal Vent Field on the Mid-Atlantic Ridge at 46°N using the Irish RV *Celtic Explorer* and *Holland I* ROV. Dr. Wheeler is the Head of Geology (acting) in the School of Biological, Earth & Environmental Sciences at University College Cork and also Vice Head of the School. He is an elected member

of the Royal Irish Geosciences Committee and Chair of the Committee of Heads of Irish Geosciences Institutes (CHIGI). Dr. Wheeler received his PhD from Cambridge in 1994 before moving to Queen's University of Belfast and University College, Cork. He has published over 35 peer-reviewed articles on marine geology including a Science publication and has co-authored 3 books. He can't wait to get back to Moytirra...



Dr. Alfredo Aguillón Robles (Mexico) has been a researcher at the Institute of Geology, Universidad Autónoma de San Luis Potosí for more than 20 years. He studied for his PhD at the Université de Bretagne Occidentale at Brest, France and since then, has continued with research in petrology and geochemistry of volcanic rocks in Central Mexico. He has also participated in projects within

the Sierra Madre Occidental volcanic province, one of the largest volcanic provinces of the world. During 2010, Dr. Aguillón participated for the first time with a French group at the Pacific Ridge, studying in particular the evolution of the rocks here. As the Mexican Correspondent for InterRidge, Dr. Aguillón is looking forward to building relationships between this institution, other research groups and the geological communities at San Luis Potosí and elsewhere in Mexico.



Dr. Richard Hobbs (UK) is an internationally renowned researcher in controlled source seismology who has made landmark contributions to geophysics and oceanography. He has a broad spectrum of interests that span geosciences with ongoing collaborative research projects that include: seismic oceanography, 3-D mapping of facies in basalts, geophysical modelling, pattern recognition, quantifying uncertainty,

tectonics and the inversion of geophysical data. He is a senior lecturer at Durham University.

During his tenure as director of the British Institutions Reflection Profiling Syndicate (BIRPS) (1990-1998), he oversaw the seismic mapping of key geological structures in the crust and upper mantle around the UK and worldwide, including the 65 Ma Chicxulub impact crater in Mexico and the 3-D ARAD survey over the overlapping spreading centre on the East Pacific Rise at 9°N. Recent research, on the north-west continental margin of Europe, has provided the tectonic framework for both academic and industrial exploration of the region.

Hobbs has recently turned his attention to monitoring ocean structure through high-resolution seismic imaging. In 2006 he won a major EU grant from the New and Emerging Science and Technology programme to develop the method with a group of leading European institutions. Though in its infancy, “seismic oceanography” is providing new information to understand and monitor ocean processes critical to the dynamics of the global thermohaline circulation. This year he has led a successful bid to NERC, with NOC, UCL and Manchester, for a major international interdisciplinary study of heat dissipation at an ocean ridge through hydrothermal circulation and the effects on both the crust and overlying ocean.

Working Groups

The Mantle Imaging Working Group (WG) was the only one of the five current IR WGs to hold an international workshop this year. It was at the Atmosphere and Ocean Research Institute, based at the University of Tokyo. A description of its programme can be read in the Workshops and Conferences section of this volume, and a full report, when available, will be posted on the website at: <http://www.interridge.org/WG/MantleImaging/workshop2011>.

Other WGs continuing into next year are: Hydrothermal Energy and Ocean Carbon Cycles, Long Range Exploration, Seafloor Mineralisation and Vent Ecology. During the year, the IR office has had discussions about several possible new Working Group topics, and one of the main foci of the “InterRidge: Third Decadal Plan 2014-2023” discussion meeting will be the development of new Working Groups to address the main scientific goals of mid-ocean ridge research. Updates on the progress of existing WGs can be seen in the Working Group Updates section of this volume.

Workshops and Conferences

The Mantle Imaging WG held a workshop in October 2011: “Ocean Mantle Dynamics: From Spreading Centre to Subduction Zone”, in Tokyo, Japan, where IR awarded prizes for best student posters. The joint IR/SCOR WG on Hydrothermal Energy and Ocean Carbon Cycles met in Hangzhou, China in October. IR also supported a workshop: “Geological Carbon Capture & Storage in Mafic and Ultramafic Rocks”, in Muscat, Oman, in January 2011. Prizes were awarded to young researchers at a special session at EGU, Vienna, Austria: “Biochemical function and diversity of chemosynthetic deep-sea ecosystems”. A workshop on Circum-Antarctic Ridges was organised in Toulouse, France in September 2011. For more information on these meetings, please see articles in the “Education and Outreach” and “Workshops and Conferences” sections.

InterRidge: Third Decadal Plan 2014-23

A meeting to discuss InterRidge's Third Decadal Plan took place in San Francisco, on 3rd December 2011. Group discussions focused on identifying the science challenges in the next ten years, followed by deciding on priorities and the means to achieve them. There is a Forum on the IR home page for continuing discussion. A draft report is expected to be available in early 2012, and this will be open for comments. A final report will be published by the summer of 2012.

Multilingual translation of website sections

A major initiative has been to obtain translations of the website areas which invite worldwide applications for the IR Student and Postdoctoral Fellowships and the Cruise Travel Bursaries, as well as the Code of Conduct and Working Group objectives. A summary of the articles which have been translated and their web addresses is shown below. Our thanks go to Melis Cevatoglu, Kirsty Choi, Hong Deng, Shinsuke Kawagucci, Abi Pattenden, Nina Rothe, and Matias Sandoval.

Language	IR Student Fellowship form and details	Cruise bursary form and details	Code of Conduct at vents	Working Group objectives
Web address	www.interridge.org/fellowship	www.interridge.org/cruisebursary	www.interridge.org/IRStatement	www.interridge.org/WG/carboncycles
Chinese	我们向大洋中脊的研究生和博士后研究人员征集奖学金项目的课题研究提案, 各奖学金金额可达5000美元。	旨在鼓励大洋中脊成员国之间的新的合作。使加入脊峰研究的起步科学家参与到大洋中脊的研究航行中。发展新的研究方向		
French	Dans le cadre de la mission InterRidge pour promouvoir les études internationales, collaboratrices et interdisciplinaires des centres d'expansion océanique, nous invitons des propositions pour les bourses d'étudiants et postdoctoraux d'InterRidge, d'un maximum de \$5000 US chacune.	Pour encourager de nouvelles collaborations entre les pays appartenant à InterRidge. Pour aider les jeunes scientifiques des dorsales à participer aux campagnes de recherche des dorsales médio-océaniques. Pour développer de nouvelles orientations de recherche.	En tant que scientifiques de la recherche marine, nous apprécions particulièrement l'originalité et la complexité de la faune et les milieux des cheminées hydrothermales, et sommes particulièrement intéressés par la préservation des cheminées pour leurs compétences scientifiques, esthétiques, écologiques, et le potentiel de valeur économique.	L'importance du transfert d'énergie hydrothermale à la biosphère par le biais de la production primaire chimio synthétique est reconnue depuis longtemps.
German	Ziel von InterRidge ist es internationale Zusammenarbeit und interdisziplinäre Studien der ozeanischen Riftzentren, wo die Erdkruste des mittelozeanischen Rücken sich öffnet, zu fördern.	Die Förderung einer guten Zusammenarbeit zwischen den InterRidge Mitgliedsnationen. Die Unterstützung junger Wissenschaftler, um diesen eine Teilnahme an einem Forschungscruise zum mittelozeanischen Rücken zu ermöglichen. Die Entwicklung neuer Forschungsrichtungen.	Als Meereswissenschaftler schätzen wir insbesondere die Einzigartigkeit und Komplexität der Lebensgemeinschaften an den hydrothermalen Quellen in der Tiefsee. Wir sind besonders daran interessiert diese Lebensräume aus wissenschaftlichen, ästhetischen, ökologischen, und wirtschaftlichen Gründen zu schützen.	Die Bedeutung des Transfer hydrothermalener Energie in die Biosphäre durch chemosynthetische Primärproduktion ist seit langem bekannt.
Japanese	私供はの院生と博士号所得者を対象にしたインターリッジ特別研究員制度への提案書を募集しています。支給額は各々米5000ドル額までです。	インターリッジ会員国間で新しい共同研究を促進できるようにするため。研究歴の浅い研究者が中央海嶺研究航海へ参加できるようにするため。新しい研究の方向性を開拓するため。	海洋研究の研究員として私供は深海熱水噴出孔の動物相や環境情況が独特で複雑であることを理解しております。私供は化学的、美学的、生態学的また、恐らく経済的にも価値のある噴出孔の保護に特に興味を持っています。	
Korean	우리는 학제간연구(學際間研究), 국제 협력적인 연구를 추진하기 위한 InterRidge 사명의 일환으로, 최대 US \$ 5000까지 대학원 학생 또는 박사 연구자의 연구계획을 지원하고자 합니다.	InterRidge 회원 국가들간의 새로운 국제협력력을 장려한다. 새로운 ridge-crest 과학자들이 중앙해령 연구선에 승선하여 연구활동에 참여 할수 있게 한다. 새로운 연구 방향을 모색하고 발전시킨다.	해양과학 연구자로서 우리는 특별히 심해저 열수 분출구의 복잡성과 단독성을 높이 평가하고 분출구의 경제학적 값어치나 생물학적, 미학적, 그리고 과학적인 가치를 보존하고자 하는데 특별히 관심을 가지고 있습니다.	열수 분출구 에너지가 생화학적 화학합성을 통한 1차 생산자로서 저서 생물권으로 전달된다는 중요성은 이미 오래전부터 알려져 왔습니다.
Russian			Как ученые-исследователи моря, мы особенно ценим уникальность и многообразие глубоководных гидротермальныхэкосистем и заинтересованы в их сохранении для научных, эстетических, экологических и, потенциально, экономических целей	
Spanish	Como parte de la misión de InterRidge dedicada a la promoción de estudios internacionales, cooperativos e interdisciplinarios de la expansión oceánica, los invitamos a presentar proyectos de hasta US\$ 5.000 cada uno para el Programa de Becas para Estudiantes Graduados y Posdoctorales de InterRidge.	Impulsar nuevas colaboraciones a través de las naciones que conforman InterRidge. Permitirles a investigadores en la etapa inicial de sus carreras la participación en cruceros de investigación de las crestas oceánicas. Fomentar nuevas direcciones en las investigaciones.	Como científicos avocados al estudio marino, apreciamos especialmente la singularidad y la complejidad de la fauna y el entorno de los respiraderos hidrotermales del fondo oceánico. Estamos particularmente interesados en preservar estas fuentes por su valor científico, estético, ecológico y potencialmente económico.	La importancia de la transferencia de energía hidrotermal hacia la biosfera a través de la producción primaria de quimio sintéticos ha sido reconocida desde hace mucho tiempo.
Turkish		Atlas Okyanusu'ndaki deprem aktivitesini sürekli olarak incelemek amacıyla Avrupa Deniz Bilimleri Enstitüsü (IUEM, Brest) tarafından HYDROBS-MOMAR projesi ortaya konulmuş tur. (cruise report)		

Google Ocean “bubble”

A videoclip from the Cayman Trough cruise in 2010, submitted by Bramley Murton, contains footage of the deepest hydrothermal vents yet discovered. To view this, go to Google Earth, enable the layers “Ocean” and “Explore the Ocean” and type in “Cayman Trough”. Our thanks go to the team at GRID-Arendal who put this together. If anyone has video material that could be similarly included, please contact the IR office.



InterRidge on Wikipedia

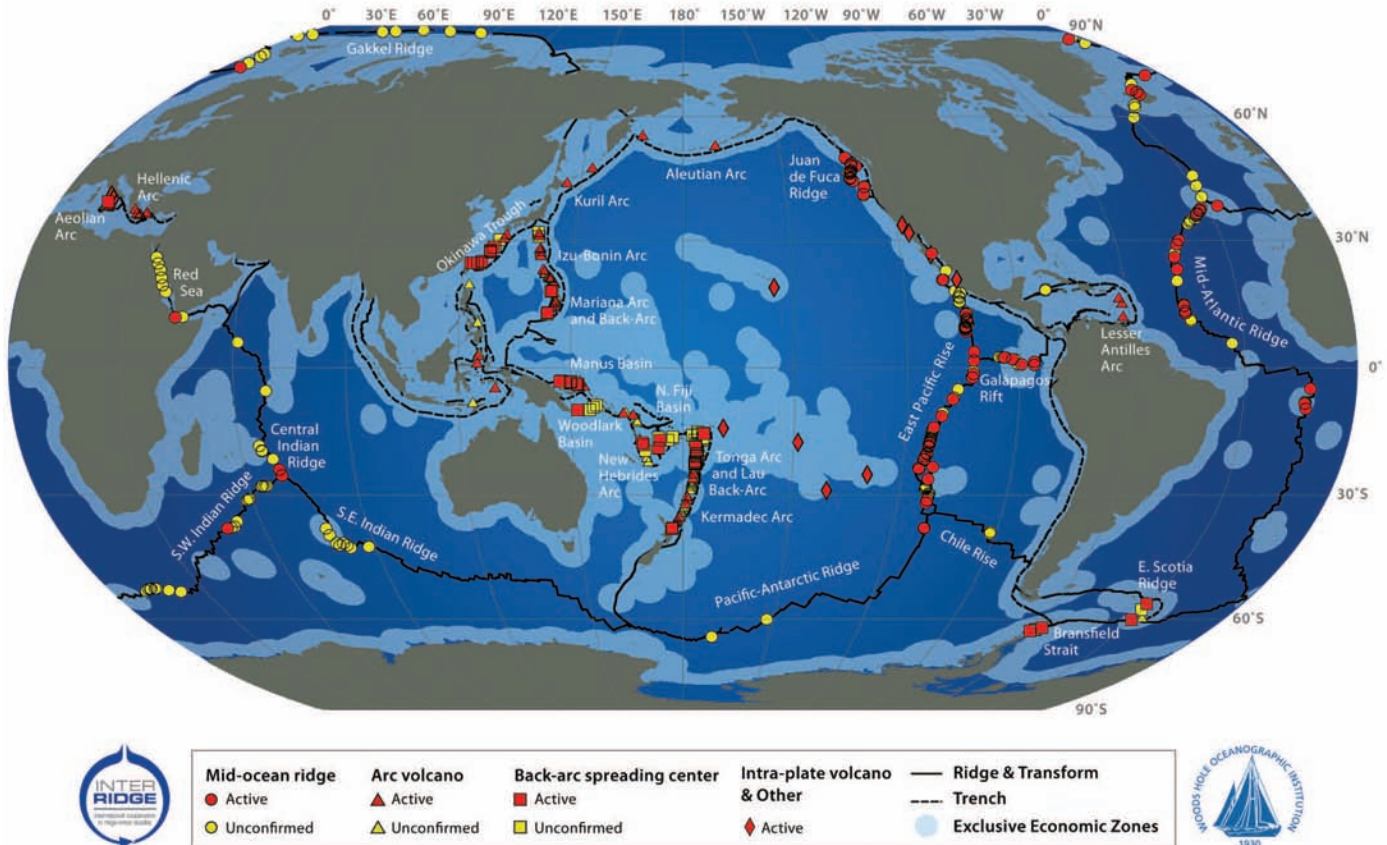
InterRidge now has a presence on Wikipedia and can be seen at: <http://en.wikipedia.org/wiki/InterRidge>. The basic structure is there but, in the spirit of Wikipedia, it requires people to collaborate by adding content and images. Please visit the site and share your knowledge!

Hydrothermal vents database and vent survey

The vents database has been updated by Stace Beaulieu and version 2.1 includes 34 new entries and 80 updates. It is available at: <http://www.interridge.org/irvents>. In February 2011, InterRidge represented the views of the community on protected vent sites to the International Seabed Authority, in advance of their decision to grant polymetallic sulphide exploration licences to the Chinese and Russians. The data and letters that were passed to the ISA can be viewed at: <http://www.interridge.org/policy>.

Figure left: Vent site at the Mid-Cayman Rise (*HyBIS* ROTV).
Figure below: Global distribution of hydrothermal vent fields (Beaulieu, 2009).

Global Distribution of Hydrothermal Vent Fields



Education and Outreach Update

Debbie Milton

2011 InterRidge Student and Postdoctoral Fellows

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

The InterRidge Student and Postdoctoral Fellowship Programme continues to develop and reach out to the global community of young ocean scientists. There was a record number of proposals submitted this year and we were able to award two InterRidge-funded Fellowships, together with three Fellowships for students from developing countries, supported by the ISA Endowment Fund. Therefore, five awards of \$5000 USD each were given to develop young scientists’ careers. The IR Steering Committee thanks all involved in this programme, in particular the many reviewers – each proposal is reviewed by two scientists (one a native, the other a non-native English speaker).

The IR Steering Committee is pleased to announce that in 2011, two InterRidge Fellowships have been awarded to:

Donato Giovannelli



Giovannelli will visit Costantino Vetriani’s laboratories at Rutgers University, USA, to develop his project entitled: “Analysis of functional gene transcripts in microbial chemosynthetic biofilms from deep-sea hydrothermal vents”. The aim of the proposed project is to investigate carbon fixation, respiratory metabolism and quorum sensing mechanisms in chemosynthetic microbial biofilm from deep-sea hydrothermal vents.

Giovannelli is a PhD student in Ecology and Microbiology at the University of Naples Federico II and Research Assistant at the Institute for Marine Science of the National Research Council of Italy, Ancona. He graduated with an MSc in Marine Biology and Ecology in 2007 from the Polytechnic University of Marche, Italy. He has participated in numerous international oceanographic cruises and expeditions and has worked on national and international projects. His PhD thesis is focused on shallow hydrothermal vent prokaryotic communities.

“This InterRidge Fellowship is a great opportunity to work on deep-sea hydrothermal vents, broaden my knowledge and build a network with some of the leading scientists in the field. It is a remarkable opportunity in my early career and it will give me the opportunity to conduct a comparative study between shallow and deep-sea hydrothermal vent ecosystems. I’ve always been fascinated by exploration and since I was a kid I was excited thinking that more people have gone to the moon than to our deepest ocean trench. The deep-sea is the ultimate Earth frontier and hydrothermal vents are one of the most exciting deep-sea ecosystems”.

Eoghan Reeves



Reeves is a Postdoctoral Fellow at the MARUM Center for Marine Environmental Sciences, University of Bremen, Germany, working with Drs. Wolfgang Bach and Kai-Uwe Hinrichs. His proposal is entitled: "An organic geochemical investigation of sulfur-bearing ligand formation in ascending hydrothermal plume particulate matter". He will be working in collaboration with Drs. Chris German and John 'Chip' Breier at the Woods Hole Oceanographic Institution, USA. They will conduct a hydrothermal plume particle sampling campaign at hydrothermal sites in the Cayman Trough in 2011. Reeves will examine samples from these plumes from an organic geochemical perspective with a view to examining whether hydrothermal sulfur is incorporated into the organic matter in the plumes. Results from this study will shed much needed light on the role organic matter plays in delivering nutrient metals from hydrothermal systems to the deep ocean.

"The InterRidge fellowship will enable me to develop international links in an emerging area of hydrothermal plume biogeochemistry, as well as allowing me to diversify the interdisciplinary nature of my research".

The three successful applicants for the InterRidge/ISA Endowment Fund Fellowships are:

Girish Beedessee



Beedessee is currently working at the Mauritius Oceanography Institute (MOI) under the supervision of Dr. Daniel Marie. The title of his project is: "Biological activities and properties of extracts derived from invertebrates and microbial communities of hydrothermal vent faunas at the Central Indian Ridge". He will work with Dr. Ken Takai of JAMSTEC, Japan.

"I am fascinated by the abundance and diversity of organisms found at hydrothermal vents, with the possibility of finding novel genes,

proteins and molecules which can contribute to interesting biological properties. This fellowship will provide me an opportunity to look at the biological properties of invertebrates and microbial symbionts sampled at vent systems of the Central Indian Ridge (CIR). There is an ongoing effort to search for new molecules in terms of marine natural products, and hydrothermal vents have proven to be a rational environment to explore. The data generated will also provide insights on the vents' host-symbionts relationship".

Srinivas Rao



Rao completed his M.Sc. in Physical Oceanography from Andhra University in 2007 and joined as a research scholar under the RIDGE project at the National Institute of Oceanography, Goa, India to pursue a PhD in Oceanography, under the guidance of Dr. P. Vethamony and Dr. K.A. Kamesh Raju of NIO, Goa. As a part of his work in NIO, he has been working on physical properties of the water column over the Indian Ocean Ridge systems. He has participated in cruises exploring the Carlsberg Ridge and Central Indian Ridge systems, to acquire physical oceanography data using CTD, MAPRs and AUV.

Rao's proposal is entitled: "Distribution of hydrothermal sources over the slow spreading Indian mid oceanic ridges", and he will be collaborating with Dr. Edward T. Baker, Pacific Marine Environmental Laboratory, NOAA, USA. "The InterRidge/ISA fellowship gives me an opportunity to learn about the processing and interpretation of deep sea physical oceanography data in relation to hydrothermal plumes/vents. I will be analyzing the water column data (with CTD and MAPR) collected during several cruises under the Indian Ridge program. The results will provide useful information about the poorly explored slow spreading ridge systems in the Indian Ocean and will be helpful in furthering my PhD work. I am grateful to InterRidge for providing me with this opportunity".

Sabyasachi Sautya

Sautya also studies at the National Institute of Oceanography, India, in the Biological Oceanography Division, under the supervision of

Dr. Baban Ingole. His proposal title is: "Exploration of the megabenthic assemblages of the Carlsberg Ridge, Indian Ocean". The Carlsberg Ridge is a large seabed mountain range in the Indian Ocean. It is generally rocky with some sediment cover. Recent research has identified possible evidence of vent-derived plumes. Little information is available on hard-substratum communities in the deep ocean, particularly in the Indian Ocean. Extensive underwater video has been collected from the ridge, which will allow assessment, for the first time, of the variation in the rocky habitats and their biological communities, as well as potential evidence for hydrothermal processes. This will allow us to link biological and geological patterns and assess ecosystem function on the Carlsberg Ridge. The training will be at the National Oceanography Centre, Southampton, UK, under the supervision of Dr. Daniel Jones.



"I have always been interested in studying extreme habitats and deep-sea life and their evolutionary perspective. Compared to the Pacific and Atlantic Oceans, there is little information about megabenthic communities at the Indian Ocean ridge system. I believe this fellowship will help me to explore a wonderful benthic world from the Carlsberg Ridge, Indian Ocean. My motivation to study the ridge fauna started after watching a WHOI video of the discovery of hydrothermal vents".

Update on 2010 recipients

Vishiti Akumbom

Vishiti Akumbom from Cameroon, received an ISA/InterRidge student award in 2010 to visit labs and work with Prof. Colin Devey. She has subsequently been awarded a 2-year German Foreign Exchange (DAAD) Fellowship to do a major part of her PhD work at IFM-GEOMAR. This is a competitive and prestigious award from the German government. Vishiti will be working on gold mineralisation on major detachment zones both underwater

(Woodlark Basin, Papua New Guinea) and on land in Cameroon. She will gain extensive experience in submarine mineral deposits, which she can directly apply to her home country, and she will be supervised by Sven Petersen, one of the world's experts in the field. For her paper on samples from the Woodlark Basin, please see the International Research section in this volume.

Shinsuke Kawagucci



Dr. Jeff Seewald, sponsor of Kawagucci, in the WHOI labs.

I visited Woods Hole Oceanographic Institution (WHOI) for seven weeks during Autumn 2010, supported by an InterRidge postdoctoral fellowship. The visit was very successful and my special thanks go to the host scientist Dr. Jeff Seewald and his colleague Sean Sylva for their great help and kindness. They supported me not only in carrying out the experiment smoothly but also in living in the US for the first time.

An experiment to investigate fluid-sediment interaction under hydrothermal conditions (pressure, temperature, and natural water-

sediment ratio) was carried out to determine (and refine) the typical thermogenic characteristics of the methane and the relative molecules (H₂, CO₂, and hydrocarbons). The origin of abundant methane in the sediment-associated hydrothermal fluid has long been debated but not much is known. While geochemical diagnosis was often used for investigating the origin, the typical geochemical signature of the thermogenic products associated with hydrothermal activities remains unidentified. The experiment had been expected to fill this critical data gap in our knowledge of the generation of sedimentary methane and other reducing gases. Once the thermogenic signature is better constrained, these chemical characteristics can be used to improve modeling of the proportions of mixed biogenic/thermogenic gases in the venting fluids at sediment-associated fields. For this purpose, seafloor sediment taken from the JADE hydrothermal site, Okinawa Trough, was used as a starting material and was put into a flexible-cell hydrothermal apparatus at WHOI, that was well established for fluid-solids reaction experiments. Stepwise heating and temporal samplings were continued for six weeks. The chemical composition of sampled fluid was analysed by ion chromatography and gas chromatography, while some aliquots of the samples were preserved for future analyses on stable carbon and hydrogen isotope ratios of hydrocarbons. All the operations on the experiment were first done by Jeff/Sean and then on my own. The experiment went well and an excellent, publishable dataset was obtained. Following this, I gave a seminar to introduce my research to people related to InterRidge and/or interested in hydrothermal activity. A forty-minute talk in English was indeed very hard for me, especially as a non-native English speaker; however, I

believe that everyone could understand me and was interested in my research. After the seminar, I had a chance to discuss with Dr. Chris German about future collaborative cruises between JAMSTEC and WHOI.

During my visit, I lived in one of the WHOI guesthouses. It was very comfortable and I had two roommates: Longtao Sun from the South China Sea Institute of Oceanography who is to collaborate with Dr Jian Lin, and Mark Van Middlesworth, a WHOI Engineer Assistant II in the Deep Submergence Lab from the Applied Ocean Physics and Engineering department. They were both nice to me. I also enjoyed being in the WHOI soccer team and loved playing football on lunch breaks. My visit as an InterRidge fellow was very successful. I hope that this program continues to provide opportunities for many students/postdocs from around the world. Finally, I would like to thank everyone who keeps the fellowship programme running, for their great efforts and warm support.

This report is available in Japanese at:
<http://www.interridge.org/2010awards>

Baby Divya

Ms Divya is currently completing her PhD and afterwards will be making arrangements to use her InterRidge fellowship by working with Dr. Raul Bettencourt, at the University of the Azores, Portugal.



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



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

Call for Proposals for the 2012 Fellowships will be released in January 2012

Deadline: 31 March 2012

Awards announced in June 2012

InterRidge cruise travel bursaries

The InterRidge Cruise Travel Bursaries have been instigated by the UK IR Office, and the first awards have proven to be very successful. The aim is to link early career scientists with established scientists from other nations, to develop international collaborations and to enable participation in mid-ocean ridge research cruises. The awards can be applied for in two ways – either as a young scientist or as someone who has a spare berth on an upcoming cruise. Details are at: <http://www.interridge.org/cruisebursary> or contact the IR Office.

Adrien Bronner



I will be participating on a cruise to the Perth Abyssal Plain in November 2011 aboard the *Southern Surveyor*, working onboard with Dr. Dietmar Müller, having initially developed a collaboration with Dr. Jo Whittaker, as she is interested in mid oceanic ridges as well as continental margins. Her background in worldwide plate tectonics and especially Australian margins could be complementary to my work on Iberia-Newfoundland rifting history. Moreover, the cruise proposed on the Perth Abyssal Plain is exactly the kind of research to allow my investigations on continental breakup as well as on deep-tow magnetic data.

My PhD is part of a project called “Rift2Ridge”. It deals with magnetic data from passive margins (Iberia-Newfoundland, S-Atlantic, S-Australia and Aden margins) and from ultra slow spreading ridges such as the South-West Indian ridge. My research is focused on the seaward termination of the continent. I am interested in areas where seafloor-spreading anomalies are ill-defined and controversial. I am investigating processes and sources responsible for these anomalies (especially in exhumed mantle domains) in order to better constrain rifting history and continental breakup. For that purpose, I am working in collaboration with people interested in mid-oceanic ridges as well as continental margins. The aim of this project is to better understand processes leading from continental thinning to oceanic spreading.

The first part of my PhD was focused on the Iberia-Newfoundland margins and especially the magnetic signal at the seaward edge of the ocean-continent transition. We have proposed a model based on

forward modeling of magnetic anomalies constrained by seismic refraction and drill-hole data. We show that the main anomaly, the J anomaly in the Newfoundland basin (NB) and the Iberia Abyssal Plain (IAP) can be explained by underplated mafic material and surface lava flows produced by a ~112 Ma event of excess magma which finally resulted in crustal breakup and seafloor spreading. Thus, the J anomaly does not correspond to the beginning of the M sequence of seafloor spreading anomalies in the IAP and NB but is interpreted as a “breakup anomaly” which marks the edges of the “true” oceanic crust. This working hypothesis has to be tested at other different margins, which is why I am really interested in the study of the Perth Abyssal Plain.

During October 2010, I was a geophysicist on the R/V *Marion Dufresne* for a cruise at the South-West Indian Ridge (MD183 Smoothseafloor cruise) where I was mainly involved in the processing of the deep-tow magnetic data. This cruise was my first experience in marine geophysics and it was a really good opportunity for intense scientific exchange, and a good way to improve my scientific knowledge. Moreover, we are now working on a new method of calibration of the fluxgate magnetometer, based on the 9 errors of the sensor (offset error, sensitivity coefficient for each of the three sensors, and the three non-orthogonality angles). This method has given promising results on the data collected during the Smoothseafloor cruise and my research is currently focused on the processing aspect of this method.

Melis Cevatoglu



Melis studies at the Kandili Observatory and Earthquake Research Institute, University of Bogazici, Istanbul, and she received an InterRidge cruise travel bursary for the HYDROBS-MOMAR2 cruise in June 2011. The scientific goal of the HYDROBS-MOMAR2 survey was to understand the distribution of the low magnitude seismicity of mid-Atlantic ridges using hydrophones moored in the SOFAR channel. The scientific objectives of Cevatoglu were to learn how to deploy hydrophones and become familiar with oceanographic surveys and to understand the

methodology by programming the parameters of the hydrophones. This cruise was a turn-over of the five hydrophones moored south of the Azores around the MOMAR area. One year's data was recovered and the hydrophones re-deployed. Newly recorded hydroacoustic data will be processed and interpreted in Brest, leading to better understanding of the seismogenic character of the Mid Atlantic Ridge. It will also provide insights about the dynamics of an active ridge system – tectonism, magmatism and hydrothermalism.

Adam Schaen



Adam Schaen is studying geochemistry at Bridgewater State University, MA, USA, and has conducted independent research with Drs. Peter Saccocia (Bridgewater State University) and Jeff Seewald (WHOI). He has conducted experimental studies of interactions between pyrophyllite-quartz-alunite-illite rock and seawater and was able to reproduce the mildly acidic fluids common for high-temperature vent fluids in the PACMANUS hydrothermal systems. His objective aboard the SO216 cruise was to collect samples of diffuse fluids from the Fenway and Snowcap areas in the PACMANUS area. He studied how interactions between rocks and vent fluid-seawater mixtures modify the compositions of diffuse fluids. Adam also worked with Dr. Eoghan Reeves (MARUM) in geochemical and isotopic studies of dissolved gases and low-molecular-weight organics in vent fluids.

His report on the cruise R/V *Sonne*, Leg SO-216 is in the “International Research” section of this volume.

Student awards at EGU

At the EGU, 3-8th April 2011, InterRidge presented two awards to students participating in the Special Session: Biochemical function and diversity of chemosynthetic deep-sea ecosystems.

Annie Bourbonnais, from the University of Victoria, Canada, received the “hottest” oral presentation award for her talk entitled: “Denitrification as the dominant N-elimination process in hydrothermal vents of the Juan de Fuca Ridge, North-East Pacific Ocean”. Annie is a PhD student in Prof. Kim Juniper’s laboratory at the University of Victoria, Canada. Her research is focused on the N cycle and the related microbial community in subsurface

hydrothermal vent systems of the Juan de Fuca Ridge in the Northeast Pacific Ocean. Nitrogen is an essential macronutrient for all organisms. A better understanding of bacterially mediated N-cycle dynamics is critical to characterize metabolic processes taking place in the subsurface biosphere of hydrothermal vent systems. Her research applies a combination of biogeochemical and molecular biology methods to vent fluids sampled by submersible vehicles. Annie’s work focuses on reactions removing bio-available N in hydrothermal vent fluids, which are ultimately affecting chemosynthetic primary productivity in these ecosystems.



Antje Buss (left) and Annie Bourbonnais (right) - winners of InterRidge Student awards at EGU.

On the significance of this conference, Annie wrote: “Attending this important international meeting allowed me to expand my horizons and gain new perspectives on my research. I met, for the first time, the European scientific community working on hydrothermal vent systems. Other scientists from around the world were also present at the meeting. Attending meetings like these is crucial for early-career scientists to find new scientific collaborations”.

Antje Buss studies at the University of Bremen, Germany, and she was awarded the “hottest” poster award, for her work entitled: “Hydrothermal ^3He in the near field of natural CO_2 seeps in the Okinawa Trough”. Her Masters thesis deals with hydrothermal vent systems in the Okinawa Trough, western Pacific where subsequent venting of liquid CO_2 bubbles has been observed. In the current concern about reducing atmospheric CO_2 , carbon storage in the deep sea is an option. This is generating studies about the dispersal of CO_2 in the water column and its impact on the deep sea ecosystems, for which the Okinawa Trough provides the perfect study area.

Antje said: “The EGU General Assembly is the biggest geoscience conference in Europe and therefore provided a good opportunity for me to get an overview of different research areas in my field. I attended the conference for the first time and it was a huge delight for me to receive an award for my poster and I really thank InterRidge for this highly motivating experience”.

Battling through the thermal boundary layer: Deep sampling in ODP Hole 1256D during IODP Expedition 335

Damon A.H. Teagle, Benoit Ildefonse, Peter Blum and the IODP Expedition 335 Shipboard Scientists*

Phase 1	Open hole to full depth, cement to stabilize hole (920-960 mbsf)	15 days (9 reentries)
Phase 2	Core (4 cores, 8% recovery); Coring bit destroyed	~ 2 day (1 reentry)
Phase 3	Fish/mill junk, ream/clean hole	19 days (13 reentries)
Phase 4	Logging	~ 2 day (1 reentry)
Phase 5	Core (1 core, 35% recovery), cement to stabilize hole (BOH to 1510, 940-910 mbsf)	~ 1.5 days (1 reentry)
• 24 reentries, ~150 miles (~240 km) of pipe trip		
• 920-940 mbsf zone: stabilized (15 trips through after cementing end of Phase 1 without any trouble)		
• Hole: clean and clear of cuttings, no metal junk left at bottom		
• Cone: clear		
• “Fieldwork” samples from ocean crust thermal boundary layer		

Table 1: Summary of operations on IODP Expedition 335.

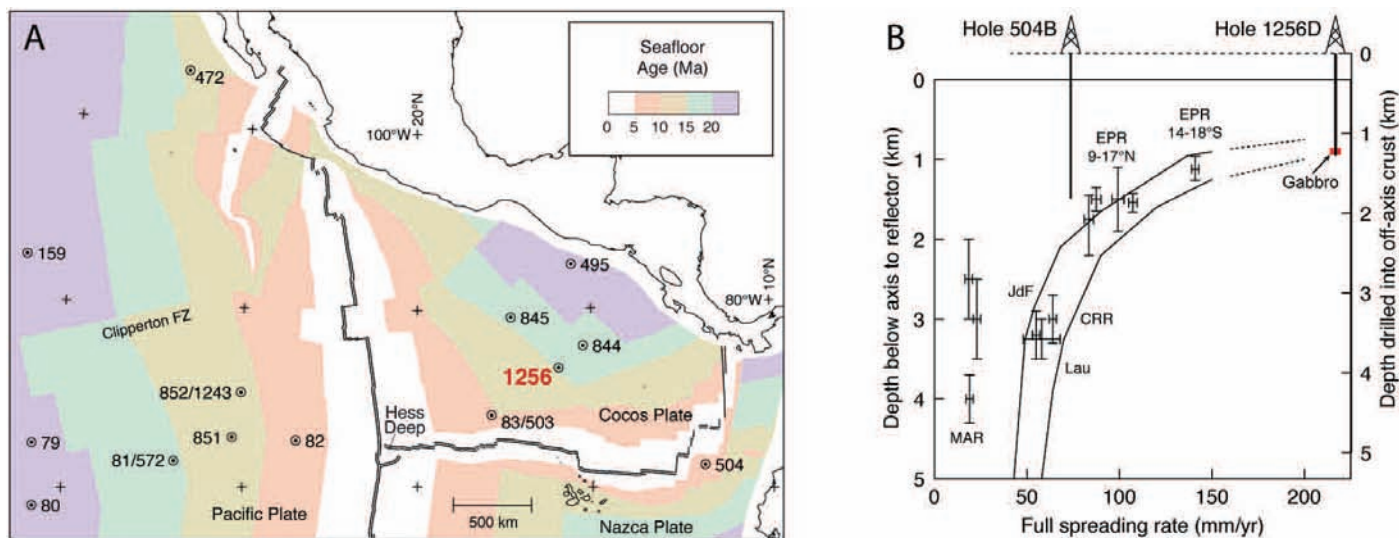


Figure 1 – A. Age map of the Cocos plate and corresponding regions of the Pacific and Nazca plates. Isochrons at 5 m.y. intervals have been converted from magnetic anomaly identifications according to the timescale of Cande and Kent (1995). Selected DSDP and ODP sites that reached basement are indicated by circles. The wide spacing of the 10 to 10 m.y. isochrons to the south reflects the extremely fast (200–220 mm/y) full spreading rate. FZ = fracture zone. **B.** Depth to axial low-velocity zone plotted against spreading rate (Purdy et al., 1992; Carbotte et al., 1997). B. Depth versus spreading rate predictions from two models of Phipps Morgan and Chen (1993) are shown, extrapolated subjectively to 200 mm/y. Penetration to date in Holes 504B and 1256D is shown, with the depth at which gabbros were intersected indicated by the red box. Following core descriptions, a thickness of ~300 m of off-axis lava is shown for Hole 1256D and assumed for Hole 504B. EPR = East Pacific Rise, JdF = Juan de Fuca Ridge, Lau = Valu Fa Ridge in Lau Basin, CRR = Costa Rica Rift, MAR = Mid-Atlantic Ridge.

*Natsue Abe, Bénédicte Abily, Yoshiko Adashi, Jeffrey C. Alt, Ryo Anma, Graham Baines, Jeremy Deans, Henry J.B. Dick, Daisuke Endo, Eric C. Ferré, Lydéric France, Marguerite Godard, Gilles Guérin, Michelle Harris, Yoon-Mi Kim, Juergen H. Koepke, Mark D. Kurz, C. Johan Lissenberg, Sumio Miyashita, Antony Morris, Ryo Oizumi, Betchaida D. Payot, Marie Python, Parijat Roy, Jessica L. Till, Masako Tominaga, Douglas S. Wilson, Natalia Zakharova

Abstract

IODP Expedition 335 “Superfast Spreading Rate Crust 4” returned to ODP Hole 1256D with the intent of deepening this reference penetration of intact ocean crust a significant distance (~350 m) into cumulate gabbros. Three earlier cruises to Hole 1256D have drilled through the sediments, lavas and dikes and 100 m into a complex dike-gabbro transition zone.

Operations on IODP Expedition 335 proved challenging throughout, with almost three weeks spent re-opening and securing unstable sections of the Hole. When coring commenced, the destruction of a hard-formation C9 rotary coring bit at the bottom of the hole required further remedial operations to remove junk and huge volumes of accumulated drill cuttings. Hole-cleaning operations using junk baskets recovered large (up to 3.5 kg) irregular samples that document a hitherto unseen sequence of evolving geological conditions and the intimate coupling between temporally and spatially intercalated intrusive, hydrothermal, contact-metamorphic, partial melting and retrogressive processes.

Hole 1256D has been thoroughly cleared of junk and drill cuttings that have hampered operations during this and previous Expeditions. At the end of Expedition 335, we briefly resumed coring before preserving problematic intervals with cement. It would be prudent for ocean drilling to return to Hole 1256D in the near future to ensure best use is made of the huge efforts to stabilize Hole 1256D and open it to full depth.

Introduction

Drilling a deep hole through intact ocean crust formed at a fast spreading rate has been one of the prime motivations for scientific ocean drilling since its inception. Fast spreading ocean crust is targeted because geological and geophysical observations indicate that for long distances ridge crests behave relatively uniformly. Consequently, the findings from a few deep penetrations should be able to be extrapolated to describe a significant portion of the Earth’s surface (~30%). Only through the recovery of a significant section of cumulate gabbro underlying the dikes and erupted lavas will we be able to test competing models of magmatic accretion at fast spreading mid-ocean ridges and evaluate the impact of these processes on the wider Earth system.

IODP Expedition 335 (13th April-3rd June, 2011) was the fourth scientific drilling cruise of the Superfast campaign (Wilson et al., 1999) and returned to ODP Hole 1256D (6°44.163’N, 91°56.061’W) to deepen this ocean crust reference penetration a significant distance into cumulate gabbros (Figure 1a). ODP Hole 1256D is located on 15 Ma-crust in the eastern equatorial Pacific Ocean in oceanic basement that formed during a sustained episode of superfast ocean ridge spreading (>200 mm/yr; Wilson, 1996). Ocean crust formed at a superfast spreading rate was deliberately targeted because there is strong evidence from mid-ocean ridge seismic experiments that gabbros occur at shallower depths in intact ocean crust with higher spreading rates (Figure 1b). Therefore, the

often difficult-to-drill upper ocean crust should be relatively thin. Expedition 335 follows on from ODP Leg 206 in 2002 and IODP Expeditions 309/312 in 2005 (Wilson et al., 2003; Teagle et al., 2006) that prepared the first scientific borehole for deep drilling by installing a large reentry cone (Fig. 2), secured with almost 270 m of 16-in casing through the 250 m-thick sedimentary overburden and cemented into the uppermost basement. Hole 1256D was then deepened through a ~810 m-thick sequence of lavas and a thin (~346 m) sheeted dike complex, the lower 60 m of which is strongly contact metamorphosed to granoblastic textures. The first gabbroic rocks were encountered at 1407 meters below seafloor (mbsf) where the hole entered a complex dike-gabbro transition zone that includes two 20 to 50-m thick gabbro lenses intruded into granoblastic dikes. As of the end of Expedition 312 in December 2005, Hole 1256D had a total depth of 1507.1 mbsf and was open to its full depth.

It was hoped that even with a shortened cruise (~6 weeks), coring on IODP Expedition 335 would be able to deepen Hole 1256D ~350 m, completely through the dike-gabbro transition zone and varitextured gabbros and a significant distance into true cumulate gabbros.

Science Objectives of IODP Expedition 335

The specific scientific objectives of IODP Expedition 335 that were to be addressed by deepening Hole 1256D a significant distance into cumulate gabbros were:

- What is the major mechanism of magmatic accretion in crust formed at fast spreading rates? Is the lower crust formed by gabbro glaciers or sheeted sills (e.g. Korenaga and Kelemen 1998) or by some mixed or unknown mechanism?
- How is heat extracted from the lower oceanic crust? Specifically, what is the role of hydrothermal circulation in extracting latent heat from the lower oceanic crust?
- What is the geological significance of the seismic layer 2/3 boundary at Site 1256?
- What is the magnetic contribution of the gabbro layer? Can the magnetic polarity structure of the lower crust be used to constrain cooling rates?

Operations

Expedition 335 re-entered Hole 1256D more than five years after the last expedition to this site (Fig. 2). The expedition encountered and overcame a series of significant engineering challenges, each of which was unique, although difficulties were not unexpected when drilling in a deep, uncased, marine borehole into igneous rocks (Table 1; Expedition 335 Scientists, 2011).

The patient, persistent efforts of the drilling crew successfully cleared a major obstruction at a depth of 920 m that had initially prevented re-entry into the hole to its full depth of 1507 meters. At the bottom of the hole the very hard granular rocks that had proved challenging during the previous Superfast expedition were once more encountered. Although there may only be a few tens of meters of these particularly tenacious granoblastic basalts, their extreme

toughness once more proved challenging to sample, resulting in the grinding down of one of the hardest formation coring bits into a smooth stump (Fig. 3).

A progressive, logical course of action was then undertaken to clear the bottom of the hole of metal debris from the failed coring bit and drilling cuttings. This effort required the innovative use of hole-clearing equipment (Fig. 3), including large magnets, and involved about 240 km of drilling pipe deployments (trips) down into the hole and back onto the ship (the total amount of pipe “tripped” was roughly equivalent to the distance from Paris to the English coast, or from New York City to Philadelphia, or Tokyo to Niigata). These efforts returned hundreds of kilograms of rocks and drill cuttings (Fig. 3D), including large blocks (up to 3.5 kg) of the culprit granoblastic basalts that hitherto had only been very poorly recovered through coring (Fig. 4). A limited number of gabbro boulders were also recovered, indicating that we are tantalizingly close to breaking through into the gabbroic layer.

Scientific Results

Hole opening, remediation operations and the comprehensive destruction of a C9 hard formation coring bit resulted in a major loss of time from the coring and wireline activities planned for Expedition 335. Coring on this Expedition deepened Hole 1256D only modestly, from 1507.1 to 1521.6 mbsf (Fig. 5) at low rates of penetration and recovery (0.9 m/hr, 11% respectively).

Hole cleaning operations at the bottom of Hole 1256D, particularly those runs that deployed the reverse-circulation junk basket, brought back a unique collection of large cobbles (Fig. 4), angular rubble and fine cuttings of principally, strongly to completely recrystallized granoblastic basalt with minor gabbroic rocks and evolved plutonic rocks. The granoblastic basalts record high-temperature (granulite facies) metamorphism of previously hydrothermally altered sheeted dikes, with unequivocal evidence for hydrothermal alteration both before and after the formation of granoblastic textures (Teagle et al., 2006; Koepke et al., 2008; Alt et al., 2010; France et al., 2009). The large blocks exhibit intrusive, structural and textural relationships, and overprinting and cross-cutting hydrothermal alteration and metamorphic paragenetic sequences that hitherto have not been observed due to the one dimensional nature of drill cores and the very low rates of recovery of the granoblastic dikes during Expedition 312 (<7% recovery). Some of the rubble and ~30% of the fine cuttings recovered by fishing and cleaning operations clearly came from the lava sequences at the top of the hole on the basis of igneous textures and low temperature alteration minerals (Mg-saponite, amorphous silica). In contrast, the high extent of metamorphic recrystallization exhibited by the granoblastic basalts, and operational factors (e.g. pipe movements), provide strong evidence that the granoblastic basalts, minor gabbros and evolved plutonic rocks were sourced from the lowermost reaches of Hole 1256D (1494.9 to 1521.6 mbsf), most probably from below Gabbro 2 (Fig. 5). Hence, the rocks recovered during Expedition 335 represent a ~15 m interval of the upper crust-lower crust transition,

occurring below the ~90 m section, recovered during Expedition 312, of two gabbroic bodies (Gabbro 1 and Gabbro 2) separated by Dike Screen 1 (Fig. 6).

Conclusions

When the textural and contact relationships exhibited by the large rocks recovered from the junk baskets are placed in the geological context of the Hole 1256D stratigraphy, a vision emerges of a complex, dynamic thermal boundary layer zone. This region of the crust between the principally hydrothermal domain of the upper crust and the intrusive magmatic domain of the lower crust is one of evolving geological conditions. There is intimate coupling between temporally and spatially intercalated magmatic, hydrothermal, partial melting, intrusive, metamorphic and retrograde processes.

With only a minor depth advance in Hole 1256D, we are yet to recover samples of cumulate gabbros required to test models of ocean ridge magmatic accretion and the intensity of hydrothermal cooling at depth. Nor have we crossed the Layer 2/3 boundary at Site 1256. The total vertical thickness of granoblastic basalts is over 114 m, and Dike Screen 2 is now about the same thickness (so far) as Dike Screen 1. Highly perched, isolated gabbro intrusions are uncommon in ophiolites. The energy requirements for the granoblastic recrystallization at granulite facies condition of a >114 m-thick zone of sheeted dikes, massively exceeds the thermal capacity of Gabbros 1 and 2 (e.g. Koepke et al., 2008; Coggon et al., 2008) if a simple sub-horizontal arrangement of these layers is assumed. The enormous heat requirements for such extensive granulite facies recrystallization, the evidence for partial melting, together with the tantalizing presence of minor but not uncommon gabbroic rocks and felsic intrusives, dikelets and veins, strongly indicates that the layer of purely plutonic rocks should be at most only a few tens of meters deeper in the Hole.

Although the extensive remedial operations on Expedition 335 precluded significant deepening of Hole 1256D, significant progress was made in improving the borehole. The most problematic out of gauge zone at ~920 to 960 mbsf that caused re-entry problems on Expeditions 312 and 335 has been stabilized with cement. The bottom of the hole has been cleared of rubble and junk, and there appears to be only a short under-gauge zone (<1 m). Importantly, the regular, large sweeps of high viscosity mud (up to 200 bbls sepiolite, every ~2 hr), have finally overcome and expunged the vast amount of fine cuttings recirculating in the hole, some most likely resident since ODP Leg 206. This is shown by the absence of soft fill in the final ~5 re-entries compared to upwards of 50 m of soft fill at the end of Expedition 312. The engineering efforts on Expedition 335 have repaired and prepared Hole 1256D for further deep drilling, following 5 years of neglect. Hole 1256D is 1500 m of hard rock coring closer to cumulate gabbros than any other options in intact ocean crust and once more poised to answer fundamental questions about the formation of new crust at fast spreading mid-ocean ridges. This would be best achieved by a timely return to the site.

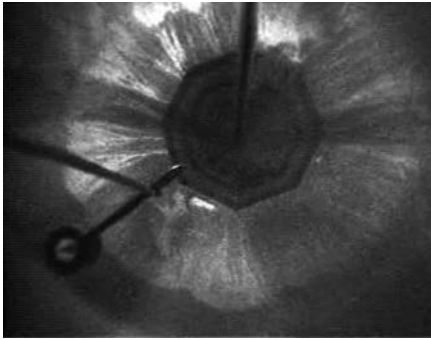


Figure 2: Still image of ODP Hole 1256D reentry cone, from the VIT (Vibration-Isolated Television) Camera, which is deployed on each reentry. This is the 19th reentry in Hole 1256D during Expedition 335. Note the drilling mud and cuttings dispersed around the reentry cone.

Figure 3: Photographs of some drilling, fishing, and milling tools illustrating the multiple operations achieved during IODP Expedition 335. **A & B.** Remains of the Ulterra C9 RCB coring bit used during Run 9. The bit was probably used for ~10 h after it disintegrated, which resulted in this spectacularly abraded and sculptured bit (“Stumpy”), something never seen before by the drillers. **C.** Bottom of the Bowen Reverse Circulation Junk Basket (RCJB), showing its hard-facing structure and the junk catcher spring fingers inside. This tool recovered a series of large scale cobbles (up to 5 kg) of granoblastic basalt. **D.** A series of RCJB runs returned a Bottom Hole Assembly packed by fine-grained cuttings. This contributed efficiently to cleaning Hole 1256D. **E.** Heavily worn and undergauge 9 inch flat-bottomed milling tool. This tool worked at the bottom of the hole for 12 h; its final state indicates the very abrasive nature of metal debris and/or rocks at the bottom of the hole and an undergauge lowermost portion (tens of centimeters) of the hole. Note for comparison the hard-facing structure of the next milling tool on the right side of the picture. **F.** 9-inch Smith FH3VPS tricone bit used for Run 16. This armored bit was efficient to ream and clean the undergauge bottom of the hole.



Figure 4: Granoblastic dike samples were recovered in abundance by fishing tools during successive hole remediation operations. Sumiyo Miyashita and Yoshiko Adashi, from Niigata University, examine unusually large rock samples from Hole 1256D.

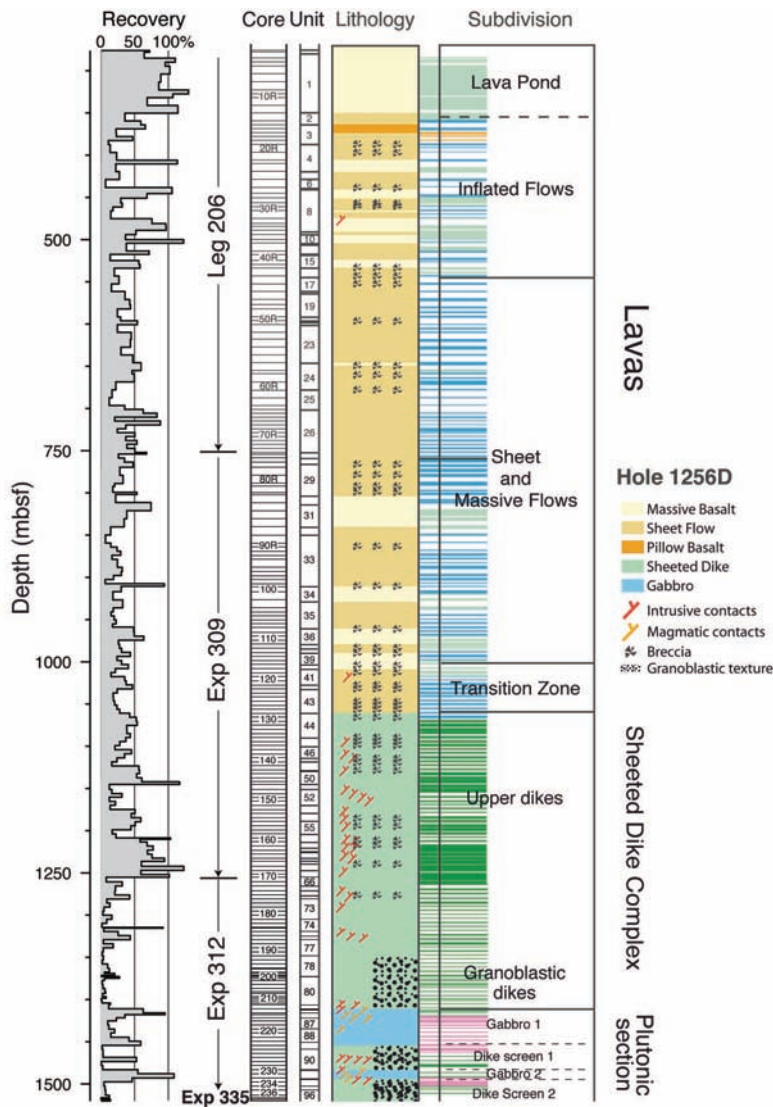
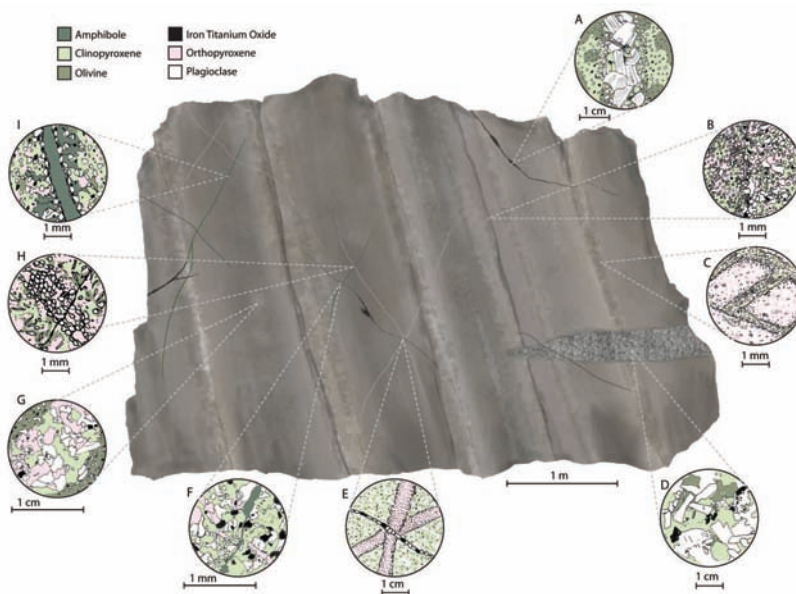


Figure 5: Stratigraphic column for Hole 1256D at the end of Expedition 335, showing the major and minor lithologic divisions of the upper oceanic crust.

Figure 6: Sketch of a hypothetical outcrop in a future Site 1256 ophiolite of the dike–gabbro transition zone showing the contact relationships observed in the cores and junk basket rocks recovered during Expedition 335. Small sketches are drawn from sample and thin section descriptions done during Expedition 335. **A.** Diorite dikelet, comprised predominantly of primary igneous amphibole and plagioclase, crosscutting granoblastic basalt. **B.** Finegrained dike chilled against coarser grained dike. The entire sample is recrystallized to granoblastic assemblages of plagioclase, orthopyroxene, clinopyroxene, magnetite, and ilmenite. Later fine postcontact-metamorphic hydrothermal amphibole veins (not shown) cut across the contact and both dikes. **C.** Chilled and brecciated dike margin recrystallized to granoblastic assemblages. Angular clasts consist of granoblastic plagioclase with minor orthopyroxene, clinopyroxene, ilmenite, and magnetite and are recrystallized from chilled dike margin breccia protolith. Clast matrix is orthopyroxene rich with minor clinopyroxene, plagioclase, and oxides and is recrystallized from hydrothermal minerals (amphibole and chlorite) that veined and cemented the breccia protolith. **D.** Subophitic texture in gabbro. **E.** Diorite vein crosscutting a conjugate set of metamorphic orthopyroxene veins. **F.** Postcontact-metamorphic hydrothermal hornblende vein cutting granoblastic basalt. **G.** Granoblastic basalt with a diorite patch. **H.** Granoblastic orthopyroxene vein, recrystallized from precursor hydrothermal vein, in granoblastic dike. Orthopyroxene vein is cut by small postcontact-metamorphic hydrothermal amphibole vein. **I.** Postcontact-metamorphic hydrothermal amphibole vein cutting granoblastic basalt, with 1 mm wide amphibole-rich alteration halo where pyroxenes are replaced by amphibole.



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Oceanic and continental margin terranes at the Sundaland-Philippine Sea Plate collision boundary: Preserved evidence on northwestern Mindoro, Philippines

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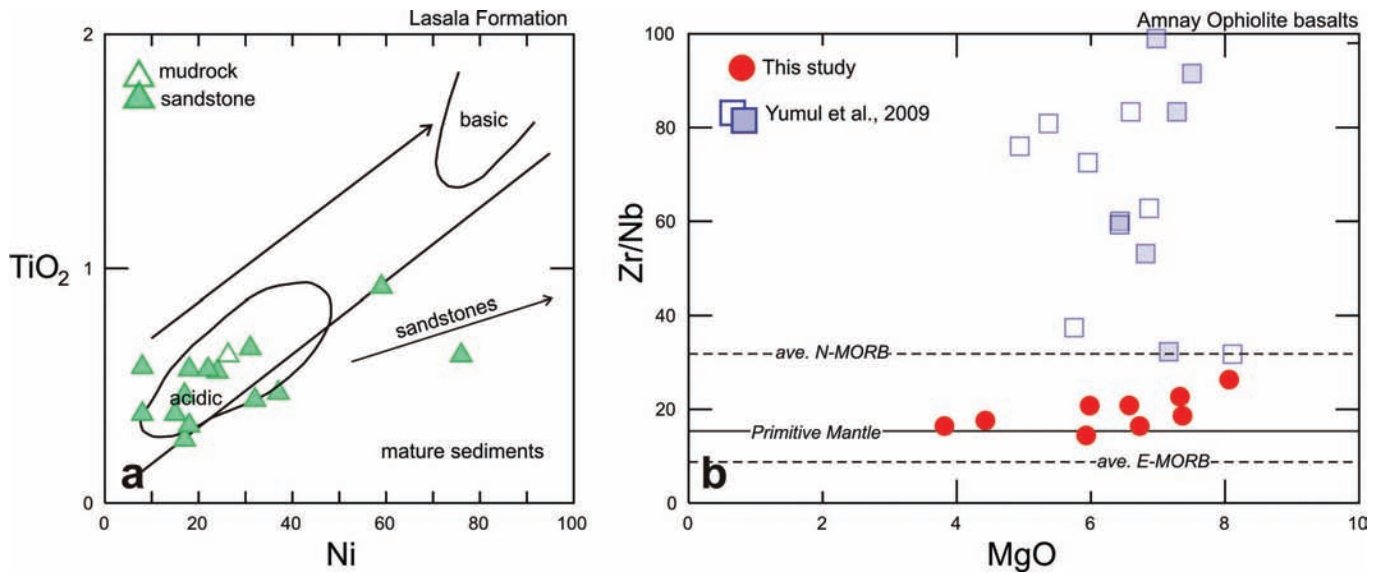


Figure 1: (A) In the TiO₂ vs. Ni diagram, the Lasala samples generally fall within the acidic field implying a felsic source. **(B)** Zr/Nb vs MgO for Amnay Ophiolite basalts. Primitive mantle and oceanic basalt ratios from Sun and McDonough (1989).

For the past several years, research initiatives led by researchers from the National Institute of Geological Sciences, University of the Philippines, have focused on the geodynamic significance of emplaced ophiolites and arc-continent processes in the Central Philippines. Research has recently focused on the island of Mindoro because of its position between the colliding terranes of the Philippine Mobile Belt and Sundaland. Its remarkable tectonic setting allowed, in a relatively small region, the preservation of several fossil oceanic crusts and continental margin materials juxtaposed with younger island arc terrane.

In the previous InterRidge News (2010), we reported preliminary observations of the upper mantle-crust sequences mapped in Mindoro Island. This included the recognition that rocks of the late Cretaceous Mangyan Ophiolitic Complex (Karig, 1983), which were mapped as sporadic isolated blocks, are in fact megaclasts within the Halcon Metamorphic Complex in northwest Mindoro. It contrasts with the more continuously exposed and complete middle Oligocene Amnay Ophiolite.

In order to compose a more complete understanding of this region, research on the petrochemical and paleomagnetic characteristics of the ophiolitic bodies and petrochemical nature of the sedimentary rocks was done. We present here a summary of the results of these studies.

Geology of the study area

South of the island of Luzon is the north-south elongated Mindoro Island. The oldest formational unit is the Jurassic Halcon Metamorphics, which is widely exposed in Paluan, Abra de Ilog and Mamburao (Teves, 1954; Hashimoto and Sato, 1968). It consists mostly of chlorite, quartz mica, talc-chlorite and graphite schists with minor phyllitic metasediments. Exposures of fragments of dismembered ophiolitic materials were found embedded in this metamorphic unit. These crust-mantle rocks were previously mapped as the Mangyan Series. However, we interpret the Halcon Metamorphics to be a regionally metamorphosed sedimentary melange that incorporated sedimentary, volcanic and ophiolitic

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materials. Regional metamorphism is believed to have occurred after the Cretaceous period.

Unconformable on the Halcon Metamorphics is the sedimentary Eocene Lasala Formation, which is composed of interbeds of minimum-grained sandstones and mudstones with minor basalt flows, conglomerates and limestones. Its age suggests deposition prior to the collision of the Palawan continental block with the Philippine Mobile Belt. Thrust on top of the Halcon Metamorphics and the Lasala Formation is the middle Oligocene Amnay Ophiolite. This complete crust-mantle sequence represents an on-ramped piece of the South China Sea crust (Rangin et al., 1985; Jumawan et al., 1998; Yumul et al., 2009). Deposited on top of these older units is the Plio-Pleistocene Balanga Formation (Agadier-Zepeda et al., 1992), which consists of interbedded tuffaceous sandstones and siltstones with minor conglomerates and coralline limestones.

Geochemical studies on the Eocene Lasala Formation

Around the world, geochemical studies of sedimentary rocks have become more increasingly useful in the study of plate tectonics (Moss, 1998; Asiedu et al., 2000; Suzuki et al., 2000; Tam et al., 2005; van Hattum et al., 2006). In the Philippines, studies that use sedimentary rocks for palinspathic reconstructions have only been recently introduced (e.g. Tam et al., 2005; Gabo et al., 2009). Petrological and geochemical investigations in northwest Mindoro offer new insights into how much of this region is continent-derived or island arc.

Petrographic information on the Lasala clastic rocks demonstrates a uniform framework composition, which is predominantly quartzose. This felsic nature is similarly reflected in their major

oxide, trace element abundance and various elemental ratios (Fig 1a). These observations support a chiefly continental, passive margin derivation and deposition of the Lasala sediments during the Eocene. Details of this research may be found in Concepcion et al. (2011).

Paleomagnetic and geochemical natures of fossil oceanic crusts

Mindoro Island is host to several ophiolitic bodies whose origins remain debatable. Hence, pillow and massive flow basalts from the Oligocene Amnay Ophiolite and the late Cretaceous ophiolitic blocks within Halcon Metamorphics, which is correlated to the Mangyan Ophiolitic Complex at the southeastern section of the island, were studied for their geochemical and paleomagnetic natures to provide more constraints to the geodynamic history of this part of the west Philippines.

Previous geochemical work on the volcanic section of the Amnay Ophiolite has shown it to be of normal mid-oceanic ridge basalt (NMORB) composition. Recent investigations into the previously unsampled sections of this ophiolite yielded enriched mantle signatures (Fig 1b). Moderately evolved tholeiitic basalts were found to have resulted from bulk mixing of $\sim 10\%$ ocean island basalt (OIB) components with depleted mantle (Perez et al., 2011a). In contrast, major and trace element examination of basalts from the Cretaceous ophiolitic materials point to derivation from an enriched source.

Paleomagnetic investigations were also done on the volcanic sections of these ophiolitic bodies (Fig. 2). Results yielded paleo-inclinations of $\sim 20^\circ$ for the older rocks within the Halcon Metamorphics.

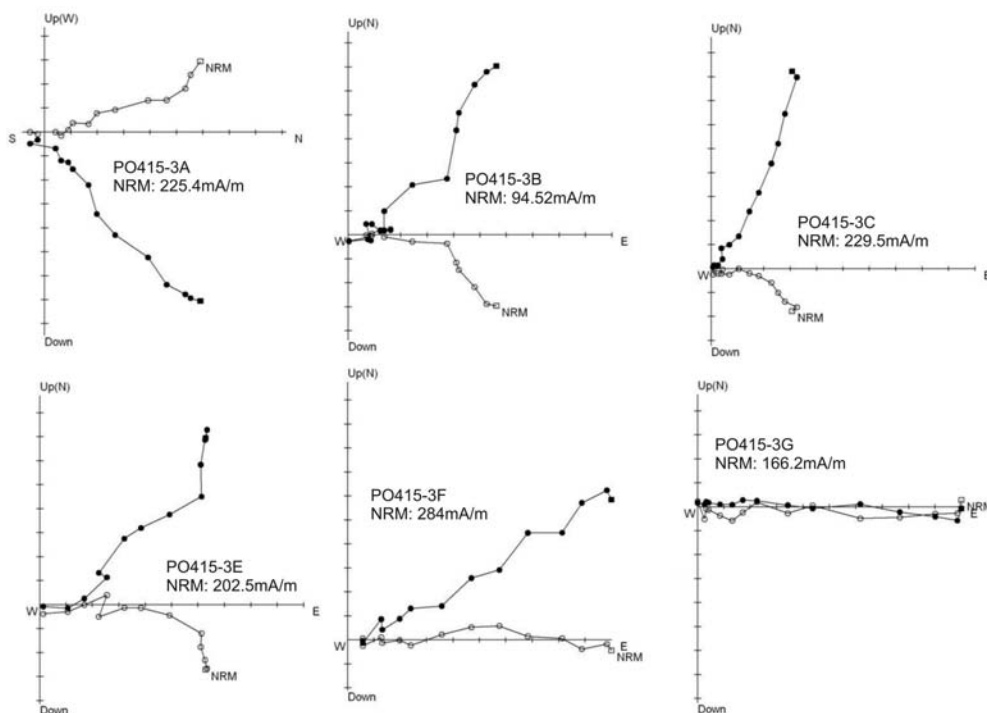


Figure 2: Vector endpoint plots (Zijderveld, 1967) showing tilt-corrected demagnetization data of ophiolitic basalts from the oceanic fragments in the Halcon Metamorphics in northwest Mindoro. Solid/open symbols are projections onto the horizontal/vertical planes. Initial NRM intensities are given in milliamperes per meter (mA/m).

Interestingly, Amnay basalts returned nearly horizontal tilt-corrected inclination values.

The combined geochemical and paleomagnetic characteristics of the Amnay Ophiolite strongly support a South China Sea origin (Perez et al., 2011b). This contrasts with results from the older crustal materials within the Halcon Metamorphics, which is more akin to Mesozoic ophiolites within the Southeast Asian region. This includes the Cretaceous Chico River Ophiolite in Central Cordillera (Queaño et al., 2009) and the Jurassic-Cretaceous Obi Ophiolite in Indonesia (Ali et al., 2001), which all yield shallow inclinations and are suggested to be of Philippine Sea Plate origin. These similarities are taken to indicate a possible similar origin for the Cretaceous ophiolitic materials incorporated in the Halcon Metamorphics.

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Keys to ancient Fe-Si formation: low-temperature hydrothermal oxide deposits along modern oceanic ridges

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Several new hydrothermal fields were discovered on the Southwest Indian Ridge (SWIR) during 2-3 cruises of R/V *Dayang Yihao* from 2007 to 2009 (Tao et al., 2007; Chen and Li, 2009). A variety of geological samples including sulfides, basalts, sediments and Fe-Si oxides were collected using TV-guided Grabs in the vicinity of these hydrothermal fields, along with numerous bivalve and gastropod shells (Chen and Li, 2009). Of these, the hydrothermal Fe-Si oxide deposits were more pervasive than the sulfides in each of the newly discovered fields. Since these deposits are generally considered to be analogues of the banded iron formations (BIFs), Fe-Si exhalites and even umbers in ancient time, we carried out a series of investigations on these samples after the cruises, in which we described these deposits in terms of their structure, morphology and chemical composition on a fine scale.

In Fig. 1, we show modern Fe-Si oxide deposits recovered from one of the hydrothermal fields on the SWIR. Based on the mineralogical results (XRD and SAED), the light yellow area in this sample consists mainly of amorphous silica and the brown to black areas consist mainly of Si-bearing ferrihydrite.

Inspection of the structure of the precipitates by optical microscopy and scanning electron microscopy (SEM) on a fine scale showed the

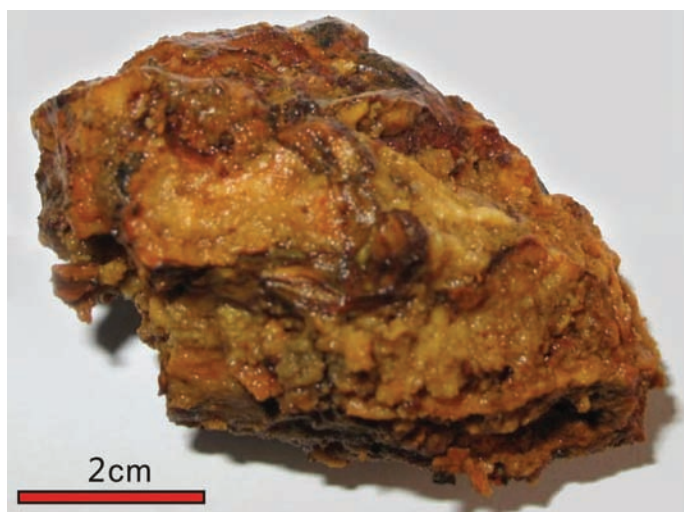


Figure 1: Hydrothermal low-temperature Fe-Si oxide deposits recovered from SWIR. Sample SL1 from 50.4678°E, 37.6587°S with water depth: 1745 m.

widespread occurrence of biogenic filaments in these samples, which represent mineralized bacteria (Fig. 2). Comparative studies with hot springs on land, and several studies of the similar samples in other hydrothermal fields, demonstrate that these bacteria are mainly neutrophilic Fe oxidizing bacteria. Based on the analysis by energy dispersive spectrometer (EDS) carried out here, all the filaments appear to be rich in Fe, Si and P and sometimes contain minor amounts of Mn.

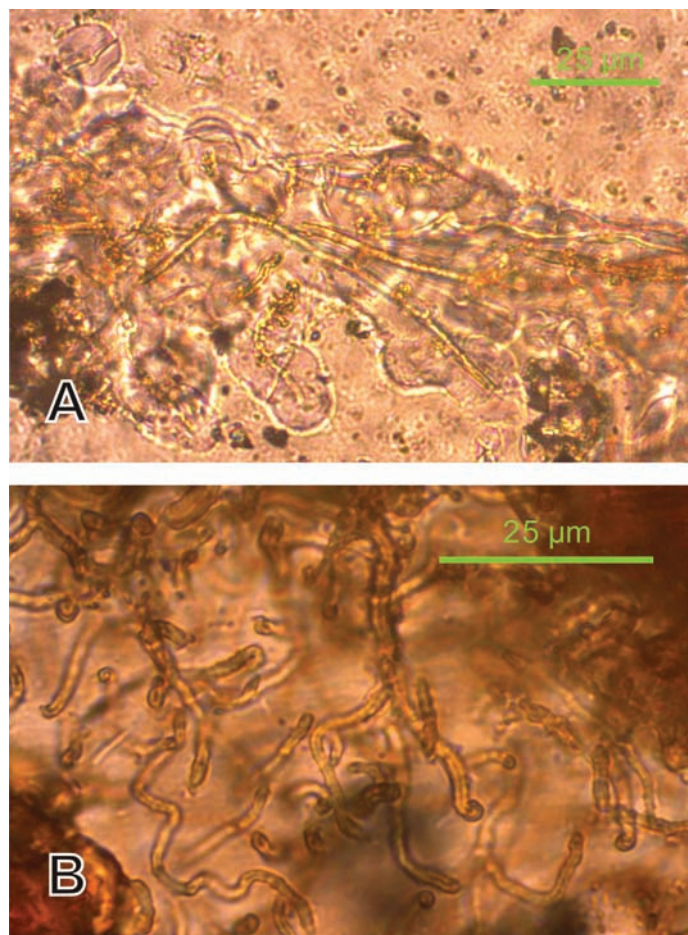


Figure 2: Mineralization of the bacteria in modern hydrothermal Fe-Si oxide deposits on SWIR. A-sample SL1 from 50.4678°E, 37.6587°S, water depth: 1745 m; B-sample SH4 from 49.6466°E, 37.7903°S, water depth: 2739m.

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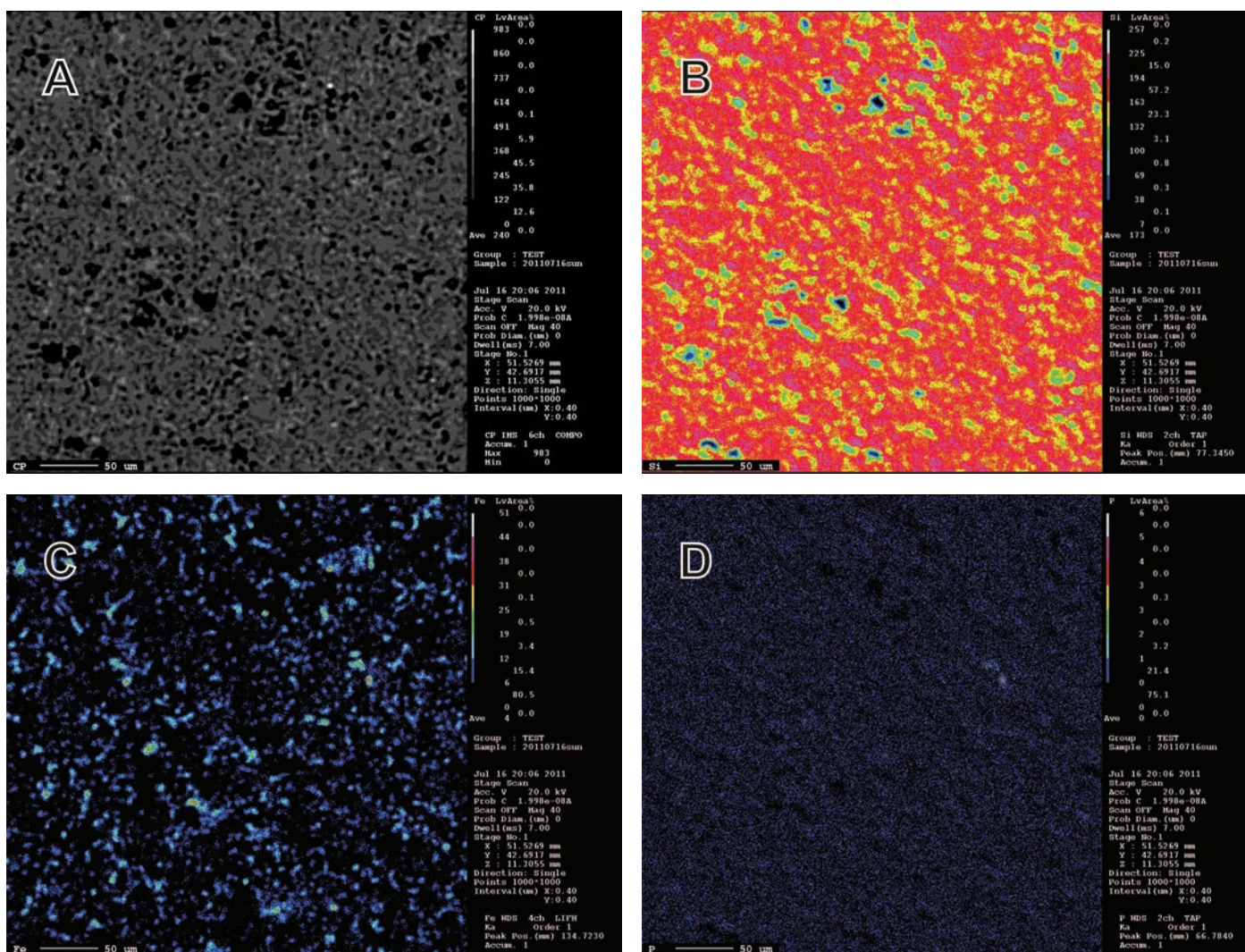


Figure 3: Elemental mapping of modern hydrothermal Fe-Si oxide deposits from the newly discovered hydrothermal fields, SWIR. Sample SH4 taken from 49.6466°E, 37.7903°S.

A common observation is that the mats have been consolidated by silicification after the formation of the Fe-rich filaments. Elemental mapping analysis of the Fe-Si oxide precipitates using an electron probe micro-analyzer (EPMA) revealed that the mats formed by mineralized filaments are not chemically homogenous and that the Fe and Si contents are decoupled (Fig. 3). The distribution of Fe is characterized by elongated rods and spheres, hinting at the presence of sheaths and stalks of Fe oxidizing bacteria, whereas the distribution of Si is characterized by a dense matrix of Fe-rich sheaths and stalks. Phosphorus shows only a faint relationship with Fe, despite the influence of the presence of abundant Si (Fig. 3).

Since the simple mixing between hydrothermal fluids and modern seawater cannot result in the saturation of these fluids with respect to silica, the presence of significant amounts of amorphous silica in the mats is considered to be the result of conductive cooling (Herzig et al., 1988). This leads to a unique structure of the filaments in which the Fe-rich core of the filament is coated by a siliceous crust.

This structure is thought to be conducive to the preservation of the microfossils since the inner Fe oxides may inhibit cellular autolytic enzymes (Leduc et al., 1982; Ferris et al., 1986). At the same time, the outer siliceous crust faithfully preserves microbial shape over a relatively long period. Moreover, the stable Fe-O-Si bonds formed by the surface complexes involved in the silicification raise the temperature of segregation between the Si and Fe oxides substantially (up to 850°C, Glasauer et al., 2000 or even higher, Sun et al., under review) and thereby elevates the tolerance of the filaments to diagenetic processes or even low grade metamorphism and increases the resulting fidelity of the biosignature.

In contrast to ancient BIFs, modern low-temperature hydrothermal Fe-Si oxides always have a limited size in the immediate vicinity of hydrothermal vents with Fe-rich mats tens of cm thick covering several hundred m². However, this does not detract from the fact that modern hydrothermal Fe-Si oxides are the analogues or even the precursors of ancient BIFs. For example, the similarity in the

composition and mineralogy of modern and ancient BIF deposits and their resemblance to the structure of modern Fe oxidizing bacteria in Precambrian BIFs (1.9-billion-year-old Gunflint iron formation; Boyce et al., 2003) together with the analogous environment in which the Fe-Si oxides precipitated (largely anoxic and rich in Fe(II) with atmospheric O₂ concentrations only a fraction of present levels; Emerson et al., 2010). Furthermore, an increasing number of studies have suggested that the iron in BIFs was probably introduced at sites along mid-ocean spreading ridges and at oceanic hotspots and sites of hydrothermal plumes (Jacobsen and Pimentel-Klose, 1988; Klein, 2005; Poulton and Canfield, 2010).

Our ongoing work has focused mainly on the relationship between modern Fe-Si oxides and their ancient BIF counterparts, especially to determine a credible biosignature for these two deposits. Since Fe-Si oxide deposits/formations probably record geobiological clues, they become important keys to reconstruct the Earth's history. So far, several similar studies have been carried out on the mid-ridges, seamounts and back-arc basins of the Pacific and Atlantic oceans, but few are based on the ultraslow-spreading ridges in the Indian Ocean, which represent 10% of the total worldwide oceanic ridges. With the recent discovery of hydrothermal deposits along the SWIR based on a series of cruises in the past 5 years to 2011, it has become clear that the SWIR will become the next focus for understanding the tectonic, biological and geochemical processes controlling the past and future evolution of the Earth.

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Lead isotope composition variations in sulfides from hydrothermal fields of the Mid-Atlantic Ridge: high-precision MC-ICP-MS isotope data

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Introduction

The slow-spreading zone of the Mid-Atlantic Ridge (MAR) with a length of ~2800 km in the range of 12°-37°N contains 12 high-temperature hydrothermal fields (HF), in which active and nonactive sulfide edifices were found located in different geological conditions at depths from 850-4080 m. Almost half of these HFs are located in the MAR zones, where accretion occurs as a result of exhumation of intrusive ultrabasic complexes along the active detachment faults. Another part of HFs is controlled by areas of basaltic lava eruption along the spreading zone (Fig. 1).

Systematic investigation of the Pb isotopic composition in sulfides from MAR HFs associated with the two different, above-mentioned, geological types of the MAR spreading zone was performed in our study (Chernyshev et al. (2007)). The high-precision method of Pb isotopic analysis, namely multicollector mass-spectrometry with inductively coupled plasma (MC-ICP-MS), applied in such investigations for the first time, allowed us to estimate the real scale and character of Pb isotopic composition variations in HFs of the Northern Atlantic Area at an accuracy level of lead isotopic ratio measurement of $\pm 0.03\%$. This exceeds the accuracy of Pb analysis in previous papers almost by one order of magnitude. This paper is based on the results of a study of four HFs: Ashadze, Semenov, Logachev, and Krasnov, located in the southern part of the MAR area (12°58'-16°38'N) and discovered quite recently. The previously obtained data of the lead isotopic study of three MAR HFs (TAG, Broken Spur, and Rainbow) located northwards (26°08'-36°13'N) (Bortnikov and Vikent'ev, 2005) were also used in the present consideration. These earlier data were obtained using the TIMS technique, and they are less precise; however their application allowed us to show the pattern of regional variations of the lead isotopic composition in sulfides from HFs of the MAR spreading zone.

Method of isotopic analysis

As is known, the accuracy of each method of Pb isotopic analysis is limited by the effect of instrumental mass-discrimination. This effect in the high-precision version of the applied MC-ICP-MS method is excluded by correction of all lead isotopes ion beams intensity measurements by the "internal" standard, namely $^{205}\text{Tl}/^{203}\text{Tl}$ isotopic ratio (Rehkamper and Halliday, 1998; Chernyshev et al. 2007). The standard Tl solution was added to each sample of

3%-nitric solution of lead. The $^{205}\text{Tl}/^{203}\text{Tl}$ value was accepted as 2.3889 ± 0.0001 . The measurements were performed on a 9-collector mass-spectrometer MC-ICP-MS NEPTUNE type (ThermoFinnigan). Substantiation and description of the applied high-precision MC-ICP-MS method of Pb analysis are given in our paper (Chernyshev et al. (2007)). Preparation of samples (10-20 mg) included chemical decomposition of sulfides and chromatography separation of Pb in HBr medium. Total ($\pm 2\text{SD}$) isotopic analysis error for $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ did not exceed $\pm 0.03\%$.

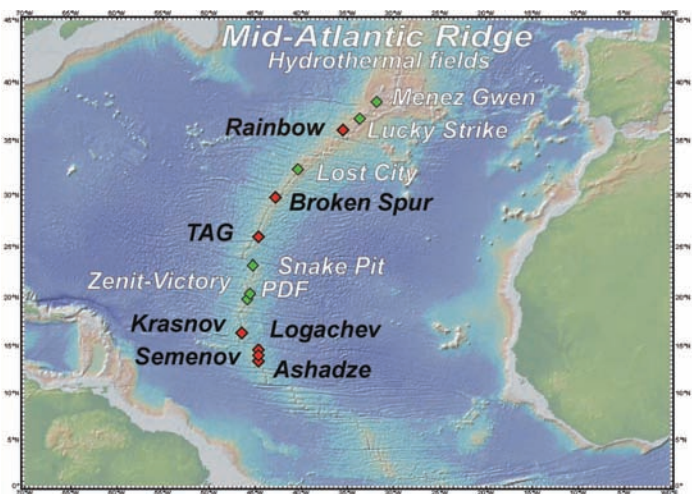


Figure 1: Hydrothermal fields location in the Mid-Atlantic Ridge spreading zone.

Results and Discussion

Sulfide Pb-isotope ratios variation scale in the four studied HFs have been estimated: 0.04-0.09‰ for $^{206}\text{Pb}/^{204}\text{Pb}$, 0.02-0.04‰ for $^{207}\text{Pb}/^{204}\text{Pb}$, and 0.04-0.07‰ for $^{208}\text{Pb}/^{204}\text{Pb}$, while analytical error was $\pm 0.03\%$ (Figure 4). These variations are lower by a factor of 3-4 than was evident from the data previously obtained by traditional TIMS for HFs in the MAR and Pacific Ocean, which are characterised by a precision of $\pm 0.1-0.2\%$. Using the high-precision MC-ICP-MS method, we did not reveal dependence of the Pb-isotope composition on the type of HFs sulfide mineral and total Pb concentration in it.

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The problem of correlation of the Pb isotopic composition in HF's and basalts is of special interest. Decreasing the number of basalt samples to a narrow range of geographic latitudes closely related to the corresponding latitudes of the HF position of the MAR Krasnov, Ashadze, Semenov, and Logachev, results in a decrease of the value range of the Pb isotopic ratios in basalts. At the same time, such a decrease demonstrates that in this latitudinal range of the MAR, lead isotopic characteristics of basalts and sulfides of HF's become close to all three isotopic ratios. In this study we used only high-precision MC-ICP-MS data, which are available for the four-

mentioned HF's. The contour of the Pb isotopic compositions of basalts in Figure 3 corresponds to the length of their sampling along the MAR for ~550 km. Because of this, the problem of relationships between the Pb isotopic composition of hydrothermal sulfides and the underlying basalts should evidently be considered only at quite close similarity of the coordinates of hydrothermal fields and places of basalt sampling. Such comparison of the isotopic compositions is possible only for the Krasnov HF (16°38'N) using the corresponding data on basalts from Dosso et al. (1993). The data for basalts sampled close to the other studied HF's are still absent.

Lead of basalts sampled at a latitude of 16°38'N consistent with the latitude of the Krasnov HF with an accuracy of one minute are characterized by $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ isotopic ratios of 18.29-18.33 and 37.77-37.84 respectively, whereas the average values of

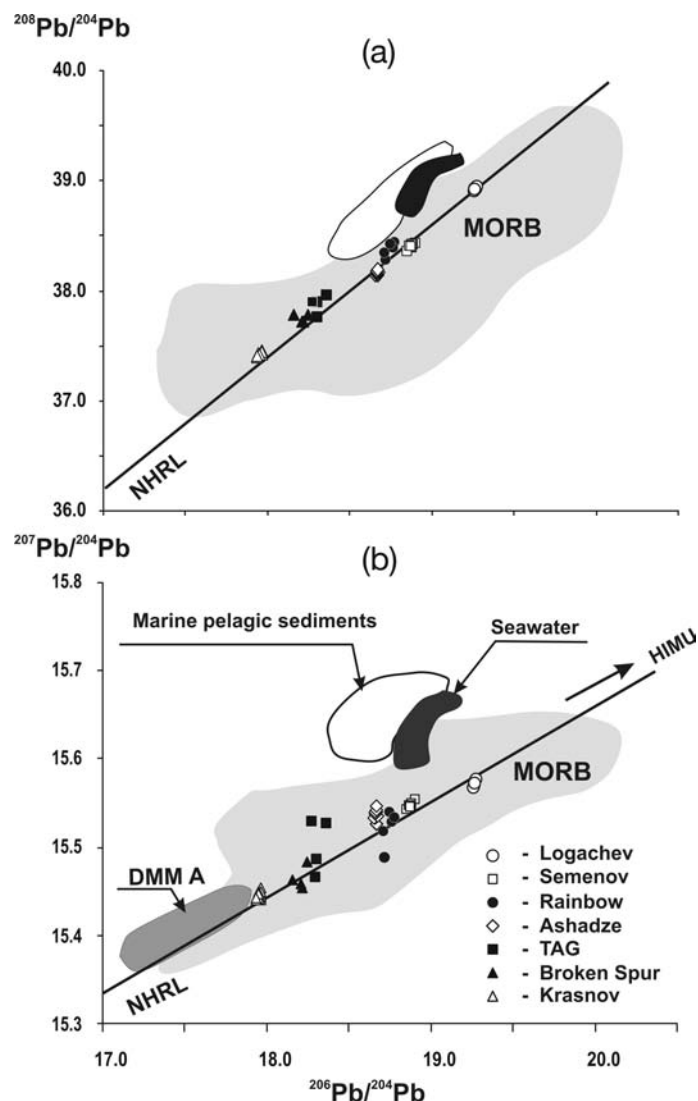


Figure 2: (a) $^{208}\text{Pb}/^{204}\text{Pb}$ - $^{206}\text{Pb}/^{204}\text{Pb}$ and (b) $^{207}\text{Pb}/^{204}\text{Pb}$ - $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams for sulfides from seven hydrothermal fields of the MAR. Fields of the lead isotopic compositions of MAR basalts (10°-70°N), pelagic sediments, and water of the Atlantic Ocean are given after Andrieu et al. (1998). NHRL is the correlation line of the Pb isotopic composition of MAR basalts from the northern hemisphere (Hart, 1984).

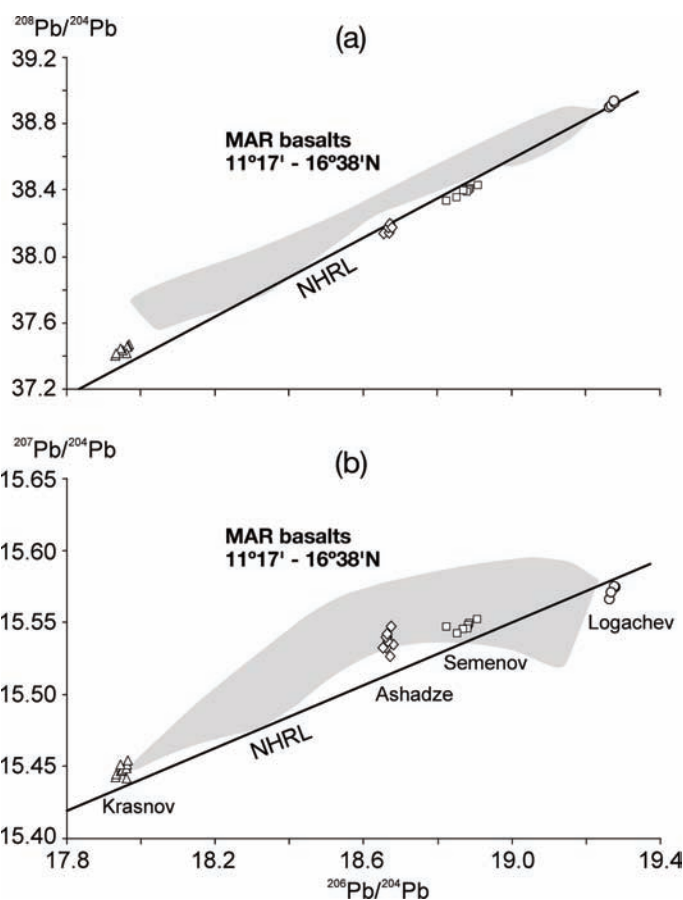


Figure 3: (a) $^{208}\text{Pb}/^{204}\text{Pb}$ - $^{206}\text{Pb}/^{204}\text{Pb}$ and (b) $^{207}\text{Pb}/^{204}\text{Pb}$ - $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams for sulfides from the MAR hydrothermal fields located in the segment 11°17'-16°38'N. Only the data for sulfides from four hydrothermal fields (see Fig. 2 for abbreviations) with lead analyzed by the high-precision MC-ICP-MS method are given. The area of the isotopic compositions of MAR basalts dragged in the MAR segment of the same latitude range is given after Dosso, (1993;1991).

these isotopic ratios in sulfides of the Krasnov HF are 17.952 and 37.428. By now this, the only example demonstrating the differences of the Pb isotopic composition between basalts and sulfides far

beyond the analytical error limit, in our opinion, is the reason for the special lead isotopic study of basalts, which are spatially associated with sulfide formations of HFs.

No	Sample	Mineral	Pb, ppm	Isotopic ratios		
				²⁰⁶ Pb/ ²⁰⁴ Pb	²⁰⁷ Pb/ ²⁰⁴ Pb	²⁰⁸ Pb/ ²⁰⁴ Pb
Ashadze hydrothermal field (12°58' N)						
1	1320-2II	Cu and Fe sulfide aggregate	69	18.6689	15.5264	38.1388
2	1320-3	Sphalerite	685	18.6585	15.5323	38.1468
3	1320-5II	Pyrite-marcasite-sphalerite aggregate	14	18.6540	15.5324	38.1430
4	1321-T-2	Sphalerite with admixture of Cu sulfides	1500	18.6789	15.5347	38.1720
5	DV-2-2	Sphalerite	830	18.6665	15.5400	38.1641
6	DV-2-4		600	18.6631	15.5372	38.1591
7	DV-4-11		790	18.6633	15.5401	38.1694
8	DV-4-16		1110	18.6658	15.5421	38.1750
9	DV-4-18		280	18.6719	15.5474	38.1987
Average				18.6657	15.5370	38.1630
s, %				0.04	0.04	0.05
Semenov hydrothermal field (13°31' N)						
10	344/2	Marcasite	115	18.9048	15.5526	38.4293
11	363/4		130	18.8862	15.5495	38.4118
12	363-Бс	Pyrite	72	18.8803	15.5479	38.4078
13	364/1		61	18.8521	15.5427	38.3533
14	365/5		124	18.8666	15.5459	38.3991
15	375/3		39	18.8790	15.5454	38.3971
Average				18.8782	15.5473	38.3997
s, %				0.09	0.02	0.07
Logachev hydrothermal field (14°44' N)						
16	DV-6-1	Sphalerite	61	19.2783	15.5749	38.9329
17	DV-6-1	Covellite	204	19.2757	15.5755	38.9399
18	DV-6-2-2	Pyrite	12	19.2615	15.5665	38.9045
19	DV-7-10	Covellite	110	19.2670	15.5711	38.9151
Average				19.2706	15.5720	38.9231
s, %				0.04	0.03	0.04
Krasnov hydrothermal field (16°38' N)						
20	139 M1	Pyrite	153	17.9635	15.4481	37.4402
21	139 M2		232	17.9630	15.4406	37.4192
22	178 M1	Sphalerite	312	17.9671	15.4532	37.4561
23	187 T1	халькопирит	54	17.9465	15.4456	37.4238
24	DV-8-03	Pyrite	5640	17.9650	15.4502	37.4484
25	DV-8-08		90	17.9464	15.4502	37.4352
26	DV-8-13		59	17.9505	15.4469	37.4261
27	DR-10-29		55	17.9328	15.4412	37.3980
28	DR-10-2-11		730	17.9361	15.4435	37.4065
Average				17.9523	15.4466	37.4282
s, %				0.07	0.03	0.05

Figure 4: Pb isotopic composition of sulfides from hydrothermal fields of the Mid-Atlantic Ridge (12°-36°N).

Conclusion

The results provide the following regularities (Chernyshev et al. (2011)).

- (1) At small (close to 0.03%) variations of the Pb-isotope composition of sulfides from an individual HF, the latter differ significantly from each other by all isotope ratios.
- (2) Sulfides of HFs related to serpentinized peridotites have more radiogenic Pb-isotope composition in all isotopes (^{206}Pb , ^{207}Pb , and ^{208}Pb) in comparison to HFs occurring on tholeiitic basalts.
- (3) On the evolutionary Pb-Pb isotope diagrams, the Pb-isotope compositions of HFs sulfides discretely plot in the area of MAR basalts and are located exactly along the NHRL.

The Pb-isotope characteristics of sulfides from MAR HFs permit participation of two mantle sources of Pb (DMM and HIMU) in their formation with the first being prevalent. Sulfides of MAR HFs are similar to MORB by the total range of the Pb-isotope composition; because of this, the data obtained do not contradict the idea that hydrothermal solutions and then sulfides inherit the Pb-isotope composition from underlying rock series. As above represented data show, convective cells provide exceptional homogenisation of Pb isotope composition for individual HFs.

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Accelerator Mass Spectrometry to understand hot vents history and precipitation of seafloor sulfides

¹G.S. Roonwal, Pankaj Kumar and S. Chopra

Accelerator Mass Spectrometry (AMS) is a highly sensitive technique used to determine the concentration of long-lived radionuclides that occur naturally in our environment. These long-lived radionuclides have various dating and tracing applications in studies related to geological sciences. Radionuclide ^{10}Be is produced by the interaction of secondary cosmic rays with ^{14}N and ^{16}O present in the atmosphere, and then transported to the natural archives with dry and wet fallout. The decay of ^{10}Be is very slow, with a half-life of 1.387 million years (Korschinek et al., 2010), and therefore it is one of the ideal candidates to decipher the history and period of hydrothermal activities up to tens of millions of years.

Hydrothermal activity connected with the formation of volcanogenic massive sulfides (VMS) of Fe, Zn and Cu, associated with the formation of oceanic basaltic rock at sea floor spreading

centres, has been one of the fascinating discoveries since 1979. The VMS and black smokers formation has since been a topic of study by several groups from the USA, Canada, France, UK, Germany, Japan and others. One of the investigated areas is the rapidly spreading axis of the East Pacific Rise (EPR), which defines the boundary between the Pacific and Nazca plates. Here, recent surveys have resulted in the identification of several new sites of black smoke chimney clusters. All the major occurrences of hot vents and associated sea floor sulfides have been reviewed by Rona and Scott (1993) and in several other publications since then.

Hydrothermal sulfide deposits on the sea floor are characterised by the presence of mounds of partially cemented Fe, Zn and Cu mineral aggregates, topped by chimneys of similar material through which vigorous venting of hydrothermal solutions occurs. One may

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refer to Spice et al. (1980), Haymon (1982), Marchig, Gundlach and Shipboard Scientific Party (1987) and Marchig et al. (1997) for complete information, besides other recent work.

We record here our interest in investigating VMS from EPR collected from onboard RV *Sonne*. The geochemistry of associated basalts has been investigated by Pandey et al. (2007), Pandey et al. (2009), as well as the work of Marchig et al. (2001).

We attempt to investigate vent sulfides from the EPR spreading axis, to build geological history and the period of hydrothermal activity by investigating radionuclide measurements of ^{10}Be ($T_{1/2} = 1.387\text{Ma}$). We are encouraged to read work of Valette-Silver et al. (1987), which has shown that ^{10}Be is included in the hydrothermal system - the black smoker chimney - either from sediments, which are able to retain ^{10}Be , or directly from Be dissolved from sea water. It is understood that beryllium moves quite rapidly through the ocean – sediment system into the hydrothermal vents (Tuniz et al., 1998). ^{10}Be present in the hydrothermal system is at an ultra low level and Accelerator Mass Spectrometry is the only available technique to detect such a low concentration of ^{10}Be and with high accuracy.

Collected geological samples have many elements other than ^{10}Be , and therefore samples are treated chemically to reduce the concentration of unwanted elements prior to the AMS measurement. The analysis of samples is done in a clean environment to avoid the mixing of elements present in environmental dust. At IUAC, a clean laboratory of about 6000 class has been developed for this purpose. The laboratory is metal-free and equipped with the required instruments. Laminar flow units of 100 class air environment are used for performing ion exchange column chemistry.

Returning to sea floor VMS, they comprise pyrite, chalcopyrite, sphalerite, arsenopyrite and intermediate products marcasite and covellite. Minerographic study of polished sections of sulfides shows presence of a colloidal and/or gel texture with some clear euhedral grains (Marchig et al., 1997). The most characteristic feature is the simultaneous occurrence of low and high temperature sulfide minerals and textures (Roonwal and Sharma, 1993). At this stage we shall attempt ^{10}Be concentration and subsequently fine tune to investigate low and high temperature precipitated sulfide minerals from the samples available, and thus try to establish paragenesis of minerals within a time scale.



Figure 1: Clean chemistry laboratory for AMS sample preparation.

IUAC at New Delhi has established a functional AMS facility for ^{10}Be and ^{26}Al radioisotopes (Pankaj Kumar et al., 2011). Increasing interest in the Indian geosciences group is encouraging. At the IUAC in recent years we have carried out studies on (a) sediments obtained through cores from the southwestern Indian Ocean (Khare et al., 2011), (b) sediments from the Arctic region and (c) the land mass studies within India we have investigated ^{10}Be in the sediments from a lagoon near Puducherry in southern India (Pattanaik et al., 2007 and Pattanaik, 2009) and plan to investigate ^{10}Be in granitic rocks of Ladakh region of northernmost India and other parts of the Himalayas. Apart from the above-mentioned activities, various other studies are in progress using the IUAC-AMS facility.

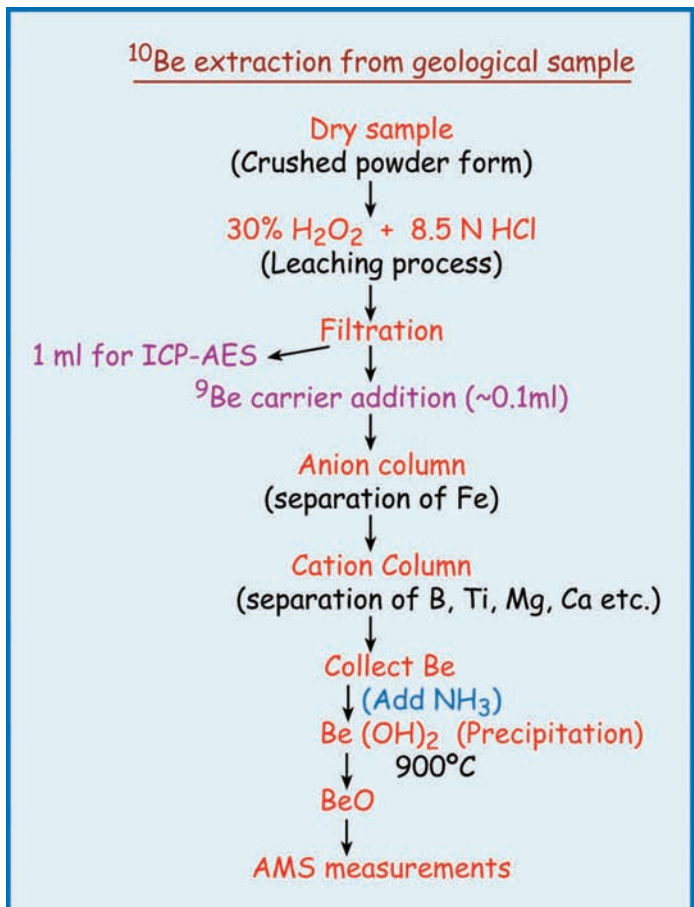


Figure 2: Chemical processing steps for the extraction of Be from geological samples.

We are investigating ^{10}Be within (a) hydrothermally altered basalts and (b) fine grained basalts with glassy top. The phase of hydrothermal activity, we assume, should correspond to the vent activities and sulfide precipitation.

Through this communication we invite interested groups for collaboration in this study. Email: gsrnoonwal@hotmail.com

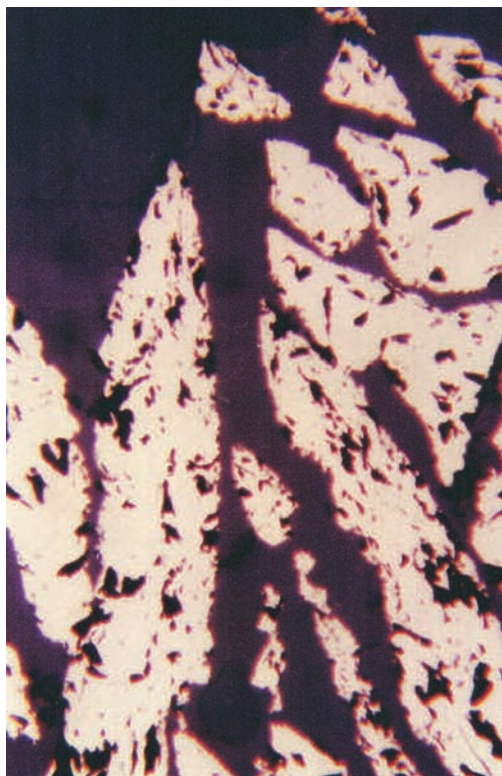


Figure 3: Showing large olivine megacryst with spread of gangue (black) along a tubeworm channel (scale magnification x100).

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Ocean Exploration at the Mid-Cayman Rise

Chris German¹

In August 2011, former InterRidge Co-Chair Chris German (WHOI, USA), together with his former Census of Marine Life/ChEss Project Co-Chair Paul Tyler (NOCS, UK) led a novel form of expedition to investigate hydrothermal systems on the Mid-Cayman Rise in the Western Caribbean. The expedition was undertaken aboard the NOAA Ship *Okeanos Explorer* equipped with the Institute for Exploration's ROV *Little Hercules*. The *Okeanos Explorer* (or *EX* for short) is the USA's only ship dedicated explicitly for exploration of the oceans and, as well as the ROV, we were equipped with a high resolution multibeam swath mapping system and a dedicated SeaBird 9/11 CTD rosette equipped with additional optical back scatter and redox sensors for plume detection.

Unlike many other ROVs used for Mid Ocean Ridge research, the *Little Herc* was not equipped with manipulators - consistent with its mission to explore the seafloor rather than focus upon the process-oriented studies that dominate the funding cycle of other research agencies worldwide. To compensate, however, the vehicle was equipped with a top of the range HDTV Camera, as was NOAA's new *Seirios* vehicle to which the ROV was lightly tethered and through which the ROV was decoupled from ship motions at the ocean surface. Working together, the two vehicles were used in tandem to explore sections of the Mid-Cayman Rise at depths of up to 3500 m (the ROV had a depth limit of 4000 m) which meant that it was the oceanic core complexes of the MCR that received just about all the attention during our 11-dive expedition, including a number of dives to the new Von Damm hydrothermal field first described in last year's issue by Connelly et al. (2010).

Altogether, three separate OCCs were mapped in detail during the cruise with a cumulative area of nearly 11,000 km². A series of 7 vertical CTD casts and 4 tow-yos were also completed, as well as 12 *Little Herc/Seirios* dives. Remarkably this was all done with just 3 scientists aboard ship. How? Well the *EX* is a pioneer of the use of so-called Tele-Presence. Chris and Paul took it in turns to oversee the team of ROV operators during day-time dives to the seafloor, but they were aided and abetted by a team of additional scientists. These were connected to the ship and all the ROV video-feeds in near real-time via satellite communication to an Exploration Command Center (ECC), set up specially for this purpose at the Inner Space Center at the University of Rhode Island. Core members of the shore party at the Rhode Island ECC were PhD students Diva Amon (Biology, NOCS), Jill McDermott (Geochemistry, WHOI) and Jameson Clarke (Biology, Duke University Marine Lab), together with Profs. Bobbie John and Mike Cheadle (U. Wyoming). Graduate student Santiago Herrera (a veteran of two previous *EX* expeditions, along with his advisor Tim Shank) also manned a satellite mini-ECC at WHOI and a number of Woods Hole-based colleagues (from both WHOI and MBL) also took advantage of this capability.

Overnight, while Paul took charge of writing up dive summaries, Chris and WHOI geochemist Cameron McIntyre (the 3rd and final member of the science team) took on CTD tow-yo and/or hydrocast operations, together with Drs Sarah Bennett (NASA-JPL) and Julie Huber (MBL) who were also able to join in remotely via an Internet 1 feed that sent real-time data-feeds ashore, along with one-



Figure 1: The site where 'chemosynthetic' shrimp and tubeworms were observed together for what scientists believe is the first time in the world. (Credit: NOAA *Okeanos Explorer* Program, MCR Expedition 2011, NOAA-OER).

¹WHOI, USA.

way voice communications from the ship. To send instructions back, without requiring access to an ECC, these colleagues made extensive use of an Event Log “chat room” that relied upon simple Instant Messaging protocols and, despite wariness from the “old dog” science-leads out at sea, proved remarkably effective.

During ROV dives, the watch leader (Paul or Chris) not only had access to all the video feeds coming from the ROV but had real-time voice communication available with the ROV operations team, their science lead alternate (watching from a remote station aboard the *EX*), the science team at the ECC in Rhode Island and also any of the additional scientists participating from the secondary ECC in Woods Hole.



Figure 2: Staff and students watching the live broadcasts at the National Oceanography Centre, UK.

In addition, this expedition also trialed - and proved, very successfully - the opportunity to broadcast live from the seafloor over the internet. At its height, our “broadcasts” were reaching 2,500 individual “hits” from different computers around the world each day. Some of those “users” were just interested individuals but in some circumstances - e.g. at the NOCS UK (home of the InterRidge Office), there were up to 100 individuals taking advantage of their video-conferencing suite to monitor what was happening - all with no more than a 2-second delay from ship to shore - and, using IM and SKYPE, channelling information, requests, scientific suggestions and more back to the ECC science teams in New England and out to the ship. Indeed, during the course of the expedition, we logged input from scientists from across the US, UK, Canada, Denmark, Spain, Portugal and Germany.

With all this technological wizardry at our disposal it was, of course, rather important that the Mid Cayman Rise offered up something more than just holothurians to keep such a broad and diverse team of participants engaged. Happily, the ridge crest did not disappoint (does it ever?). Biological highlights included the first observation of live tube-worms at a vent-site in the Atlantic Ocean (nearest known neighbours exist at cold seeps in the Gulf of Mexico but we also learned, during the course of the expedition, of a new and potentially related find at Marsili seamount off Italy in the Mediterranean). What was particularly interesting about this is that

these tube-worms, complete with symbiotic chemosynthetic bacteria, seemed to be inhabiting a vent-site that also hosts *Rimicaris*-like shrimp (based on morphology & appearance) that also appear to host chemosynthetic symbionts.

Geologically, Mike and Bobbie (from the self appointed Wyoming Oceanographic Institute or WYOI) were in seventh heaven directing mapping operations through the small hours of the night, and then using these to pick geologic exploration dive-tracks through all depth ranges (and lithologies) of the Mt Dent OCC and eventually driving us right up the wall (literally) with a transect up the northern side of the Cayman Trough fracture zone to end the expedition.

For myself, as well as the discovery of the tube-worms (in 25 years I have never visited an EPR vent-site), key moments that stick in my memory will be:

- the 8 m tall chimney at the summit of Von Damm with a 1 m wide orifice that was wider than the ROV itself.
- the multiple sites of fluid flow that we’ll be looking forward to returning to and sampling for geochemistry - as well as related microbiology and macrobiology studies - in a follow-on expedition in 2012.
- and last but not least, the evidence of ropey lava flows that provide clear evidence that even the slowest spreading ridges, with all their tectonic predominance, must still be able to put on a hell of a show volcanically - at least once in a while!

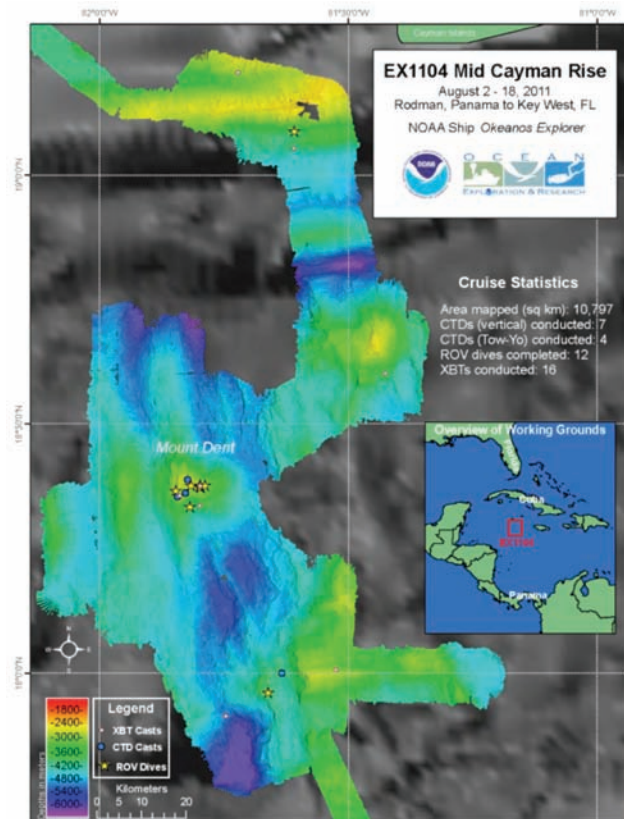


Figure 3: Map of the Mid Cayman Rise explored by *Okeanos Explorer*, August 2011.

Ultramafic hydrothermal systems on the Rainbow abyssal hill: a wide variety of active and fossil chemosynthetic habitats

F. Lartaud^{1,2}, M. de Rafelis², C.T.S. Little³, J. Dymant⁴, G. Bayon⁵, B. Ildefonse⁶, and N. Le Bris¹

Introduction

A large variety of high- and low-temperature hydrothermal vents and associated ecosystems occurs on slow spreading ridges (Rona et al., 2010). On the Mid-Atlantic Ridge, the diversity of basement rocks and tectonic environments results in three classes of vent systems: high-temperature vents hosted on basaltic crust (i.e. Lucky Strike); high-temperature vents hosted on gabbroic and ultramafic material (i.e. Rainbow, Logatchev); and low-temperature vents, thought to be predominantly influenced by mantle and exothermic serpentinization reactions from ultramafic rocks (i.e. Lost City) (Kelley and Shank, 2010).

This tectonic and host rock diversity is reflected in differing end-member fluids (Charlou et al., 2010) and provide access to a wide range of geochemical energy sources for chemosynthetic organisms (Schmidt et al., 2008; Le Bris and Duperron, 2010). The flexibility of symbiotic associations is a key to the success of some invertebrate species (i.e. multiple symbionts with various abundances reflecting the availability of chemical substrates) (Dubilier et al., 2008; Petersen et al., 2011). In addition to sulphide and methane, the use of hydrogen by *Bathymodiolus* mussel symbionts has recently been demonstrated by Petersen et al. (2011) and iron II might even contribute to the growth of epibiotic bacterial communities in shrimps (Zbinden et al., 2004; Schmidt et al., 2009).

The available energy is not the only constraint that is exerted on chemosynthetic fauna. Many questions remain concerning the ability of invertebrate species to colonize vent habitats. Two recent studies based on the exploration of the Rainbow hydrothermal vent field area in the MOMAR (Monitoring of the Mid-Atlantic Ridge) integrated study site has provided new insights to this issue by revealing the existence of contrasting habitats with abundant fossil chemosynthetic fauna within a spatially limited area (Lartaud et al., 2010; Lartaud et al., 2011). The Rainbow hydrothermal site is located on the western flank of the Rainbow abyssal hill (36°13.50'N; 33°54.25'W), in ~2300 m of water. High-temperature vents occur along the shoulder of the west-facing hanging wall of a tilted ultramafic block, and are characterized by methane, hydrogen, and metal rich fluids (Charlou et al., 2002). Current macrofauna

communities are dominated by bresiliid shrimp swarms (*Rimicaris exoculata*) and mussel beds (*Bathymodiolus azoricus*) (Figure 1), which host a dual symbiosis composed of methanotrophic and sulphide-oxidizing symbionts (Desbruyères et al., 2001). Owing to the sulphide-depleted and hydrogen-rich environment (Le Bris and Duperron, 2010) these symbionts use hydrogen as an alternative energy source.

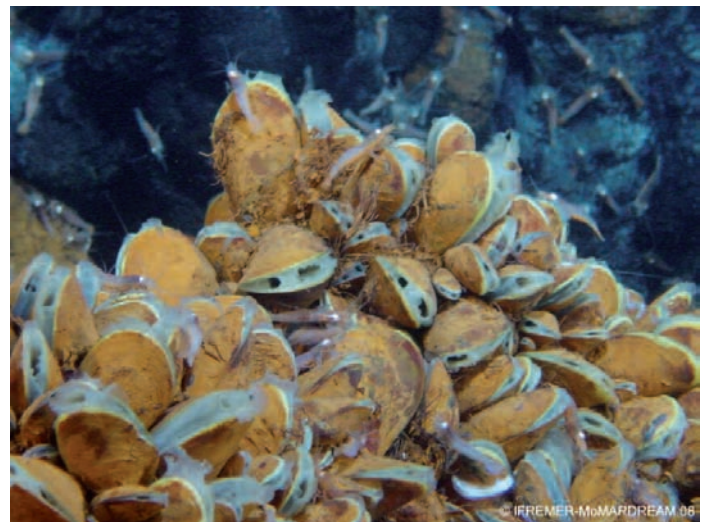


Figure 1: Living *Bathymodiolus azoricus* shells at Rainbow.

During cruise MoMARDREAM (MoMAR 08 Leg 2, August-September 2008), 15 dredge hauls were carried out to further sample the basement rock diversity on the Rainbow Hill (Dymant et al., 2009). Two dredge hauls and a detailed ROV survey revealed fossil chemosymbiotic bivalve faunas on the Rainbow Hill, which are distinct from the living communities at the high temperature vents. Biological, mineralogical and geochemical analyses of the fossil faunas expands knowledge about 1) the diversity of chemosynthetic invertebrate genera that can be hosted on slow spreading ridge systems, and 2) the ability of *Bathymodiolus* species and associated fauna to form high-biomass communities at Lost-City type vent fields.

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Sedimented vents on slow spreading ridges offer habitats for opportunistic chemosynthetic genera

Dredged rock samples 2.5 km east of the Rainbow field (Figure 2), at the summit of the Rainbow Hill (Clamstone site), reveal numerous dead bivalve shells (~ 25 kyr BP using ^{14}C dating) associated with clays, serpentinized peridotites and carbonate veins (Lartaud et al., 2010). A detailed survey by ROV *Victor 6000* identified eighteen fields of bivalve shells sparsely distributed over an area covering 100 m x 300 m. The shell distribution is very uneven, varying from small groups to aggregations covering several square meters with a density greater than 150 individuals per m^2 . Shells were found dissociated, partly buried in the sediment, or formed small banks on cracks in the underlying rocks (Figure 2). Abundant bivalve molluscs of the family Vesicomyidae are represented by the genus *Pbreagena*, the first record of this genus in the Atlantic Ocean. This genus is found in various reducing biotopes including submarine volcanoes (*P. edisonensis*), cold seeps (*P. soyoae*, *P. kilmeri*, *P. ochotensis*, *P. nankaiensis*) and hydrothermal vents (*P. okutanii*, *P. nankaiensis*). Only two species, *P. okutanii* and *P. nankaiensis*, inhabit both hydrothermal vents (the Mid-Okinawa Trough) and seeps (Sagami Bay and the Nankai Trough). *Pbreagena* is distributed in the western and eastern regions of the Pacific Ocean

and in the northern region of the Indian Ocean (Krylova and Sahling, 2006). Vesicomyid species were previously discovered on the MAR: *Pliocardia atalanta* at the Logatchev hydrothermal field (14°45'N), a species also described at the REGAB pockmarks and in the Gulf of Cadiz, and *Abyssogena southwardae* at Anya's Garden, a sedimented vent field in the Logatchev area, but *Pbreagena* sp. is the shallowest and northernmost proof of vesicomyid species on the MAR. The second bivalve species described at Clamstone comprises rarer specimens of *Thyasira* aff. *southwardae*, a species congeneric with *T. southwardae* from the Anya's Garden sedimented vent field at Logatchev and *T. vulcolutre* from the Captain Arutyunov mud volcano in the Gulf of Cadiz. These two clams seem therefore to present close relationships with seep taxa along the continental margin, and were likely associated with sedimented vent fields.

Although the chemosynthetic lifestyle of living representatives of these genera is mostly thiotrophy (Dubilier et al., 2008), the shell isotopic signatures cover a wide range of values of bivalve shells from hydrothermal and cold seep environments (Figure 3). This observation is considered to reflect both habitat differences and the occurrence of methane-rich sediments. Indeed, the shell isotopic signature of the burrowing species *Thyasira* suggests exposure to ^{13}C -depleted sediment pore water DIC, likely resulting from methane

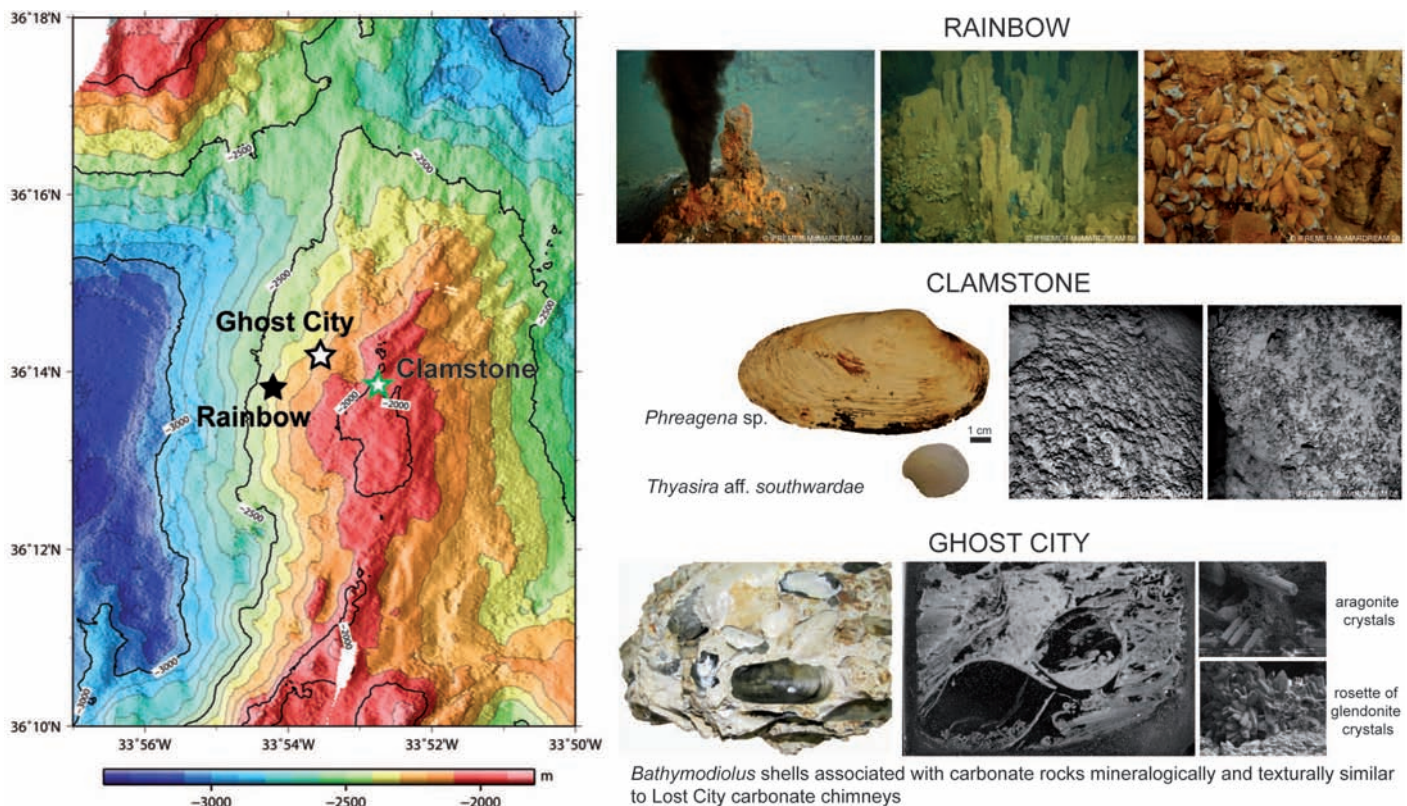


Figure 2: Location of the two fossil bivalve sites discovered on the Rainbow Hill. The active Rainbow vent field is located on the western flank of the Rainbow Hill. The Ghost City fossil site is located on the northwestern flank of this structure ~1200 m northeast of Rainbow vent field, and the Clamstone fossil site is located on the summit of the Rainbow Hill, about 2.5 km east of the Rainbow vent field.

oxidation (Lartaud et al., 2010). Conversely, *Pbreagena* shells are enriched in ^{13}C , more consistent with a higher contribution of seawater DIC in their habitat at the sediment-water interface.

The discovery of the Clamstone fossil sedimented vent site, close to the Rainbow active vents, suggests that this type of vent, already known at Logatchev (e.g. Anya's Garden), is not limited to spreading ridges located near continental margins such as the Guaymas Basin, but seem more widespread on slow-spreading ridges than previously thought.

Lost City-like habitats can support high biomass mussel-dominated chemosynthetic communities

Another dredge on the flank of the Rainbow Hill (Ghost City site), 1.2 km north-east of the Rainbow field (Figure 2), revealed mussel shells and pieces of white to ivory carbonates, associated with serpentinized peridotites and some troctolites and gabbros. The 110 kyr old carbonate rocks (based on U/Th dating) consist of varying proportions of authigenic carbonate cements and infilling pelagic calcitic and aragonitic fossils. The authigenic carbonate cement, which encloses numerous mussel shells, exhibits layered textures closely similar to the anastomosing aragonite structures of Lost City carbonate chimneys, and lacks metallic oxide or sulphide minerals (Lartaud et al., 2011). The mineralogical association includes radial aggregates of acicular crystals of aragonite, calcite and sparser rosettes of glendonite crystals, a pseudomorph after ikaite typically associated with elevated alkalinity, high pH (>10) and dissolved

phosphate enrichments (Figure 2). Glendonite has not been reported in Lost City carbonates, but the presence of ikaite in the walls of active chimneys was suspected from the observation of rapid dissolution of elongated carbonate crystals during sampling (Ludwig et al., 2006).

The Ghost City faunal assemblage is dominated by *Bathymodiolus* aff. *azoricus* shells of large size at high densities, together with *Pbreagena* and *Thyasira* shells, conspecific with those from the Clamstone sedimented vent site (Lartaud et al., 2010). Additionally, four species of gastropods occur in the Ghost City carbonates (*Lurifax vitreus*, *Paralepetopsis* aff. *ferrugivora*, *Protolira* aff. *tbovaldssoni*, *Phymorhynchus* sp.) (Figure 4). These taxa are also found in MAR axial high-temperature vent communities.

The isotopic signature of the Ghost City *Bathymodiolus* shells is similar to that of the authigenic carbonates (Figure 3), which support an in situ growth, also indicated by nested articulated specimens. Conversely, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of the mussel shells greatly differ from those of the infilling pelagic sediment and of living *B. azoricus* shells from the Rainbow high-temperature hydrothermal vent site, but are consistent with the isotopic signatures of carbonates from other serpentinite-hosted ecosystems (e.g., South Chamorro Seamount, Conical Seamount). The low $\delta^{13}\text{C}$ values recorded both in the *Bathymodiolus* shells and the carbonate cements from Ghost City suggest a contribution of depleted DIC from oxidized methane.

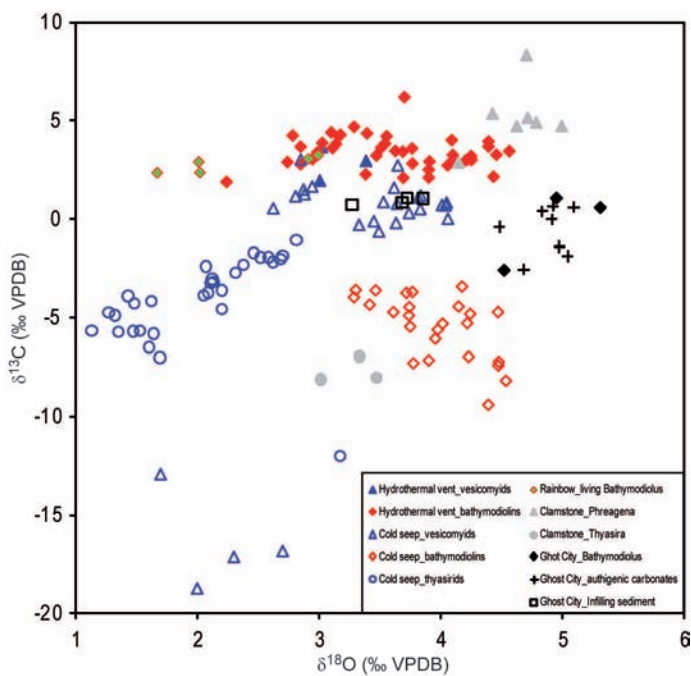


Figure 3: Oxygen and carbon isotopic composition of shells from the Rainbow Hill (Rainbow, Clamstone and Ghost City sites) compared to reference data of shells from hydrothermal vents and cold seeps (modified after Lartaud et al., 2010 and Lartaud et al., 2011).

Despite the proximity with Rainbow high-temperature vent field, the lack of polymetallic sulphide precipitates in the Ghost City carbonate samples precludes a high-temperature metal-rich hydrothermal fluid contribution in their formation. More likely, Ghost City fluids were formed from low-temperature hydrothermal circulation related to serpentinization, conditions closely similar to those at Lost City, which is the only known active example of a hydrothermal system primarily driven by serpentinization.

Despite hundreds of broken shell fragments downslope away from the active chimney areas at Lost City, only two living specimens of *Bathymodiolus* aff. *azoricus* have been found there (DeChaine et al., 2006). It is unclear why Lost City currently lacks large chemosynthetic assemblages such as *Bathymodiolus* mussel beds or bresiliid shrimp swarms. Notwithstanding, the discovery of Ghost City communities clearly shows that serpentinization-related fluids, unaffected by high-temperature hydrothermal circulation, can occur on-axis and are able to sustain high-biomass communities of invertebrates.

Conclusion

Various chemosynthetic communities have been present in the Rainbow area for at least 110 kyr, with abundance and diversity patterns that differ from the modern vent communities at Rainbow, Lost City or Logatchev sites. Our results show that diverse chemosynthetic species, from genera currently known to be

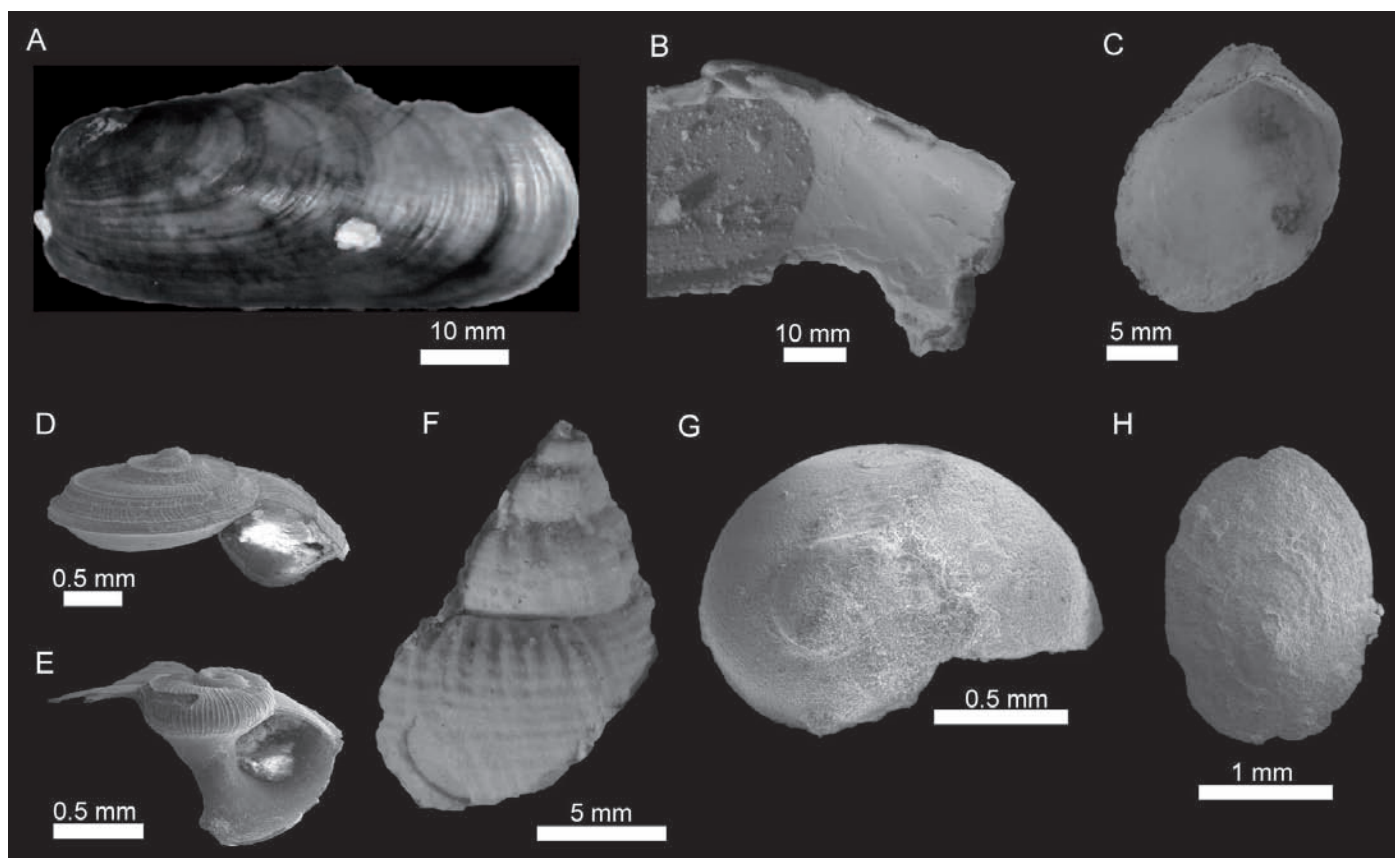


Figure 4: Fossils from Ghost City carbonates. (A) Specimen of *Bathymodiolus* aff. *azoricus*. (B) Silicone rubber cast of *Phreagena*, right valve interior. (C) *Thyasia*, left valve interior. (D) Gastropod *Lurifax vitreus*, oblique apertural view. (E) Gastropod *Anatomia* sp., oblique view of damaged specimen (F) Silicone rubber cast of gastropod *Phymorhynchus* sp., side view. (G) *Protolira* aff. *thorvaldssoni* gastropod viewed under SEM. (H) Limpet *Paralepetopsis* aff. *ferrugivora*, abapertural view of slightly corroded specimen.

abundant at vents and seeps, can form high-biomass assemblages in serpentinite-hosted vent habitats. Owing to their expected widespread spatial distribution and their geochemical diversity, these habitats might have played a major role in the ability of chemosynthetic fauna to disperse over oceanic basin scales.

To date, most deep-sea hydrothermal exploration has focused on ridges axes, since methods used to detect hydrothermal activity require that neutrally buoyant hydrothermal plumes form in the water column from high-temperature vents. This approach has limited the capacity to find off-axis, fault-related diffuse vent fields. Such systems display a variety of suitable habitats for both vent and seep-related species, and offer great opportunities to better understand the biogeography and temporal dynamics of hydrothermal vent and chemosynthetic communities through geologic time.

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Moytirra: a newly discovered hydrothermal vent field on the mid-Atlantic Ridge between the Azores and Iceland

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For many years, the Mid-Atlantic Ridge (MAR) between Iceland and the Azores has been the subject of intense speculation about whether it hosts hydrothermal activity and if so, the biogeographical affinity of any vent biota. The biological imperative has been to test the hypothesis that vent fauna cannot migrate across shallow areas such as around the Azores archipelago and Iceland. The possibility exists that this portion of the MAR might form a completely new biogeographic province for vent fauna. In addition, there is a geological interest as to whether volcanic edifices dominate in driving and hosting hydrothermal systems on slow spreading ridges. While volcanic and magmatic activity clearly drives the majority of, if not all, hydrothermal systems on fast spreading ridges, on the slow and ultra-slow spreading ridges this relationship is not so clear (Rona et al., 2010). For a significant number of hydrothermal sites on the MAR, tectonic context seems to be as important as the magmatic one and diversity of geological setting is the rule. What is the scenario at this new slow-spreading site?

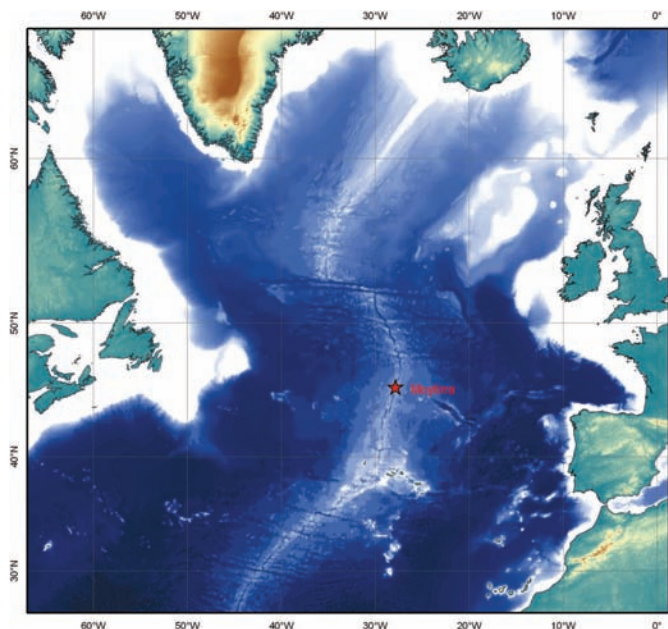


Figure 1: Moytirra vent field location showing its position at 3000 m water depth on the Mid-Atlantic Ridge, half way between the Azores Plateau and the Charlie Gibbs Fracture Zone.

The VENTuRE survey (Vents & Reefs deep-sea ecosystem study of the 45° North MAR hydrothermal vent field and the cold-water coral Moira Mounds, Porcupine Seabight) was undertaken between 11th July - 4th August 2011, with the primary objective of discovering a hydrothermal vent field. The survey was undertaken on the Irish national research vessel RV *Celtic Explorer* using the Irish deep-water ROV *Holland I*. Here, we report on the success of this survey, which was also documented for the upcoming National Geographic Television documentary series *Alien Deep*.

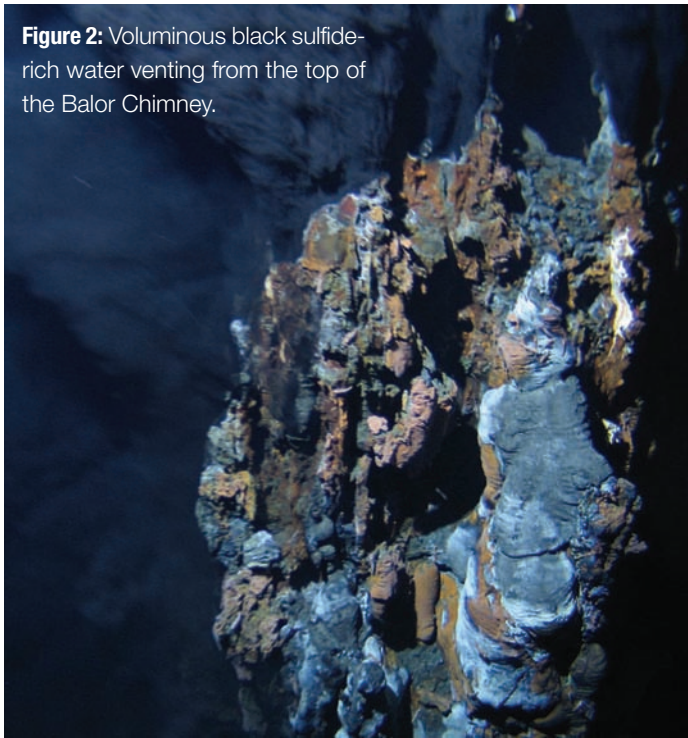
The survey capitalised on reconnaissance water column studies in 2008 on-board RRS *James Cook* (cruise JC24 of National Oceanography Centre, UK) that indicated hydrothermal activity near the ridge segment centre. In order to discover the source of the high-temperature hydrothermal venting on the seafloor, 14 CTD deployments were undertaken. Most deployments comprised multiple up and down casts, between 1400 m and 3000 m depth and along transects conducted at low speed (<0.5 kts), often described as 'tow-yos'. Real-time data, including sub-sea navigation, optical transmission, redox potential (Eh) and temperature, were streamed to the surface and interpreted using the 3-D visualisation software 'Fledermaus' to plan the ongoing survey and ultimately home in on the source of venting.

The initial deployment, located where the signal was previously noted during 2008, detected only very faint Eh and optical transmission anomalies. However, after just one and half days of near-continuous CTD work, during which we ran a series of perpendicular surveys centred on the maximum plume signal of the preceding line, we located a near-vent target for ROV exploration. This target later proved to be within just 30 m of the actual vent site, showing the efficiency of our tow-yo CTD and 3-D visualisation strategy. Near to the vent site, strong and structured optical transmission signals with associated positive temperature anomalies and strong negative deviations in Eh indicated the presence of a buoyant plume of 'black smoker' hydrothermal fluid rising from multiple chimney structures on the seafloor.

Our ROV dive found the plume-rich water at 2400 m and traced it down to 3000 m, where the first visual contact of the vent site was made at 22.30 on 24th July 2011, just 2 hours into our second scientific dive.

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Figure 2: Voluminous black sulfide-rich water venting from the top of the Balor Chimney.



The vent site is located off-axis and to the east of the axial volcanic ridge close to the base, but fixed to the wall, of the youngest axial valley fault scarp on the European Plate. It is a compact vent site and consists of three major chimney complexes with multiple spires and beehive structures. From its structure and morphology, we named the vent field “*Moytirra*” which, in Irish mythology, was a legendary battleground between good and evil forces - the mysterious and dark “Field of the Pillars”. The Irish mythology cycle was the source of inspiration for all subsequent names. Searches to the north and south with sonar did not reveal any more sites although we were unable to explore the deepest parts of the base of the fault scarp.

We named the largest chimney, or more accurately hydrothermal tower, “*Balor*” after an evil and powerful giant. Balor is a huge pillar-shaped edifice formed from a coalition of chimneys, beehives and pipes and is c.18 m tall and >1 m across near the top. The chimney surface includes grey areas of relatively fresh sulfides which, with age, have oxidised to a rust-coloured brown. White areas of anhydrite mineralisation are more common towards the top of the chimney implying that such parts of the chimney surface are at least 150°C. Balor is actively venting voluminous quantities of black mineral-rich water, starting from approximately three quarters of the way up the structure, with the main flow from its summit.

Balor is surrounded by slightly shorter and more slender chimneys named “*The Fomorians*”, in a horseshoe arrangement. The Fomorians have a number of well-developed beehives on top of pipes with venting occurring at the summit. Anhydrite is also common here. To the east, close to the base of the fault scarp, is a complex of

chimneys and crusts named “*Dian Cecht*” (pronounced Dee-an Kekt) venting a strongly reduced fluid. Balor, the Fomorians and Dian Ceht all have organ pipes and beehive structures, are composed of friable and porous sulfide with anhydrite indicative of surface temperatures of 150°C. Immediately above Dian Ceht, on the cliff face, is a wide area of diffuse flow where extensive sulfide crusts have developed, as well as significant accumulations of bacterial mat.

To the south is an older, and almost inactive, chimney complex characterised by a large number of slender fingers and organ pipes. These are more lithified and have very little active venting. This complex is appropriately named “*Mag Mell*” – after the Irish mythological abode of dead warriors.

The entire site was mapped using ROV-based multibeam sonar echosounder (RESON 7125 with a ping-rate of 30 Hz) that allowed us to map individual chimneys with centimetre accuracy. Individual chimneys, their sulfides and fauna were photomosaiced using HD camera footage and digital stills photography.

The faunal assemblage at the Moytirra vent field includes alvinocaridid shrimp, which were observed on vent chimneys and on the valley wall above the vent edifices. We sampled at least three distinct morphotypes of this decapod family. Other crustaceans included haustoriid amphipods, and brachyuran crabs were present on vent chimneys, the axial valley-fault wall, and sulfide rubble at the base of vent edifices. Chordates recorded at the vent field include zoarcid, macrourid, and ophidiid fish. Specimens of polynoid, terebellomorph, and spionid polychaetes, and peltospirid, skeneid, and turrid gastropods were also collected. Microbial mats of at least two colours were widespread on the sulfides and on the axial valley-fault wall above the vents.

Overall, the assemblage at the Moytirra vent field shows some high-level taxonomic similarities to assemblages at other known Mid-Atlantic vent fields, but also some differences in assemblage structure. Subsequent analysis of specimen identities to species level using morphological and molecular tools will be required to resolve the biogeographic affinity of the assemblage at this site. High-definition video was recorded with laser scale to quantify faunal microdistribution. In addition, samples were collected for further analyses of stable isotopes, population genetics, reproductive patterns, physiological pathways, metal content of tissues, microbiological analysis and for biodiscovery.

Sulfide samples, also taken by the geology team, span a range of types from old weathered to fresh fragile examples. The oldest have a thick coating (2-4 mm) of red iron oxyhydroxide forming a cauliform texture on the outer surface of the chimney. Inside this layer is fresh, fine- to medium-grained and slightly porous sulfide. The interface between the oxidised and reduced iron layers is marked by a layer of black material. This is probably rich in manganese and possibly, for the oldest samples, uranium oxide precipitated from seawater.

Younger vent-sulfide samples have thin iron oxyhydroxide coatings with fresh porous sulfide interiors. These rocks are very friable and have a high porosity. Inside are tubular pipes with coarse sulfide linings with anhydrite forming a matrix for much of the porous sulfide.

The next youngest sulfide group comprises of leafy, tabular chimney fragments with a mixture of coarse and fine-grained pyrite mixed with anhydrite in their matrix. Veins are present on the interior side with anhydrite-dusted coatings on the external side. The leafy structure of these sulfides indicates a hollow structure for some parts of the chimneys.

Active beehive structures form the next freshest group and these have an anhydrite coating on the external side, which is itself ornamented with annular ribs. These ribs have asymmetric profiles such that they are steepest on the side facing upwards. Inside the beehives is a fine-grained porous sulfide and anhydrite matrix exhibiting pipe-structures lined with coarse-grained pyrite. The annular ribs are apparent internally as annular layering of fine and coarse sulfide.

The final group of sulfide samples form a group of fragile tubes. These range from 10 to 30 cm long, 2-4 cm in diameter and have anhydrite dusting on the exterior and coarse sulfide crystals in the pipe walls.

Together, the sulfide sample groups represent a stratigraphic profile with increasing height from the base of the sulfide chimney structures to the top. The oldest sulfides are from Mag Mell and the

rest from more active chimneys. From these samples, we plan to develop a model for the construction process of the chimneys and hence the major sulfide edifices themselves. We will also investigate the weathering process by which elements are exchanged with seawater as the sulfides are exposed to oxygenating seawater.

Two vent fluid samples were taken for chemical analysis onshore at NOC. It is hoped that these fluids will yield insights into the water-rock conditions and its depth beneath the Moytirra vent site.

As well as work on the hydrothermal vent, some limited work was done on contextualising the geological setting of the mid-Atlantic Ridge in this region. Basalt samples were collected from two flat-topped seamounts; one at an off-axis location and one located on the axial valley floor. The off-axis samples are all weathered with glass rinds altered to palagonite and sericite. Interiors are fresh and have olivine \pm clinopyroxene phenocrysts. The on-axis samples are fresh with glass rinds and have generally aphyric, vesicular interiors. Samples from the axial valley wall adjacent to the vent site are both dolerites and basalts. The dolerites are aphyric to plagioclase phyric with sulfide and iron oxide coatings and fresh interiors. They are probably derived from shallow-level dykes. Some are altered and have sulfide veins in a clay matrix. The basalts are plagioclase phyric, fresh to slightly altered with fresh glass rinds in places indicating a pillow lava provenance.

These samples will be integrated with the those collected during the 2008 UK cruise (JC24) in our on-going collaborative effort to understand this fascinating segment of the Mid-Atlantic Ridge.

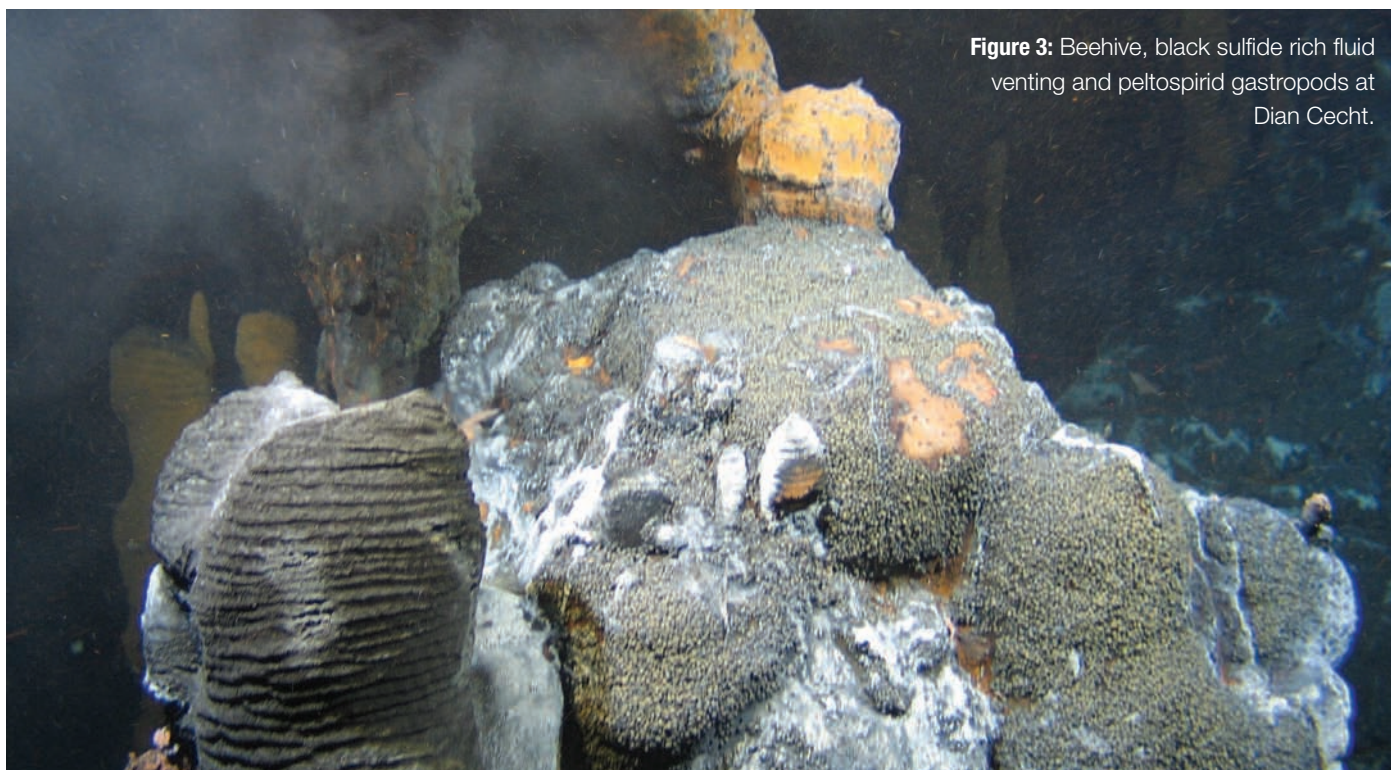


Figure 3: Beehive, black sulfide rich fluid venting and peltospirid gastropods at Dian Cecht.

New hydrothermal field on the Mid-Atlantic Ridge

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Abstract

A new inactive hydrothermal field with seafloor massive sulfide (SMS) deposits “Peterburgskoe” (19°52'N) was discovered during regional works at the segment 20°30'–19°47'N of the Mid-Atlantic Ridge (MAR). “Peterburgskoe” is located at depths of 2800–3100 m, 16 km to the west of the rift axis. It is situated on the conjunction of the large non-transform discontinuity with the second rift mountains which are in parallel to the rift valley. Seven SMS mounds were detected within the field. The largest one has dimensions of 100×280 m. SMS are represented mainly by Cu-Fe sulfides with the proposed age of 63.3–176.2 ka.

The Russian geologists are carrying out ridge-related works mainly in the northern equatorial zone of the Mid-Atlantic Ridge (MAR). These annual studies made by the Polar Marine Geosurvey Expedition (PMGE), in cooperation with VNIIOkeangeologia and some other academic institutes, resulted in the discovery of six large hydrothermal fields between 12°50' and 20°10'N segment of the MAR (Figure 1; Cherkashov et al., 2010).

Two latest discoveries were made during the course of regional studies between 19°15' and 20°08'N (Figure 1). The CTD casts (with light scattering sensor), geophysical profiling (side-scan with electric potential (EP) sensor), as well as geological sampling, were aimed at recognising hydrothermal anomalies in the water column and in the bottom sediments. The first deposit, “Zenith-Victory” was detected in 2008 (Cherkashov et al., 2010). The second one (“Peterburgskoe”) was discovered during Cruise 33 (2010) of the R/V *Professor Logatchev* as a result of ground truthing of EP anomaly recorded during geoelectrical profiling. The presence of hydrothermal input apart from EP anomaly is evidenced also by mineral and chemical markers in the sediments found on this site earlier during Cruise 31 (2008) of R/V *Professor Logatchev*.

The hydrothermal field lies at depths of 2800–3100 m on the eastern slope of the southern closure of the second rift ridge of the western flank of the rift valley, at the junction with the extensive non-transform discontinuity at 19°47'N at 16 km distance from the rift axis (Figure 1). Such a long distance of deposit from the rift axis is

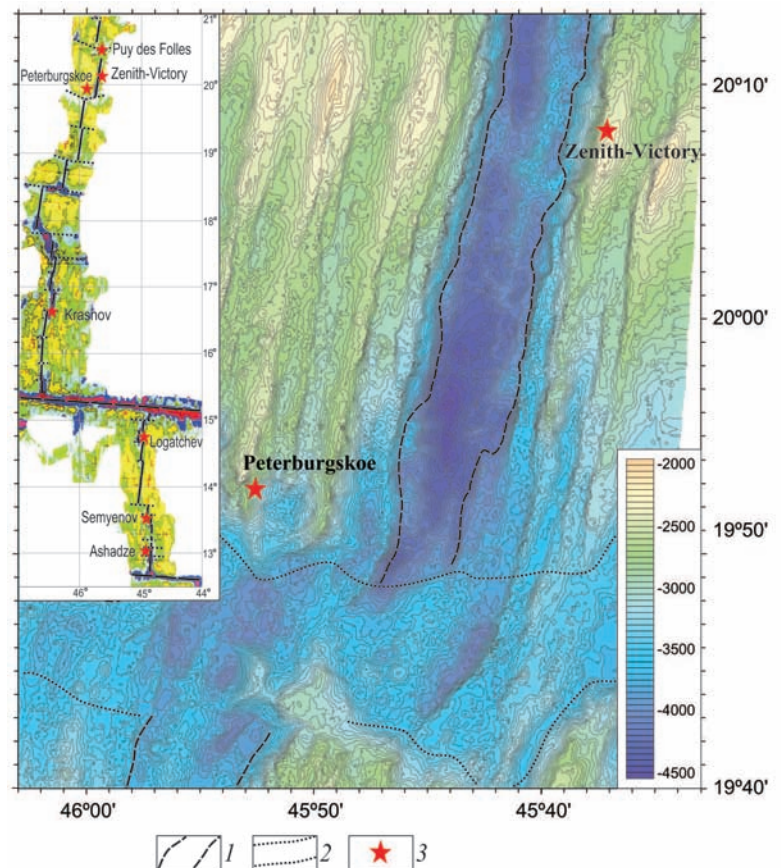


Figure 1: Bathymetry with structural elements and new SMS deposits. Inset - SMS distribution along 12°50'–20°10'N segment of the MAR. 1- rift valley floor; 2- non-transform discontinuity; 3- SMS deposits.

maximal for all known ore fields on the MAR (Fouquet et al., 2010) and undoubtedly determines peculiar features of its evolution and composition.

Basalts are ore-hosted rocks subjected to intense hydrothermal alteration in the form of chloritization and sulfidization up to total disappearance of primary igneous structures. The ore field outlined along the boundary of metalliferous sediment distribution extends meridionally and is 1400×800 m in size. Geological sampling and interpretation of TV observations recorded seven ore bodies within the field area (Figure 2). Sizes of bodies are equal respectively 100×150 m (I), 100×280 m (II), and 130×180 m (VI). Ore bodies III

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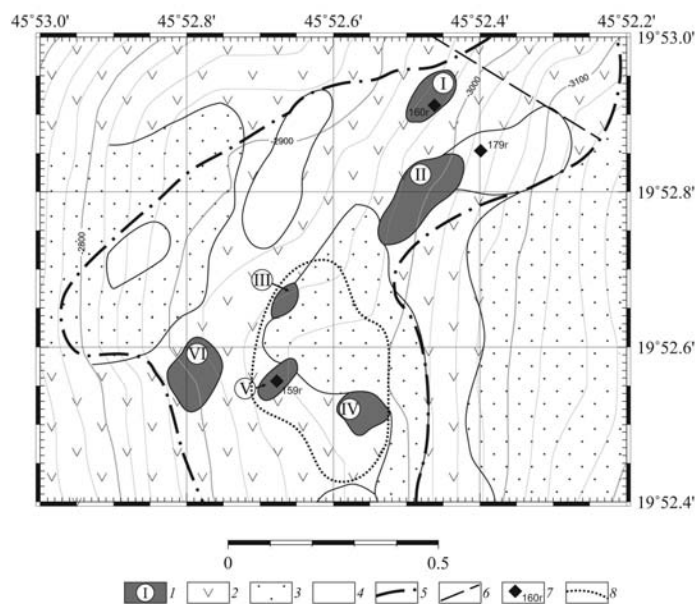


Figure 2: Geological setting of “Peterburgskoe” hydrothermal field. 1- Sulfide mounds (ore bodies) and its numbers; 2- basalts; 3- pelagic sediments; 4- metalliferous sediments; 5- outline of hydrothermal field; 6- tectonic elements; 7- sampling stations; 8- outline of proposed subsurface hydrothermal mound.

(50x100 m), IV (110x130 m), and V (50x120 m) occupy the central part of the field within the outline limits of an inferred hydrothermal mound overlain by sediments. The outline of the mound extends in a north-westerly direction and is 350x550 m in size. Ore body VII was discovered and sampled later in 2011 during Cruise 34 of the R/V *Professor Logatchev*. It is located 200 m to the north-east from ore body I, has dimensions 150x200 m and is partly overlain by sediments.

Hydrothermal mineralization is represented by massive sulfides, low temperature precipitates and metalliferous sediments. Massive sulfides are composed mainly of Cu-Fe and Fe varieties and strongly oxidized. Chalcopyrite, bornite, pyrite (pyrrhotite), and marcasite are major sulfide minerals. Iron hydroxides in individual samples amount to 10%. Mean values of copper and zinc for three samples equal 4.53% and 0.13%. Ore structure in hydrothermal edifices as a rule is massif-porous, concentrically-zoned and layered. Diffuser/bee-hive-like structures were mostly described at ore body 7. The texture of ores is fine crystalline with a relict aphanitic structure of marcasite framework. Low-temperature precipitates are dominated by iron hydroxides and contain fragments of Fe-Si small chimneys. There are ferro-aragonite and ferro-manganese crusts containing atacamite on the sediment surface just above sulfide edifice (station 159). Metalliferous sediments have maximal exposed thickness of 43 cm (station 179).

Based on the U/Th chronology, one sulfide sample has an age of 176.2+/-59 Ka. Two other datings (98.3+/-3.3 and 63.3+/-4.8 Ka)

also points to a relatively old age of sulfide mineralization. The age of metalliferous sediments identified on planktonic foraminifera assemblages equals 0-2 (?) and 11-80 Ka.

With due account of the dating implying the formation of the deposits during a long time interval, along with a certain relationship between the age and mineralization extent [2], one can assume sizable extent and high potential resources of the “Peterburgskoe” ore field. The above assumption will be confirmed during detailed works on this site of the MAR.

No anomalies in the near-bottom waters pointing to present-day hydrothermal activity on the “Peterburgskoe” field have been recorded.

Conclusions

1. Regional works in 2010 led to the discovery of a new inactive hydrothermal field “Peterburgskoe” (19°52’N). It lies at a distance of 16 km from the rift valley (maximal for all known ore fields on the MAR), namely, within the second rift ridge of the western flank of MAR.
2. Seven sulfide bodies partly overlain by sediments are included in the ore field. SMS are mainly represented by Cu-Fe minerals and are strongly oxidized.
3. The obtained age dating suggests a long-term multi-stage history of the SMS deposit formation. The maximal age of sulfides on the “Peterburgskoe” field is (176.2 +/-59 Ka). These dates are the highest for sulfide mineralization within the known SMS deposits on the MAR.

Acknowledgements

Cruises of R/V *Professor Logatchev* were supported by the Federal Agency for Management of Mineral Resources of the Ministry of Natural Resources of Russian Federation. Geochronological studies were funded partly at the cost of RFBR (grant No. 11634.31.0025).

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Dredged samples from the ocean floor at Woodlark Basin provide evidence of hydrothermal fluid circulation and wall rock alteration

^{1,2}Akumbom Visbiti

Introduction

Marine Geology/Oceanography is a discipline that is still in its infancy in several less developed countries of the world. In an attempt to bridge this gap, the ISA through its InterRidge fellowship scheme calls for proposals from young scientists around the world to participate in various research projects linked to marine geology. In 2010, I was awarded one such fellowship and since arriving at IFM-GEOMAR, Kiel, Germany, I have been working on very exciting submarine volcanic rock samples (from segment 1 of the Woodlark Basin, Fig. 1) with a broad range of alteration and deformation styles typical of fault rocks altered by multiple fluid circulation in the shallow oceanic crust. My intention to participate on one or more cruises organised by the GEOMAR as originally envisaged in my fellowship application has not been fulfilled due to logistical difficulties, but hopefully this may materialise in the future.

However, working in this multicultural and multidisciplinary setting, on these previously unstudied samples dredged from the ocean floor (DR-59), (Fig. 2), is equally as exciting and offers opportunities for gaining more skills in laboratory analytical procedures. This article presents an overview of the rock types in this basin and our intention of tracking the relationship between alteration type, whole

rock geochemistry and the role of hydrothermal fluid circulation in generating mineral deposits.

Samples and alteration categories

The rock types thus far dredged and partially studied are basaltic to rhyolitic in composition (Fig. 3). These rocks are located along an active fault and are therefore altered into various fault rock types (Fig. 4). Rocks are monomictic to polymictic breccias with subangular to subrounded clasts and are coated with MnO. Reflected light photomicrographs of samples show framboidal pyrite aggregates (Fig. 5) that result from the mechanical reworking of detrital compact pyrite grains formed from the circulation of hydrothermal fluids. This deformation is visible even at a microscopic scale. Brecciation is an excellent ground preparation event as circulating fluids will readily interact with the fractured rock. Wall rock alteration in these samples is being studied using various techniques. X-ray diffractometry shows that sulphidation of the brecciated volcanics resulted in the formation of pyrite and chalcopyrite.

Also zeolites formed (Fig. 6) within vesicles, pointing to hydrothermal alteration at relatively low temperature. The sulphide-rich samples have as much as 5530 ppm As, 9 ppm Hg and 125 ppb Au. This suggests that sulphidation leads to the precipitation of gold from a Hg-bearing-fluid. This promises to be a significant scientific finding as the work progresses.

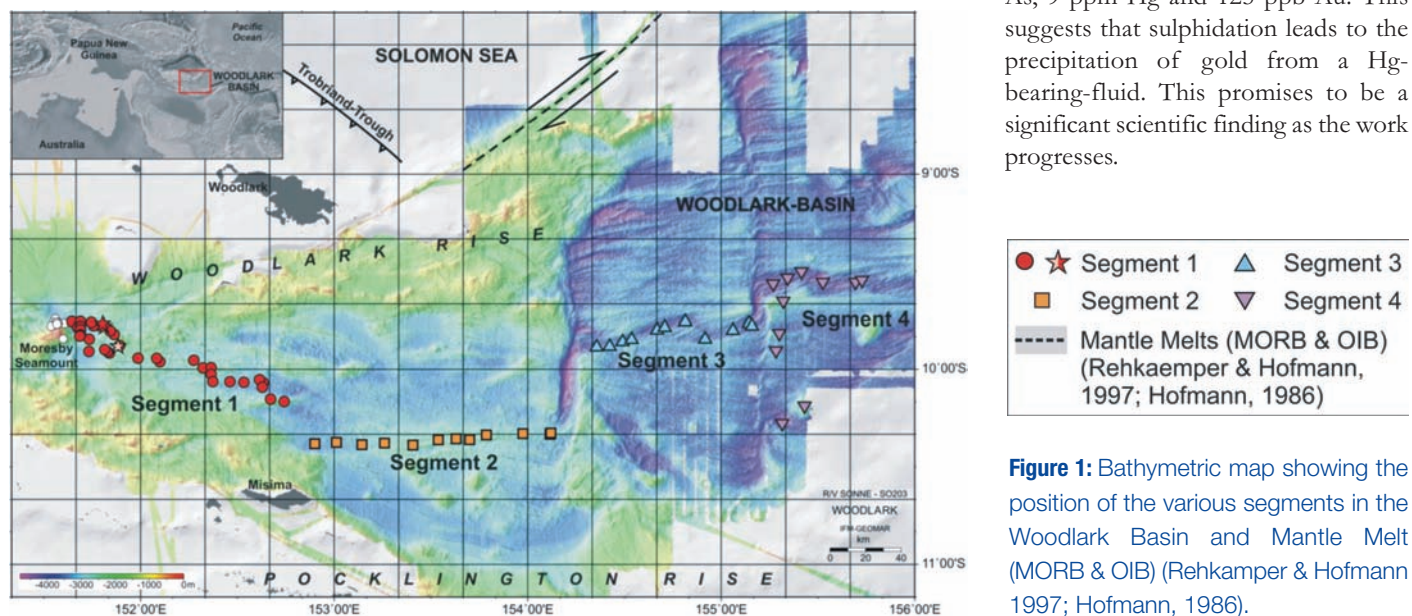


Figure 1: Bathymetric map showing the position of the various segments in the Woodlark Basin and Mantle Melt (MORB & OIB) (Rehkaemper & Hofmann 1997; Hofmann, 1986).

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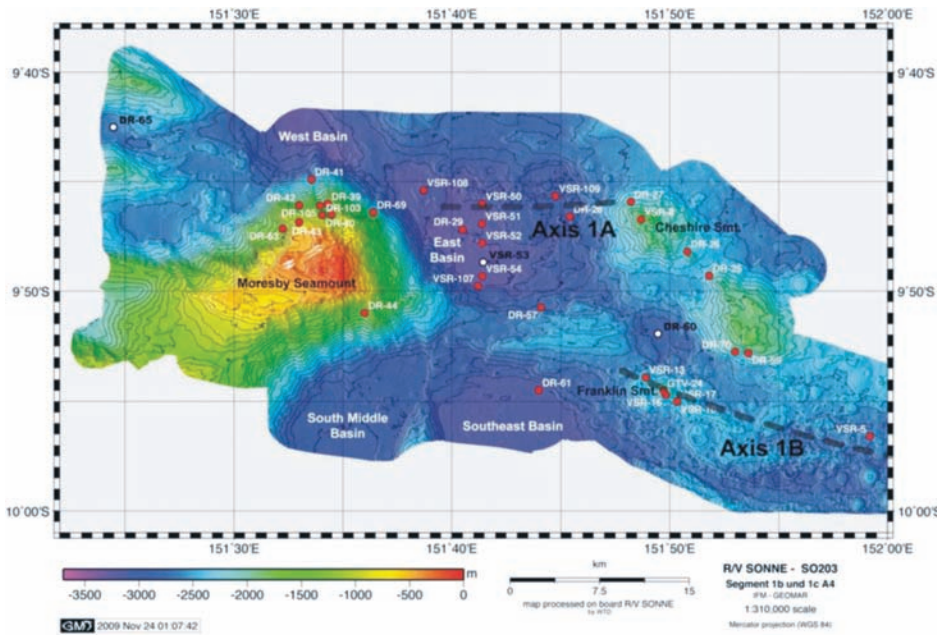


Figure 2: Bathymetry and sample locations in the Moresby seamount/segment 1A&B region. Samples in this study were dredged from DR-59 (segment 1B) southeast of the Cheshire Seamount. Successful sampling stations are shown by red dots. The supposed locations of axis 1A and 1B are marked by dark grey lines. Location after Binns et al., 1987; ridge axes after Goodliffe et al., 1997.

Figure 3: Total alkalis versus silica plot (Le Maitre et al., 1989) of DR-59 samples from segment 1B, SE of Cheshire Seamount Woodlark Basin. Major elements cover a wide range from mafic to felsic lavas. Most samples retain a dacitic affinity, with basalts being the least evolved and rhyolite the most evolved samples.

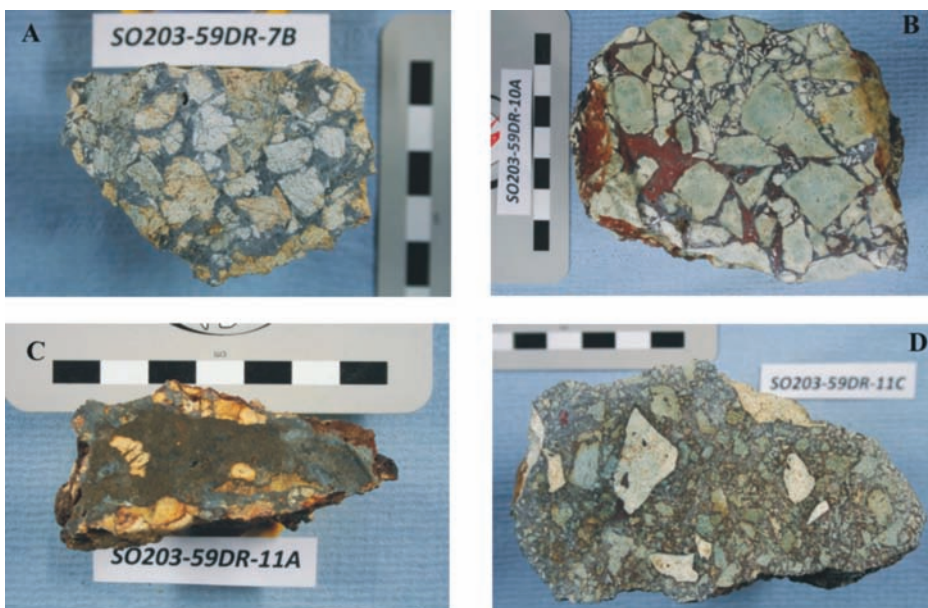
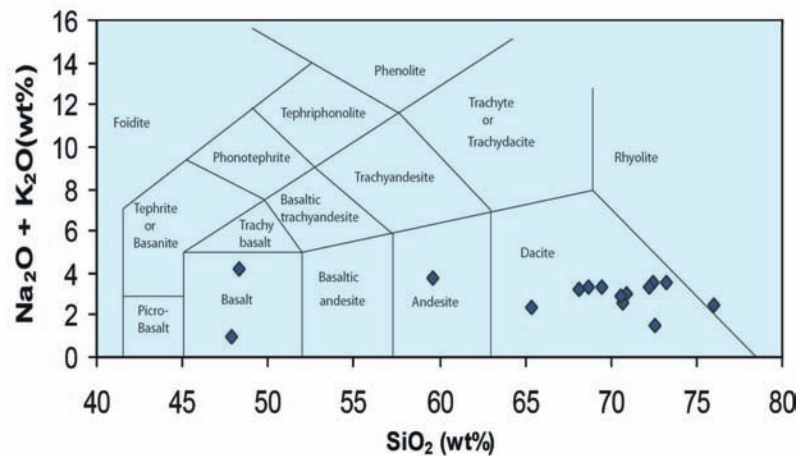


Figure 4: Altered DR-59 fault rocks coated with MnO A) Polymictic, matrix supported rhyolite breccia with a dark grey quartz matrix. Notice the breccia in breccia texture and vesicles in the matrix. B) Red hematite quartz matrix supported dacite breccia with monomictic altered clasts. Matrix is vesicular. The distinctive shard clasts result from explosive brecciation. C) Pyrite-quartz matrix supported basalt breccia. Notice vesicles in the matrix. D) Variably altered polymictic, clasts embedded in a fine grain dark brown matrix dacite breccia. Both clasts and matrix are vesicular. Rock is intensely clay altered. (A and B) are mosaic breccias while (C and D) are chaotic (Woodcock and Mort, 2008, classification of fault rocks).

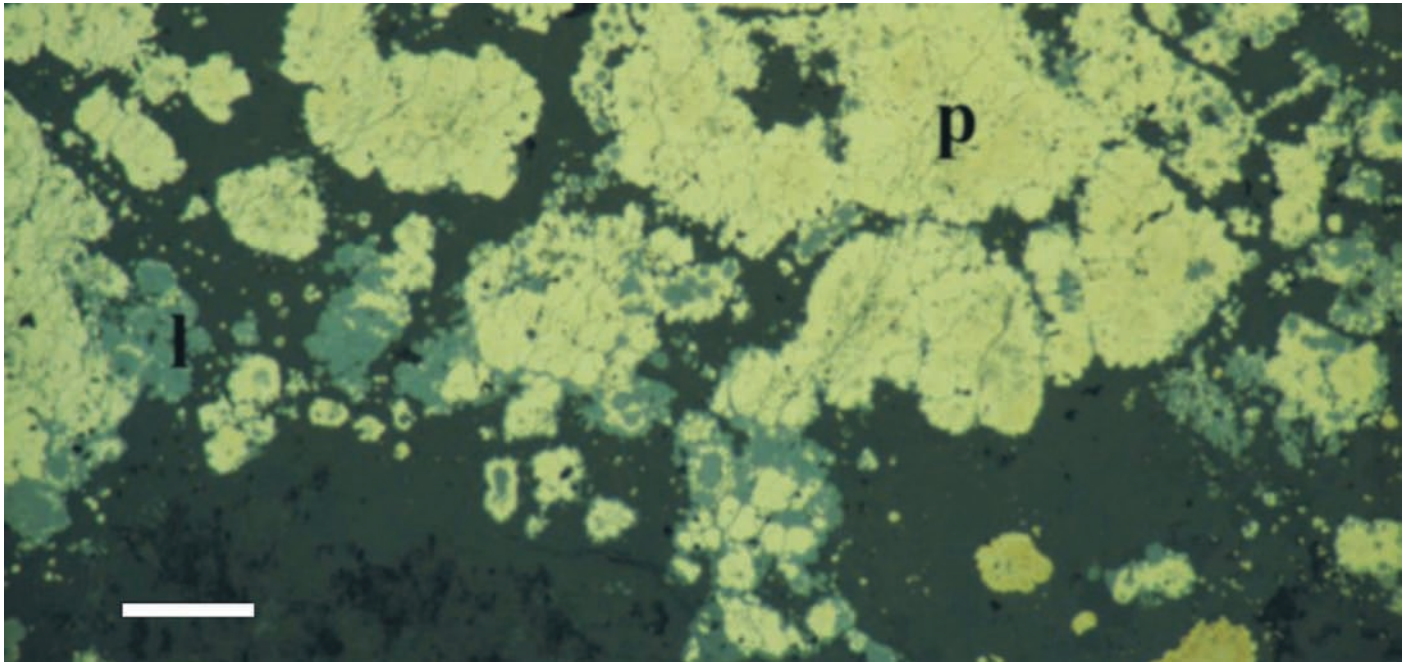


Figure 5: Reflected light photomicrograph of sample showing framboidal aggregates of pyrite (p) rimmed by limonite (l) due to hydrothermal alteration. Scale is about 1cm.

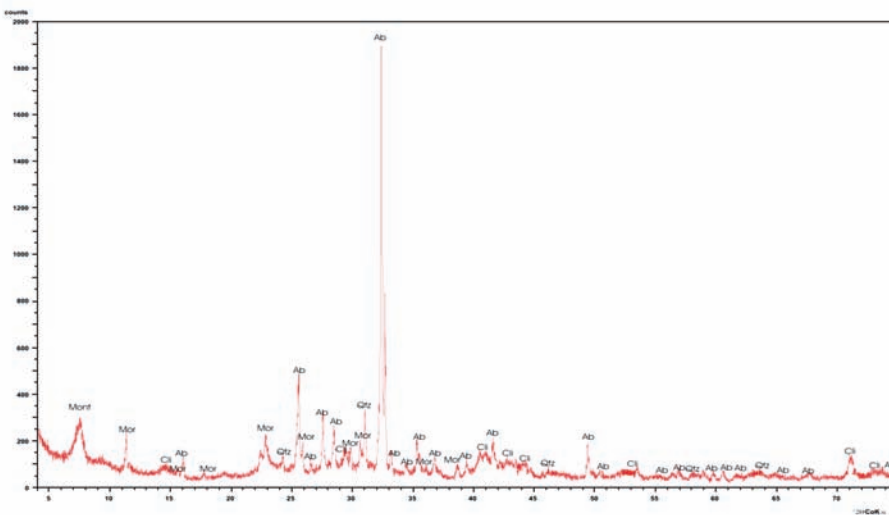


Figure 6: Representative XRD pattern (CoKα) showing mineral association in rocks. Montmorillonite (Mont), Mordenite a Zeolite (Mor) Clinoclore a chlorite end member (Cli), Albite (Ab) and Quartz (Qtz). Thus the following alteration types, Chloritization, Albitetisation, Silicification and clay alteration.

Perspectives

This present work is in line with my career ambition in the area of hydrothermal fluid circulation and wall rock alteration, notably in marine settings. There clearly is a link between deformation, volcanism and ore deposit formation and these samples from the Woodlark Basin, which is a modern volcanic arc environment, allows for inferences to be drawn from there that are applicable to other ancient parts of the earth’s crust.

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Hydrothermal activity in the Eastern Manus Back-arc Basin, Papua New Guinea, with focus on fluid geochemistry

Cruise Report, R/V *Sonne*, Leg SO-216, BAMBUS (*Back-Arc-Manus-Basin-Underwater-Solfataras*)

Adam Schaen¹ assisting Eoghan Reeves²

The primary goals for the BAMBUS cruise SO-216 were to obtain vent fluid and biota samples from hydrothermal systems in the eastern Manus Basin using the ROV MARUM Quest 4000m. Secondary objectives focused on geophysical mapping and echosound surveying of the basin as well as the collection of volcanic rocks and vent precipitates using a TV grab. Hydrothermal fluid sampling was accomplished using Isobaric Gas-Tight (IGT) fluid samplers that allow for quantitative analysis of dissolved gases and major/minor elements, as well as providing real-time temperature measurements (Seewald et al., 2002). Fluid analyses at sea consisted of measuring dissolved H₂ concentrations using gas chromatography and pH (25°C). Additional fluid samples were treated and stored for land-based analyses of other major and minor dissolved species (gases and inorganic anions/cations, sulfur species, arsenic species). End member fluid chemistry data collected from the SO-216 expedition will be compared with the 2006 MGLN06MV cruise (Tivey et al., 2006, Reeves et al., 2011) in order to document any temporal changes.

Two key vent sites were visited. The first was located at North Su neovolcanic dome (3°48.0'S, 152°06.05'E) where twelve dives took place in a water depth of ~1200 m. Black smoker systems located near the summit of the dome displayed maximum measured temperatures of 332°C and 313°C and were seen to be “flashing”, as previously observed in 2006 (Tivey et al., 2006; Reeves et al., 2011). Measured H₂ concentrations ranged from 24-50 μM while measured pH values were between 3.2 and 4.8 at 25°C. Hydrothermal vents located on the flanks of the dome were clear/diffuse vents and white smokers. The white smokers were seen actively venting liquid CO₂ in the newly discovered ‘Sulfur Candles’ area, named for the spectacular molten sulfur chimneys. These fluids had maximum temperatures of 95°C and 103°C, respectively. Extremely low pH (25°C) values of 1.2-1.4 were measured at Sulfur Candles while H₂ concentrations were observed to be <5 μM, with no H₂S odour present.

Ten dives took place in the PACMANUS vent field located on Paul Ridge at 3°43.5'S, 151°40.4'E in approximately 1700 m water depth.

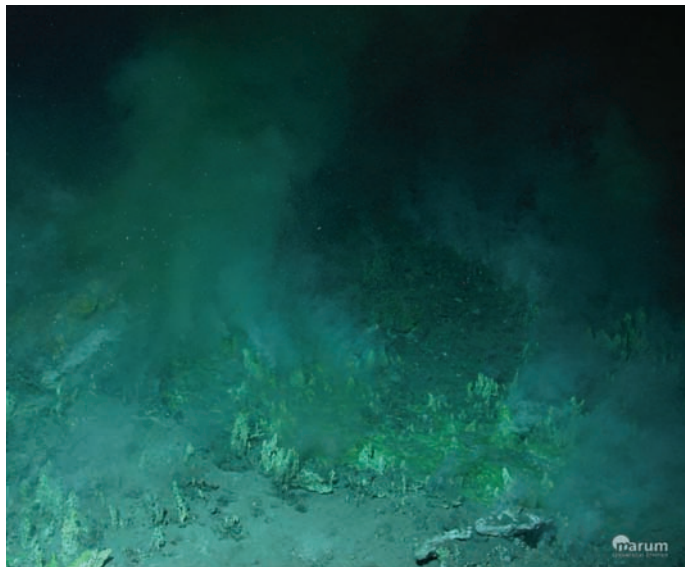


Figure 1: Newly discovered Sulfur Candles site featuring white smokers, liquid CO₂ bubbles and liquid sulfur at the seafloor.

Significant temporal changes were observed in these high temperature black/grey smoker fluids compared to the end member fluids in 2006 (Reeves et al., 2011) and at the Satanic Mills area, liquid CO₂ venting was observed for the first time. Black smoker vents sampled at Paul Ridge showed considerably higher maximum temperatures of 345°C and 339°C when compared to 2006 measurements, while the pH ranged from 2.8-3.0 at 25°C. Furthermore, the exploration of two new high temperature vent fields discovered by Nautilus Minerals was carried out during this expedition. These new fields were on the flanks of Paul Ridge and were venting hot (up to 348°C) fluids, indicating highly active systems. Shore-based analyses will further elucidate the compositional variability of the collected fluids, as well as furthering our understanding of the magmatic fluid inputs to these systems. The SO-216 expedition results will also prove extremely valuable in understanding the temporal evolution of back-arc hydrothermal fluid compositions, which have traditionally received little attention.

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Hydrothermal exploration along the southern Central Indian Ridge

Cruise report of KH-10-6, R/V *Hakuho-maru*

*Kyoko Okino*¹

The Kairei Hydrothermal Field (KHF) is located at the southern end of the Central Indian Ridge (CIR), near the Rodriguez Ridge Triple Junction. The objectives during KH-10-6 were: 1) to verify the hypothesis that hydrogen-rich KHF is controlled by the ambient crustal structure and the chemical composition of lithosphere, 2) to estimate the chemical and microbiological fluxes from KHF to seawater through hydrothermal plumes, 3) to quest an unknown hydrothermal field on the rise, tentatively called Yokoniwa Rise, north of the KHF, and 4) to develop the survey method for hydrothermal activities using AUV. We also surveyed, for comparative study, the Edmond Hydrothermal Field about 140 km north of the KHF, where the fluids do not contain much hydrogen.

KH-10-6 cruise achieved brilliant success in attaining its scientific objectives. Most of the operations were completed successfully

under the collaboration with the highly skilled Hakuho-maru crew. The preliminary results are:

1) A r2D4 #68 dive was done successfully above the Yokoniwa Rise north of the Kairei Hydrothermal Field, where the dead chimneys on ultramafic exposure were discovered in 2009. High-resolution side scan image and interferometric bathymetry was obtained with data from chemical and physical sensors. The attached magnetometer could detect the positive anomaly on the dead chimney area.

2) Surface geophysical mapping revealed the detailed feature of CIR-4 segment, where no previous data existed. The result will improve our understanding of spreading history and structural segmentation of the CIR, and will provide a key to consider the tectonic setting

of the Edmond Hydrothermal Field.

3) Total 80 mile of deep-tow magnetic profile was obtained across CIR-1 segment. The detailed spreading history since 2 Ma was revealed, that will constrain the evolution of detachment faults around the Kairei Hydrothermal Field.

4) A number of lower crust / mantle materials were collected around the Kairei Hydrothermal Field. Focused dredge hauls on the Yokoniwa Rise will lead us to a reliable model of Yokoniwa formation.

5) Systematic sampling of mid-ocean ridge basalts with fresh glass along the ridge axis will provide a good opportunity to study the mantle heterogeneity beneath the southern CIR.

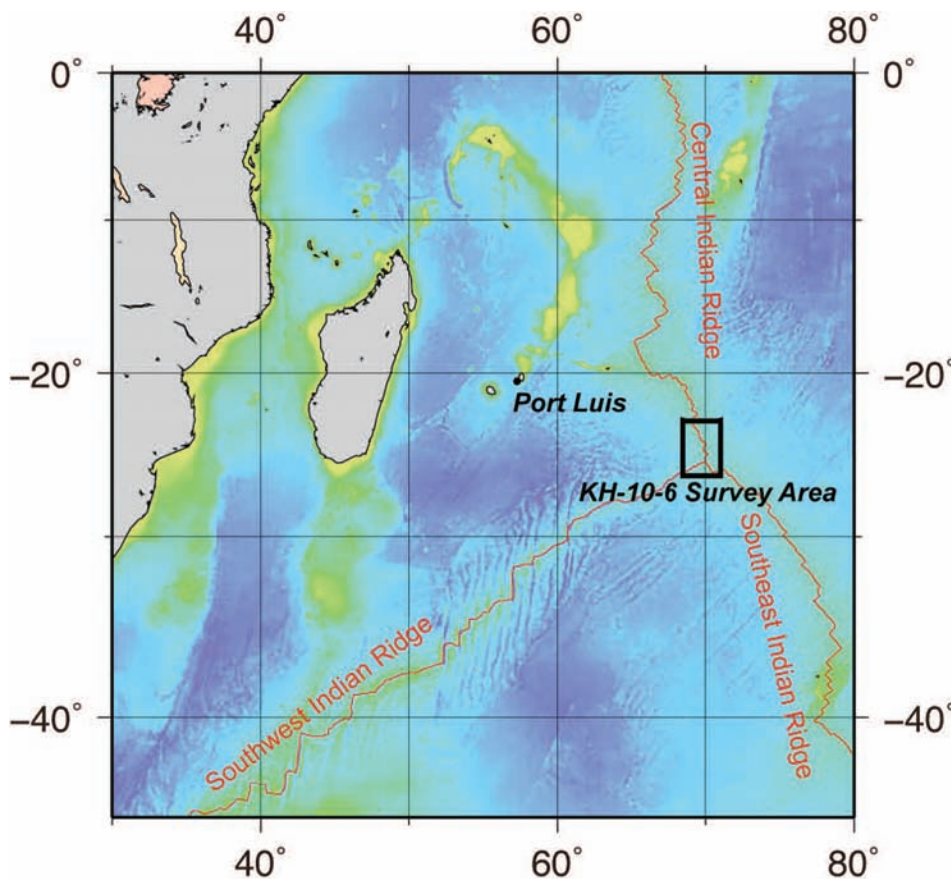


Figure 1: The location of KH-10-6 survey area.

¹Ocean Research Institute, University of Tokyo.

6) Total ten CTD tow-yo surveys and three vertical casts could reveal the spread of hydrothermal plumes and their chemical and physical properties around the Kairei and Edmond Hydrothermal Fields. The anomalies of pH, turbidity, alkalinity, Mn, ΣCO_2 and DO were detected around the Kairei Hydrothermal Field. Very high concentration of hydrogen was also confirmed.

7) Newly developed pH sensor and turbidity meter were attached to the wire during most of the dredge hauls and plankton net operations. Distinct turbidity anomalies were detected at some sites, which could prove the effectiveness of “dredge-attached” sensors.

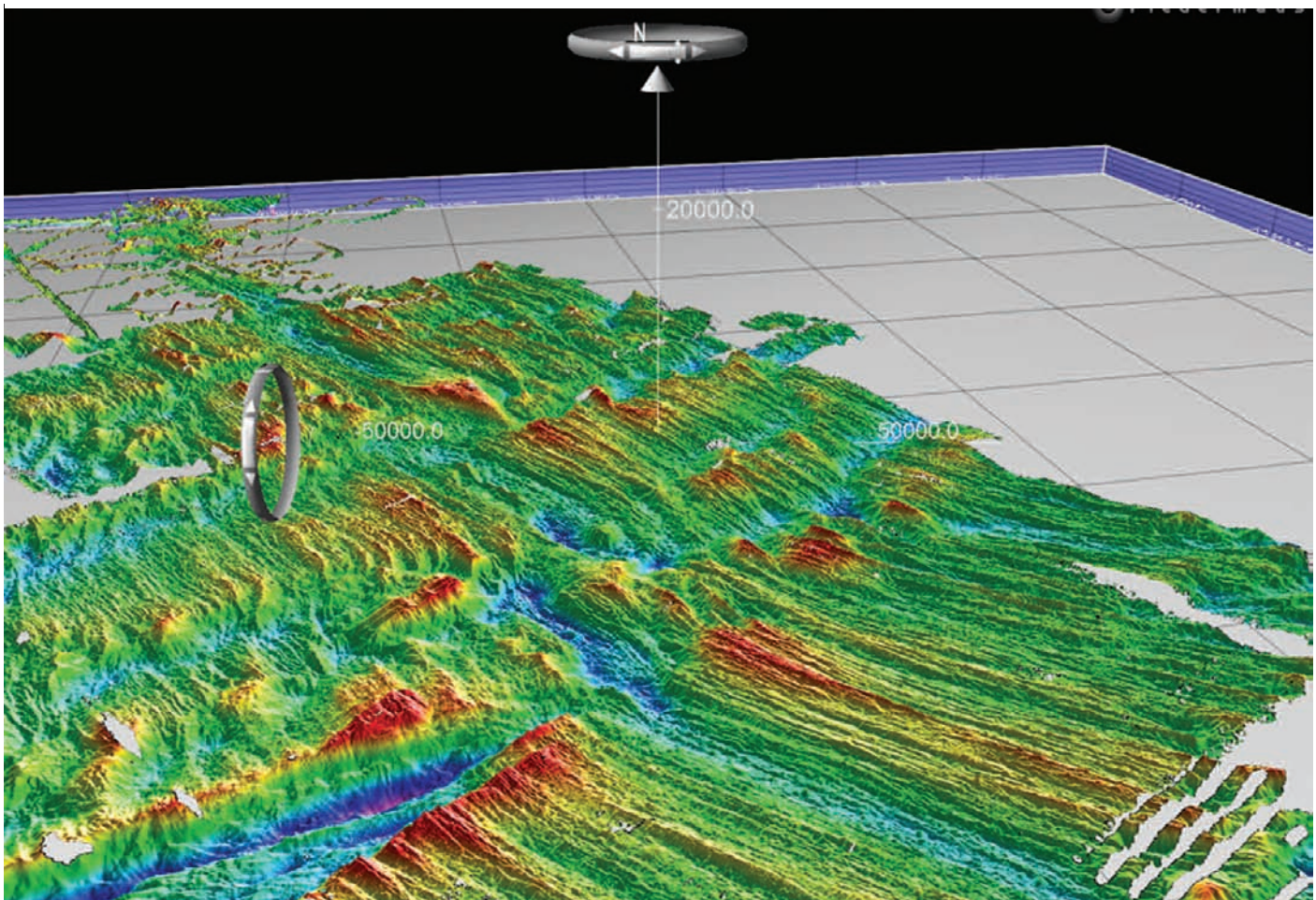
8) Approximately double-dense microbial cell density was detected within the hydrothermal plume above the Kairei Hydrothermal Field. The detailed distribution will provide a new insight into microbiological flux through the plume.

Motoko Yoshizaki, from the Tokyo Institute of Technology, was on board this cruise and wrote:

My research theme is the experimental study of H_2 generation by hydrothermal alteration of ultramafic rocks. The experimental conditions, such as temperature, pressure and chemical composition of host rock, should be set based on the observation of natural hydrothermal systems. It was so nice for me to see how actual surveys were conducted in deep sea hydrothermal systems. Many researchers from various disciplines joined in this cruise including geophysicists, geochemists, geologists and microbiologists. So, I was happy to watch whole picture of the deep sea survey.

I joined the team describing rocks collected by dredging. I enjoyed looking at various rocks retrieved from seafloor. Especially, I was excited when serpentinite, my research object, was retrieved. In this cruise, all scientists actively discussed subseafloor structure and its origin using the data collected everyday, and the decided the next day's target. It was a great opportunity for me to see how scientists renewed our knowledge on board daily.

Figure 2: 3-D bathymetry of the area.



Three new hydrothermal fields found at 13-14°S Mid-Atlantic Ridge

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During January to February 2011, the 2nd Leg of the COMRA's 22 Cruise found three hydrothermal fields on 13-14°S Mid-Atlantic Ridge (MAR). They were temporarily named as Rainbow Bay North, Valentine Valley and Tai Chi, respectively.



Figure 1: Chinese research ship R/V *Dayang Yihao*.

Hydrothermal activity along the southern MAR has been investigated and documented by several cruises. German et al. (2008) reported two high temperature hydrothermal fields at 4°S and 4°48'S. Hasse et al. (2009) found the Lilliput hydrothermal field which extends to 1000 m × 250 m at a depth of 1,500 m. However, no hydrothermal vents south of 13°S along the southern MAR were reported before 2009. In 2009, two active hydrothermal fields were found in COMRA's 21 Cruise, which was temporarily named as Baily's Beads 2009 and Rainbow Bay South respectively. The Baily's Beads 2009 field is at a depth of about 2,288 m and located at 14.41°W, 13.28°S. The Rainbow Bay South field is at 14.34°W, 14.06°S on the slope of a volcano, lying on the inside corner between the axial ridge and transform fault, at a depth of about 2,900 m (Tao et al, 2011).

The Rainbow Bay North field was found at 14.36°W, 14.03°S at a depth of 1900 m, which may extend to 480 m × 780 m. Massive sulfides were collected by a ROV. The Valentine Valley field is located at 14.41°W, 13.25°S and is about 4 km south of the Baily's Beads 2009 field. It is located along the N-S fissures on the central valley. The Tai Chi field is at 14.52°W, 13.59°S and was detected using CTD. Black smoke, shrimps and bivalves were videoed by the deep tow system in this active field.

Furthermore, four hydrothermal anomalies were detected by CTD and they are located at (14.67°W, 13.60°S), (14.56°W, 13.70°S), (14.53°W, 13.75°S) and (14.54°W, 13.87°S) along the southern MAR respectively.

These newly discovered hydrothermal vents and anomalies indicate that the ridge segment of 13-14°S MAR is a promising area for hydrothermal activity.

Acknowledgements

We thank captains and crews of the COMRA's 22 cruises on R/V *Dayang Yihao* and Dr. S. Petukhov and Dr. I.Egorov from the All-Russia Research Institute of Geology and Mineral Resources of the World Ocean (VNIIOkeangeologia) who contributed to the success of this leg.

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MoMAR-Demo at Lucky Strike. A near-real time multidisciplinary observatory of hydrothermal processes and ecosystems at the Mid-Atlantic Ridge

Mathilde Cannat¹, Pierre Marie Sarradin², Jérôme Blandin², Javier Escartin¹, Ana Colaco³ and the MoMAR-demo team⁴

The MoMAR “Monitoring the Mid-Atlantic Ridge” project was initiated by InterRidge in 1998 to study the environmental instability resulting from active mid-ocean ridge processes at hydrothermal vent fields south of the Azores. It then developed into a component of the ESONET (European Seafloor Observatory Network) and EMSO (European Multidisciplinary Subsea Observatory) programs, which coordinate eulerian observatory initiatives in the seas around Europe. MoMAR experiments started in 2006 and address two main questions:

- (1) What are the feedbacks between volcanism, deformation, seismicity and hydrothermalism at a slow spreading mid-ocean ridge?
- (2) How does the hydrothermal ecosystem couple with these sub-seabed processes?

The MoMAR-Demo project started in 2010 with partial support from ESONET. It has been implemented so far by two cruises of the RV *Pourquoi Pas?* during which we successfully deployed, (in 2010), and upgraded, (in 2011), a near-realtime buoyed observatory

system. The system comprises two Sea Monitoring Nodes (SeaMoN) at the seafloor, which are acoustically linked to a surface relay buoy (BoRel), ensuring satellite communication to a land base station in Brest (France). One SeaMoN node connects to a 3-components seismometer and an hydrophone for seismic event detection, and two pressure probes for geodetic measurements. The other SeaMoN node connects to a video camera, a dissolved-iron analyzer, and an optode (oxygen and temperature probe) for ecological time studies. The BOREL transmission buoy is equipped with GPS (geodetic experiment and buoy location) and meteo station. Data and/or status signals from these sensors are transmitted every 6 hours, and put on line in compliance with the ESONET-EMSO data policy (temporary access through <http://www.ifremer.fr/WC2en/allEulerianNetworks>).

The MoMAR-Demo system also allows for interactive connections and changes of data transmission rates on demand. It is nested in arrays of autonomous sensors (OBSs, pressure probes, temperature probes in selected smokers, current meters and temperature probes in the water column), and colonization devices for time-integrated faunal studies.

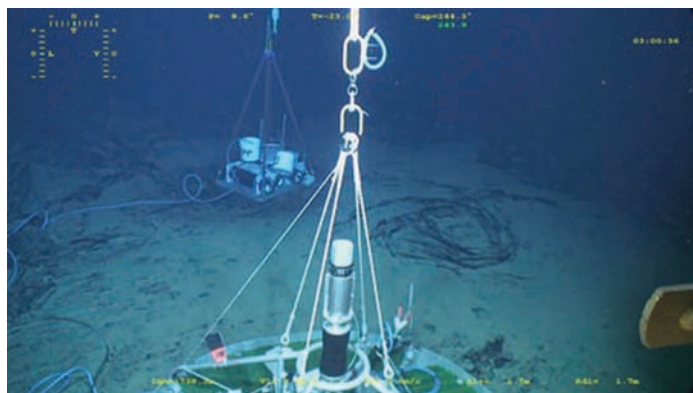


Figure 1: 3-components seismometer and a hydrophone for seismic event detection, and two pressure probes for geodetic measurements, are connected to SEAMON W.

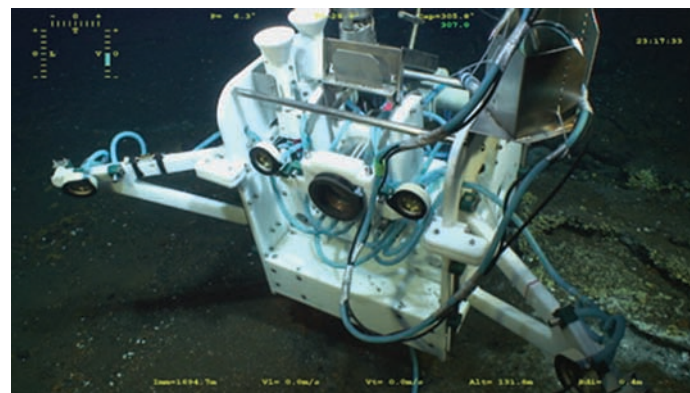


Figure 2: A video camera, a dissolved-iron analyzer and an optode (oxygen and temperature probe) for ecological time studies are connected to SEAMON E.

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International study of larval dispersal and population connectivity at hydrothermal vents in the southern Mariana Trough

Stace E. Beaulieu¹, Susan Mills¹, Lauren Mullineaux¹; Florence Pradillon²; Hiromi Watanabe³; Shigeaki Kojima⁴

Abstract

For spatially discrete habitats such as hydrothermal vents, dispersal of larvae in the plankton, settlement to the seafloor, and recruitment to reproductive age are processes that connect populations of benthic fauna. Knowledge of these processes is vital to understanding the resilience of vent ecosystems to disturbance that may include human impacts. In 2009 the first Marine Protected Area (MPA) for vents in the U.S. EEZ was established as part of the Marianas Trench Marine National Monument (MTMNM). The vents in this region are located along the Mariana back-arc spreading center (BASC) and volcanic arc. In 2010 we conducted the first cruise dedicated to vent fauna at the southern Mariana BASC. Cruise YK10-11 on R/V *Yokosuka* was one of several to this region as part of the Japanese multi-disciplinary program TAIGA (Trans-crustal Advection and In-situ biogeochemical processes of Global sub-sea floor Aquifer). Benthic invertebrates and their larvae were collected at vents on-axis (Snail, Yamanaka) and off-axis (Archaeon, Urashima, Pika) at ~3000 m depth. Our objectives included characterization of benthic communities, assessments of larval abundance and diversity, estimates of local-scale larval dispersal (on the order of 10 km), shipboard visualization of larval swimming behavior, and genetic diversity of populations at each vent site and genetic deviation between sites. Operations during the cruise included nine dives with the submersible *Shinkai 6500* and seven deployments of sub-surface moorings. Results of our local-scale study will be considered in the regional context of ecosystem management and protection in the MTMNM and also in the broader context of biogeography of deep-sea vent fauna, through our involvement with the International Network for Scientific Investigations of Deep-Sea Ecosystems (INDEEP).

Introduction

Deep-sea hydrothermal vents have received attention recently for protection of biodiversity and ecosystem function (Baker et al., 2010; Van Dover, 2010). Hydrothermal vents may be impacted by human activities including scientific research, eco-tourism, bioprospecting and polymetallic sulfide mining (Ramirez-Llodra et al., 2011; Van Dover et al., 2011). In year 2000, InterRidge convened the first international workshop on management and conservation of hydrothermal vent ecosystems (Dando and Juniper, 2001). A workshop in 2010, also sponsored by InterRidge, identified a critical knowledge gap for spatially based management of vent ecosystems:

“Knowledge of connectivity is critical if we are to understand the sensitivity of populations to removal of one or more sources of propagules” (Van Dover et al., 2011). Because hydrothermal vents are such discrete habitats and may be ephemeral on both short (ecological) and long (evolutionary) time scales, biologists often ask the question: “How are these vent sites colonized?” and, more specifically, “How are the faunal populations established and maintained at these habitats?”

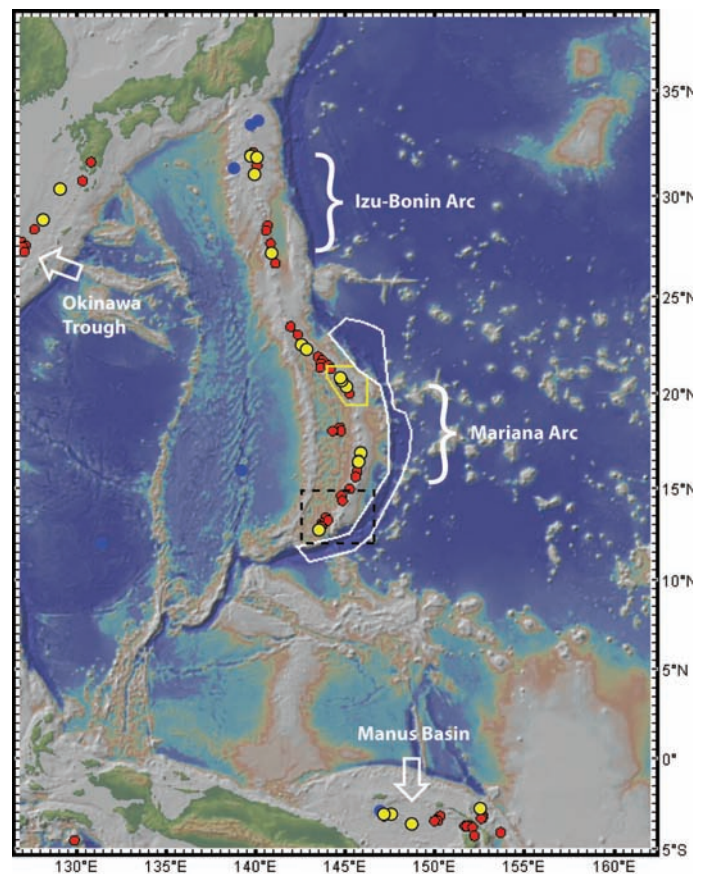


Figure 1: All known submarine hydrothermal vents in the MTMNM in the context of other vents in the western Pacific. White outline is MTMNM Trench Unit; yellow outline is Islands Unit. Vents from (Beaulieu, 2010): red confirmed active, yellow inferred active, blue inactive. Bathymetry from (Ryan et al., 2009). Dashed box indicates vents mentioned in the southern Mariana region.

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In the past decade, four marine protected areas (MPAs) have been established for deep-sea hydrothermal vents, with the most recent being the establishment of the U.S. Marianas Trench Marine National Monument (MTMNM) in 2009. In the MTMNM, hydrothermal vents are found along the Mariana back-arc spreading center (BASC) in the Mariana Trough and at submarine volcanoes along the Mariana Arc (Fig. 1). From 2008-2012, the southern Mariana BASC is being studied as part of the Japanese multi-disciplinary program TAIGA (Trans-crustal Advection and In-situ biogeochemical processes of Global sub-sea floor Aquifer). In 2010, the InterRidge Long-Range Exploration Workshop identified the southern Mariana region as a high priority for the next decade of internationally-coordinated ridge research. The region is of interest for geophysical and geochemical studies due to the proximity of subduction and the volcanic arc to the spreading center. The region is also of interest to biologists, for many reasons including the possibility of a biogeographic “break” for vent fauna. In terms of biogeographic provinces, fauna from vents in the Mariana Trough surprisingly group with the SW Pacific back-arc vent fauna, indicating a connection to the Manus Basin, ~1700 km south of the southernmost vent in the MTMNM (Bachraty et al., 2009). Other biogeographic models still group the Manus Basin and Mariana regions, but instead put both with the NW Pacific province (Van Dover, 2010).

Connectivity – the exchange of individuals among marine populations – involves dispersal of larvae in the plankton, larval settlement to the seafloor, and recruitment to reproductive maturity (Cowen and Sponaugle, 2009). The distance between vents, water depth, and chemical composition of the venting fluids are all expected to affect the larval supply and benthic community composition at the Mariana vents. Horizontal distances average ~60 km between known vent fields along the arc and almost 600 km between known vent fields near 13° and 18°N on the BASC. In addition to distance, hydrodynamics on regional and local scales and larval behavior must be considered when determining trajectories for larval dispersal (e.g. Thurnherr et al., 2011). In terms of depth and chemical composition of the venting fluids, different animal species (or their microbial symbionts) may have different depth tolerances and may be better adapted to certain chemical environments or temperatures. The vents in the MTMNM have a broad range in depth, with vents ranging from < 200 m to almost 3000 m water depth at submarine volcanoes along the arc and ranging from about 2900-3600 m on the BASC. Vent fluid chemistry is expected to differ between BASC- and arc-associated vents due to different tectonic and volcanic settings and host rock composition.

In 2010 we initiated an international study of larval dispersal and population connectivity at selected hydrothermal vents in the southern Mariana Trough. In this project, U.S. and French scientists with experience in dispersal of vent larvae in the eastern Pacific teamed with Japanese scientists with experience in population genetics and phylogeography of vent fauna in the western Pacific. Although vents on the northern portion of the Mariana BASC had been discovered and studied in the mid-1980’s (Hessler and

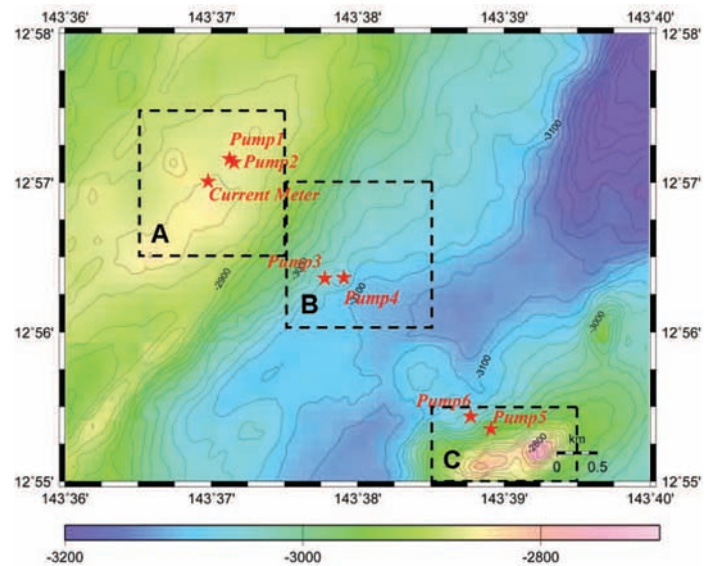


Figure 2: Study areas for cruise YK10-11, with mooring positions indicated. Dashed boxes indicate areas visited on dives with *Shinkai 6500*: A – Dives 1220, 1227 and 1228 to Snail and Yamanaka vents on-axis; B – Dives 1221, 1223 and 1224 to Archaean vent 2-km off-axis; C – Dives 1222, 1225 and 1226 to Urashima and Pika vents 5 km off-axis. Depth (m) indicated by color bar. Contour interval 20 m. Bathymetrical data used here were collected during cruises YK10-10 (N. Seama and J. Miyazaki) and YK10-11.

Lonsdale, 1991), the vents that we are studying in the southern portion of the BASC at ~3000-m depth were only recently discovered in 2003 and had not yet been characterized for faunal composition. The faunal composition at a relatively nearby but shallower (1470 m depth) vent on the arc, Forecast Vent, appears similar to the northern BASC vents (Fujikura et al., 1997). Larval sampling and benthic community composition at other Mariana arc vents (depths 265-1610 m) are reported in a recent paper (Metaxas, 2011). However, the faunal composition at TOTO Vent, the southernmost known vent on the arc – nearby our study area and at similar depth - appears to be very different than the northern BASC/Forecast Vent fauna (Gamo et al., 2004; Kojima et al., 2006).

Cruise operations

In September 2010 we conducted the first cruise dedicated to the study of vent-endemic fauna at the southern Mariana BASC. Our cruise focused on local-scale larval dispersal and population connectivity at several BASC-associated vents that are distributed in a line perpendicular to the spreading ridge axis to 5 km off-axis (Fig. 2). Operations during Cruise YK10-11 on R/V *Yokosuka* included nine dives with the submersible *Shinkai 6500* and seven deployments of sub-surface moorings (Fig. 2). Larval, juvenile, and adult specimens of benthic invertebrates were collected at two vents on-axis (Snail, Yamanaka) and three vents off-axis (Archaean, Urashima, Pika) at ~3000 m depth. Our objectives were to:

- characterize faunal composition of the southern Mariana BASC vents;
- collect specimens for population genetics of abundant benthic species;
- assess larval abundance and diversity through morphological and molecular genetic identification;
- conduct shipboard experiments to visualize larval swimming velocities; and
- obtain a current meter record to enable a preliminary estimate of local-scale larval dispersal (on the order of 10 km).

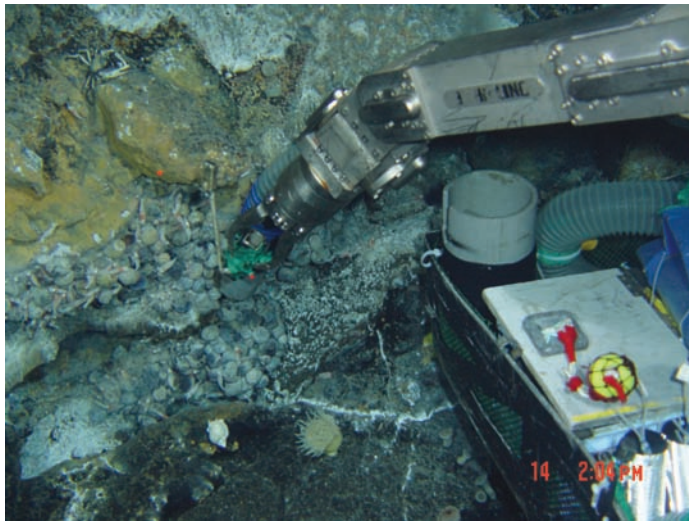


Figure 3: (Upper) Photo of diffuse vent (low temperature) community sampled at Snail vent. For scale, the laser dots are 20 cm apart (external still camera, Dive 1228). (Lower) Photo of black smoker (high temperature) community at Archaean vent. For scale, shrimp are approx. 2 cm length (frame grab of external video camera, Dive 1223). Photos courtesy JAMSTEC.

Benthic collections were performed during *Shinkai 6500* dives in three study areas (Fig. 2). All diffuse (low temperature) vents were sampled, and high-temperature collections were at off-axis vents (Fig. 3). Some benthic fauna (e.g. mobile fauna including shrimp) and larvae were also collected near-bottom with a slurp sampler. The volume filtered per slurp sample was up to 3500 L, with up to six

slurp samples per dive. On the final dive of the cruise, we deployed a colonization experiment at a diffuse vent community at Snail site for recovery on a future cruise. We have deployed the same type of colonization “sandwiches” in previous studies of hydrothermal vent communities in the eastern Pacific (Mullineaux et al., 2010).

Mooring operations included six deployments of large-volume plankton pumps (McLane WTS-LV50) to assess larval abundance and diversity and one deployment of a current meter (Aanderaa RCM-8) to measure near-bottom flow on-axis during the cruise. Plankton pumps were deployed near bottom in paired sub-surface moorings on-site and off- (by 100 to 300 m) near three of the vents (Snail, Archaean, and Urashima; Fig. 2). Each pump was scheduled to sample for 24 hrs at 30 L/min over a 63 μ m mesh filter. We filtered five samples of ~40000 L each and one sample of ~1000 L. The current meter was deployed near bottom on-axis near Snail vent for 10 days. Upon recovery, samples on pump filters were rinsed with filtered seawater into trays on ice and examined live. To estimate larval swimming velocities, individual larvae of several species were introduced into a vertically-oriented, flat-faced vial and/or horizontally-oriented dish for high-definition imaging at 1 atm in light. Each of these individuals was preserved either frozen or in 99.5% ethanol for molecular genetic analyses.

For more information and photos of cruise operations, daily dispatches during the cruise are posted online at: <http://ventlarvae.blogspot.com>

Our cruise report is also available at JAMSTEC’s online GODAC database: <http://www.godac.jamstec.go.jp/cruisedata/yokosuka/e/YK10-11.html>

Post-cruise analyses

Observations during the *Shinkai 6500* dives and preliminary identifications of collected specimens indicate that these vents on the southern Mariana BASC have similar macrofauna to the better-studied BASC vents ~600 km to the north (Kojima, Watanabe and Pradillon, unpub. data). Benthic collections included gastropods (e.g., *Alviniconcha bessleri*, *Phymorhynchus* aff. *starneri*, *Shinkailepas* aff. *kaikatensis*), barnacles (*Neoverruca brachylepadoformis*), shrimp (*Chorocaris* aff. *vandoverae*) and polychaetes (e.g. *Paralvinella bessleri*) (Kojima, Watanabe and Pradillon, unpub. data). Size compositions of the collected fauna were also recorded to evaluate environmental differences among the vent fields. Local-scale population connectivity is being determined via molecular genetic analyses of mainly the benthic specimens. The population genetic study may be extended to the regional scale when linked to other analyses for specimens collected at vents elsewhere in the MTMNM and to the larger, biogeographic scale when linked to sequences posted to GenBank or the DNA Data Bank of Japan (DDBJ) for the same species in other regions (e.g. Manus Basin). For *Alviniconcha bessleri*, a representative vent-endemic species of the MTMNM, population structure and gene flow between on-axis and off-axis vent sites are

being analyzed by various nuclear and mitochondrial DNA markers. The analysis is extending to the entire distributional range of this species using specimens collected during previous cruises.

Post-cruise analyses are also underway for larval abundance and diversity, larval swimming velocities, and local-scale larval dispersal. Larvae were sorted morphologically at 25 to 50X, and a subset of specimens was identified via genetic bar-coding to phylotype and, when possible, to species. Preliminary results indicate 13 morphotypes of polychaete larvae and 15 morphotypes of gastropod larvae (Beaulieu, unpub. data), with many of the morphotypes matching to genetically distinct phylotypes (Pradillon, unpub. data; Kojima and Watanabe, unpub. data). Larval swimming velocities were analyzed by tracking larvae in high-definition video files using Matlab software. Current meter data were analyzed for along-axis mean flow and across-axis tidal variability.

Management and protection of hydrothermal vent ecosystems in the MTMNM

Results of our initial study of larval dispersal and population connectivity at these deep-sea vents will be considered in the context of ecosystem management and protection in the MTMNM. An ultimate goal would be to develop a regional hydrodynamic model that could be coupled with a particle-tracking model to estimate a connectivity matrix between vent sites (e.g. North et al., 2008). We are developing plans with physical oceanographers and modelers in the U.S. and Japan to propose a more regional-scale study. Our work will also be considered in the broader context of connectivity of deep-sea, chemosynthesis-based ecosystems, through our involvement with the International Network for Scientific Investigations of Deep-Sea Ecosystems (INDEEP) working group on population connectivity.

As follow-up to the cruise, Beaulieu, Kojima and Watanabe attended the HADEEP Trench Connection Symposium at AORI, University of Tokyo, in November 2010, and Beaulieu attended the NOAA workshop for science and exploration in the MTMNM in September 2011. Many questions are just beginning to be addressed in terms of connectivity within the MTMNM as an MPA for hydrothermal vents, and in the larger context of connectivity of populations of vent-endemic species to other regions outside of the MTMNM. Within the MTMNM, are larvae exchanged between BASC- and arc-associated vents? Are the local populations at vents in the MTMNM sources or sinks for the metapopulation, which extends out of the region and into a much larger biogeographic province? Is there any larval exchange or gene flow between vent populations in the Manus Basin, where polymetallic sulfide mining is intended to start in 2013, and the Mariana region? Even in the deep sea, it is becoming increasingly important to study processes such as larval dispersal and population connectivity that contribute to ecosystem resilience and sustainability and to apply the results to ecosystem management and protection (Baker et al., 2010). We encourage collaborative studies that include both larval dispersal (one-generation time scale) and population genetics (several-generation time scale), as well as

continued development of technologies to improve our abilities to sample at deep-sea vents.

Acknowledgement

We would like to thank the captain, crew, *Shinkai 6500* team, and all scientists onboard R/V *Yokosuka* cruise YK10-11. The cruise was funded by MEXT (Japanese Ministry of Education, Culture, Sports, Science and Technology) as part of the TAIGA program. U.S. participation on the cruise was funded by NSF OCE-1028862. We thank Thomas Sayre-McCord for analyses of larval swimming velocities, funded by a WHOI Summer Student Fellowship. We thank Kanae Komaki for analyses of current meter data.

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National News

China



Y. John Chen and Jiabiao Li

2011 has been another fruitful year of mid-ocean ridge research in China. Several important areas of progress are as follows:

1. Chinese scientists on board R/V *Dayang Yibao* have completed 7 consecutive ridge cruises and have collected evidence for active hydrothermal vents on the East Pacific Rise, Southern Mid-Atlantic Ridge and the Southwest Indian Ridge. For the first time, the Chinese ROV *Ocean Dragon II* was employed during the survey for hydrothermal vents in the Southern Mid-Atlantic Ridge. The Chinese Deep-tow Side-scan Sonar system (DTA 6000) was also deployed to obtain detailed seafloor topography and side-scan images of the targeted ridge segment.
2. Five test dives were successfully completed to a depth of 5,188 m by the Chinese manned submersible “*Dragon 7000m*” (Figure 1) during a test cruise to the East Pacific in July 2011. Chinese divers performed a series of tasks during these dives, including collecting sediments and rock samples on the seafloor using the mechanical arms. This event was broadcast live on Chinese national TV and generated great public interest in deep-sea research and science. It was another success in public outreach for the Chinese scientific community in recent years, after sending the first Chinese astronaut into space.
3. The Chinese National Natural Science Foundation granted a new 8-year program “South China Sea Deep”, with a total of 150 Million RMB (about US \$24 M), to conduct scientific research on marine, geological, oceanographic and biological processes of the South China Sea. This is the second such major program for the earth sciences in China, following the “North China Craton” program which started in 2008.

4. The 2nd International Ocean Sciences Summer School and PhD Student Forum, focusing on multidisciplinary research of geobiochemical interactions in the ocean and at the seafloor, was held at Xiamen University on 1-7 July, 2011. The summer school admitted 150 formal and 50 audit students, most of them graduate students in all fields of ocean sciences, including marine biology/microbiology, geology/geophysics/geochemistry, ocean chemistry, physical oceanography and ocean engineering. The summer school featured 16 science lectures from the international science community, including ocean ridge researchers Jian Lin, Anna-Louise Reysenbach and Rick Colwell. The lectures and discussion focused on six science themes: (1) Understanding the ocean within the Earth system; (2) The deep sphere: Seafloor and sub-seafloor as a deep and “black” geological and ecological system; (3) Seafloor-ocean interactions: Energy, chemical and biological; (4) Meso-pelagic system: The largest unknown ocean; (5) Upper ocean and air-sea interactions: Their roles in climate change; and (6) Progress towards a holistic view of the Earth as an integrated system of spheres and between geological and biological processes. The

summer school also featured a PhD student forum, poster sessions and outreach science education in two local high schools.



Figure 1: Chinese *Dragon* manned submersible during a test dive in the East Pacific.

France



Jérôme Dymont

Year 2010 was an excellent year for mid-ocean ridge research in France, with nine cruises in all oceans. Year 2011 was not so good in term of cruise numbers, with only four cruises, although compensated by the success of the MoMAR observatory demonstrator, which marks a major turn for the French community.

Cruises MoMARSAT and BIOBAZ took place in June and July 2011 on R/V *Pourquoi Pas?* The purpose of the MoMARSAT experiment (P.I. M. Cannat, J. Blandin, P.M. Sarradin) was to recover and reinstall the MoMAR observatory demonstrator for an additional year on the Lucky Strike hydrothermal site. The observatory includes two SEAMON (Sea Monitoring Node, IFREMER) nodes, dedicated to geophysics and ecology, respectively. The geophysical node, SEAMON West, is made of a cabled deep-sea seismometer (IPGP) and a pressure gauge. The ecological node, SEAMON East, is made of a TEMPO module (IFREMER) – including a video system, a CHEMINI chemical analyzer and temperature probes - and a Fe²⁺ chemical analyzer (NOC). A BOREL buoy (IFREMER) connects the observatory to the world by satellite link for real-time observations. Experiment BIOBAZ (P.I. F. Lallier), "integrated BIOlogy of Bathymodiolus AZoricus", involved the collection of hydrothermal mussels for further experimentation ashore, as the initial step of a pluri-annual project.

Also related to the MoMAR project, cruise HydrobsMoMAR (P.I. Julie Perrot), in June-July 2011 on R/V *Le Suroit*, recovered and re-



Figure 1: R/V *L'Atalante* of IFREMER at dawn in Manzanillo harbour, Mexico, March 2011. Cruise Parisub, P.I. P. Gente. (Photo credit: J. Dymont).

moored the hydrophone network in the SOFAR channel, which has been monitoring the seismicity of the Azores area almost continuously for the last decade.

After a successful initial experiment in 2009, project Oha-Sis-Bio (P.I. Jean-Yves Royer) has moored another hydrophone network in

the southern Indian Ocean, onboard the R/V *Marion Dufresne* voyages during the austral summer 2010-2011. These hydrophones will record the seismicity of the three Indian ridges as well as the presence of marine mammals.

Last but not least, a cruise devoted to the mineral exploration of the French EEZ around Wallis and Futuna Islands in the SW Pacific, and supported by industry, is planned for the end of 2011 onboard R/V *L'Atalante*.

For the sake of efficiency, the four government organizations in charge of parts of the French oceanographic fleet have decided to join efforts and create a unique structure to schedule the fleet and coordinate its evolution. This structure, known as UMS FOF (for "Unité Mixte de Service Flotte Océanographique Française"), was launched in March 2011. At present, there is no information available on cruise schedules for 2012.

Germany



Colin Devey

Despite the fact that the German Science Foundation-coordinated ridge research program SPP1144 ended late in 2009 (or perhaps as a long-term result of this program and its lasting effects on the community), ridge research is alive and well in Germany. In 2011 German scientists will have carried out three cruises to ridge-related targets.

The first was in January and February, when scientists from IFM-GEOMAR in Kiel, together with colleagues from the King Abdulaziz University in Jeddah, Saudi Arabia, made the first cruises in the "Jeddah Transect" project to study the Deeps of the Red Sea rift. Because of the unique brines which fill these rifts, scientists not normally involved in mid-ocean ridge research also participated. Results of particular note include the highest-resolution maps of the Deeps ever produced, which are allowing tectonic/volcanological models for the origin of the Deeps and their brines to be developed. Some volcanic samples were also collected from the spreading axis.

In June and July, an international group of scientists led by Wolfgang Bach from the University of Bremen aboard R/V "*Sonne*" visited

the Manus Basin to study the hydrothermal vents, their precipitates, their fluids and their life. Using the Bremen "*Quest*" ROV the team collected rock, fluid and biological samples and carried out in situ experiments and measurements using, among others, an in situ mass spectrometer.

And finally in November, researchers from IFM-GEOMAR, together with colleagues from the University of Hawaii, will be studying the volcanology and hydrothermal activity of the Northeast Lau Basin spreading axis aboard the R/V *Kilo Moana*, in a joint project with Nautilus Minerals. This represents the first industry-academia joint project for German spreading axis researchers and will no doubt be an informative experience for all concerned. The German scientists are hoping to collect a wealth of bathymetric data over the spreading axis from their deep-diving AUV "*ABYSS*" and so learn more about tectonic and volcanological processes in a back-arc spreading centre.

India



Kamesh Raju

The Indian Ridge program completed the first deep-sea AUV cruise over the Central Indian Ridge in 2010. The cruise was onboard R/V *Sagar Nidhi*, owned by the Ministry of Earth Sciences and operated by the National Institute of Ocean Technology (NIOT), Chennai, India. The AUV *ABYSS*, hired from IFM-GEOMAR, was deployed over the slow-spreading Central Indian Ridge. We surveyed

a 40-mile segment between 10°10'S to 10°50'S. Shipboard multibeam, CTD and MAPR surveys were conducted prior to the deployment of the AUV. The dive locations were selected based on the shipboard multibeam and CTD-MAPR data. AUV dives consisting of two mapping missions and one dive of photography were successfully completed. High resolution bathymetry with 200

KHz Reson multibeam system, temperature, turbidity and Eh data were collected. Based on the CTD-MAPR-AUV investigations, we located a zone of high turbidity and anomalous Eh in the region. We found that the CTD-MAPR-AUV is a powerful combination for the exploration of hydrothermal vents.

We have plans to further explore this segment during future expeditions to the Central Indian Ridge. Excellent cooperation with the *ABYSS* team of IFM-GEOMAR, led by Dr. Nico Augustine, resulted in acquiring high quality data during this cruise. Thanks are due to Prof. Colin Devey and Dr. Klas Lackschewitz for their efficient pre- and post-cruise coordination. This is one fine example of cooperation among the members of the InterRidge community. Scientists, technicians and students from CSIR-National Institute of Oceanography (CSIR-NIO), Goa, the CSIR-National Geophysical Research Institute (CSIR-NGRI), Hyderabad, National Institute of Ocean Technology (NIOT), Chennai participated in this cruise. The project is funded by the Ministry of Earth Sciences, Government of India, New Delhi.



Figure 1: Launching of AUV *ABYSS* from the Indian research vessel *R/V Sagar Nidhi*.

Japan

Kyoko Okino

First we wish to thank you for the message of sympathy from the IR chair following the tsunami disaster on 11 March. InterRidge-Japan members also personally received many sincere mails from IR friends. I would like to take this opportunity to express our thanks. We are deeply shocked by the catastrophic damage caused by the M9 quake and the following tsunami at the northern Pacific coast of our country. After six months, more than 4000 people are still missing and the situation of the nuclear power plant is unpredictable. We are deeply aware that we are fragile and our knowledge is very limited. The impact on our daily life and research activity is immeasurable, but we try to continue efforts to promote ridge-related studies in Japan and to expand our community.

Domestic and International Meetings

An InterRidge-Japan symposium was held on 4-5 November 2010, at the Atmosphere and Ocean Research Institute, University of Tokyo. About sixty scientists participated in the symposium, sharing recent research activities. The second day was dedicated to the international session 'Frontier studies on hydrothermal activities' under the collaboration with a Japan-New Zealand workshop on marine resources. We also had a business meeting on 26 May 2011, at the Japan Geoscience Union Meeting, where we shared information on budget, cruise, workshops and international affairs, and discussed the InterRidge-Japan annual activity plan. We agreed that the annual contribution to InterRidge will be shared by the

TAIGA project and JAMSTEC. We also planned to host the international workshop on 'Ocean Mantle Dynamics: From Spreading Center to Subduction Zones' led by the IR Mantle Imaging WG, 4-6 October 2011.

Ongoing Project "TAIGA" and related cruises in FY2010

The interdisciplinary research project TAIGA, Trans-crustal Advection and In-situ biogeochemical processes of Global sub-seafloor Aquifer, was launched in 2008. The project is funded by MEXT (Ministry of Education, Culture, Sports Science and Technology) from FY2008 to FY2012. We received a high evaluation in a mid-term external review in 2010 and the project is now approaching its final phase.

As we described in the last IR News, we focus on subseafloor fluid advection, which carries huge heat and chemical fluxes from the interior of the earth and supports the growth of biosphere (beneath and on the seafloor). Three integrated study sites have been selected: the southern Mariana Trough as TAIGA of sulfur, the Indian Triple Junction as TAIGA of hydrogen, and the Okinawa Trough as TAIGA of methane. In the southern Mariana Trough, the submersible dive survey was designed using the detailed seafloor mapping by AUV *Urashima*. A new hydrothermal vent was discovered at an off-axis seamount, where the AUV near-bottom survey predicted possible hydrothermal activity. The deep



crust/upper mantle imaging using OBSs and OBEMs was also conducted in the same area. In the Okinawa Trough as TAIGA of methane, the *Chikyu* deep drilling (Exp. 331 <http://www.jamstec.go.jp/chikyu/eng/Expedition/okinawa/exp331.html>) was successful and a large extent of sub-seafloor hydrothermal fluid flow was confirmed, giving a key to understanding the Kuroko-type mineralization. We have also had several cruises to investigate the geological/geochemical/microbiological environments before and after drilling. In the Indian Triple Junction area, previous studies showed the exposure of lower crust/mantle rocks in the area, which may be a key to understanding the hydrogen-rich Kairei hydrothermal field. R/V *Hakubo-maru* visited the Indian Ocean Triple Junction with AUV *r2D4* in November 2010, and integrated AUV surveys, rock dredging, water and plankton sampling in hydrothermal plumes were done. More than fifty scientists joined the project, and many seagoing studies are planned, mainly in the integrated study sites. Further information can be checked at the project web site (<http://www-gbs.eps.s.u-tokyo.ac.jp/~taiga/en/index.html>).

International collaboration in the Lau Basin

Under the US-Japan collaboration, a cruise using R/V *Roger Revelle* was done in the Lau Basin to deploy OBS, OBM and OBEMs (PI D. Wiens, Japanese Scientist: N. Seama). These instruments were successfully recovered using R/V *Kilo Moana* in 2010.

Enhanced interest in seafloor resources

Besides the rehabilitation from the serious earthquake-related disaster, seafloor resources e.g. gas-hydrates, massive sulfides and REEs, attracted great interest in Japan. JAMSTEC launched a project-oriented research division, Submarine Resources Research Project, in April 2011. Coinciding with this, JAMSTEC also plans to build a set of AUV and ROV to promote such research.

Cruises in FY2011

In reaction to the M9 earthquake in March, the operation schedule of our research ships was forced to change drastically. A substantial amount of ship time was devoted to monitoring radioactive levels

offshore from Fukushima in the first couple of months, and many urgent studies including aftershock surveys by OBSs, sea-bottom crustal movement, surface environmental change etc. were carried out and are continuing. In this context, the scheduled R/V *Yokosuka*



Figure 1: Examining samples aboard cruise KH-10-6 at the Indian Ocean Triple Junction.

cruise in the Indian Triple Junction was cancelled this year. Fortunately, the cruises in the Okinawa Trough area will be conducted according to the initial plan. The BMS (Benthic Multi-coring System) drillings were conducted during the *Hakurei-Maru* No.2 cruise in May (PI T. Urabe). Six cruises with ROV *Hyper Dolphin* were planned in the Iheya, Izena and Tarama hydrothermal areas from August to September. The integrated survey of plume detection and near-bottom mapping will be conducted in the Dai-Yon-Yonaguni hydrothermal site using AUV *Urashima* in December. Along the Izu-Bonin backarc rift, the R/V *Hakubo-maru* cruise revealed its rift structure and hydrothermal systems.

As I informed the IR mailing list, Dr. Kensaku Tamaki, Professor at Tokyo University and former InterRidge Chair, passed away suddenly on April 6 at the age of 62 during his stay in New York. He led the Japanese ridge community for many years and it is still hard to realize his sudden passing. His career with some photos and the message to IR colleagues from his wife can be seen at memorial web site: <http://ofgs.aori.u-tokyo.ac.jp/~okino/TamakiMemorial/>

InterRidge-Japan web site (in Japanese): <http://ofgs.ori.u-tokyo.ac.jp/~intridgej/>

Korea

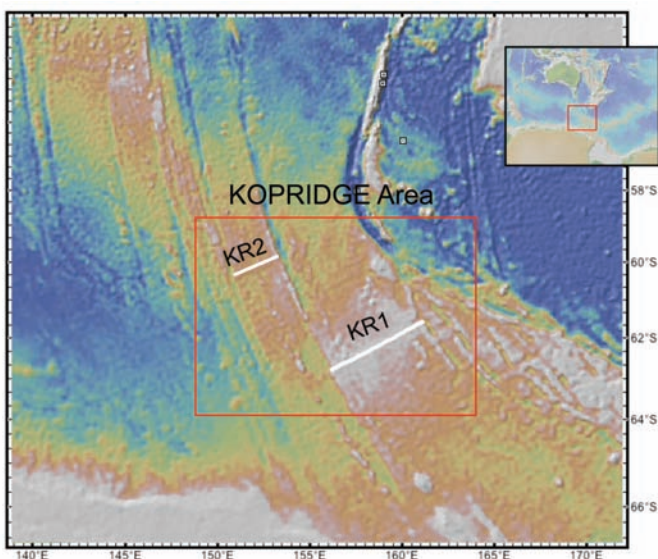


Sung-Hyun Park

KOPRI Cruise (KOPRidge Leg.1)

From 28 Feb - 15 March 2011, the Korea Polar Research Institute (KOPRI) conducted a short survey of two segments at 160°E (KR1) and 152.5°E (KR2) of the Australian-Antarctic Ridge (AAR; Figure 1) using the icebreaker *Araon* (P.I. Sung-Hyun Park). This was an historic cruise because AAR is the largest unexplored expanse of the global mid-ocean ridge system. In very rough sea conditions, we obtained a multi-beam map and 16 rock core samples from the two segments. Also, we found strong signals of hydrothermal venting using MAPR (Miniature Automatic Plume Recorder) profiles from the ridge at both segments. As well as nine Korean scientists, international participants (Charles Langmuir, Harvard University and Jian Lin, Woods Hole Oceanographic Institution) also joined the cruise. Below are some brief results of the cruise.

Figure 1: 2011 KOPRidge area (made from GeoMapApp).



Geomorphology

The spreading rate of the AAR is intermediate and its axial depth is relatively shallow (~2100 m). The axial morphology varies from an axial high (west) to a well-developed rift valley (east) in the KR1 segment, suggesting magma supply has varied on short spatial scales. Magma supply at the western end of the KR1 segment is excessively high and its morphology looks like a plateau. The western end abuts a transform fault with a strike towards the Balleny Islands, providing a possible source of excess magma supply and shallow axial depth. KR2 is deeper than KR1 and can be divided into two segments by an offset. East of this offset is a rift valley, while the western segment has an axial high. A small seamount is located in the north of the western segment. Magma supply has also varied in this segment, but it is lower than KR1.

Rock samples

We obtained fresh glasses from 16 rock cores. Recoveries of rock cores were from 2-50 g. Nine rock cores showed over 20 g of recoveries. Glasses show diverse petrographic characteristics from aphyric to phyric and from vesicular to massive. MgO contents are mostly between 6~7 wt. %. Fe-Ti basalt and dacite were found at the western end of the KR1 segment where magma supply appears most robust. Most samples from KR1 are slightly enriched except one sample from the western end, but the eastern segment is slightly depleted. KR2 samples are more primitive than KR1. All samples from the eastern segment of KR2 (rift valley) are depleted. On the other hand, two of the three samples from the western segment (axial high) are enriched. Enriched samples may be influenced by the seamount in the north of the segment.

Figure 2: Science party of the KOPRidge cruise.



Hydrothermal Vents

We attached MAPR into the wire for rock cores, so we also obtained 16 MAPR profiles from the two segments. In the KR1, it appears that hydrothermal vents are mainly distributed in the central part of the segment. Four MAPR profiles from the central part of KR1 have a strong turbidity anomaly. Among them, one profile shows double peaks with the strongest turbidity anomaly. It appears that hydrothermal activities are very strong in the area. However, any profiles do not show a significant change in oxidation-reduction potential, so vent sources are not very close from the sampling locations. To confine the vent locations more precisely, more MAPR profiles should be obtained. In the KR2 segment, hydrothermal vent signals were mainly found in the western part of the segment. Three MAPR profiles of this part show significant turbidity anomalies up

to 300 m thick near the bottom, with the westernmost profile showing a significant change in oxidation-reduction potential. The source of hydrothermal vents may be located in the west of this site and probably very close. It is worth noting that vent signals were not found in the excessive magma supply area, but in the intermediate magma supply area.

Next Cruise

In December 2011, we will revisit the KR1 and KR2 to obtain more rock core samples, MAPR profiles and multi-beam data (KOPRI Leg. 2). We can confine the hydrothermal vent locations after this

cruise. KOPRI is now making long term plans to survey the AAR including AUV and ROV.

KORDI (Korea Ocean Research and Development Institute) cruises

KORDI conducted two ROV cruises on the Tonga Arc using *Araon*, the first cruise being from 24 Mar- 8 April 2011. The second cruise was from 9-25 April 2011. The main purpose of the cruises was to find proper mining sites. During the cruises, they observed hydrothermal vent biology using ROV and obtained rock and sediments.

New Zealand



Malcolm Clark, Richard Wyszczanski, and Matthew Leybourne

Research voyage

Hydrothermal vent research in the Kermadec Arc continued over the past year. The New Zealand R/V *Tangaroa* spent most of March in the southern Kermadec Arc, surveying volcanoes under a collaborative GNS-NIWA-WHOI research project supported through the New Zealand government Oceans2020 programme. The research is directed at improving understanding of the mineralisation processes associated with the formation of seafloor massive sulphides, which are of increasing interest to mining companies. The geological and geophysical objectives were complemented with biological studies to address the association of faunal communities with the benthic habitat, and their vulnerability to human impact. The survey was both international and multidisciplinary, and deployed a wide array of equipment from the vessel: the WHOI autonomous underwater vehicle *Sentry*, TowCam (a towed seafloor camera system), CTDs, *Tangaroa's* new EM302 multibeam system, magnetometer and gravimeter sensors, and direct sampling using rock dredges and epibenthic sleds.

The survey focused on three core seamounts: Rumble II West, Clark, and Healy, as well as Rumble III, which was a secondary objective. Opportunistic sampling was carried out on Cotton and Lillie, as little data were available from any previous sampling on these features (Figure 1).

From 58 epibenthic sled tows, a total of almost 3700 invertebrate and fish specimens were catalogued during the survey, comprising taxa from 13 phyla. Many groups were infrequently caught, but sponges, anemones, crabs, crinoids, corals, brittle stars, hydroids and polychaetes were found on most seamounts. Ophiuroids were the most numerous, with over 500 individuals recorded from the sled catches. The catch from Lillie seamount was one of the most diverse

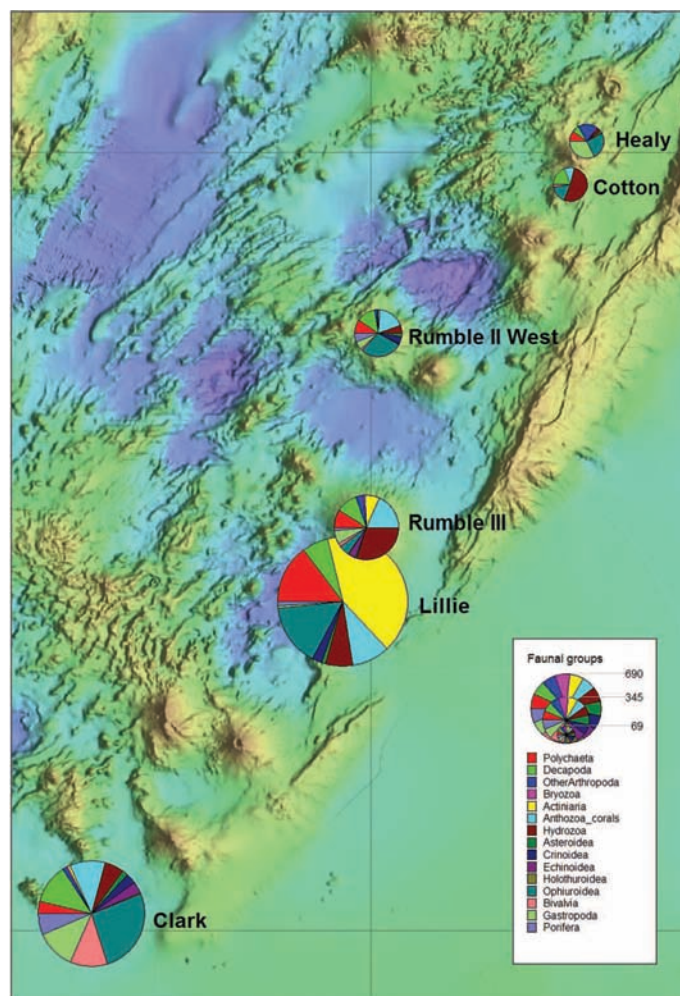


Figure 1: Faunal groups on seamounts in the Kermadec Arc.

and abundant, whereas lower or about equal numbers were recorded in sled tows on Healy, Rumble III and Rumble II West. The specimens collected during the voyage are currently being examined by taxonomists, and it will be some time before formal identifications are completed.

There were marked differences between faunal groups on the various seamounts (Figure 1). Relative abundance was highest at Lillie (numbers of individuals standardised to a tow length of 1 n. mile) where anemones, polychaetes and ophiuroids were abundant. Faunal numbers were also high at Clark seamount, but there the main taxa were more evenly distributed: ophiuroids, corals, bivalves, gastropods and decapods (mainly shrimps, squat lobsters and hermit crabs). Hydrozoans were common on Rumble III as well as on Cotton, whereas ophiuroids were the most abundant fauna on Rumble II West and Healy. Overall numbers of animals were relatively low on these last three seamounts.

Japan - New Zealand Workshop on Seafloor Resources

In November 2010, a workshop was held in Tokyo between New Zealand and Japanese scientists to discuss the future direction of SMS research in Japan and New Zealand. The workshop was held at the University of Tokyo on 1-2 November 2010, and was followed by a two-day field excursion. The fieldtrip was to Misasa mine and surrounding area. This region hosts SMS deposits now exposed on land, and it gave us all a chance to see first hand the type of deposits that we explore on the seafloor.

There were 10 New Zealand participants (including two students) from NIWA, GNS and Victoria University of Wellington. Funding for the New Zealand participants was from the Royal Society of New Zealand. The Japan Society for the Promotion of Science funded the conference and fieldtrip in Japan.

Norway

Rolf Pedersen



Researchers from the Centre for Geobiology (CGB) at the University of Bergen continue to undertake most of the ongoing ridge research activity in Norway. During summer 2011, several CGB research teams returned to the Arctic ridges. This year the focus was on the Mohns Ridge near the volcanic island of Jan Mayen. The team, which also included researchers from University of Washington, ETH Zürich and University of Girona, returned for more detailed sampling of the two hydrothermal fields discovered in 2005. An overriding focus for this summer's cruise activity was to use the natural CO₂ leakage from these relatively shallow hydrothermal fields to test gas sampling and sensors, and in particular the use of acoustic methodologies to detect and quantify seafloor CO₂ leakages. Such methodologies are also relevant for

CGB's participation in CO₂-related projects such as the collaborative EU project, ECO₂ that focuses on the safety of subseafloor CO₂ storage and monitoring strategies.

The teams continued to use and develop AUV procedures for detailed imaging of the seafloor, using a combination of multibeam echo sounder and side scan sonar systems, as well as photo mosaicing. This year we particularly tested the use of synthetic aperture sonar (HISAS) mounted on a Kongsberg Maritime HUGIN AUV (see Figure 1). As with previous cruises, CGB researchers continued to be active in sampling and characterization activity that is relevant for bioprospecting.

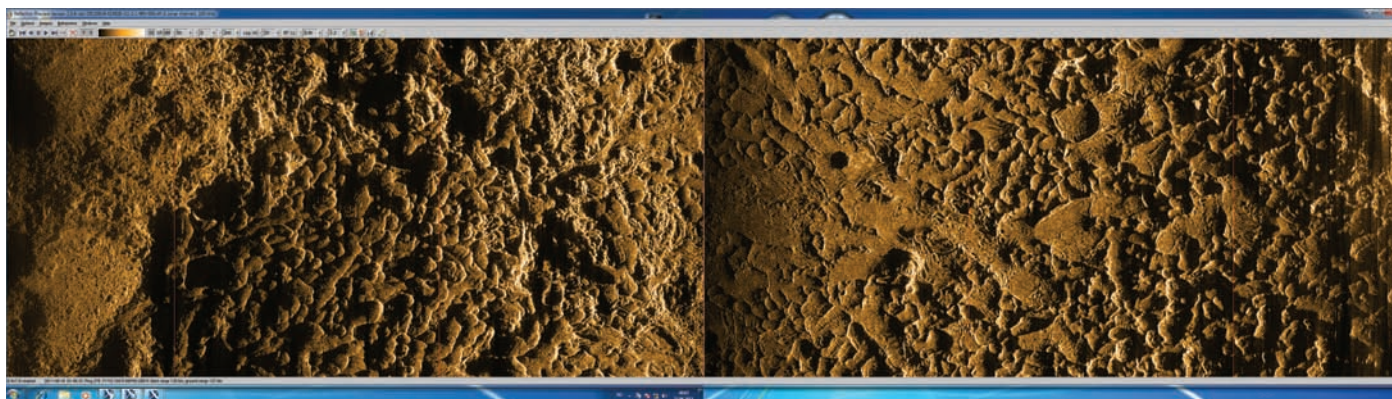


Figure 1: Pillow lava: image using synthetic aperture sonar (HISAS) mounted on a Kongsberg Maritime HUGIN AUV.

Philippines



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

Dr. Yumul has submitted a paper by way of reporting on work done in the Philippines in 2011. Please see: “*Oceanic and continental margin terranes at the Sundaland-Philippine Sea Plate collision boundary: Preserved*

evidence on northwestern Mindoro, Philippines” in the International Research section of this volume.

Russia



Sergei Silantyev

Russian ridge cruises in spring-autumn 2011 included: R/V *Professor Logachev* (Polar Marine Geological Expedition - PMGE, Ministry of Natural Resources) at the Mid-Atlantic Ridge (MAR) between 12°-20°N, in an area claimed for the prospecting of polymetallic sulfides by the Russian Federation at the 17th Session of the International Seabed Authority (11-22 July 2011, Kingston, Jamaica). Multidisciplinary explorations in the Northern Atlantic and Western Arctic region were continued by R/V *Akademik Nikolai Strakhov* (Geological Institute, RAS).

The biennial workshop of Russian-Ridge was held in Moscow on 1-2 June 2011 at the Institute of Ore Deposits, Petrography, Mineralogy and Geochemistry of Russian Academy of Sciences. The topic of this workshop was “Main Results in Russian Study of the Mid-Oceanic Ridge Processes in First Decade of XXI”. Scientists from different Russian scientific centres participated and presented results obtained during the first decade of the new century. We would like to highlight the following:

Big hydrothermal cluster including ore deposits have been discovered during 2000-2011 in the MAR rift valley between 12°58'N and 14°45'N (Ashadze (12°58'N), Semenov (13°31'N) and to the north of this region (Krasnov (16°38'N), Peterburgskoye (19°52' N) and Zenit-Victory (20°08' N)).

Many Russian scientific centres participated in these expeditions, and onshore investigations.

Big dataset on petrology and geochemistry of different rocks, composed of oceanic core complex widespread at MAR axial part between 13°-15°N, was obtained and published (with IFREMER and IPGP-CNRS UMR, France).^{1,2,3,4,5}

Collections of plutonic rocks were made during cruises 22 and 26 of the R/V *Professor Logachev*, Cruise 41 of the R/V *Akademik Mstislav Keldysh*, and the Russian-French expedition *Serpentine* aboard the R/V *Pourquoi pas?*. The data obtained suggest that the oceanic core complexes of the Ashadze and Logachev hydrothermal fields were formed via the same scenario in the two MAR regions.

On the other hand, the analysis of petrologic and geochemical characteristics of the rocks indicated that the oceanic core complexes of the MAR axial zone between 12°58' and 14°45'N show a pronounced petrologic and geochemical heterogeneity manifested in variations in the degree of depletion of mantle residues and the Nd isotopic compositions of the rocks of the gabbro-peridotite association. The trondhjemites of the Ashadze hydrothermal field can be considered as partial melting products of gabbroids under the influence of hydrothermal fluid. It was supposed that the presence of trondhjemites in the MAR oceanic core complexes could be used as a marker for the highest temperature deep-rooted hydrothermal systems. Perhaps, the region of the MAR axial zone, in which petrologically and geochemically contrasting oceanic core complexes are spatially superimposed, served as sites for the development of large hydrothermal clusters with a considerable ore-forming potential.

For the first time the oceanic core complex from MAR-Sierra Leone RTI (5°-6°N) was sampled and studied.^{2,3}

A big sample collection representing all rock types composed of MAR axial zone between 5°-6°N has been studied. These samples were collected during the 10th cruise of R/V *Academic Ioffe* and the 22nd cruise of R/V *Professor Logachev*. The MAR region near its intersection with Sierra Leone FZ is a typical example of oceanic core complex with wide development of extension structures, including various faults and fragmented rift valleys. The area is characterised by extensive outcrops of altered mantle peridotites and gabbroic rocks; fresh basaltic pillow lavas play a subordinate role here. The majority of the studied plutonic rocks form the main trend of regular change in the compositions, from troctolites through olivine gabbros, gabbros and gabbronorites to diorites. It was proposed that the formation sequence of the oceanic crust in MAR between 5°-6°N was realized at three major episodes: (1) Formation of two types of plutonic rocks: primitive gabbro derived from MORB-parental melts, and Fe-Ti-gabbro related to siliceous Fe-Ti oxide series; and 2) The recent eruptions of fresh pillow lavas MORB-type with chilled glassy margins.

The U-Pb dating of Zr from oceanic plagiogranites and associated gabbroic rocks from two MAR oceanic core complexes (12°58'N and 5-7°N) were carried out.^{1,2,3,5}

In recent decades, progress in the application of methods of isotope geology for dating the rocks of oceanic basement was related to the study of behavior of U-Pb system in zircon extracted from gabbroids and associated oceanic plagiogranites. The isotopic study of zircons from gabbros of the axial MAR zone at 5°-6°N (Markov deep) using laser ablation showed that all samples of gabbroites dredged in this area from the same dredging site contain zircons with very young ages, up to 1-2 Ma. The U and Pb isotope composition of zircon from the same collection was previously analysed using a SHRIMP ion microprobe. Based on this study, two zircon generations were distinguished in these rocks: young zircons and very old with ages up to 3170 Ma. The U-Pb dating and Lu-Hf isotope analysis of zircon grains extracted from trondhjemites and host gabbros in the oceanic core complex of the Ashadze hydrothermal field (MAR, 12°58'N) demonstrated that zircons both from trondhjemites and gabbros are dated at close to 1 Ma. It should be especially emphasised that zircons from trondhjemites of the Ashadze field are similar to those extracted from associated gabbros in terms of trace element distribution. Available data on the age of zircon from felsic rocks and associated gabbros indicate that the best statistically justified U-Pb age determinations are ages of MAR plagiogranites within the range of 0.76-1.95 Ma. This age obviously marks the oceanic plagiogranites as being related to the late magmatic stage of the evolution of the oceanic core complexes of MAR. The proportions of felsic rocks that compose the oceanic core complexes make it possible to believe that oceanic plagiogranites were formed at the final stages of their magmatic evolution. Therefore, the same age data on zircons indicate that exhumation of the oceanic core complexes of MAR began no earlier than this time.

New data on chemistry and mineralogy of the ore edifices from different Atlantic hydrothermal fields were obtained.^{2,5,6}

Research of fluid inclusions in minerals from samples, selected during the 32nd cruise of R/V *Professor Logatchev* at the Semyenov-4 and Semyenov-5 hydrothermal fields (13°31'N) in the Central Atlantic was carried out. Physicochemical parameters of hydrothermal ore-forming processes have been defined by means of the analysis of fluid inclusions in barite from sulfide ore samples and in anhydrite from samples of ore edifices (hydrothermal field Semyenov-5). A comparison of results of this study, with data available from a near located hydrothermal field, has shown that clear differences of temperature and salinity of fluid exist in fluid inclusions from sulfides composed of ore edifices widespread in the hydrothermal cluster at MAR between 13° and 15°N.

The high-precision MC-ICP-MS method of Pb-isotope analysis has been applied to the study of sulfides from four hydrothermal fields in MAR between 12°58'-16°38'N: Ashadze, Semenov, Logachev, and Krasnov. The Pb-isotope characteristics of studied sulfides permit participation of two mantle sources of Pb (DMM and HIMU) in their formation, the first being prevalent. Obtained results

demonstrate also that sulfides from examined hydrothermal fields are similar to MORB by their Pb-isotope composition.^{2,5}

The study of metallic-ferrous and ore-bearing sediments located within northwestern (active) and eastern (non-active) hydrothermal fields of the Semenov ore deposit was the first for data on lithology and biostratigraphy of sediment cores sampled in the Semenov field.^{1,3,5,7}

Geodynamic model of serpentinite-hosted hydrothermal systems was proposed on the basis of numerical modeling as well as empirical data.¹

Kinetic and thermodynamic simulation of the interaction of seawater and its metamorphosed derivatives with peridotites and gabbros in the slow-spreading ridges have been used for reconstruction of phase transformations and matter balance in serpentinite-hosted hydrothermal systems. Simulations were carried out on a simplified vertical crustal section of a slow-spreading ridge of the Hess type that consists only of mantle peridotites (spinel harzburgites). Main results of modeling allow the proposal of the geodynamic model for formation of the Serpentinite Hosted Hydrothermal Systems (SHHS). The simulated mineralogical facies of hydrothermally modified slow-spreading ridge peridotites are in good agreement with the stability fields of secondary minerals in the MSH system. The proposed model suggests that differences in the compositional parameters of hydrothermal vents at the different SHHS are predetermined by the different depths of the corresponding hydrothermal circulation systems. The same modeling was used to reconstruct the geochemical and mineralogical trends of evolution of gabbros during their hydrothermal interaction with marine fluid. The results of simulation offered a new insight into some problems of material balance and ore formation during hydrothermal processes in the slow-spreading ridges.

Modeling of the geodynamic processes in the oceanic spreading center.⁸

The main approach in this study was the method of numerical and analogous modeling of processes of oceanic crust accretion and structure-forming in spreading zones. There are three main factors controlling formation of crustal magmatic chambers and zones of focused mantle upwelling in axial zones of mid-oceanic ridges: spreading velocity, mantle temperature, and intensity of magmatic supply. Thickness of crust can possibly indicate the last one. Relationships of these factors can vary significantly in different geodynamical regimes of spreading. Finally, they determine the presence or absence of magmatic chambers and their shape and extent. Experimental thermo-mechanical modeling of accretion processes gives an opportunity to establish qualitative connections between thickness of axial lithosphere and the extent of its heating, with peculiarities of segmentation and structure forming in various spreading regimes. Processes of topography formation in zones of slip and extension were studied by this method. It was concerned also with various processes including formation of transform and non-transform offsets of rifting axis. Colloidal systems composed

on the basis of solid and liquid hydrocarbons were applied as experimental materials. Tests were conducted on the experimental complex, including a reservoir with moving wall and a system of internal heating of model material. An electromechanical engine provided movement of the wall with predefined velocity. Experiments replicated different spreading conditions with different velocities and directions of extension, thickness of model lithosphere, width of heating zone and amplitudes of offsets. In this study, the following problems have been considered: formation of axial spreading zones and their stability; formation of transform and non-transform offsets of the rift valley; definition of peculiarities of accretion and off-axial topography of rift valley; and interaction of spreading ridges with hotspots.

New data on geochemistry of hydrothermal vent ecosystems and species diversity of vent communities were obtained.⁴

General patterns of vertical distribution of hydrothermal vent communities were analysed. Two main groups of hot vent communities can be distinguished: «shallow-water» - occurring shallower than 200 m and «deep-water» lying deeper than 200 m. In deep-water communities, symbiotrophic species play an important role in biomass, in shallow-water ones their role is not important. It is suggested that below 4000 m the structure of hot vent communities changes since some vent-obligate taxa do not occur at such great depth.

The distribution of chemical elements in biotic and abiotic ecosystem components at six hydrothermal vent fields at the Mid-Atlantic Ridge (Menez Gwen, Rainbow, Lost City, Broken Spur), the East Pacific Rise (9°50'N) and the Guaymas Basin has been studied. Samples were collected during the 49th and 50th cruises of the Russian R/V *Akademik Mstislav Keldysh* (with *Mir-1* and *Mir-2* submersibles). For the first time, by using a unified approach of collection and chemical analysis, data on the elemental composition

of not only the organisms (n=250) but the environment as well (suspended particulate matter, fluids, biotope water) were obtained. The Fe, Mn, Zn, Cu, Co, Ni, Cr, Pb, Cd, Ag, As, Sb, Se and Hg concentrations in the samples were determined by atomic absorption (flame and flameless) spectroscopy (AAS), instrumental neutron activation analysis (INAA), and inductively coupled plasma-atomic emission spectroscopy (ICP-AES).

“Mantle windows” and non-magmatic spreading in the South-East Indian Ocean.^{5,7}

This study is based on about 16,500 km of MCS, gravity and magnetic data as well as 40 sonobuoys, which were acquired in the South-Eastern Indian Ocean - on the East Antarctic margin conjugated with Australia (between 102°E and 152°E) during four cruises of Russian R/V *Akademik Karpinsky*. Interpretation of these data combined with data collected previously by USA, Japan, France and Australia (in total about 30,000 km of MCS lines) gives a good basis for understanding the complex crustal structure and tectonic evolution of the studied region. The studied Antarctic margin developed as a result of extreme crustal extension and syn-rift mantle unroofing, culminating in the formation of peridotite/gabbro highs and ridges. The zone of mantle unroofing (transitional crust) has a width of 100-150 km and is well defined by a positive linear gravity anomaly.

¹Vernadsky Institute of Russian Academy of Sciences; ²Institute of Ore Deposits, Petrography, Mineralogy and Geochemistry of Russian Academy of Sciences; ³Geological Institute of Russian Academy of Sciences; ⁴Shirshov Institute of Oceanology of Russian Academy of Sciences; ⁵PMGE, Ship owner of R/V *Professor Logachev*, Ministry of Natural Resources; ⁶Institute of Geology and Mineralogy of the Siberian Branch of Russian Academy of Sciences; ⁷VNIIOkeangeologia, Ministry of Natural Resource; ⁸Moscow State University.

SOPAC Division of the Secretariat of the Pacific Community

Akuila Tawake

SPC-EU Deep Sea Minerals Project Implementation Update

The discovery of 'high grade' Seafloor Massive Sulphide (SMS) deposits and the recent granting of commercial mining leases in Papua New Guinea (PNG) territorial waters have triggered growing interest in marine polymetallic deposits, including manganese nodules and cobalt-rich crust throughout the Pacific Islands region. This has resulted, within a space of five years, either applications for, or granting of, exploration licenses in Fiji, Vanuatu, Solomon

Islands, New Zealand, Papua New Guinea, Palau and Federated States of Micronesia, with additional interest being expressed for exploration within the waters of the Cook Islands and Kiribati.

In response to the growing interests in deep sea minerals exploration and mining in recent years within national jurisdiction of the Pacific Islands region, the Secretariat of the Pacific Community (SPC) has proposed a regional approach to addressing the aforementioned issues. This was endorsed by member countries, the Pacific Island Forum Secretariat (PIFS) and the European Union (EU). As a result,



Figure 1: Participants at the Inaugural DSM Project Regional Workshop, Nadi, Fiji.

the EU has agreed to provide financial support under the 10th European Development Fund to SPC for the implementation of the SPC-EU EDF10 Deep Sea Minerals (DSM) Project.

The overall objective of the project is to expand the economic resource base of Pacific ACP States by developing a viable and sustainable marine minerals industry. The specific purpose is to strengthen the system of governance and capacity of Pacific ACP States in the sustainable management of their deep sea mineral resources through the development and implementation of sound and regionally integrated legal, fiscal and environmental frameworks, improved human and technical capacity and effective monitoring systems.

The DSM Project officially commenced with the signing of the Contribution Agreement between the European Union (EU) and

the Secretariat of the Pacific Community (SPC) on 6 August 2010 in the margins of the Pacific Islands Forum Leaders meeting in Port Vila, Vanuatu. Additionally, the inaugural DSM Project regional workshop: “High Level Briefing on the Status of Deep Sea Minerals in the Pacific Islands Region and Planning for a Regionally Integrated Way Forward” was held in Nadi, Fiji, on 6-8 June and was attended by various stakeholders within and outside the region. A total of 97 participants attended the workshop (Figure 1).

The main objectives of the workshop were to present the SPC-EU Deep Sea Minerals (DSM) Project and to provide an opportunity for country representatives to be briefed on various aspects of deep sea minerals. A full report can be viewed at:

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

UK



Richard Hobbs

My interest in being the new UK correspondent for InterRidge stems from my research having an underlying theme of using remotely sensed data to understand the subsurface. In particular, how well one can quantify the uncertainty in the model given the observed data and the risky topic of how well does the model actually represent the real subsurface. My recent research has focused on using seismic data to map thermohaline structure in the oceans, and the development of joint inversion with Bayesian based

uncertainty analysis for combinations of seismic tomography, magnetotelluric and gravity data.

So why the sudden interest in ridges? Many years ago I was the director of the British Institutions Reflection Profiling Syndicate (BIRPS) and, together with colleagues from the US, we acquired the first 3D seismic survey of the overlapping spreading centre at 9°N on the East Pacific Rise (a.k.a. ARAD survey). About 6 years ago I

met up with Vincent Tong (UCL), a student who worked on the ARAD data at Cambridge and, together with Christine Pierce (Durham), hit upon the idea of looking in detail at the early evolution of the ocean crust and the role of hydrothermal fluids using a joint geophysical approach. Since then the project has grown, with additional input from contacts in oceanography (Miguel Morales Maqueda and David Smeed (NOC), Christopher Ballentine (Manchester)) into an inter-disciplinary project - OSCAR - that will examine the role of fluids in ocean crust formation and their subsequent discharge and heating of the abyssal ocean.

The target is the Costa-Rica Ridge in the Panama Basin. The principal reasons for the choice were: the ODP hole 504B that will provide 'ground-truth' of the evolution of layer 2 from the ridge to borehole, based on high-resolution geophysics which, requiring profiles of only ~200 km from the ocean ridge, is practical; and the shape of the Panama Basin, bounded on the north-west and south by ~2000 m high ridges formed by the Galapagos hot-spot, and to the north-east and east by Central and South America. There is a known source of cold water in-flow along the Ecuador Trench and the only way out is through mixing and uplift caused by thermal heating which, we hypothesise, is largely driven by hydrothermal circulation.

The Irish-led VENTuRE scientific expedition aboard the national research vessel R/V *Celtic Explorer* (CE11009) has discovered a previously uncharted field of hydrothermal vents along the Mid-Atlantic Ridge, the first to be explored north of the Azores. The mission, led by Andy Wheeler of University College, Cork (UCC), together with Bramley Murton and Darryl Green from the National Oceanography Centre and Jon Copley and Verity Nye from the University of Southampton, UK, and scientists from NUI Galway and the Geological Survey of Ireland, discovered the vent site at a depth of 3,000 m using the Remotely Operated Vehicle (ROV) *Holland 1*. The expedition was supported by the Marine Institute, Ireland and the National Geographic Society, who filmed the work for inclusion in an upcoming National Geographic Channel series, '*Alien Deep*', premiering globally in 2012. A paper on the Moytirra vent field is in the International Research section of this volume.

In November-December, Jon Copley is planning to dive with an ROV on the vent field on the SW Indian Ridge that was discovered by a Chinese research cruise in 2007 (cruise JC67 and will follow Alex Rogers' cruise (JC66)) studying SWIR seamounts. This will be the third vent field on an ultraslow-spreading ridge to be sampled for biological investigations, after Mohn's Ridge and the Mid-Cayman Spreading Centre. The fauna photographed by the *ABE* AUV during the 2007 cruise suggest possible similarities to the assemblages that a UK Consortium has found on the East Scotia Ridge, and samples will be collected to determine the taxonomy and molecular phylogenetics of SWIR vent fauna for the first time.

The NERC-Funded UK-GEOTRACES Consortium is investigating the fluxes of micronutrient metals such as iron and zinc to the highly productive region of the South Atlantic around 40°S. This is a region

where life flourishes in the surface ocean, but where the source of the required micronutrients is uncertain. In the deep ocean at this latitude, waters are flowing northward to provide micronutrients to the productive equatorial Atlantic, and southward to the micronutrient-starved Southern Ocean. So understanding micronutrient fluxes at 40°S has implications on a much wider scale. Micronutrient fluxes to the South Atlantic may come from dust, rivers, sediments, or the Mid-Atlantic Ridge (MAR). As part of a research cruise in January 2012 on board the RRS *James Cook* (JC68 - PI Gideon Henderson), consortium members will seek to assess the relative importance of these fluxes. This will involve extensive water-column and sediment sampling over the MAR. In the water, the combination of multiple chemical tracers, together with measurements of the micronutrients themselves, will constrain the fluxes of metals such as iron from on- and off-axis venting to the oceans in particulate and dissolved phases. This work will indicate the role of the South Atlantic MAR in influencing ecosystems and the carbon cycle over a wide swathe of the Atlantic.



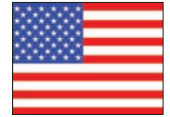
Figure 1: Recent picture of the new *Discovery*, currently being built by C.N.P. Freire, SA at Vigo, Northern Spain. The new ship will join the NERC research fleet in mid-2013 ready to undertake ridge-related science. (Source: Edward Cooper, NERC).

The *James Clark Ross* cruise (JR275) forms part of the British Antarctic Survey (BAS) core EvolHist work package which will be a joint cruise with the JR259 leg and the Halley Research Station relief, sailing from Stanley, Falkland Islands (51°42'S 57°51'W) to the Filchner Trough area (~72°00'S, ~35°00'W) and back. While the target research area for JR275 is the Filchner Trough, the marine geophysical cruise JR259 is targeting sites in the South Scotia Ridge (SSR) and southern South Sandwich Islands (SSI). During JR259 (PI Philip Leat) will survey very poorly known parts of the Scotia Sea using an EM122 multibeam echosounder and sea floor sampling. Target areas will be segments of the West Scotia Ridge spreading

center which stopped spreading at 6 Ma but which erupted post-spreading alkaline lavas at 300 ka, the South Scotia Ridge, a transform plate boundary between Weddell Sea and Scotia Sea

oceanic plates, and active seamounts of the southern South Sandwich arc and associated East Scotia Ridge back-arc spreading centre.

USA



Dan Fornari, Ridge 2000 Chair, WHOI

The Ridge 2000 Program in the US formally ended at the start of FY2011. While dedicated funding for R2K science ended in late 2010, NSF program managers have indicated that R2K scientific goals remain a priority and the ~\$4 million in targeted R2K funding originally slated to continue through 2011 would be reprogrammed into the overall NSF OCE research funds. Field and laboratory programs with MOR foci would be considered for any site along the global MOR, not just the R2K Integrated Study Sites (ISS). Important research efforts are still required to complete analysis of recently collected R2K data, and complete, report, integrate and synthesize results from R2K activities. All of these efforts will help to ensure optimal scientific utilization of the large quantity of R2K data archived in the MGDS R2K Data Portal¹ and other applicable data repositories.

The community workshop, held in fall 2010 in Portland, OR, stimulated R2K investigators and other researchers to share and integrate data across disciplinary and geographic boundaries. Researchers who participated in the 2010 meeting working groups are collaborating on data comparisons including topical and ISS geographic syntheses and modeling of MOR processes to provide new insights on how spreading centers operate at all levels. These studies will lead to publications in peer-reviewed journals that will serve as part of the intellectual legacy of R2K. In addition, a special issue of *Oceanography Magazine*, focused on R2K research results will be published in March 2012. Manuscripts are currently being received by the co-editors of the special issue (S. Beaulieu, D. Fornari, J. Holden, L. Mullineaux and M. Tolstoy) and are being sent out for review prior to compilation and layout of the special issue.

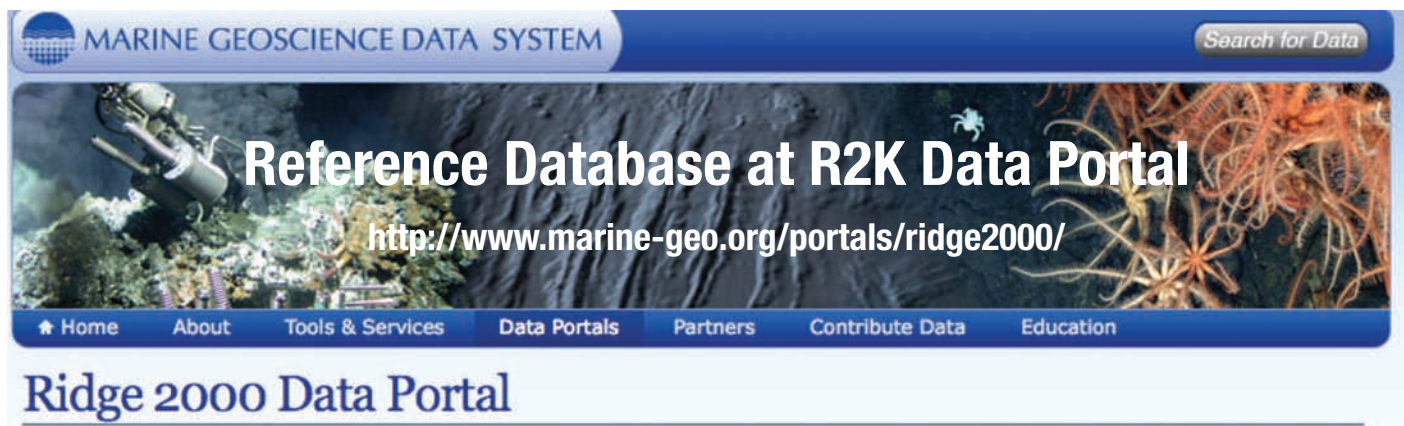


Figure 1: Reference database developed by LDEO-MGDS and R2K Office staff.

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

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

Studies Sites (ISS) and elsewhere). All environmental metadata and field data from R2K-funded cruises are archived and discoverable through the R2K Data Portal¹. Over the past 12 months, a large volume of new derived data has also been submitted.

Ridge 2000 Program Priorities

The highest priorities for post-Ridge 2000 Program activities are to capitalize on new insights gleaned from recently collected data through additional field and laboratory studies, modeling efforts to describe MOR processes in quantitative or conceptual models, and synergistic, multidisciplinary studies that compare geological, biological or geochemical aspects of MORs between and within ISS and other oceanic spreading centers. Research that will help fulfill R2K Program objectives includes:

- Research that synthesizes existing datasets within and across ISSs to achieve greater understanding of how all or parts of oceanic spreading centers operate. This includes all relevant ISS, TCS (Time Critical Studies), in addition to well-constrained data sets from other sites.
- Integrating different observations into conceptual, semi-quantitative, and/or quantitative models to help understand the forcing functions of ridge crest phenomena and their responses to changing conditions and perturbations.
- Collecting missing critical data that will inform how all or parts of oceanic spreading centers operate and/or are essential to developing or proving various models or ideas.
- Continued discovery of important multidisciplinary processes related to oceanic spreading centers. The TCS component of R2K is especially well suited to facilitating this type of discovery activity.

Ridge2000 related US cruises

Although there will be no umbrella organization in the U.S. to coordinate MOR research in 2012, several other programs are ongoing and include field studies at ridges. First, the National Science Foundation's Ocean Observatories Initiative (OOI) is establishing a Regional Scale Node (RSN) at Axial Volcano on the Juan de Fuca Ridge. An RSN network of observatories, including cabled arrays of sensors on the seafloor and up into the water column, will span the Juan de Fuca plate. An OOI cruise with R/V *Thompson* (Aug. 20 - Sept. 1, 2011), led by John Delaney and Deb Kelley of University of Washington, streamed live HD video from ROV ROPOS dives to Axial Volcano: <http://www.interactiveoceans.washington.edu/visions11>.

Just prior to the OOI cruise, an eruption was discovered at Axial Volcano and investigated by two expeditions: on R/V *Atlantis* with ROV *Jason II* led by Bill Chadwick, and on R/V *Western Flyer* with ROV *Doc Ricketts* led by David Clague. The last eruption at Axial Volcano occurred in 1998. Chadwick and Scott Nooner had been monitoring Axial Volcano for more than a decade, and in 2006 published a paper in the *Journal of Volcanology and Geothermal Research* in which they forecast its eruption before the year 2014. Other Legs of the MBARI 2011 Pacific Northwest Expedition visited North Cleft, Coaxial Seamount and the Endeavour segment of the Juan de Fuca Ridge. (<http://www.mbari.org/expeditions/Northern11/index.htm>). The Ridge 2000 ISS at Main Endeavour Field is a cabled observatory in the NEPTUNE Canada program.

The Center for Dark Energy Biosphere Investigations (C-DEBI) Program (<http://www.darkenergybiosphere.org/research/schedule.html>) is also funding cruises to MORs. C-DEBI is an NSF-funded

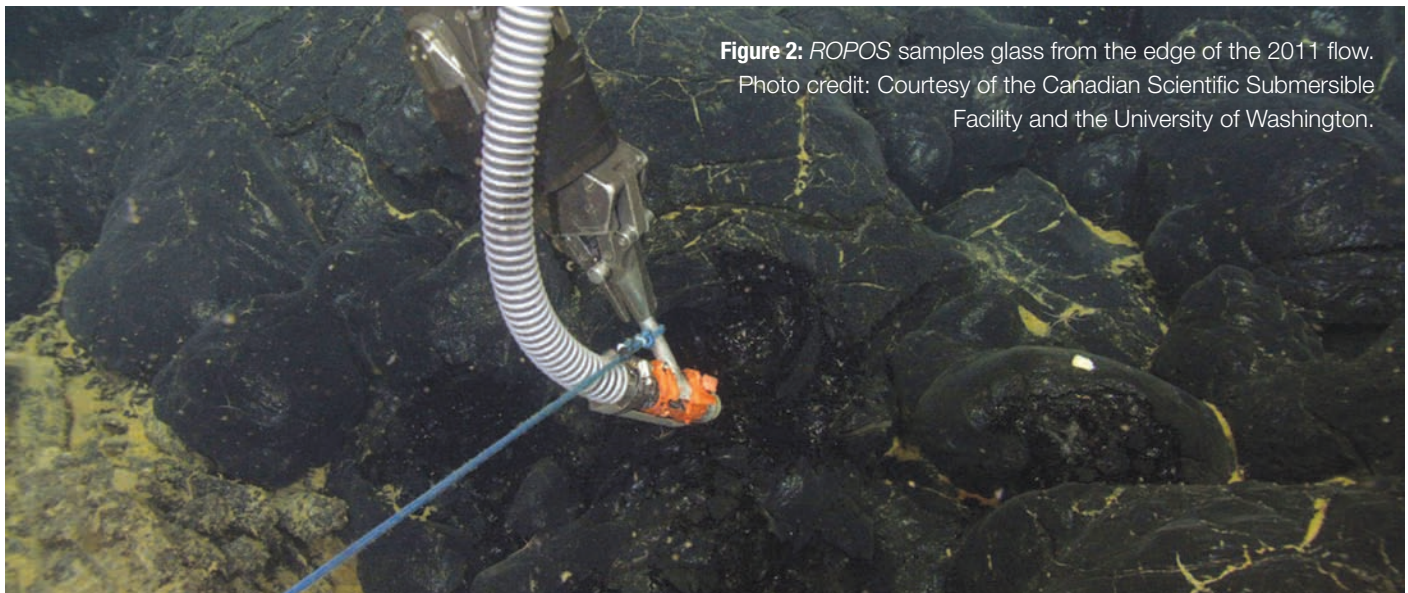


Figure 2: ROPOS samples glass from the edge of the 2011 flow. Photo credit: Courtesy of the Canadian Scientific Submersible Facility and the University of Washington.

¹The R2K data portal is administered by the Data Management Office (DMO), part of the Marine Geophysical Data System (MGDS) at Lamont-Doherty Earth Observatory (LDEO). See: <http://www.marine-geo.org/portals/ridge2000/> <http://www.marine-geo.org/portals/ridge2000/docs.php#data>

Science and Technology Center on the deep biosphere, with the mission to explore life beneath the seafloor and make transformative discoveries that advance science, benefit society, and inspire people of all ages and origins. Cruise AT18-07 led by Keir Becker on R/V *Atlantis*, 26 June-14 July 2011, was a direct follow-on to IODP Expedition 327, when subseafloor observatories (CORKS) were placed on the eastern flank of the Juan de Fuca Ridge. This cruise had a number of education and public outreach components, including the “Adopt a Microbe” project (<https://sites.google.com/site/adoptmicrobe3/>). IODP Expedition 336, North Pond - Mid-Atlantic Ridge Microbiology, is scheduled for 17 Sept-20 Nov 2011, with co-chief scientists Katrina Edwards (U.S.) and Wolfgang Bach (Germany): http://iodp.tamu.edu/scienceops/expeditions/midatlantic_ridge_microbio.html).

Other funding agencies have sponsored U.S. ridge research, including NOAA Ocean Exploration, which featured two expeditions on the NOAA Ship *Okeanos Explorer* in 2011: Leg 2 of the GALREX 2011 expedition to the Galapagos Rift, 8-28 July 2011 (<http://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/welcome.html>), and an expedition to the Mid-Cayman Rise, 2-14 August 2011 (<http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/welcome.html>). The Mid-Cayman Rise research was conducted in partnership with U.K. scientists, both on-shore and at sea, and also benefited from recent cruises and data provided from France and Japan. Other sponsors of the Mid-Cayman Rise studies included NASA ASTEP (Astrobiology Science and Technology for Exploring Planets).

Additional information on Ridge 2000 related cruises can be found at: <http://www.ridge2000.org/science/index.php>. The UNOLS

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

R2K Distinguished Lecture Series (DLS) Speakers

The Ridge 2000 Distinguished Lecture Series ended in 2010-2011. By all measures it was a very successful outreach program that brought the excitement of a diverse cross section of mid-ocean ridge research and technology to students at many small US colleges and universities. DLS program information and past speakers and venues are available at: http://www.ridge2000.org/dls/speaker_list.php

Ridge 2000 Education & Outreach Activities (E. Goehring, Penn. State Univ.)

No new Education & Outreach Activities took place in CY2011 as there was no funding in the R2K budget to support these activities. Past activities and materials are summarized at the following websites.

- <http://flexe.psu.edu> (FLEXE project overview, including access to curriculum and login to FLEXE system).
- http://flexe.psu.edu/forum_archive (archived versions of FLEXE Forums, so that information may be accessible until a live version/format is made available through GLOBE).
- <http://classic.globe.gov/projects/flexe> (original FLEXE project page on GLOBE site will be moved to new GLOBE site when it is available).

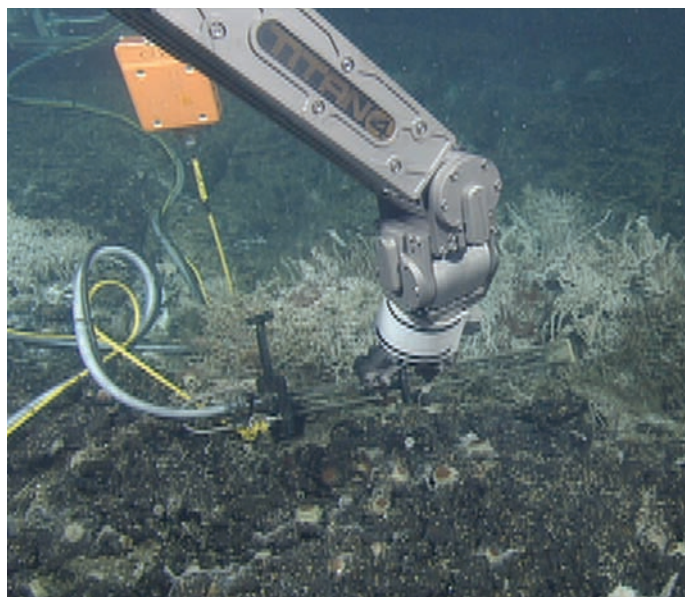
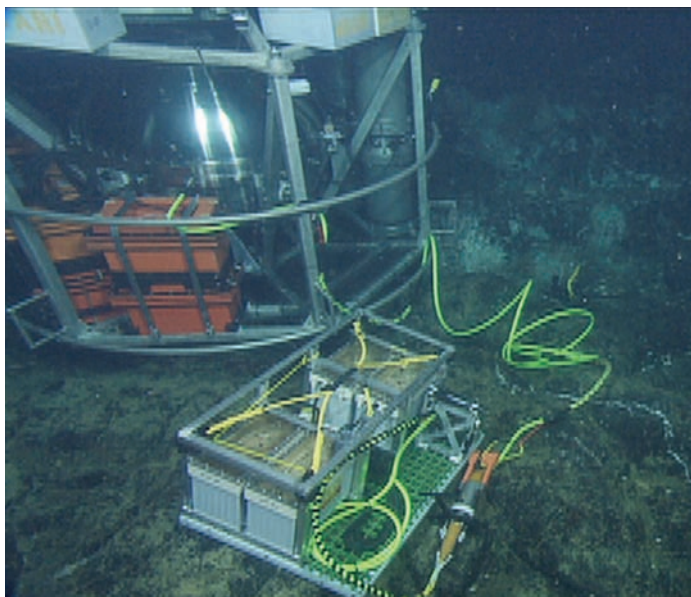


Figure 3 & 4: The MBARI Expedition to Axial Seamount also included deployment of the Deep Environmental Sampling Processor (Deep-ESP). Photo courtesy Chief Scientist Peter Girguis.

Working Group Updates

Hydrothermal Energy Transfer: its Impact on the Ocean Carbon Cycles

InterRidge WG jointly with SCOR WG 135



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

The WG has welcomed a new associated member, Dr Sylvia Sander, from Marine and Freshwater Chemistry, Department of Chemistry, University of Otago, New Zealand. She is a specialist in trace metal speciation in natural aquatic systems and has published several papers on the complexation of metals issued from vents by organic ligands (Sander and Koschinsky, 2011). Beyond providing a very important and complementary scientific expertise, she will add to the international representation of the WG. New Zealand is indeed part of the South Pacific countries that were previously under-represented in our WG.

The annual meeting took place in Hangzhou, China 10-11 October 2011. It was hosted by Xiqiu Han at the 2nd Oceanographic Institute of China. As presented in the WG terms of reference and detailed in our last report, the meeting was dedicated to drafting two synthesis papers and to setting the plans for the 2012 international workshop. Synthesis will build on existing publications and on-going studies, particularly from WG members, which have developed as a substantial effort in the last 24 months.

In terms of field programs, the group members have been active in a number of new collaborative experiments or explorations for which discussions at the WG level have had significant outcomes. Several projects associating different WG members have been recommended for funding by NSF and are in the process of receiving official approval.

A non-exhaustive list of significant recent or forthcoming cruises:

1) Fall 2010. MenezMAR cruise on the Mid Atlantic Ridge. (N. Dubilier, Chief Scientist, W. Bach co project-leader, invited participants: N. Le Bris and P. Girguis). Interdisciplinary geological, chemical and biological studies at the Menez Gwen hydrothermal vent field, Mid-Atlantic Ridge, at 37°50'N. Two of the objectives were particularly related to the WG focus: How does conductive heating of seawater and conductive cooling of hydrothermal fluids affect the composition of diffuse fluids and the vent biota? What are the dominant sources of energy for vent life in the subsurface, surface and hydrothermal plume?

2) Summer and January 2011 (C. German): a pair of forthcoming research cruises to the ultra-slow Mid-Cayman Rise with large emphasis on C-org cycling near-seabed and during the buoyant as well as non-buoyant phases of hydrothermal plumes.

3) Fall 2011. IODP drilling leg for deep biosphere, North Pond (Mid-Atlantic Ridge flank) (K. Edwards, as co-Chief Scientist and other WG members including W. Bach). Key themes include functions and rates of global biogeochemical processes; the extent of life in the deep biosphere; limits to the existence of life; and evolution and survival in the deep biosphere – all of which are directly relevant to the scope of this WG.

4) 2012-2013. GEOTRACES cruise investigating biogeochemical cycling in the South EPR hydrothermal plume (as well as Peru upwelling) has (informally) been approved in the US with C. German as Co-Chief Scientist (alongside Jim Moffett for the Peru Margin component).

5) 2012-2013. Indian and Caribbean cruises (K. Takai, with other WG members) particularly focusing on the linkages between geosystem and ecosystem of hydrothermal vent via chemistry.

A substantial number of papers have been published by WG members in 2010 and 2011, including several reviews on specific topics (see below). These works significantly expand our knowledge on 1) the rates and metabolisms fuelling autotrophic and methanotrophic carbon fixation, 2) the distribution and structure of chemosynthetic habitats on and below the seafloor and the diversity and variability of available chemical energy sources, 3) the flow of kinetically stabilized iron that can be exported from vents over long distances, and organic carbon export from vents. In addition, a couple of recent publications on the ocean circulation and dynamics near the crest of the EPR has been published (A. Thurner and co-workers), paving the way to further integration for an assessment of the impact of vent-derived material to the ocean carbon deep ocean budgets. An update of German and Von Damn (2004) overview paper on Hydrothermal Processes for the Treatise on Geochemistry can be mentioned as well as an upcoming publication led by Chris German and Bill Seyfried.

We also acknowledge the support that was provided by InterRidge as part of its fellowship programme to one student (D. Giovannelli) and a post-doc (E. Reeves), who are conducting studies in direct link with our focus. D. Giovannelli will visit Costantino Vetriani's laboratories at Rutgers University to develop a project entitled: "Analysis of functional gene transcripts in microbial chemosynthetic biofilms from deep-sea hydrothermal vents". The aim of the proposed project is to investigate carbon fixation, respiratory metabolism and quorum sensing mechanisms in chemosynthetic microbial biofilm from deep-sea hydrothermal vents. E. Reeves is a Postdoctoral Fellow at the MARUM Center for Marine Environmental Sciences, University of Bremen, Germany, working with Drs. Wolfgang Bach and Kai-Uwe Hinrichs. His proposal is entitled: "An organic geochemical investigation of sulfur-bearing ligand formation in ascending hydrothermal plume particulate matter". He will be working in collaboration with Drs. Chris German and John 'Chip' Breier at the Woods Hole Oceanographic Institution, USA. They will conduct a hydrothermal plume particle sampling campaign at hydrothermal sites in the Cayman Trough in 2011.

Publications by WG members (2010-2011)

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Figure 1: Members of the IR-SCOR 135 WG meeting in Hangzhou, October 2011. From left to right: Xiqiu Han, Debbie Milton, Zhu Yongling, Nadine Le Bris, Sylvia Sander, Toshi Gamo, Stefan Sievert, Loka Bharathi, Chris German, Louis Legendre, George W. Luther III.

Long Range Exploration

Chair - Colin Devey (IFM-GEOMAR, Germany)

A proposal to form a Working Group to study the Southern Mid-Atlantic Ridge has grown out of the activity of the Long Range Exploration WG. This is currently before the Steering Committee and there are no further details at present.

Mantle Imaging

Chair – Nobukazu Seama (Kobe University, Japan)

The Mantle Imaging Working Group was very active in the past year, organising an international workshop on ocean mantle dynamics. This was held in October 2011 at the Atmosphere and Ocean Research Institute, University of Tokyo, Japan. For more details about this workshop, please see the article in the Workshops and Conferences section of this volume and the workshop website (<http://www.interridge.org/WG/MantleImaging/workshop2011>).

Seafloor Mineralisation

Chair – Maurice Tivey (WHOI, USA)

The Seafloor Mineralization Working Group added a new member, Dr. Sven Petersen, from IFM-GEOMAR, Germany, to its membership. Several Working Group members attended the 40th Underwater Mining Institute in Hilo, Hawaii, 14-16 Sept 2011. It was the largest attendance of any UMI meeting in its recent history. In addition to the UMI meeting, a special session on Marine Resources was hosted at the MTS/IEEE Oceans '11 conference in Waikoloa, Hawaii 20-21 Sept 2011 chaired by Steve Scott and John Wiltshire. A list of the abstracts and some relevant papers by Working Group members are listed below in the reference section. A workshop was sponsored by the International Seabed Authority (ISA) in the summer of 2010 in Dinard, France in part as a follow-up to the SMWG recommendation on investigating the impact on hydrothermal ecosystems of undersea mining of polymetallic sulfides. The report was published in 2011 by Working Group Member Cindy Van Dover and others. This Dinard report is available from the ISA website at: <http://www.isa.org.jm/files/documents/EN/Pubs/TS9/index.html>. Cindy Van Dover is also leading a group to develop background information for a workshop proposal on deep-sea habitat restoration: guidelines for management - a high-level look at practices in restoration ecology and applications to deep-sea activities (3 Duke University work-study students are reviewing the restoration practices literature to discover leaders in

the field and key concepts. A special session at Ocean Sciences in Salt Lake City (19-24 Feb 2012) is planned on “Deep-Sea Conservation Imperatives in the 21st Century” and will be chaired by Lisa Levin, Cindy Van Dover, Jeff Ardron and Craig Smith.

At the end of 2010, InterRidge was asked by the Legal and Technical Commission of ISA to provide them with a list of hydrothermal vent fields for protection from the recently released “Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area” (ISBA/16/C/L.5). InterRidge canvassed the community for feedback and sent a memo to the ISA expressing concern about singling out specific sites and to reinforce the need for clarification on rules for Marine Scientific Research, release of contractor data in a timely way and how biological issues were going to be addressed. In July 2011, the ISA approved licence plans for exploration for polymetallic sulphides in the Area by China Ocean Minerals Resources Research and Development Association (COMRA) submitted 7 May 2010 for work in the Indian Ocean and by the Ministry of Natural Resources and the Environment of the Russian Federation submitted 24 December 2010 for work in the Atlantic Ocean. Licences are expected to be issued before the end of the year.

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Vent Ecology

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

This year again, the Vent Ecology WG has mainly been interacting at distance, via the internet, as no major vent-biology meeting has taken place. Activities mainly focused on the establishment of a Sample Transfer Agreement form to facilitate sample use and exchange, as well as the developing interest of mining companies for hydrothermal polymetallic sulfide deposits.

Mining activities and protection of the hydrothermal vent environment

The marked increase in exploration permits for mining companies has raised some concerns in both the scientific community and the general public. A panel discussion was organized last year by the

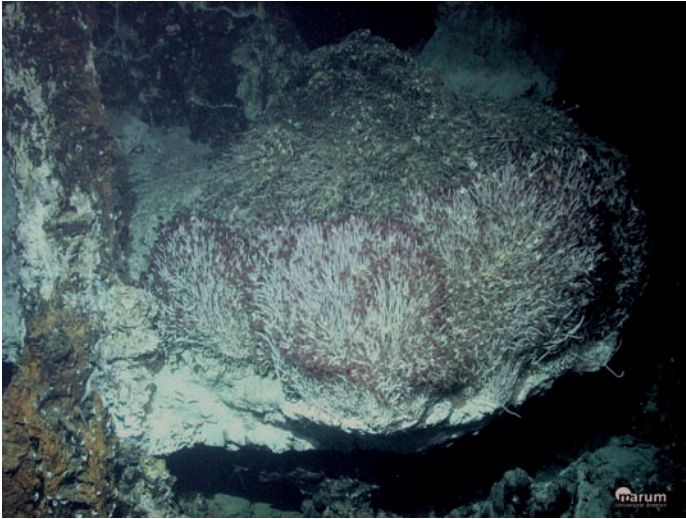


Figure 1: *Arcovestia ivanovi* bush on a hydrothermal vent chimney in the Manus Basin. Copyright Marum-University of Bremen.

French Academy of Overseas Sciences and IOC-UNESCO on “Exploitable mineral resources (polymetallic nodules, cobalt-rich crusts, hydrothermal polymetallic sulphides) in the abyssal and bathyal domains: options for the conservation and management of the biodiversity of associated ecosystems”. The meeting was held on November 10th, 2010, at UNESCO in Paris, France. Link to the agenda, background documents and discussion items: http://www.ioc-cd.org/index.php?option=com_oe&task=viewEventRecord&eventID=732

Among these different types of deep-sea mineral resources, hydrothermal deposits will be the first to be exploited. A pilot study of such exploitation is currently underway in Papua New Guinea, where the government granted Nautilus a mining lease in January 2011 (for more details on mineral extraction plans, see the Nautilus Solwara project website: <http://www.nautilusminerals.com/s/Projects-Solwara.asp>). Studies of the impact of mining activities on biological communities are also currently funded by Nautilus in this area.

Although the legal framework of mineral exploitation and its regulation in EEZs only depends on the country's own legal system, the legal framework for ocean bottom in international waters is the responsibility of the International Seabed Authority (ISA). The UNESCO panel discussion however raised the issue that there is to date, no legal authority dealing with the water column at great depths (i.e. below fishing depths and above the sea-floor). This could be an issue if the mining activity ejects large amounts of particles into the water column.

There were also some concerns of researchers (and not only in Biology) regarding their future work in areas where exploration permits have been granted to contractors for polymetallic sulfides. Adam Cook (ISA) indicated that scientific studies can continue within exploration claim areas as long as it is general marine scientific

research rather than commercial exploration for sulfide deposits. Obviously, should there be active mineral exploration there will be safety issues and these may prevent scientific research adjacent to mineral exploration equipment (in the same way that scientific exploration cannot be carried out very close to oil rigs). Conversely, contractors are required to carry out baseline surveys so there may be increased opportunities for marine scientific research.

Biological sample sharing

One of the goals of the WG is to enhance the distribution and use of specimens collected at vents (one of the tenets of the InterRidge “Code of Conduct”). We have posted a model of sample sharing agreement on the website to facilitate these exchanges should such an agreement be necessary (<http://www.interridge.org/node/16694>). Essentially, this agreement states:

- what the interested person is planning to do with the sample(s) (as a quick description),
- that the person will only do that planned work or ask for permission if he/she would like to do something else,
- that this research is not for the private sector (university and affiliated can have the samples for free),
- that he/she will not give these samples to someone else before that other person signs a similar agreement

The statement will also require that, if the shared sample should be used for a publication, the researcher should acknowledge the person who provided the sample and the grant(s) (as well as funding agencies) that allowed the sample collection. This form is only a model and can be modified. Although initially planned for biological samples, it could easily be used for other types of samples. There is obviously no possible enforcement, however our community of researchers is small and misbehavior will inevitably become common knowledge.

As listing possible samples to be shared on a website does not seem the best way to facilitate sample sharing, we are exploring the possibility of a forum hosted on the Vent Ecology WG pages where researchers in need of samples could post their requests, and researchers of the WG could re-direct these requests to people they think may possess such samples. More work will take place on this in the upcoming year.

Meetings

Panel discussion organized by the French Academy of Overseas Sciences and IOC-UNESCO on “Exploitable mineral resources (polymetallic nodules, cobalt-rich crusts, hydrothermal polymetallic sulphides) in the abyssal and bathyal domains: options for the conservation and management of the biodiversity of associated ecosystems”. The meeting was held on November 10th, 2010, at UNESCO in Paris, France. For more details, see above.

The EU-funded Coordination Action for Research Activities on life in Extreme Environments (CAREX) is organizing a conference on Life in Extreme Environments, October 18th-20th 2011 in Dublin, Ireland.

Workshops and Conferences

Geological carbon capture & storage in mafic and ultramafic rocks



IODP/ICDP Workshop, Muscat, Oman, 8-10 January 2011

Convenors: Damon Teagle; Marguerite Godard; Peter Keleman; Sobhi Nasir

Report by: Eleanor Berryman, McGill University, Canada (InterRidge-sponsored research student)



In January 2011, 87 scientists representing 15 countries gathered at Sultan Qaboos University near Muscat in the Sultanate of Oman. Their reason for being there was the three-day IODP/ICDP Workshop on Geological Carbon Capture and Storage in Mafic and Ultramafic Rocks. The attendees came from a wide range of fields and included geologists, biogeochemists and engineers. Individual research posters were organised into

themes comprising field observations (ophiolite studies, studies of oceanic lithosphere and basaltic crust, on-shore basaltic aquifers and reservoirs, sedimentary basins, industrial waste and urban soils), laboratory studies, hydrodynamic and thermodynamic modeling, and the development of new techniques with application to field scale characterisation, societal impact, and industrial applications. By bringing together this critical mass of expertise, the conference aimed to bring mineral carbonation to the forefront of research on geological carbon capture and storage (CCS). The workshop consisted of a variety of presentations that educated the audience on the current studies taking place and led into discussions on the questions that future research should address.

The conference opened with a presentation by Prof. Richard Darton, from the Department of Engineering Science at the University of Oxford. Prof. Darton emphasised the magnitude of the challenge posed by the objective of meaningful carbon capture and storage, and the scale of engineering and societal change that would be required to address it. Such a challenge can only be approached by a collection of ideas and strategies, motivating the need for diversity in scientists working together. Following this introduction, the conference proceeded directly to talks on current research taking place. Prof. Damon Teagle, from the National Oceanography Centre, Southampton, and Prof. Peter Keleman from the Lamont-Doherty Earth Observatory, Columbia University, USA, presented their field observations relating to the fundamental mechanisms controlling the natural carbonation of mafic and ultramafic rocks, respectively. Next we received insights from experimental work on mineral carbonation by Dr. Eric Oelkers from

the University of Toulouse, France, Dr. Philippe Gouze from the Université de Montpellier, France, and Prof. Bjørn Jamtveit from the University of Oslo, Norway. The first day concluded with a discussion of ideas on the practical implementation of in situ carbon capture and storage. Prof. Keir Becker of the Rosenstiel School of Marine and Atmospheric Science, Miami, USA presented hydrogeological field observations from the Integrated Ocean Drilling Program and Prof. Juerg Matter of the Lamont-Doherty Earth Observatory, Columbia University, USA, presented work on monitoring and verification of CO₂ storage.

The second day of the conference got underway with a presentation by Prof. Gregory Dipple from the Department of Earth and Ocean Sciences, University of British Columbia, Canada. Prof. Dipple discussed his work on the potential of enhanced weathering and carbon mineralisation in mine waste. Following this talk, the conference broke out into highly interactive working group sessions. Attendees formed groups of 10 to 15 people to discuss their choice of topic among various options: natural systems and in situ storage in the seafloor (processes and IODP targets), natural systems and in situ storage on land (ICDP targets), enhanced weathering options (mine tailings/industrial waste), kinetics/fluid flow/reaction/efficiencies, and monitoring, verification and accounting. Each working group summarised their ideas on the important questions that exist and the research direction required to answer them. The day concluded with presentations on ongoing projects. Prof. Sigurdur Gislason from the University of Iceland, discussed mineral sequestration of CO₂ in basalt in the context of the CarbFix Project; Dr. Pete McGrail from Pacific Northwest National Laboratory, USA, discussed the achievements and challenges of the Big Sky Project; and Roy Baria from Engineered Geothermal Systems (EGS), Cornwall, UK, presented a paper on the technical challenges and lessons from enhanced geothermal systems.

The final day of the conference started with a presentation by Dr. Andrew Bungler from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, on the creation of surface area and conductivity in ultramafic rocks using extremely closely spaced hydraulic fractures. The presentation was followed by concurrent discussions in four groups that addressed the following

topics: 1) submarine site characteristics, 2) onland site characteristics, 3) permeability, hydraulic fracture, and reactive surface area, and 4) thermal convection, pumping, and multi-phase flow. These working groups considered work that would be needed for the successful implementation of carbon mineralisation projects from the perspective of characterising and sustaining suitable carbon storage sites.

The workshop was followed by two days of optional field trips led by Prof. Peter Kelemen to the famous Samail ophiolite, where participants observed naturally occurring carbonation of ultramafic rocks. Highlights of the field trips included visits to large travertine deposits where alkaline springs are sequestering atmospheric carbon dioxide in high pH, low fO_2 , low carbon, Ca-bearing waters from the underlying altered peridotite, outcrops of listwanite, fully carbonated peridotites, as well as outcrops characterised by massive magnesite veins in brecciated, altered peridotite. These sets of outcrops reflect low and high temperature alteration of ultramafic rocks, respectively, and the visits complemented well the ideas and research goals presented during the conference.

Overall, this well organised workshop proved to be both an opportunity for scientists to gain a holistic understanding of the



Figure 1: Group photo of participants at the IODP/ICDP workshop in Oman.

CCS challenge from the perspective of different fields, as well as an important venue for scientists to discuss current research strategies, harbour new ideas, and build a network of research associates with similar interests and goals.

Circum-Antarctic Ridges

InterRidge International Workshop, Toulouse, France, 28-30 September 2011

Convenors: Anne Briais; Sung-Hyun Park

The scientific rationale for this workshop is that mid-ocean ridges around Antarctica have been poorly surveyed, mostly because of their location in high latitudes and areas of rough seas. However, circum-Antarctic ridges are unique due to their shallow water depths, ultra-slow or intermediate spreading rate, and complicated series of transform offsets compared to low-latitude ridges. A number of scientific issues at various scales in space and time are ideally addressed in these areas, such as:

- The boundaries and fluxes between the « Pacific-Atlantic » and « Indian » mantle domains.
- The along-axis variability in ridge morphology, magma supply and basalt chemistry at constant spreading rate.
- The migration and exchanges between biological communities.

Circum-Antarctic ridges represent over one third of the global mid-ocean ridge system. They remain the last unknown sections of ridge, but a lot of science cruises occur in the southern ocean, involving mostly oceanographic studies. It is time to focus an international effort to survey these ridges, to discover new tectonic contexts, new hydrothermal vents, new species and new ways to connect all these. These ridges will most probably have an important place in the IR

research objectives for the next decade and one of the main objectives of the workshop was to discuss the possibility of an InterRidge Working Group on this subject. At the time of going to press, a workshop report was not available.

InterRidge supported five young researchers from NOC Southampton, UK, to attend the workshop and they wrote:

The InterRidge International Workshop recently held in Toulouse was a fantastic opportunity for circum-polar ridge scientists, at all stages of their career, to meet and discuss current research and future opportunities for collaboration. We all attended the pre-conference fieldtrip, which was a great way to explore the local geology and admire the beautiful Pyrenean scenery, accompanied by some of the knowledgeable workshop conveners. Discussions began as soon as the 'ice had been broken', outlining the workshop objective: to form a new, efficient, collaborative working group. The workshop was well-planned and included a diverse selection of informative talks that raised many of the important issues currently faced by scientists working in hostile polar environments. As a mixture of PhD (Cathy Cole, Jeff Hawkes and Laura Hepburn) and

Masters (Jack Hitch) students, and a post-doctoral researcher (Alfred Aquilina), we were able to discuss our recent work with an international community of scientists from different disciplines that proposed valuable, alternative insights into our data interpretation.

We would like to thank InterRidge and the workshop conveners for making this meeting possible and look forward to the opportunity of working with our international colleagues, as we advance our knowledge of some of the phenomena fundamental in shaping the structure of our planet.

Figure 1: Workshop participants learning about lherzolites in the Pyrenees.



Ocean Mantle Dynamics: From Spreading Center to Subduction Zone

International Workshop, 2-6 October 2011, AORI, Tokyo, Japan
Convenor: Nobukazu Seama

The main question posed at this workshop was: What have and can we derive from crustal and mantle imaging beneath the ocean together with laboratory and numerical studies? Recent high quality seismic surveys with dense OBS (Ocean Bottom Seismograph) arrays reveal variations in the velocity structure of ocean crust, the uppermost mantle, and the Moho transition zone, even if they were formed at a fast-spreading ridge system. Moreover, recent progress in long-term observational technology on the seafloor enables the imaging of regional mantle structure using both seismological and electromagnetic techniques. The resulting velocity and resistivity structures, combined with results from laboratory experiments on mantle rocks and numerical simulations, provide important constraints toward understanding ocean mantle dynamics.

In this meeting, there was a focus on three objectives of crustal and mantle imaging, with an emphasis on mantle dynamics:

- 1) the structure of oceanic lithosphere (including the crust and sub-crust) and asthenosphere
- 2) melt migration beneath the spreading axis to form oceanic crust
- 3) the role of water, especially for subduction and back-arc spreading dynamics.

Each topic is closely inter-related but for each topic, we first reviewed all the available structural images of crustal and mantle structure. Second, recent laboratory experiments on crustal and mantle rocks were presented in order to help interpret the images. Then, petrological and geochemical characteristics of the crust and

mantle were used to address variability of crustal formation, and to provide constraints on melt migration and the role of water. Finally, investigations from numerical simulations are expected to help identify the parameters controlling melt migration, crustal formation, and mantle structure.

(This meeting is taking place as this volume goes to press. A report will be available on the IR website shortly).



Figure 1: Olivine crystal in the Horoman peridotite; scale: 8mm crystal.

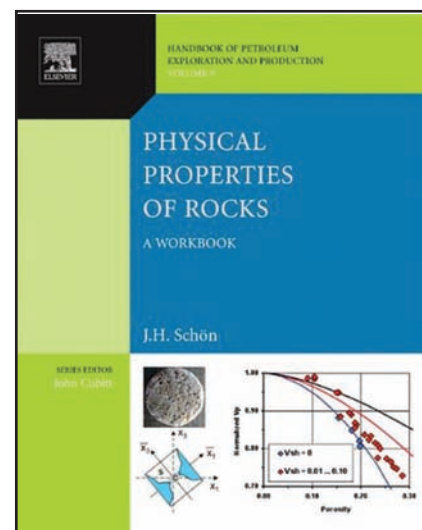
Publications

Physical Properties of Rocks

A workbook

J.H. Schön

This book focuses on the applications of geophysics in addressing rock properties for petroleum geoscience, geotechnical, and geothermal applications. Sophisticated geophysical techniques deliver a fascinating collection of physical data-but they are essentially indirect: information on the velocity of seismic waves, electrical conductivity, nuclear spectra, etc. must be translated in terms of lithology, porosity, fracturing, fluid saturation, permeability, and geomechanical properties.



Ofioliti: changes to editorial policy

As you may know, Ofioliti is an independent international journal with the main goal of diffusing the knowledge on ophiolites and modern oceanic lithosphere. In 35 years of activity, Ofioliti published high-quality original papers dealing with geodynamics, petrology, geochemistry,

stratigraphy, tectonics, biostratigraphy and palaeogeography. The Ofioliti journal is present in all the bibliography main search engines and databases (Scopus, Science Citation Index Expanded, ISI Alerting Service, Current Contents/Phy. Chem. & Earth Science, Geobase, Geological Abstract, Georef, Pascal Thema etc.). Ofioliti is in the ISI journal catalogue since 1998, with an Impact Factor (IF) that places it at medium-high levels in the "Geology" category (17th out of 48, corresponding to the Q2 quartile of the category). The IF over the last 5 years is 1.35 (1.52 in 2010).

From the June 2011 issue, the Ofioliti journal is presenting to the international scientific community an important change in its editorial scope. Ofioliti aims to become a fundamental journal for the publication and promotion of scientific knowledge of the modern oceanic lithosphere. The journal will still remain a key reference for all researchers devoted to the understanding of ophiolites and meta-ophiolites in mountain belts from all over the world.

Ofioliti's Editorial Committee now has five editors. Benoît Ildelfonse, from CNRS/Montpellier 2 University, France, and Aral Okay, from the Technical University of Istanbul, Turkey, joined Valerio Bortolotti, Michele Marroni and Riccardo Tribuzio as Chief-Editors. The Editorial Board is also largely renewed, with many experts in the different disciplines related to both the ophiolites and the modern oceanic lithosphere (<http://www.edizioniets.com/ofioliti/board.htm>).

The editorial policy of the Ofioliti journal is moving towards larger diffusion of the journal, and greater scientific impact of the published contributions. We ensure a rigorous peer-review process and a short publication time. In addition, Ofioliti is willing to become a "low-cost journal". To favour a large diffusion of the journal, a free of charge distribution of the published contributions is being tested. This represents a radical choice, opposite to the general strategy of the main international editorial groups. All papers published in Ofioliti from 1998 to 2010 are now available online for free. Voluntary donations are welcome.

Manuscripts may now be submitted electronically to the journal, through its web site (<http://www.edizioniets.com/ofioliti/>). In October 2011, a new version of the Ofioliti web site will be available. The whole archive of past issues (since 1976) will then be available for downloading. We encourage all researchers working on ophiolites and/or on modern oceanic lithosphere to submit the results of their studies to Ofioliti, and we look forward to a fruitful collaboration with the international ocean lithosphere community.

Best regards, The Editorial Committee

Upcoming Events



Dec. 03, 2011

InterRidge: Third Decadal Plan 2014-2023 discussion meeting, San Francisco, USA

Dec. 05-09, 2011

AGU Fall Meeting 2011, San Francisco, USA

Feb. 16-20, 2012

AAAS Meeting, Vancouver, Canada

Feb. 19-24, 2012

Ocean Sciences Meeting, Salt Lake City, USA

Apr. 09-12, 2012

VentBase 2012 Workshop, Galway, Ireland

Apr. 22-27, 2012

European Geosciences Union (EGU) General Assembly 2012, Vienna, Austria

Aug. 05-10, 2012

International Geological Congress 2012, Brisbane, Australia

Aug. 13-17, 2012

Asia Oceania Geosciences Society (AOGS), Singapore

Dec. 03-07, 2012

13th International Deep-Sea Biology Symposium, Wellington, New Zealand

Also in 2012 (*dates and venues to be determined*):



InterRidge Steering Committee



Hydrothermal Energy and Ocean Carbon Cycles, SCOR Working Group, European venue



International Conference: Indian Ocean Ridges and Hotspots, Mauritius

Visit the InterRidge website for Upcoming Event listings:

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

InterRidge: Third Decadal Plan

2014-2023



Setting InterRidge's science and policy goals for the next decade

A draft report will be published in early 2012:

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

Please view and submit your comments to the InterRidge Office:

coordinator@interridge.org **OR** <http://www.interridge.org/forum>

Country	Dates	PI	Ship	Cruise ID/Location	Research Objectives
Australia	Nov 2011	J. Whittaker	R/V Southern Surveyor	Perth Abyssal Plain	To understand the formation history of the Perth Abyssal Plain and the crustal nature and tectonic history of a number of surrounding submerged plateaus.
Australia	May-June 2012	D. Arculus	R/V Southern Surveyor	The northern Lau Backarc Basin	Magmatism, tectonics and hydrothermal activity.
Canada	May-June 2012				These two NEPTUNE Canada cruises will complete the following tasks (timings yet to be decided):
Canada	Sept 2012				Repair of Barkley site and its re-instrumentation, the lay of the tsunami array at the ODP 1027 site, the installation of the Mothra site at Endeavour and a broad band seismometer across the ridge from our site.
France	Dec 2011	N. Le Bris; F. Lallier	R/V L'Atalante	EPR 9-15°N; Mescal 2	
France, Japan	6 Feb - 18 March 2012	Anne Le Friant; Osamu Ishizuka		IODP 340 Lesser Antilles	Drilling volcanic landslides deposits and volcanoclastic sediments in the Lesser Antilles arc: implications for hazard assessment and long-term magmatic evolution of the arc.
Germany	Dec 2012 - Jan 2013	V. Schlindwein	R/V Polarstern	SWEAP, SWIR	
Germany	Mar 2013	G. Bohrmann		Sandwich Plate	
Germany	June 2014	A. Boetius		AUORA, 83°N Gakkel Ridge	Will use a new hybrid ROV/AUV system developed by WHOI for under-ice diving in collaboration with C. German (WHOI).
Japan	Nov-Dec 2011		R/V Yokosuka	Southern Okinawa	
Japan	Mar 2012			Iheya North Izena	
Japan	2012	K. Takai		Indian Ocean	Focusing on the linkages between geosystem and ecosystem of hydrothermal vent via chemistry.
Korea	21 Nov - 14 Dec 2011	S-H. Park	Araon	Australian-Antarctic Ridge	Sampling and mapping.
UK	Nov - Dec 2011	A. Rogers	RSS James Cook	JC66, SWIR	Biology of SW Indian Ridge seamounts.
UK	Dec 2011	J. Copley	RSS James Cook	JC67, SWIR	Ecology and biogeography of hydrothermal vents on the SW Indian Ridge.
UK	2012	J. Copley		Cayman Rise	Microbiological and geochemical studies in sediment-rich hydrothermal sites.

UK	Jan 2012	G. Henderson	RSS James Cook	JC68, S Atlantic MAR	Investigation of fluxes of micronutrient metals at 40°S.
UK	2012	P. Leat	James Clark Ross	JR259, South Scotia Ridge	Surveying segments of the West Scotia Ridge, South Scotia Ridge, active seamounts of southern South Sandwich arc and associated East Scotia Ridge back-arc spreading centre.
USA	1 Dec 2011	M. Zumberge	R/V R.G.Sproul	Axial volcano	To test a new seafloor marine geodetic instrument.
USA	9 Dec 2011-22 Jan 2012	R. Stern	R/V Thomas G. Thompson	The Southeast Mariana Forearc Rifts and Southernmost Mariana Trough Spreading Center	Tectonics and Magmatism of Intraoceanic Arcs.
USA	4 Jan 2012	C. German	R/V Atlantis & ROV JASON	Jason Cayman Vents	Jason ROV to dive on and sample two (or more) hydrothermal fields recently discovered on the Mid Cayman Rise.
USA	17 Jan - 6 Feb 2012	D. Blackman		IODP 340T Atlantis Massif Oceanic Core Complex	To obtain sonic and temperature logs in the existing deep basement hole at Site U1309, on the young flank of the Mid-Atlantic Ridge, and to assess the state of the borehole in order to design a Vertical Seismic Profile (VSP) experiment.
USA	9 May - 11 June 2012	C. Langmuir	R/V Knorr	MAR 27N	Do symmetric and asymmetric segments on the mid-Atlantic Ridge have distinct geochemical signatures? Mapping and petrological sampling.
USA	11 June - 8 Jul 2012	S. Carbottle	R/V Marcus Langseth	Ridge to trench: NE Pacific off the Oregon/Washington coast to the Juan de Fuca Ridge	Evolution and hydration of the Juan de Fuca crust and uppermost mantle: a plate-scale seismic investigation from ridge to trench.
USA	28 June - 12 Jul 2012	D. Toomey	R/V Thomas G. Thompson	Cascadia margin and Juan de Fuca plate	Deployment and recovery of ~70 OBSs for the Cascadia Initiative.
USA	27 Jul - 9 Aug 2012	A. Fisher	R/V Thomas G. Thompson	Eastern flank, Juan de Fuca Ridge	Completion of single- and cross-hole hydrogeologic experiments on the eastern flank of the Juan de Fuca Ridge using a borehole network.
USA	14 - 24 Aug 2012	M. Tivey	R/V Thomas G. Thompson	Northern Juan de Fuca Ridge	
USA	2012	A. Koppers	R/V Revelle	SW Walvis Ridge	To study the young Walvis Ridge through mapping and dredging of 40 seamounts.
USA	Sept 2012 - Jan 2013	H. Tobin		IODP 338 NanTroSEIZE Plate Boundary Deep Riser-2; Pacific Ocean	To sample the deep interior of the accretionary complex in the midslope region beneath the Kumano forearc basin.
USA	2012 - 2013	C. German; J. Moffett		South EPR	Investigating biogeochemical cycling in the South EPR hydrothermal plume (as well as Peru upwelling).

Updated Oct. 2011

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Cover: Multibeam echosounder DTM of the Balor chimney in the newly discovered Moytirra Hydrothermal Vent Field, Mid-Atlantic Ridge. Image collected during the University College Cork, Ireland-led VENTuRE survey using the Marine Institute's RV *Celtic Explorer* and *Holland I* ROV. Multibeam hardware supplied by the University of Limerick. Data acquisition was funded through an Irish National Shiptime grant and by National Geographic Television.

Back Cover: Olivine crystal collected from a dunite channel in the Horoman peridotite complex, Hokkaido, Japan. The peridotite represents a tectonic slab of orogenic Iherzolite emplaced during the Miocene in the high-T low-P Hidaka Metamorphic Belt. The size of the crystal is about 8 mm. Photo taken by Anna Suetake, Niigata University.