2013

InteRidge News

PROMOTING INTERNATIONAL COOPERATION IN RIDGE0CREST STUDIES

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Coordinator update

Zengxi Ge

January 2013 marked the move of the InterRidge (IR) Office from the National Oceanography Centre, Southampton, UK to Peking University, Beijing, China. We would like to thank the UK office, and those involved at PKU, for the very efficient changeover of the website – in particular, Xianbing Zhang in Peking university. Also, Debbie Milton (IR Coordinator 2010-2013) and Stace Beaulieu (IRcoordinator 2007-2009) have provided invaluable advice and support to the new office during this first year – thank you!

Membership

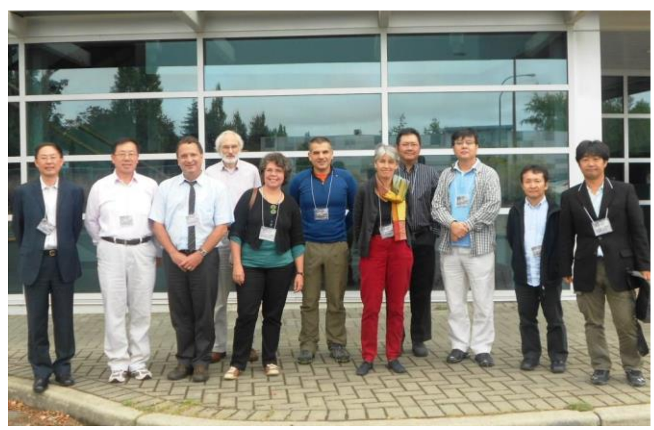
Individual membership is currently ~ 2600, representing 62 nations and regions. The new office took the opportunity of refreshing the mailing list of members but found many undeliverable addresses.
Please check the details we have for you by logging in at: http://www.interridge.org and going to "My Account". From here, apart from changing any details, you can sign up to support the Statement of Responsible Research and also request a hard copy of the annual Newsletter (under "Edit/Other Info").
The "interridge-mail" e-news is sent to >1200 members on a biweekly basis and disseminates news pertinent to the ridge community. Nearly 180 IR members receive "interridge-classifieds" - our mailing list for job postings.
Our website doesn't open for individual registration since there are so much spam trying to login. If you or any of your colleagues would like to join interridge, please feel free to send an email to coordinator (at) interridge.org. I will add you to our member area and mailing list soon after I receive your request!!

Steering Committee

The IR Steering Committee (StComm) meeting was held in Victoria, Cananda in August 2013 (see photo). The report of this meeting is posted at: http://www.interridge.org/stcom/reports.
Two members will rotate off the StComm this year: we thank Jér.me Dyment and Jun-ichiro Ishibashi, for his service to IR. Marcia Maia attended as the new StComm member and National Correspondent for France and Toshiya Fujiwara attended as the new StComm member of Japan.

National Correspondents

In INTERRIDGE NEWS each year, we report on ridge-related activity around the world, through the National News section of this volume. This is the chance to tell the IR community about cruises, conferences and workshops that have been organised or attended by your national members, as well as reporting on general scientific achievements and technologies. Currently we have 31 Correspondents, but many more nations and regions are represented by individual members for whom there is no Correspondent and so we have not heard their news!



**IR STEERING COMMITTEE IN WINCHESTER, UK, AUG 2013:
FROM LEFT TO RIGHT: JIABIAO LI, JOHN CHEN, KIM JUNIPER, RICHARD HOBBS, MARCIA MAIA, STEPHANE HOURDEZ, NADINE LE BRIS, RICHARD LEE, SUNG-HYUN PARK, TOSHIYA FUNIKURA, MICHINARI SUNAMURA**

National News

China

Report by Y. John Chen and Jiabiao Li, Co-Chairs, Steering Committee of InterRidge China
johnyc@pku.edu.cn; jbli@zgb.com.cn

The China ridge community pays more attention to the geological and ecological processes of the global mid-ocean ridges and their hydrothermal vents, completed several ridge cruises and developed some deep sea scientific equipment in 2012-13.

Ridge-Crest Surveys

In 2012, Chinese scientists used two research vessels to conduct their ridge-crest survey. Geology and ecosystem for active hydrothermal vents have been investigated during 6 consecutive ridge cruise legs on the Carlsberg Ridge and Mid-Atlantic Ridge on board R/V "*Dayang Yihao*" in April to October 2012. At the same time, a geophysical survey including multibeam bathymetry, gravity, and magnetics were conducted on the Carlsberg Ridge in the Indian Ocean using the R/V "*Zhukezhen*" in May to June 2012.

For 2013-14 the Chinese ridge program will be using four research vessels for the researches in the Indian and Mid-Atlantic ridges. R/V "*SONNE"* will be rent by COMRA to make a seafloor massive sulfide drilling and AUVs acoustic survey in the Southwest Indian Ridge in late 2014. Scientists from Germany, Cameroon, Zambia, Kiribati, and Argentina, are invited to participate in some of the cruise legs for joint research.

During the cruises, we revisited the TAG hydrothermal field in MAR. Six lines of TEM (Transient Electro-Magnetic) survey were deployed, with four of which across the ODP 158 drilling area. Besides, and other two lines of SP (Self-Potential) survey were also across the ODP drilling area for their comparison. Preliminary results show that the TEM and SP methods are capable of revealing the horizontal and vertical distribution of the seafloor hydrothermal fields. Then a dive was conducted by the ROV *Ocean Dragon II* dived at a deep-sea hydrothermal field on the Southern Mid-Atlantic Ridge, to be used to clarity the characteristics of the geology, ecosystems, and the environmental conditions around the hydrothermal field. Some evidence for a new hydrothermal vent was collected in equatorial Mid-Atlantic Ridge.

In the Carlsberg Ridge, a new hydrothermal vent was found and one sediment trap has been moored in the vicinity of this active hydrothermal vent to study the composition and sedimentation of hydrothermal plume particles. The morphotectonic characteristics of the northern part of the Carlsberg Ridge near the Owen Fracture Zone have been preliminary studied and 9 oceanic core complexes have been identified. Our observation displays that vigorous tectonic extension occurred in the segment of Carlsberg Ridge between 10.4°N - 8.8°N. Further geological sampling would provide information on the nature of the potential OCC formation for the study of the emplacement and evolution of lower ocean crust and upper mantle of the investigated area of Carlsberg Ridge.

The IODP proposal 735-CPP titled "Opening of the South China Sea and its implications for Southeast Asian tectonics, climates, and deep mantle processes since the early Mesozoic" (*by Chunfeng Li, Pinxian Wang, Dieter Franke, Jiabiao Li, et al.*) was submitted to IODP in late 2011 and received in 2012. In 26 Jan-30 March 2014, IODP Expedition 349 *(P.I. Chunfeng Li and Jian Lin*) will drill the oceanic crust to present investigations and new insights of Mesozoi c pre-rifting tectonic background, Cenozoic rifting mechanisms, ages and sequences of seafloor spreading, and their climatic and deep mantle aftermaths.

New Device and Equipment

In July 2012, the Chinese manned submersible *Jiaolong* has completed six dives to 7000 m depth in Mariana Trench. In June 2013, the submersible *Jiaolong* has been planned to eight dives in the northern South China Sea (SCS) to investigate the chemosynthetic communities, biology and geochemical system of the cold seeps, and to explore the volcanic seamounts in the deep sea basin of SCS with a focus on geochemical and geological processes of the basin. After that, the submersible *Jiaolong* is scheduled to explore and sample the benthos in the polymetallic nodules exploration area of China's contract in the Pacific Ocean in August 2013.

Symposiums and National Conference

1. One international symposium "Unlocking the Opening Processes of the South China Sea" was held on January 31-February 1, 2012, at Tongji University, Shanghai. About sixty scientists participated in the symposium to boost further international collaborations in geological researches in SCS and refine both regional questions related to East Asian geology and fundamental issues regarding continental breakup and basin formation.

2. The 2nd national conference of "Deep Sea Research and Earth System Science Symposium" was held in Shanghai on July 2-4, 2012. Over 800 scientists and students participated in this national conference. This conference strongly focused on interdisciplinary studies in ocean science including biological evolution and environment, ocean and climate, biogeochemical cycle, deep-sea resource and technology, and dynamic process of deep earth.

3. The 41st Conference of the Underwater Mining Institute "Marine Minerals: Finding the Right Balance of Sustainable Development and Environmental Protection" was held in Tongji University, Shanghai, 15-20 October, 2012. Over 100 scientists participated in this international conference. Co-sponsor of COMRA, Mr. Jiancai Jin, and co-chair and host of the conference, Dr. Huaiyang Zhou were invited to give key-note speeches discussing issues for the exploration of metal resources and its impact in the deep-sea environment. After the meeting, a field guide provided geological and mineralogical perspectives of the landscape in the Xinqiao Cu-S-Fe-Au Deposit (large-scale polymetallic deposit) in Anhui Province, China.

4. The 4rd symposium of "Global Mid-ocean Ridge Spreading Processes and Implications for the South China Sea Evolution" organized by Dr. Zhen Sun, was held at South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, 12-14 September, 2012. Over 100 scientists and students from various parts of China participated in this symposium. Distinguished international keynote speakers included Dr. Henry Dick, Dr. Jian Lin (Woods Hole Oceanographic Institution, USA), and Dr. Yaoling Niu (Durham University, UK).

Fifth dive to depth 7062 m by HOV *Jiaolong* in the Mariana Trench, July 2012.
(Photo by pilot Jialing Tang)

France

Marcia Maia.

In 2013, the French ridge community is pursuing several projects over different spreading centres around the world. The projects cover a wide panel of themes, including deep-sea observatories, hydroacoustics, ridge magmatic and tectonic processes, vent ecology and biology. Some projects developed in the scope of an international collaboration, such as RHUM-RUM (Germany) and COLMEIA (Brazil).

As in the previous years, much effort was focused on the study of the Mid-Atlantic Ridge, especially on the MoMAR (Monitoring the MAR) deep-sea observatory, located on the Lucky Strike volcano, south of the Azores. The annual cruise targeted to service the stand-alone observatory (MOMARSAT 2013) took place on board the R/V Pourquoi Pas? with the ROV Victor 6000 in August-September 2013 (P.I.s M. Cannat and P.-M. Sarradin). During the 16 days of the cruise, the two seafloor SEAMON (Sea Monitoring) seafloor stations and their connected instruments, i.e. a 3-components seismometer, two pressure probes for geodetic measurements, a turbidimeter, a video camera, a dissolved-iron analyzer, and an optode (oxygenand temperature probe) for ecological time-studies, were maintained and reinstalled. Sensors not connected to the SEAMON stations were also maintained (one pressure gauge, four OBS) as well as several microbial colonizers and 20 temperature probes. The BOREL transmission buoy, equipped with GPS and meteo station was also maintained. This buoy is used to transmit data from the seafloor stations to the Ifremer node of the EMSO (European Multidisciplinary Subsea Observatory) data center. The MoMAR site, part of the EMSO network, is one of the priorities for the French ridge studies. Another cruise targeting the study of the Lucky Strike ridge segment and related to the MoMAR site was ranked high in the priorities for 2014, HYDROBSMOMAR 2 (P.I. J.Perrot), with the objective of redeploying the hydrophone network moored in 2011-2012 to monitor the seismicity of the Azores area. Still in the Azores area, the study of the hydrothermal mussel *Bathymodiolus azoricus* was the objective of the BIOBAZ cruise, on R/V Pourquoi Pas? and with ROV Victor 6000 in August 2013 (P.I. F. Lallier).

Other cruises targeted the study of the accretion processes and vent ecology on the Mid-Atlantic Ridge. The COLMEIA cruise (P.I.s M. Maia, S. Sichel and R. Santos) took place on board the R/V L'Atalante in January -February 2013, as part of a collaboration between France and Brazil for the study of the Equatorial Mid-Atlantic Ridge. The cruise surveyed and dredged the ridge portion inside the St. Paul FZ system and the St. Peter-St. Paul mylonite ridge. Five hydrophones were moored in the area to monitor the seismic activity as well as whale vocalizations and will be retrieved with a Brazilian ship mid-2014.

OCEANOGRAFLU cruise (P.I. F. Lucazeau, R/V L'Atalante, June-July 2013) investigated the heat flux on the area of the Oceanographer FZ.

ODEMAR cruise (P.I. J. Escartin) is scheduled for November-December 2013 on board R/V Pourquoi Pas?. Its objective is the detailed study of the structure of the OCCs mapped at 15°N, using ROV Victor 6000. BICOSE (P.I.s M.A. Cambon and M. Zbinden), scheduled for early 2014 on the Pourquoi Pas?, also with the ROV Victor 6000, will study the ecology of the TAG and the Snake Pit hydrothermal fields.

The Indian Ocean mid-oceanic ridges were also important targets for the French community. The OHA-SIS-BIO experiment aims the monitoring of the seismic activity of the three Indian ridges as well as whale vocalizations through an array of hydrophones, moored between Réunion Island and the French Austral and Antarctic Territories (TAAF). The network is annually serviced during the R/V Marion Dufresne cruises for maintenance of the TAAF stations in Crozet, Amsterdam and Kerguelen islands. This year, due to technical problems with the ship, the cruise took place in February-March. This site is also considered as one of the priorities for French ridge studies. Another important experiment is RHUM-RUM (P.I.s G. Barruol and K. Sigloch), a collaboration between France and Germany for the study of the deep mantle of the Indian Ocean, including imaging the Réunion plume and ridge-hotspot interactions with the Central Indian Ridge. 55 OBS were deployed in 2012 using the R/V Marion Dufresne and will be retrieved in October-November 2013 using FS Meteor. Still in the Indian Ocean, SISMOSMOOTH cruise (P.I. M. Cannat), to investigate the structure of the SWIR using OBSs, as part of the effort to study this ultraslow spreading center, and STORM (P.I. A. Briais), to investigate the structure of the ridge between Tasmania and Antarctica and the mantle flow between the Pacific and Indian oceans, were ranked as priority cruises for the next years.

No cruises took place in the Pacific Ocean in 2013, after a year of intense efforts, especially on the exploration of hydrothermalism and mineral resources in the French EEZ of Wallis and Futuna Islands, (Futuna cruises) supported by the industry. It is expected a continuation of this project for the following years.

Concerning deep-sea mineral exploration, France has asked ISA for a permit to explore mineral resources in an area on the Mid-Atlantic Ridge south of the Azores.

Completed in the end of 2012 and beginning of 2013		Scheduled for the end of 2013 and beginning of 2014	
RHUM-RUM 21/09-26/10/2012 Réunion-Réunion	Marion Dufresne	MOMARSAT 2013 23/08-07/09/2013 Horta-Horta	Pourquoi Pas ?
COLMEIA 23/01-28/02/2013 Recife-Recife	L'Atalante	ODEMAR 15/11-20/12/2013 Cap Vert-Point à Pitre	Pourquoi Pas ?
OHA-SIS-BIO (MD 139) 02-03/2013 Réunion-Réunion	Marion Dufresne	BICOSE Early 2014	Pourquoi Pas ?
OCEANOGRAFLU 04/06-03/07/2013 Ponta Delgada-Ponta Delgada	L'Atalante	Expected in 2014-2015	
BIOBAZ 02/08-21/08/2013 Horta-Horta	Pourquoi Pas ?	MOMARSAT 2014, SISMOSMOOTH, HYDROBSMOMAR 2, OHASIS-BIO, STORM	

Germany

Colin. Devey

As in 2012, Germany still has no centrally-organized ridge program since the SPP1144 ended in 2009, nevertheless there is significant ridge-related research occurring and planned in the near future. The possibility of Germany being able to continue paying IR fees in the future (and even in 2013) is becoming increasingly unlikely, however, both because of this lack of a centrally-organized project and also because of the limited visibilty of InterRidge in the German ocean science community at present.

Ridge-related cruises carried out since the last report include: MSM25 (with RV Maria S Merian, PIs Colin Devey and Maren Walter) to the Southern Mid-Atlantic Ridge (33-13°S) using AUV and CTD to investigate the linkages between volcanism, hydrothermalism and tectonics and the influence of ridge structure on deep-water oceanography; a recent cruise with RV "Sonne" to the Mariana back-arc (PI Karsten Haase, Erlangen) investigating volcanism and hydrothermalism there.

German ridge research in the polar regions increased with several cruises with the RV Polarstern taking place or planned: a) Vera Schlindwein from the AWI will lead a second cruise to the ultra-slow spreading Southwest Indian Ridge in Dec 2013, b) Gerhard Bohrmann from MARUM led a cruise to the Sandwich Plate/Scotia arc in March 2013.

Ridge research in Germany (and other EU countries) received a boost with funding through EU initiatives related to marine mining and its environmental impacts. Particularly the Blue Mining consortium (involving industry partners mainly from the Netherlands and scientists from UK, Germany, Portugal and elsewhere) which will examine possible sulphide mining processes and their impacts, will bring attention to bear on the TAG area of the Mid-Atlantic Ridge.

Japan

Kyoko Okino

The InterRidge-Japan program continues efforts to promote ridge-related studies in Japan and to expand our community. The outline of the ongoing project and other activities are described below.

Domestic Meeting

We designated the incoming IR steering committee member, Toshiya Fujiwara (JAMSTEC), as Hidenori Kumagai's successor. He will be in charge from 2013 to 2016.

We had a business meeting on May 22, 2012, at a Japan Geoscience Union Meeting 2013, where we shared information on a budget of the IR, cruises, workshops and international affairs, and discuss the InterRidge-Japan annual activity plan. We are forced to get along without an umbrella project supporting the annual contribution to IR in FY2013 and try to find a way to continue our activity. We held a research meeting entitled "Ecology of Hydrothermal System: Ecosystem Research and Environmental Impact Assessment" on May 27,28 2013 at AORI, University of Tokyo.

Closure of Project "TAIGA"

The interdisciplinary research project TAIGA, Trans-crustal Advection and In-situ biogeochemical processes of Global sub-seafloor Aquifer, funded by MEXT (Ministry of Education, Culture, Sports Science and Technology), ended March 2013.

During 5 years project, we focused on subseafloor fluid advection which carries huge heat and chemical fluxes from the interior of the earth and supports growth of biosphere (beneath and on the seafloor). Three integrated study sites were selected: the southern Mariana Trough as TAIGA of sulfur and iron, the Indian Triple Junction as TAIGA of hydrogen, and the Okinawa Trough as TAIGA of methane. More than fifty scientists joined the project, and many seagoing studies were conducted, 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). A part of our results was presented in last AGU Fall meeting and we are preparing an open access e-book that compiles our achievements in the project. The book will be published on-line from Springer in March 2014.

Finished and ongoing cruises FY2012-2013

The R/V Yokosuka cruise in the Indian Ridges were conducted in Jan. to Mar. 2013. Dives of Shinkai 6500 are planned to clarify the characteristics of geology, geochemistry and ecosystem around the hydrogen-rich Kairei hydrothermal site and two newly discovered hydrothermal sites in Central Indian Ridge Segment 15/16. Although we were forced to downscale the dive plan significantly due to bad weather condition, we could get many valuable data sets and samples. We also conducted the crust and upper mantle imaging around the triple junction by OBSs and OBEMs. This cruise is dedicated to the memory of Prof. Kensaku Tamaki, the former IR chair, and his pioneering works in Indian Ridge system. Several short cruises in the hydrothermal areas in the Okinawa Trough and the Izu-Ogasawara-Mariana arc/backarc are also conducted.

The R/V Yokosuka with Shinkai 6500 is now going on a cruise around the world. The outline and recent results (including the surveys at Indian Ridges in March) are posted at the web site (http://www.jamstec.go.jp/quelle2013/e/index.html). The ship is now in the world deepest ridge, the Mid-Cayman.

A new 1200t-class multi-purpose research vessel Shinsei-Maru has just been launched. The ship is owned by JAMSTEC and is used as an inter-university research facility in academic community. The ship is equipped state-of-art instruments, various winches and onboard laboratories. The Shinsei-Maru will be dedicated mainly for surveys in off-Sanriku area, where M9 large earthquakes and the following tsunami and nuclear plant accident destroyed the marine environment and ecosystem. But we have a chance to use the new ship for backarc and hydrothermal studies near Japan.

United Kindom

Richards Hobbs

A major change this year is the transfer of the InterRidge office from the UK to China. So Bramley Murton at Southampton is free of duties! The work of the past three years whilst the office has been based in the UK is summarised in InterRidge News volume 21 but I highlight a few items here:

enlarged InterRidge membership;

broadened remit to include arc and backarc systems;

fellowships and bursaries to encourage young researchers and give them experience on cruises.

Also we have had a new funding arrangement for the UK subscription. The UK research council (NERC) withdrew its direct funding of schemes like InterRidge. Bramley approached the universities and institutes that had a strong interest in ocean ridge research and we now raise a Principal Member subscription direct from those that benefit from interaction with InterRidge ($5k from each of Universities of Durham, Plymouth & Southampton, National Oceanographic Centre and the NERC)

Mid-Cayman Spreading Centre

In February Jon Copley and Bramley Muton (NOC/Southampton) were aboard the RRS James Cook on research cruise JC82 which spent 18 science days at the Mid-Cayman Spreading Centre (MCSC). The cruise was the sequel to RRS James Cook research cruise JC44 in April 2010, which pinpointed and sampled the two confirmed hydrothermal vent fields of the MCSC (Connelly et al., 2012, Nature Communications, 3: 620) based on water column plumes indicated by previous CTD casts by our US colleagues. Cruise JC82 completed 6 ROV dives at the Von Damm Vent Field (depth ~2300 m) and 5 dives at the Beebe Vent Field (depth ~5000 m), with the UK's Isis ROV achieving a total of 196 hours of bottom time. During which time Isis collected: data to make ultra high-resolution bathymetry maps; samples of the mineral deposits and vent fauna; water and gas samples from the vents; and deployed temperature loggers. The deepest hydrothermal activity was observed at 5015m. Other JC82 activities included CTD profiles, plume sampling, and rock dredge sampling at the base of an Oceanic Core Complex. The cruise is part of the multidisciplinary NERC project on "Hydrothermal activity and deep-ocean biology of the Mid-Cayman Rise" and on-going collaborations with US and Japanese colleagues studying the MCSC. Cruise JC82 also included the first live video links from RRS James Cook at sea to outreach audiences ashore, at the Natural History Museum and schools in the UK and France. Parts of the cruise were filmed by a BBC news team, with live broadcast and commentary from the ROV control van being fed to the two most popular news slots at 6pm and 10pm. Footage was also incorporated in a BBC documentary by BBC Science correspondent David Shukman discussing the issue of deep-sea resources and their potential impact from future exploitation. Work is now underway by a dedicated research team at the National Oceanography Centre to unravel the biogeography of the fauna, the origin of the unusual fluid composition and the nature of the mineral deposits at the two sites. Dr Jon Copley was the chief scientist for the cruise, the master of the James Cook was Captain Peter Sarjent, and the research was funded by two NERC research grants awarded to Copley and Murton (NE/I01442X/1 and NE/F017758/1).

Figure caption. The figure shows 3D perspective views of the bathymetry (at 20cm resolution) of (i) the Beebe Vent Field, viewed towards the southeast, with areas of vent fluid emissions and sulphide deposits indicated by the black arrows; (ii) the Von Damm Vent Field, viewed towards the west, with hot vent fluid emissions indicated by the white arrows.

East Scotia Ridge

Results from the NERC funded consortium grant ChEsSO (NE/DO1249X/1) and cruises JC042 and JC055 that studied the vent ecology on the East Scotia ridge, continue to be published and presented at conferences. The latest cruise, JC080 (December 2012 – January 2013), used the Isis ROV to map site E2 (56° 5.3' S, 30° 19.1 W), using multibeam together with CTD casts (see www.bodc.ac.uk/data/information_and_inventories/cruise_inventory/report/11599/ for a full cruise report). Abstract to report reads "JC 80 was to sample the vents sites at E2 and E9 on the East Scotia Ridge, and the Kemp and Adventure craters at the southern end of the South Sandwich Islands. The sampling programme at E2 was very successful completing all the objectives assigned to that site. In addition, we found evidence of an additional vent site at E2 north. It was not possible to access the southern sites at E9 and the Kemp and Adventure craters because the sites were covered in ice as a result of the very hard austral winter, although we were optimistic this would be possible before the end of the cruise. As we were about to complete the study at E2 a crew member became ill and after 24h observation it was decided to evacuate him to land. The ship set sail to Montevideo, considered the most convenient port, which effectively ended the JC80 scientific programme."

An international 3-day meeting took place in Grenada, Spain, to discuss geodynamic and multidisciplinary topics related to the evolution of the Scotia Sea was held in May 2013. The region is of critical importance because of its role as a major ocean gateway which opened during Eocene-Miocene times, and because of its impact on global ocean circulation, with possible importance for Palaeogene-Neogene palaeo-environmental change, early phases of development of Antarctic ice sheets, gene flow, and resulting biodiversity. The Scotia Sea includes several major spreading centres, minor ocean basins and volcanic arcs, whose evolutions are the subject of ongoing debate.

Other research

Palaeomagnetic constraints on lower oceanic crustal processes (IODP Expedition 345 Hess Deep Plutonic Crust (Antony Morris, Plymouth, Andrew McCaig, Leeds). Generation of ocean lithosphere by seafloor spreading at mid-ocean ridges is one of the fundamental geological processes operating on Earth. One of the most important yet most intractable problems is to understand how the magma reservoir beneath ridges generates the lower crust, especially at fast spreading rates. Gabbroic rocks from the lower crust are normally inaccessible, but are exposed tectonically on the flanks of the Hess Deep rift in the Pacific Ocean. IODP Expedition 345 aims to provide a unique suite of lower oceanic crustal samples from this locality that will yield insights into magmatic and tectonic processes involved in seafloor spreading. (gtr.rcuk.ac.uk/project/7C9FF93B-A37F-4B5E-9032-B6612C6184FB).

Hydrothermal systems, thermal boundary layers and detachment faults in slow-spread ocean crust Andrew McCaig (Leeds). Over the last 12 years improved sonar surveys of the mid Atlantic Ridge have revealed a new mode of seafloor spreading where a significant part of the plate divergence is taken up by slip on long-lived, convex upward detachment faults, rather than mainly by magmatic intrusion. In this project we are investigating this boundary layer more thoroughly, as well as the complex interrelationships between faulting, magmatism and hydrothermal circulation at slow spreading ridges. We are addressing this problem by building thermal and hydrothermal numerical models to predict both the asymmetric thermal structure produced by detachment faulting and the hydrothermal circulation patterns associated with permeable fault zones and localised magmatism. complex interactions between the ocean and the crust that occur as a result of this process. The project is also modelling the Lost City Hydrothermal Field. (gtr.rcuk.ac.uk/project/A9EBE81E-4438-4B88-A28D-669154B7FB9C)

The evolution of mid-ocean ridge magma chambers and the growth of slow-spreading oceanic crust (Johan Lissenberg (Cardiff), MIT & University of Hawaii). Recovered sections of lower oceanic crust have provided much information on crustal accretion mechanisms, but the key element of time has remained largely unconstrained due to the absence of precise dating tools. As a result, the temporal evolution of the accretion process has remained enigmatic. Combining high-precision zircon dating with trace element analyses, we will reconstruct how long magma chambers along a slow-spreading ridge segment were active, how they evolved over time and how quickly they cooled by analysis of samples from the lower oceanic crust recovered from the Vema Lithospheric Section (11 degrees N, Mid-Atlantic Ridge). This will provide an unprecedented view of the evolution of mid-ocean ridge magmatic systems over time. The pattern of the age variation of the samples with distance from the spreading ridge will constrain where magma was delivered to the crust. This allows a test of our hypothesis that slow-spreading oceanic crust forms in two fundamentally different modes, one dominated by symmetric spreading and melt delivery at shallow levels (inferred for Vema), and the other by asymmetric spreading, detachment faulting and deep magma emplacement. (gtr.rcuk.ac.uk/project/2CC07F42-1FDC-490C-8CC3-20F2A401B9AB).

Reactive melt migration in the lower oceanic crust and its implications for the evolution of mid-ocean ridge basalt (Johan Lissenberg (Cardiff)). Mid-ocean ridge basalt (MORB) is the most abundant magma on Earth. It is generated beneath mid-ocean ridges by decompression melting of upwelling mantle, and, following processing in lower crustal magma chambers, erupted onto the seafloor. For more then four decades igneous petrologists and geochemists have relied upon MORB as their major window into the mantle, deriving its composition, melting processes and melt migration mechanisms from the erupted lavas. However, this approach assumes that modification of melts in crustal magma chambers occurs exclusively by fractional crystallisation, and can thus be easily corrected for. Within the last decade evidence has emerged that melt may react extensively with existing cumulus crystals as it migrates through mid-ocean ridge magma chambers. If so, this requires a fundamental reassessment of MORB petrogenesis and its use as a messenger from the mantle. Thus, in order to understand MORB petrogenesis, and its implications for mantle studies, a robust model that fully characterises the nature and extent of reactive flow in oceanic magma chambers is required. I will obtain extensive textural and mineral chemical analyses, acquiring the first systematic dataset on reactive melt migration in the lower oceanic crust. The melt-rock reaction history as deduced from the rock record will then be modelled, allowing its role in MORB evolution to be quantified. Combined, the data and models will provide an unprecedented view of reactive melt migration through mid-ocean ridge magma chambers and its role in the evolution of MORB. Ultimately, this will determine the fidelity of MORB as recorders of mantle properties and processes. (gtr.rcuk.ac.uk/project/9BAA5C4D-67A4-4F34-AA70-F89BC18EF9F5)

The Louisville Ridge-Tonga Trench collision: Implications for subduction zone dynamics Christine Peirce (Durham) & Tony Watts (Oxford) with IGNS New Zealand and Universite Pierre and Marie Curie Paris. Subduction zones provide the mechanism for the destruction of oceanic lithosphere but are also responsible for the construction of arc lithosphere whose features include some of the largest and most active volcanoes on Earth and the majority of large earthquakes. Understanding the dynamics of this system is complicated by the diversity in the age, morphology and tectonic setting of the material that is entering the subduction zone, and yet it is the influence of this material which is a major factor in determining the architecture and composition of the entire trench, island arc, and back-arc system. Between ~5S-35S in the SW Pacific, the Tonga-Kermadec Trench subduction system has a deep, linear topographic depression at which Cretaceous Pacific oceanic crust is subducting beneath the Indo-Australian plate. However, at ~25S the Tonga Trench intersects with the Louisville Ridge, a linear chain of seamounts that runs obliquely to and is being subducted at the fastest rate of plate convergence on Earth (~80 mm/yr). Subduction of this ridge locally deforms the trench, and the point of collision is progressively moving north-to-south at ~118 mm/yr due to the oblique subduction geometry. Gepphysically derived images of the crust, uppermost mantle and seabed will allow us to determine how the crust was constructed, modified and deformed, and how the plate boundary system is evolving over time in response to the subduction of significant plate topography. (gtr.rcuk.ac.uk/project/617D42A8-21AC-4E05-86AF-722896DA874D)

Upcoming Cruises and projects

OSCAR - Oceanographic and Seismic Characterisation of heat dissipation and alteration by hydrothermal fluids at an Axial Ridge. NERC consortium grant (NE/I027010/1) (Richard Hobbs & Christine Peirce (Durham); Miguel Angel Morales Maqueda, David Smeed & Alexis Megann (NOC); Vincent Tong (UCL); Christopher Ballentine (Oxford); together with international partners Marion Jegen (Geomar), Bob Lowell (Virginia Tech), Rob Harris (Oregon State) & Sue Humphris (WHOI)) has been scheduled for January/February 2015. This two-ship programme will investigate the the heat and mass transfer through the seabed at the Costa Rica Ridge and its flanks out to crustal age of about 6 Ma using both geophysical and oceanographic measurements. The geophysical model will be tied to the ODP hole 504B (about 200 km from the ridge). The geophysical data will focus on two 3D Ocean Bottom Seismometer (OBS) surveys at the ridge and hole 504B tied together with three long-offset (>9 km) controlled source seismic profiles with MT (electrical resistivity) and potential field data (gravity and magnetics). The oceanographic data will sample the water inflowing into the basin along the Ecuador trench, current/tidal flows over the Carnegie ridge, map the temperature/salinity structure and turbulence within the Panama Basin. (gtr.rcuk.ac.uk/project/F6313720-CB84-47E4-A2A5-8B167A6C5170)

Role and extent of detachment faulting at slow-spreading mid-ocean ridges Chris MacLeod (Cardiff), Tim Reston (Birmingham), and Christine Peirce (Durham) (together with Roger Searle, technically as 'consultant'). We will utilise a variety of seismic techniques, at the Mid-Atlantic Ridge axis in the 13°N area, to test competing models for the nature and significance of detachment faults and associated oceanic core complexes. We will combine a passive micro-earthquake study with active source experiments to attempt to document the sub-surface geometry and continuity of detachment faults at depth and the spatial/temporal relationship between melt emplacement and faulting. The project will require two cruises, in order to give sufficient duration for the passive experiment. The cruises are not yet scheduled. (gtr.rcuk.ac.uk/project/B6389C92-8A3E-4DEB-83A1-D913492FFB6F)

Volatile Recycling at the Lesser Antilles Arc: Processes and Consequences (NE/K010824/1) (a project involving UK Universities of Durham, Southampton, Liverpool, Bristol, Imperial, East Anglia & Leeds with international partners University of the West Indies, ETH Zurich, Potsdam & the NSF-funded GeoPRISMS program, project is led by Jon Davidson at Durham) proposes an innovative multidisciplinary experiment to track volatiles at a subduction zone. Questions to be answered include: How do volatiles influence the types and amounts of magmas generated? How do they control where volcanoes, such as Le Soufriere, Montserrat and Mt Pelee, Martinique, are located and how explosive they are? How do volatiles dictate where ore deposits are formed? How do volatiles mediate the seismogenic behaviour of subduction zones - whether there are large "megathrust" earthquakes like Japan and Sumatra or whether slip is less violent? The plan is to use novel seismic approaches complemented by geochemical analyses and integrated using numerical models to identify and quantify where volatiles are in the down-going plate, where they are released at depth, and how they are transported from the subducting plate through the mantle wedge to the arc. Together with a unique suite of rocks from deep in the crust which have been carried up in volcanoes to help understand how magmas evolve, and what allows them to concentrate ore metals. Mapped water pathways will be compared with seismic and volcanic activity, as well as with those inferred at other subduction zones. (gtr.rcuk.ac.uk/project/B98BE408-BEA0-43EB-B069-B7FCBD04BC43)

Korea

Sung-Hyun. Park

Korea Polar Research Institute (KOPRI) had 3rd cruise on Australian-Antarctic Ridge, easternmost Southeast Indian ridge in January this year (2013) using RV Araon. The one of purposes of this cruise was to locate the hydrothermal vent site more precisely, which was found and briefly located by former two cruise. As well as locating the vent site, we did more mapping on the ridge including the seamount in the south of the ridge and got the magnetic data using proton magnetometer. We also did dredging and rock coring to get rock and biological samples.

The cruise was very successful. Using CTD Tow-yo, we confined the vent site ("Araon vent field") with in 2 km circle. CTD Tow-yo was very effective because we attached OBS and ORP sensors into seabird in collaboration with NOAA. The CTD water samples were analyzed and strong 3He, CH4, Mn, and Fe were detected, confirming OBS and ORP anomalies originated from hydrothermal vent. We also found very interesting features in the bathymetry, gravity and magnetic anomalies. In the geochemistry, very unique mantle heterogeneity was found. Highlight of this cruise is finding of new hydrothermal vent biology using dredging: Kiwa crab and seven arm starfish. DNA analysis was done for these biology and we can confirm they are new species. Probably these vent biology were taken for the first time from the long mid-ocean ridge system in southern ocean from Rodriguez triple junction in Indian Ocean to western end of Pacific Antarctic ridge. We think these new species have similarity with the vent biology reported in East Scotia Sea rather than western Pacific one.

We think first stage of KOPRIDGE project successfully complete its mission and it should advance to next step. We are planning ROV cruise on the new vent site "Araon" and expand the research area to further east where still only a few research survey was done.

Norway

R. Pedersen

In Norway, researchers from the Centre for Geobiology (CGB) at the University of Bergen continue to undertake most of the ongoing ridge research activity. The ridge research carried at CGB comprises studies of crustal accretion processes and hydrothermal systems - including seafloor and subseafloor geomicrobial activity and vent fauna ecosystems. The ultraslow spreading Arctic ridges are the primary field area. The research on ridge accretion processes is currently focusing on: 1) interactions between the multiple mantle domains present below the Arctic ridges; 2) dynamics of oblique spreading and core complex formation; and 3) the evolution and architecture of axial volcanic ridges. The latter is partly based on the acquisition of microbathymetry using AUV. Our studies of hydrothermal activity have for the last years focused on the Soria Moria, Troll Wall and Loki's Castle vent fields that were discovered in 2005 and 2008. The cruise this summer aimed at locating new vent fields, and at estimating the hydrothermal activity over larger ridge segments. By searching for bubble plumes using hull-mounted multibeam echo sounder systems, two new vent fields were located at the relative shallow parts of the ridge system close to the Jan Mayen. In the deeper parts of the ridge system to the north, three other venting areas were found by searching for chemical signatures in the water column.

Studies of water-rock-microbe interaction and geomicrobiology are presently focused on low-temperature Fe-oxyhydroxide and baryte deposits that are associated with the Arctic vent fields. These studies involve microbial growth experiments, metagenomics, microtextural and geochemical analyses - including heavy stable isotope systematics. A comparison of these modern deposits with Archaean examples is also ongoing. This year, two bioprospecting projects that target novel enzymes in the thermophiles and hyperthermophiles are starting up with industry support.

Following the 2008 discovery of the Loki's Castle vent field and an associated novel vent fauna, a major objective for the Norwegian ridge research program has been to characterize and document this vent fauna. As of today, 20 new species have been found at the Loki's Vent field. With this year's discovery of several new vent fields occurring at water depth from 150 to 2500 m, the diversity of this Arctic vent fauna province will be further explored in the coming years.

In early August this year, the Norwegian Minister of Environment visited the University of Bergen to learn more about the deep-sea and the part of the ridge systems that is present within Norwegian waters. One of the issues that were raised at the meeting was whether Norway should and could proceed towards establishing deep-sea marine sanctuaries at some of these vent fields.

Russia

Sergei Silantyev

The biennial workshop of Russian-Ridge was held in St.-Petersburg on 24-25 June 2013 in VNIIOkeangeologia, St. Petersburg. The topic of this workshop was "The Mid-Oceanic Ridges - new data on geology and mineral deposits". Workshop brought up for discussion most important results of multidisciplinary investigations of the Mid-Oceanic Ridges obtained by Russian scientists during last two years, R-Ridge activities as well as upgrade of the R-Ridge web-site.

Among the most important results of investigations of ridge processes carried out by Russian scientists during 2012 - 2013 and presented on Russian Ridge Workshop'13 it should be to highlight the following:

1. Mid-Atlantic Ridge Hydrothermal ore deposits

- Information on main results of investigations of MAR Sulfide Ore Deposits obtained during 2011-2012 at Russian exploration area has been reported. In July 2011 on the 17-th session of International Seabed Authority of UN (ISA) Russian application was granted for exploration of polymetallic sulfides at the Atlantic ocean at the area situated at the axial zone of Mid-Atlantic Ridge between latitudes 12°48,36'N and 20°54,36'N was considered and approved. In November 2012 Russian Federation signed the contract with ISA, giving sole priority during 15 years to operate searches and explorations at the limits of declared location, hereinafter called Russian exploration area. The main contractors are Polar Marine Geosurvey Expedition ("PMGE") and "VNIIOkeangeologia n.a. I.S. Gramberg". Russian exploration area embraces 100 blocks about 10 × 10 km in size and total square 10 000 sq. km. By 2010 seven important ore objects were identified at the territory of Russian exploration area: ore cluster "Ashadze" (12°58'-12°59'N); ore cluster "Semyenov" (13°31'N); ore cluster "Logachev" (14°43'-14°45'N); ore field "Krasnov" (16°38'N); ore field "Peterburgskoye" (19°52'N); ore field "Zenith - Victory" (20°08'N) and ore field "Pui-de-Folle" (21°30'N). Total predicted ore deposits until today are estimated at 88—89 ml. tons (*Beltenev V., Ivanov V., Samovarov V., Sergeev M. - PMGE and Sevmorgeo, St. Petersburg*).

- A practical approach to the classification of sulfide ore deposits and new data on their mineralogy and composition in the Russian Prospection Area of MAR has been presented (*Andreev S., Babaeva S., Stepanova T. - VNIIOkeangeologia, St. Petersburg*).

- A relationships between age of ore deposits and their size were established by ^{230}Th/U dating of sulfide ores (*Черкашёв Г., Кузнецов В., Бельтенёв В. - VNIIOkeangeologia, PMGE, University of St. Petersburg*)

- New method for prospecting of hydrothermal ore deposits in MAR has been proposed. This method based on the detecting discharged and strained areas of the oceanic crust (*Petukhov S., Aleksandrov P., Kolchina N. - VNIIOkeangeologia, St. Petersburg*)

- Current situation with data bases and information analysis for support of works in the Russian prospecting area have been discussed. To implement the Russian Contract for prospecting deep-sea polymetallic sulfides (DSPS) in the MAR (2012—2026) at all stages, an information analysis support is provided for the geological prospecting and environmental works at all stages. The information analytical supports of geological prospecting and environmental works enables efficient studies in the International section of the ocean at all stages of prospecting. The Data Bank serves as a basis for compiling maps, prediction of useful minerals, processing and interpretation of geological and geophysical data, evaluating and calculating DSPS reserves. It includes an informative data base, reference base, DBMS, database inquiry library, and application software library. The DB is a relational one; it operates in the Microsoft Access 2007 environment. The basic information on DSPS ore nodes and fields was obtained during 33 cruises in 1986—2012 to the MAR region, carried out by FGUP PMGRE. The data arrays contain information from 2026 geological stations (850 by box sampler, 222 - by grab (tv- grab), 655 - by dredge, 51 - by flow pipe), as well as from 711 rhydrological stations. The data contained in the DB allow not only evaluating the existing hydrothermal nodes and fields, but also show the possible ways of their extension. (*Kolchina N., Petukhov S. - VNIIOkeangeologia, St. Petersburg)*

2. Petrology and Geochemistry of igneous rock assemblages in the Mid-Oceanic Ridges

- Relations between MAR tectonic features and igneous rocks geochemistry for region between 13º - 14ºN have been examined. The work is based on melt compositional varieties revealed by analyses of quench basalt glasses from 55 sites. At least 6 compositional melt groups using new data on TR were established in this region. All reported melt compositions are not significantly affected by crystallization, but are mostly the functions of the source composition and degree of melting. The prominent melt compositional variations between 13°30'–13°35'N suggest heterogeneous mantle source of Rift Valley magmatism in MAR segments examined. (*A.Pertsev, Bortnikov N., Beltenev V., Shatagin K. - IGEM, Moscow; PMGE, St. Petersburg).*

- Synthesis petrologic and geochemical data on Zircon from oceanic crust was undertook for reconstruction accompanied petrogeneitic conditions (An example of Sierra-Leone RTI – Markov Deep, 6ºN). MAR area at 6ºN represent an example of oceanic core complex where altered mafic-ultramafic plutonic rocks are exposed on oceanic floor. Obtained data indicate that zircon in the rocks of oceanic lithosphere is not ideal “container”, but together with host rocks is incorporated in all tectono-metamorphic processes and experiences recrystallization. By the example of the zircon populations from altered gabbros of the Sierra Leone at least three types of transformations have been established: 1) related to the recrystallization of primary magmatic zircon under conditions of high-temperature ductile deformation; 2) zircon grains in relation with granite formation often contain numerous inclusions of secondary silicate minerals and acid glass; 3) Porous rims, which overprint both primary and already transformed zircons. The interaction with weakly saline aqueous solutions of elevated alkalinity may facilitate the extraction of high-field TR thus causing simultaneous crystallization of zircon and baddeleyite and increase of Ti content in zircon. Partial or complete recrystallization of primary magmatic zircon and growth of a new zircon generation may proceed in diverse settings typical of core oceanic complexes of the slow-spreading ridges. The formation of plagiogranites during partial melting of gabbros is accompanied by crystallization of zircon from acid melt. Thus, the complex study of structural-morphological and geochemical features of oceanic zircons, inclusions (ingrowths) in them, and phase composition of the host rocks provide insight into processes leading to the crystallization and subsequent evolution of this mineral under conditions of oceanic lithosphere. *(Zinger T., Aranovich L., Sharkov E., Bortnikov N. - Institute of Precambrian Geology and Geochronology RAS, St. Petersburg, IGEM RAS, Moscow).*

- Analysis of Origin of the compositional and isotope Variety of MORB from Equatorial MAR was presented (*Skolotnev S. - Geological Institute RAS, Moscow).*

- Data on existence of regional and local geochemical anomalies of Rift Zone magmatism in the South Atlantic and Scotia Sea have been discussed *(Sushevskaya N., Belyatsky B., Dubinin E. – Vernadsky Institute, Moscow; Institute of Precambrian Geology and Geochronology RAS, St. Petersburg; Moscow State University).*

- In close cooperation with German colleagues from GEOMAR new data on peridotites from Stalemate FZ (NW Pacific) were reported. Samples of ultramafic rocks examined were dredged during German R/V Sonne cruise SO201-KALMAR Leg 1b in frames Russian-German Project KALMAR. The Stalemate Fracture Zone (SFZ) is characterized a 500 km at length, SE-NW strike and situated between the northernmost late-Cretaceous Emperor Seamounts and the Aleutian Trench. The data reported suggest that lherzolites dredged at SFZ are mantle residues after near-fractional melting of mantle source. The mantle melting started in the garnet stability field at a depth more than 100 km and then continue in the spinel stability field. The close location of the Stalemate Fracture Zone to the Hawaiian-Emperor Volcanic Chain suggest the influence by Hawaii Plume on the geochemical peculiarities of peridotites exposed along the SFZ and on the melting process that took place 100 Ma ago. *(Krasnova E., Portnyagin M., Silantyev S., Werner R., Hoernle K. - Vernadsky Institute, Moscow; GEOMAR, Kiel, Germany.*

3. Geophysics data and Tectonic in the Mid-Oceanic Ridge Crest Zones

- The peculiarities of tectonics, structure-forming and magmatism of ultraslow spreading ridges are considered on example of Reykjanes, Kolbeinsey, Mohns, Knipovich, Gakkel and South-West Indian ridges. It is shown that the decisive role in formation of structural plan of their rift zones belongs to temperature of mantle, thickness of crustal brittle layer, and obliquity of spreading. *(Dubinin E., Kokhan A., Sushchevskaya N. - Moscow State University, Vernadsky Institute, Moscow).*

- Voluminous geophysical data obtained in South-Eastern Indian Ocean are presented. Study is focused mainly on the Antarctic part of this Basin. Totally about 30 000 km of seismic, gravity and magnetic data as well as more than 60 sonobuoys have been acquired here by Russian, Australian, Japanese, USA and French Antarctic Expeditions. During pre-oceanic (rift) stage the studied region was developed as a result of extreme crustal extension and mantle unroofing. The zone of exhumed mantle is well defined by linear long-wavelength gravity and magnetic anomalies. The western part of the Oceanic Basin (both on the Australian and Antarctic sides) is complicated by conjugate chains of oblong basement highs which formed during the Paleogene time. These chains are interpreted to be peridotite (partly serpentinized) and gabbro core complexes representing amagmatic accretionary paleoridge segments which are common features of slowly divergent plates. (*Leitchenkov G., Guseva Yu., Varova L.- VNIIOkeangeologia, St. Petersburg; PMGE, St. Petersburg*

Listed above data are presented in more detailed design on the web-site of Russian Ridge as abstract Volume of Workshop-RR'13 (open access): http://russianridge.ihed.ras.ru

International Research

Development of different modes of detachment faulting, 16.5N at the Mid-Atlantic Ridge

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Abstract

During May and June of 2013, we surveyed and sampled a region of the Mid-Atlantic Ridge (MAR) centered on 16.5N. In this region detachment faulting occurs along ~120 km of the western flank of the ridge axis which exhibits varying local magmatic budgets. The study area presents excellent examples of several different modes of active detachment faulting. Regional multibeam bathymetry, gravity, and magnetic data were collected out to about 60 km (~5 Ma) on each side of the axis to understand the spreading history. Autonomous Underwater Vehicle (AUV) Sentry collected high-resolution multibeam bathymetry, side-scan, magnetic, chirp, and water column data in critical locations complemented by photographs from the WHOI Towcam. We also completed an extensive dredging program in the region. The data are being used to characterize fault terminations, assessing where detachment faults are active, how they evolve off-axis, whether they link along the axis, and their relationship to magma budget at the axis. Here we present a preliminary description of four modes of detachment faults that accommodate extension of the western rift valley wall.

Study area

Figure 1 shows the location of the study area near 16.5N at the MAR. A previous study identified two distinctive, parallel linear ridges (East and West Ridges, Figures 2 and 3) on the west side of the axis as the rotated tops of detachment faults (breakaways) [Smith et al., 2008]. East Ridge, because it is closer to the volcanic axis, was interpreted as a newly emerging detachment fault forming a rafted block sitting on the top of the older West Ridge detachment. The corrugated massif at the south end of West Ridge was identified as a core complex. On the east side of the ridge axis at 16.63N, Krasnov, a large, extinct hydrothermal vent field (Figure 3), has been the focus of several studies [e.g., Cherkashov et al., 2008].

The 16.5N region has a high rate of seismicity. There are 29 teleseismic events listed in the NEIC catalog (http://earthquake.usgs.gov/earthquakes/eqarchives/epic/). In addition, 391 hydroacoustically-recorded events were identified during four years of monitoring [Smith et al., 2003] yielding an astonishing average of about one earthquake (roughly > magnitude 2.5-3.0), every three days. Based on the seismicity rate and their interpretation of the morphology, Escartín et al. [2008] concluded that the west flank of the 16.5N area is one of active detachment faulting.

Data

During R/V Knorr Voyage 201 Leg 05, regional SeaBeam multibeam bathymetry, gravity, and magnetic data were collected out to ~5 Ma on each side of the axis (tracklines, Figure 1) to understand the spreading history. Corrugations west of North and West Ridge detachment faults (labeled on Figure 3) indicate that in this region detachment faulting has dominated the west flank of the ridge for at least 3 Ma.

AUV Sentry completed 14 dives and collected Reson 7125 multibeam bathymetry (~1 m horizontal resolution compared to ~100 m for SeaBeam), side-scan (125kHz and 400kHz), magnetic, Edgetech chirp, and water column data in each of the survey boxes shown in Figure 2. Sentry seafloor photographs were obtained along short lines during two of the dives (box immediately east of East Ridge and the westernmost box over the North detachment fault, Figure 2). In addition, bottom photographs and water column data were collected in areas of interest during 9 dives of the WHOI Towcam (short blue lines, Figure 2). Finally, an extensive dredging program was completed in the region. Rocks were obtained in 73 dredges adding to the samples previously collected by our Russian colleagues (G. Cherkashov personal communication). The types of rocks collected and their locations are shown in Figure 2 (smaller circles indicate Russian samples). Dredges and Towcam dives were run during and between AUV Sentry surveys. The extensive suite of data collected in the 16.5N region allows us to interpret detachment faults and core complexes with confidence.

Detachment faulting at 16.5N

Here we describe the characteristics of the faults on the western flank of the MAR in the 16.5N area. South core complex is a classic, corrugated, domal massif. The corrugations have wavelengths varying between 400 and 1600 m, and relief of 50-100 m. The exposed footwall close to where it emerges from beneath the hanging wall has a dip of < 10o. The termination of South core complex fault is located ~8 km from the axial volcanic ridge (AVR), which is broad (~4.5 km wide) and has a relief of about 300 m. Towcam photographs at the top of the AVR (short blue line, Figure 2) show pillow flows with varying degrees of sediment between the pillows. Despite several attempts, we were unable to sample the lower footwall of South core complex, which we speculate is due to it consisting of a massive smooth fault surface that exposes gabbro. Similar sampling problems have been encountered at other oceanic core complexes exposing massive gabbro that have not been broken by mass wasting and cross-faulting.

East Ridge is a medium-offset normal fault that is active close to the spreading axis. Its termination lies ~3.5 km from the AVR, which is consistent with a new normal fault dipping at 60o that cuts the base of a 6-km thick crust at a point beneath the magmatic axis. We think that the section of older detachment (West Ridge, Figure 2) behind East Ridge ceased being active when extension on East Ridge detachment fault was initiated. We interpret the corrugated surface behind East Ridge as the abandoned section of West Ridge detachment fault. Several dredges on the inward facing slope of East Ridge recovered pillow basalts indicating that the fault throw is insufficient as of yet to expose lower crust or dikes.

The dip of the outward-facing slope of East Ridge is ~20o and the axis-facing scarp 30-40o yielding a normal fault with an initial dip angle of between 50-60o (obtained by summing the inward and outward dips) and indicating significant flexural fault rotation [Buck, 1988]. The AVR adjacent to East Ridge is approximately 3 km wide with a relief of 300 m, similar to the AVR just to the south. Towcam photographs of the AVR (short blue line, Figure 2) show pillow flows also similar to what was seen to the south.

The dip of the footwall of West Ridge detachment fault near the termination is about 18o, which is steeper than observed at South core complex

(<10o). The termination of West Ridge fault is about 5 km from the AVR. Numerous dredges on the inward facing slope of West Ridge detachment fault recovered peridotite, diabase and pillow basalt. The rougher terrain and ease with which it was dredged indicates that this terrain was more easily disrupted by faulting and mass wasting than the penecontemporaneous uniformly smoothly corrugated footwall of South core complex. This is consistent with a stratigraphy of massive serpentinized peridotite cut by diabase dikes overlain by scattered pillow basalts. The AVR adjacent to West Ridge fault is narrower (1.5-2 km wide) than to the south, but its relief is the same (300 m). In addition, the top of the AVR is on average a few hundred meters deeper than the AVRs in front of South core complex and East Ridge. Towcam photographs (short blue line, Figure 2) of the AVR appear similar to those obtained to the south. Volcanism may be weaker in this section or the AVR may be currently building.

The North detachment fault borders a deep, narrow rift axis (Figure 3), which suggests that this section of the ridge is magma starved. On the west flank of the ridge, three fault blocks have been carried off axis. West of these fault blocks is a massif from which we sampled gabbro and peridotite. We interpret the western flank of the axis in this region as a detachment fault that may be covered by short-lived rider blocks, with a basement composed of small gabbro intrusions in serpentinized peridotite overlain by scattered pillow basalts.

Discussion

Here we summarize some of the preliminary results from the Knorr 210-05 cruise within the context of previous studies. Numerical modeling has suggested that long-lived detachment faults form primarily in regions of reduced magma supply [Buck et al., 2005; Olive et al., 2010; Tucholke et al., 2008], and this is supported by their common occurrence at the end of segments where it is inferred that magma supply is low [Tucholke et al., 2008]. In our study region, however, these ideas do not hold up. In fact, the most robust AVR appears to be adjacent to South core complex suggesting abundant volcanism and high magma supply. These observations are opposite to what has been previously proposed (i.e., that corrugated surfaces form in regions of low magma supply and rider blocks form toward the center of the segment where local magma budget is high [e.g., Reston and Ranero, 2011]). Our preliminary results suggest that variations in local magma budget may not be the only mechanism controlling the surface expression of detachment faults.

Acknowledgments: We would like to thank the captain and crew of the R/V Knorr for their hard work during the cruise. The over-the-side operations (Sentry, Towcam, dredging) were handled efficiently and with expertise, and allowed us to meet our demanding schedule.

References

Buck, W.R., Flexural rotation of normal faults, Tectonics, 7 (5), 959-973, 1988.

Buck, W.R., L.L. Lavier, and A.N.B. Poliakov, Modes of faulting at mid-ocean ridges, Nature, 434, 719-723, 2005.

Cherkashov, G., V. Bel'tenev, V. Ivanov, L. Lasareva, M. Samovarov, V. Shilov, T. Stepanova, G.P. Glasby, and V. Kuznetsov, Two new hydrothermal fields at the Mid-Atlantic Ridge, Mar. Geores. Geotech., 26, 308-316, 2008.

Escartín, J., D.K. Smith, J. Cann, H. Schouten, C.H. Langmuir, and S. Escrig, Central role of detachment faults in accretion of slow-spread oceanic lithosphere, Nature, 455, 790-794, doi:10.1038/nature07333, 2008.

Olive, J.-A., M.D. Behn, and B.E. Tucholke, The structure of oceanic core complexes controlled by the depth distribution of magma emplacement, Nature Geo., 3, doi:10.1038/NGEO888, 2010.

Reston, T.J., and C.R. Ranero, The 3-D geometry of detachment faulting at mid-ocean ridges, Geochem. Geophys. Geosys., 12, Q0AG05, doi:10.1029/2011GC003666, 2011.

Smith, D.K., J. Escartin, M. Cannat, M. Tolstoy, C.G. Fox, D. Bohnenstiehl, and S. Bazin, Spatial and temporal distribution of seismicity along the northern Mid-Atlantic Ridge (15o-35oN), J. Geophys. Res., 108, doi: 10.1029/2002JB001964, 2003.

Smith, D.K., J. Escartin, H. Schouten, and J.R. Cann, Fault rotation and core complex formation: Significant processes in seafloor formation at slow-spreading mid-ocean ridges (Mid-Atlantic Ridge, 13-25oN), Geochem. Geophys. Geosyst., 9, Q03003, doi:10.1029/2007GC001699, 2008.

Tucholke, B.E., M.D. Behn, W.R. Buck, and J. Lin, Role of melt supply in oceanic detachment faulting and formation of megamullions, Geology, 36, 455-458, doi:10.1130/G24639A.1, 2008.

Figure Captions

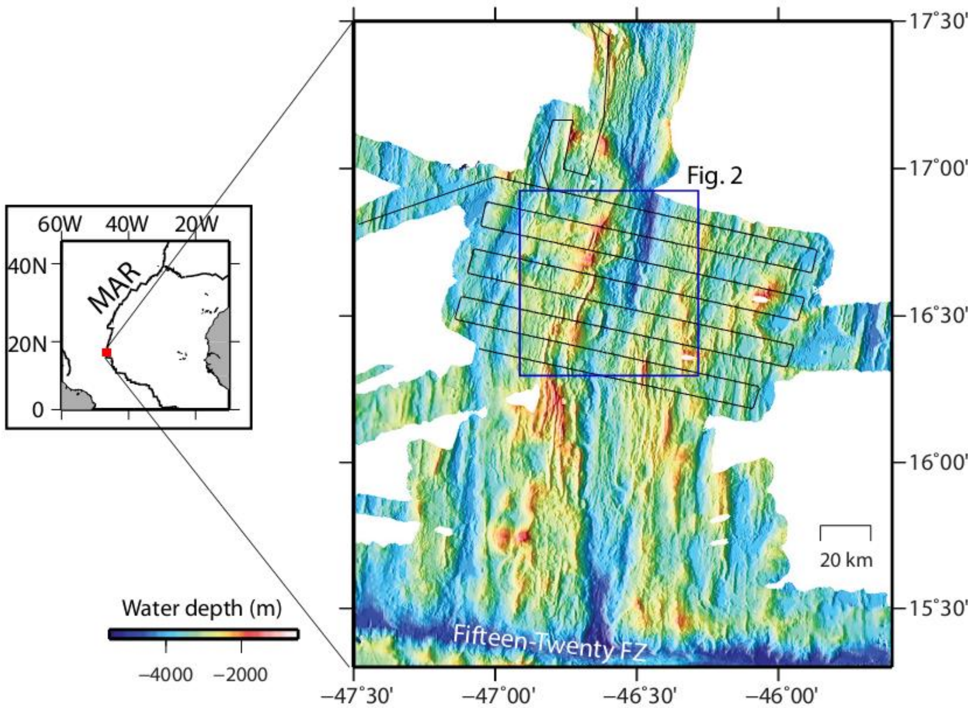

Figure 1. Location of the study region near 16.5N at the MAR. Regional survey track lines are shown in black. The location of Figure 2 is marked by the box.

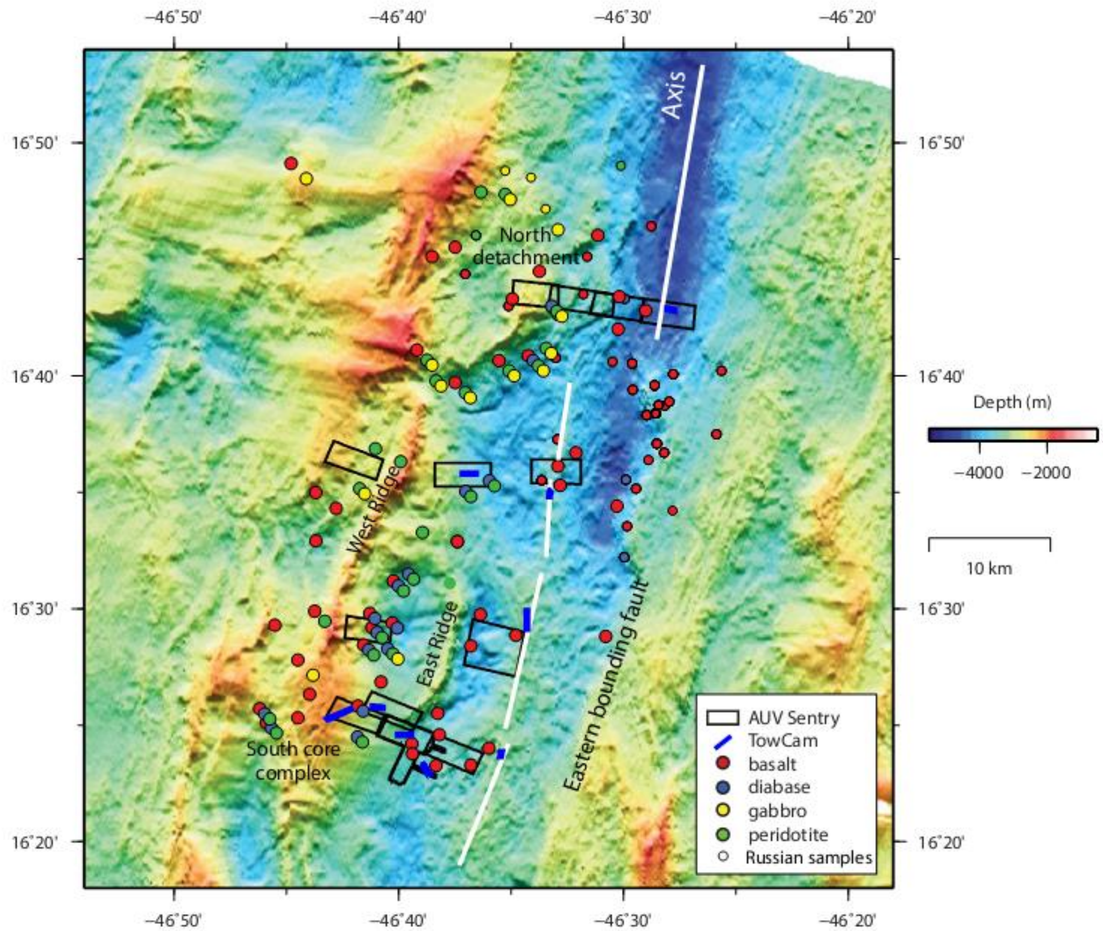

Figure 2. Bathymetry map showing the locations of the AUV Sentry dives, Towcam dives, and rock samples obtained during R/V Knorr 210-05. Also included are sample locations from the Russian data archive. The Russian samples are primarily located on the eastern side of the axis and in the north.

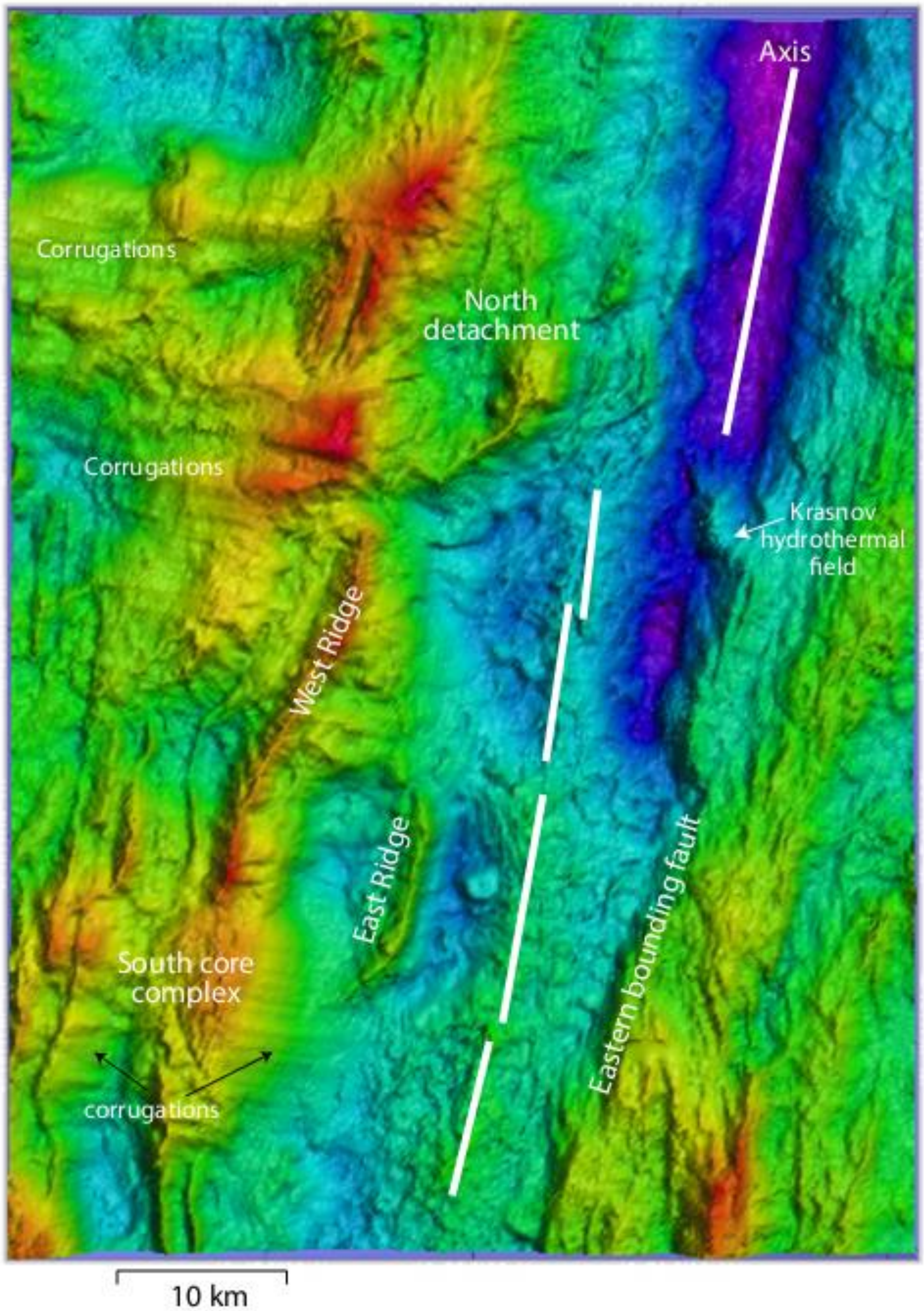

Figure 3. Bathymetry map centered on 16.5N. Major features near the axis are labeled. Straight white lines indicate the spreading axis.

InterRidge Vents Database joins the semantic web of Linked Data

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Abstract
The InterRidge Vents Database underwent a thorough makeover earlier this year. You may have noticed the new interactive mapping feature – but you probably didn't notice something that happened out of sight "behind the scenes" – the database is now part of the world wide semantic web of data.

Manuscript
You may have noticed that a revised, new version of the InterRidge Vents Database is available now at: http://vents-data.interridge.org. What you may not know – because it is happening "behind the scenes" – is that this new version of the database has joined the semantic web of Linked Data. The semantic web refers to a global collaborative initiative, led by the World Wide Web Consortium (W3C), to utilize standard technologies to support a "web of data" (for more information, see: http://www.w3.org/standards/semanticweb/). To join the "web of data" - also known as Linked Data- much of the information in the vents database is coded in a standard way, using Resource Description Framework (RDF), and matched to authoritative vocabularies published on the web by others using Linked Data. Effectively, by joining others who are using the same technologies and vocabularies, the InterRidge Vents Database is now part of a global, federated database, meaning that it can be queried and associated automatically with content in many other databases out on the world wide web. In particular below, we will highlight the connection with the Integrated Ocean Drilling Program (IODP). An ultimate goal is to enable interoperability with many other oceanographic databases including the U.S. Biological and Chemical Oceanography Data Management Office (*BCO-DMO*) and Rolling Deck to Repository (R2R) databases.

The purpose of the InterRidge Vents Database (full name: InterRidge Global Database of Active Submarine Hydrothermal Vent Fields) is to provide a comprehensive list of active and inferred active (unconfirmed) submarine hydrothermal vent fields for use in academic research and education. A manuscript is currently in peer review for the listings in Version 2.1, which is comprehensive through the end of 2009 and forms the bulk of the listings in the new, live database. In the upgrade to Version 3, the database was migrated to Drupal 7, an open source content management system with RDF web services in its core. We implemented additional contributed modules for query over the web using the SPARQL standard. Most database content and taxonomy terms are mapped to default RDF namespaces, with three important exceptions: we mapped the "vent field" content type to (1) an rdf:type for hydrothermal vents in a semantic knowledge base (http://yago-knowledge.org/resource/) and (2) to an rdf:type for geographical features from the Open Geospatial Consortium (http://www.opengis.net/rdf#), and (3) we mapped the latitude and longitude positions of the vent fields to a semantic vocabulary for the WGS84 geodetic reference datum (http://www.w3.org/2003/01/geo/wgs84_pos#). Another new feature in Version 3 is live Google mapping of vent field positions (Figure 1). A new Google Earth kml file for Version 3.2 will soon be posted to the

“Maps for Download” page on the website.

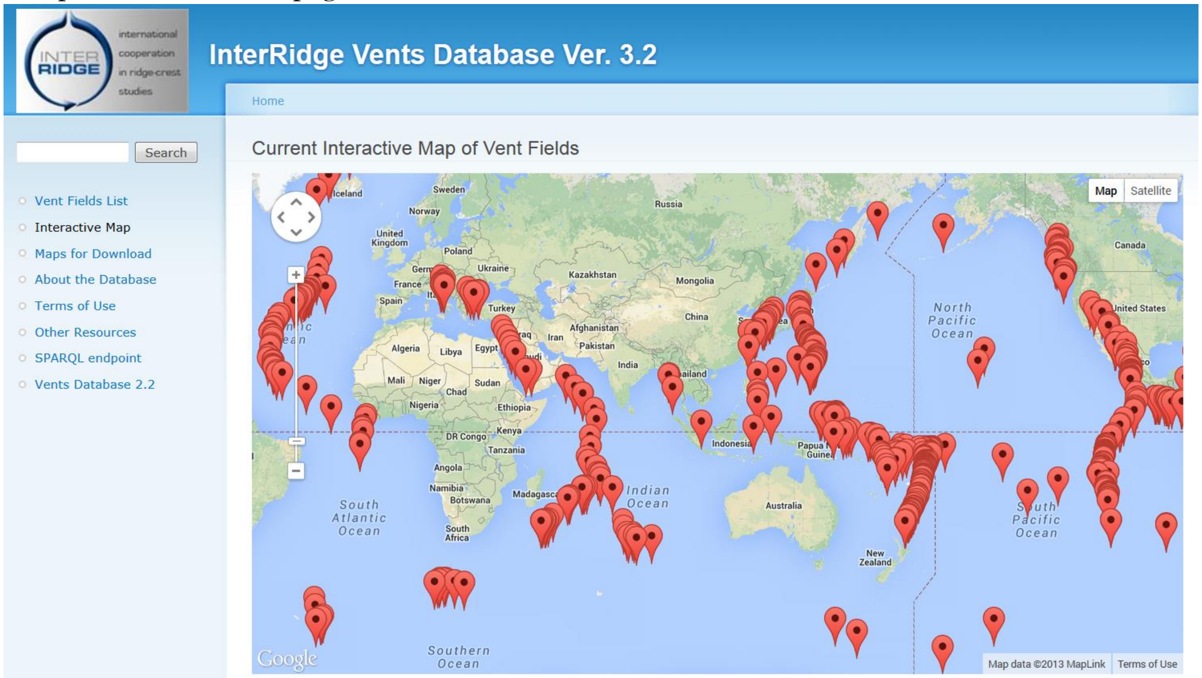

FIGURE 1: SCREENSHOT OF THE INTERACTIVE MAP ON THE DATABASE ONLINE AT: HTTP://VENTS-DATA.INTERRIDGE.ORG

Other databases using semantic web technologies can seamlessly link to the content in the vents database because elements such as latitude and longitude are coded as Linked Data. This can enable other databases to plot vent field locations as if that information was contained in their own database - when actually this is the federation of data from distributed servers. We reached an exciting milestone in performing a query of the InterRidge and IODP databases together, to ask “Where in the world are there IODP drill sites within 100 km of known vent fields?” The query was performed using SPARQL to access the vent field positions in the InterRidge Vents Database, which were loaded into the IODP database to perform a geospatial SPARQL query, and a subset of the results is shown in Figure 2. In the future, this particular query can be performed all-at-once and without requiring any local upload, when the Drupal software can accommodate the GeoSPARQL standard, a geographic query language for RDF data. Figure 2 is actually showing the results of three different SPARQL sources – two from the IODP database and one from InterRidge.

This work represents an important step forward towards linked and open data for our scientific community. We are engaged with international working groups to continue to build the web of federated databases in the

Acknowledgements

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Reference

Arko, R., C. Chandler, D. Clark, A. Shepherd, C. Moore, and S. Beaulieu. Rolling Deck to Repository (R2R): Collaborative Development of Linked Data for Oceanographic Research. EGU General Assembly, Vienna, Austria, Abstract EGU2013-9564, 2013.

ocean and Earth sciences (Arko et al. 2013).

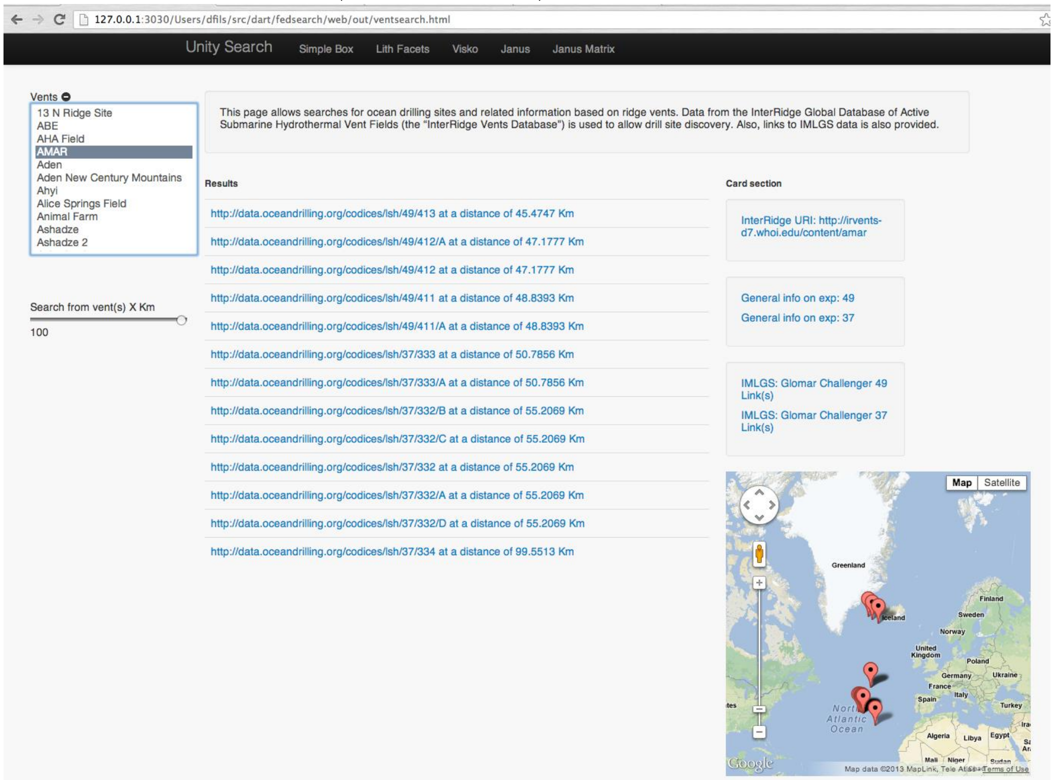

FIGURE 2 SCREENSHOT OF THE RESULTS OF THE QUERY: "WHERE ARE THE IODP DRILL SITES WITHIN 100 KM OF A KNOWN VENT FIELD?"

First data on composition of the NW Pacific Oceanic Lithosphere exposed along the Stalemate Fracture Zone

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Introduction

The nature of oceanic basement in the northwestern Pacific is still poorly known and remains a gap in our knowledge of the geological history of the Pacific Ocean. An important feature of this region is the preservation of a small fragment of the Kula plate, which was previously believed to have been entirely subducted [1]. The most thorough interpretations of the geodynamic evolution of the lithosphere beneath the Northwest Pacific derived from geophysical data and are presented in [1-5]. According to paleomagnetic data, Kula–Pacific spreading ceased at approximately 43 Ma [1]. The fossil Kula-Pacific spreading center is bounded by the Stalemate Fracture Zone in the South, which is the northwestern termination of the Kula-Pacific paleotransform (Fig.1).

The Stalemate Fracture Zone (FZ) includes a 500 km long SE-NW trending transverse ridge which originated by flexural uplift of Cretaceous (?) oceanic lithosphere along a transform fault boundary [1]. Sampling at the Stalemate FZ and the fossil Kula-Pacific Rift Valley was carried out during the German R/V SONNE cruise SO201 Leg 1b in July 2009. A broad spectrum of rocks including serpentinites (DR37), gabbro (DR7, 40), dolerites, gabbro-diorites and diorites (DR7) and basalts (DR38,41) were obtained. These rocks are thought to represent a complete section of oceanic lithosphere of Paleogene (fossil Kula-Pacific spreading center) to Cretaceous (Stalemate FZ) age. A study of these rocks allowed us to place new constraints on the magmatic and metamorphic history of the oceanic basement in the NW Pacific.

Magmatic History of lithosphere section along the Stalemate FZ

Ultramafic Rocks. Variably altered mantle peridotites were dredged from the eastern slope of the northwestern segment of the Stalemate Ridge. Dredging was carried out at depths of 4360–3955 m (Fig. 1). At site SO201-DR37, we sampled 14 strongly to moderately altered mantle peridotites [6]. According to on-board description and petrographic investigations, two major groups of samples were distinguished: (1) pyroxene-rich lherzolites, and (2) pyroxene-poor dunites (Fig.2). In order to reconstruct initial compositions of the peridotites, we analyzed relics of primary minerals (spinel, clinopyroxene and orthopyroxene). The compositions of the primary minerals change systematically from lherzolites to dunites. Spinel in lherzolites has higher Mg#, NiO, lower Cr#, Fe^{3+}# and TiO_2 (Mg#=0.65-0.68, NiO=0.26-0.34 wt%, Cr#=0.26-0.33, Fe^{3+}#=0.021-0.030, TiO_2=0.04-0.09 wt%) than spinel in dunites (Mg#=0.56-0.64, Cr#=0.38-0.43, TiO_2=0.19-0.28 wt%, NiO=0.19-0.26%, Fe^{3+}#=0.027-0.043) (Fig. 2). Clinopyroxene in lherzolites is less magnesian but enriched in NiO, depleted in TiO_2 and Na_2O and has lower Cr# (Mg#=91.7-92.4, Cr#=0.12-0.16, TiO_2=0.06-0.15 wt%, Na_2O=0.19-0.41 wt%, NiO=0.06-0.09 wt%) compared to clinopyroxene from dunite DR37-3 (Mg#=93.7, Cr#=0.16, TiO_2=0.23wt%, Na_2O=0.85wt%, NiO=0.06wt%). In general, the mineral compositions form continuous trends with end-members represented by lherzolite DR37-13, on the one side, and dunite DR37-3, on the other side. According to our modeling the lherzolites from the Stalemate FZ could result from 10-12% near fractional melting of a depleted DMM-like mantle [7]. The dunites originate through interaction of the residual lherzolites with Na- and Ti-rich melts and likely represent fragments of a network of dunite channels in the shallow mantle. The moderately refractory composition of minerals in the Stalemate FZ lherzolites distinguishes these rocks from strongly depleted peridotites from the East Pacific Rise and indicates the existence of slow- to intermediate-spreading mid-ocean ridges in the Pacific Ocean during the Cretaceous-Paleogene time [7].

Gabbro, gabbro-diorite, and diorite. Plutonic rocks occur along the entire length of the Stalemate FZ and are represented by separate gabbro fragments and those in lithoclastic breccia at site SO201-1bDR40 in the northwest and gabbro-diorite and diorite at site SO201-1b-DR7-7 in the southeast (Fig. 1). Gabbro at site DR40 is represented by angular fragments of mostly coarse-grained rocks of gabrophitic texture, consisting of plagioclase, clinopyroxene, magnetite, and secondary amphibole and chlorite. Some of the gabbro fragments are almost completely replaced by amphibole and can be classified as a typical gabbro-amphibolite. Some other gabbroic fragments dredged from this site occur as clusts in lithoclastic breccia, which contains also fragments of strongly altered dolerite. These rocks differ from separate gabbro fragments from the same site and are more strongly recrystallized and extensively replaced by uralite and contain abundant actinolite, chlorite, albite, and epidote. The SO201-1b-DR40 gabbro have a major element composition typical of MORB-type gabbro and fall within the compositional field of gabbro belonging to well studied Oceanic Core Complexes of the Mid-Atlantic Ridge (MAR) (8). The REE and incompatible-element patterns of the SO201-1b-DR40 gabbroes provide further support for their similarity with the N-MORB gabbro family: $(La/Sm)_{cn}$ = 0.06-0.19, La/Yb = 0.40-0.75. However, gabbro clasts from breccia are more likely plutonic analogues of more enriched MORB with $(La/Sm)_{cn}$ = 1.31-1.46, La/Yb = 1.65 at K_2O content of 1.07-1.30 wt %. Sr, Nd, and Pb isotopic composition of gabbro from Site SO201-1b-DR40 confirmed MORB affinity of these rocks (8). Gabbrodiorite and diorite dredged at SO201-1b-DR7 consist of plagioclase, potassic feldspar, clinopyroxene, and secondary actinolite, sphene, epidote, chlorite, and scapolite (found in single sample only). Gabbro-diorites additionally contain biotite. All the rocks exhibit undeniable evidence of variable metamorphic recrystallization. The gabbro-diorites and diorites have compositions different from those of typical MORB gabbro (8). Similar to several OPG (Oceanic Plagiogranite) in mid-oceanic ridges, gabbro-diorite and diorite from Site SO201-1b-DR7 are enriched in LREE (e.g. $(La/Sm)_{cn}$ = 2.8-4.1, La/Yb = 6.4-11.1). These rocks are however different from typical OPG due to essentially higher concentrations of K_2O and other Large Ion Lithophile Elements (K_2O = 1.14 -3.82 wt %, Ba = 294-674 ppm, and Rb = 15-126 ppm) and extremely high $^{87}Sr/^{86}Sr$ and low $^{143}Nd/^{144}Nd$ ratios ($\varepsilon Nd = +2$). Apparent similarity of these rocks to granitoids of continental provenance calls into question their in-situ origin in MOR setting. On the other hand, the diorites of exotic composition were found in several angular fragments, which have variable composition, and their origin via ice rafting of continental rocks is unlikely. The origin of intermediate plutonic rocks with continental-like geochemical features in the NW Pacific remains an important question for further studies.

Metamorphic history of lithosphere section along the Stalemate FZ

Ultramafic Rocks The strongly altered dunites are light red rocks with rare (<3%) macroscopically visible spinel relicts. The petrographic examination of these rocks revealed a texture typical of altered dunites. However, the main mineral of the altered dunites is quartz rather than serpentine. There are very subordinate amounts of chlorite, serpentine, and iron hydroxides and rare relicts of primary reddish brown spinel and bottlegreen clinopyroxene. The almost complete silicification clearly distinguishes the serpentinized dunites from the known products of hydrothermal alteration and low temperature (seafloor) weathering of peridotites in the oceanic crust. Serpentinized lherzolites of the Stalemate Fracture Zone show evidence for moderate temperature oceanic metamorphism. It should be pointed out that some samples of serpentinized herzolites contain quartz (or amorphous silica), the content of which is much lower than that in the altered dunites. Secondary alteration of the peridotites included serpentinization and also silicification of the dunites (Fig.3) caused strong enrichment of the rocks in fluid mobile elements (U, Li, Sb, Ba) (9). The enrichment of amorphous silica and quartz and unusually high SiO_2 (up to 88.7 wt %) and low MgO (up to 1.4 wt %) clearly distinguish these rocks from the known products of the hydrothermal alteration and low-temperature weathering of peridotites in the oceanic crust. There are two type of evolution: submarine and subaerial. In order to determine which of the two environments was responsible for the silicification of the Stalemate Ridge peridotites we used a thermodynamic model in the GEOCHEQ program package (10, 11). The model data indicate also that the geochemical and mineralogical effects observed in the silicified dunites of the Stalemate FZ are most similar to the expected results of the low-temperature alteration of oceanic serpentinites under subaerial conditions. The results of numerical modeling and the analysis of published data allowed us to suppose that the geochemical and mineralogical effects observed in the silicified dunites of the Stalemate Fracture Zone are consequences of the low-temperature deserpentinization of oceanic rocks under subaerial conditions. Hence, the peridotites could not be weathered under the conditions corresponding to their present day submarine occurrence at depths of approximately 4000 m. This implies that the oceanic crustal block of the northwestern Pacific perhaps since the time of its formation had movements with amplitudes of several thousand meters.

Gabbro, gabbro-diorite, and diorite All of our gabbro samples from Site SO201-1b-DR40 contain actinolite with 0.3-5.3 wt % Al_2O_3, chlorite, and albite. This mineral assemblage is typical of several MAR gabbroids and was produced under greenschist-facies conditions of oceanic metamorphism. Gabbrodiorite and diorite from Site SO201-1b-DR7 also display traces of metamorphic recrystallization: the rocks contain secondary actinolite, sphene, chlorite, epidote, and single dioritic sample additionally contains scapolite. These rocks could be metamorphosed in the presence of highly saline NaCl-H_2O fluid, as follows from mineralogical lines of evidence and from the elevated Na_2O concentration in the scapolite-bearing diorite sample.

Geodynamic evolution of the Cretaceous--Paleogene Lithosphere in the Stalemate FZ

Data briefly presented above allowed us to reconstruct the formation conditions of the basement rocks and to interpret their tectonic evolution. The genesis of gabbros found among plutonic rocks composing the Cretaceous-Paleogene lithosphere in the Stalemate FZ was related to magmatism at an ancient spreading center and provides record of the evolution of the parental magmatic melts of N-MORB. Along with related peridotites, basalts, and dolerites, these rocks can be attributed to the disintegrated the Cretaceous-Paleogene oceanic lithosphere of the Pacific Ocean. Spinel lherzolite–dunite assemblage recognized in Stalemate FZ is typical for spreading centers characterized by moderate spreading rate. The gabbro-diorite and diorite are not genetically related to the rocks of the Cretaceous-Paleogene basement of the Northwest Pacific. Thereby, the Stalemate Fracture Zone possibly reflects the complicated structure of the tectonic collage of rocks of different age. These rocks are produced in different geodynamic environments and were later tectonically brought together near the frontal portion of the Aleutian Island Arc. Judging by the isotopic-geochemical characteristics of these rocks, they cannot be classified as belonging to the family of oceanic plagiogranites. Deformations of the oceanic basement can be discerned throughout the whole Stalemate Fracture Zone as brecciation and large-amplitude vertical displacements within the oceanic lithosphere.

Acknowledgments

The authors thank the crew and captain L. Mallon of the R/V Sonne for productive cooperation that made it possible to obtain most of the rock samples for this study. This study was financially supported by the Russian Foundation for Basic Research (project no. 12-05-00002a, 12-05-31107), Program 17 "Fundamental Problems of Oceanology: Physics, Biology, and Ecology" (Theme: Mid-Atlantic Ridge: Specifics of Hydrothermal Interaction between the Ocean and Lithosphere and ore-Forming Processes) of the Presidium of the Russian Academy of Sciences, the Ministry of Science and Education of the Russian Federation (Government Contract 11.519.11.5013), and the Ministry Science and Education of Germany (KALMAR Project).

Reference

1. Lonsdale P. Paleogene history of the Kula plate: Offshore evidence and onshore implications. Geological Society of America Bulletin. 1988. V. 100. P. 733-754.
2. Erickson B.H., Grim P.J. Profiles of magnetic anomalies South of Aleutian Island Arc. Geol. Soc. Am. Bull. 1969. V.80. P.1387–1390.
3. Grim P.J., Erickson B.H. Fracture Zones and magnetic anomalies South of Aleutian Trench . J.Geophys. Res. 1969. V.74. P. 1488–1494.
4. Fullam T.J., Supko P.R., Boyce R.E. Some aspects of late Cenozoic Sedimentation in the Bering Sea and North Pacific Ocean. DSDP Initial Report. 1973. V. XIX. P. 887–896.
5. Rea D.K., Dixon J.M. Late Cretaceous and Paleogene tectonic evolution of the North Pacific Ocean. Earth Planet. Sci. Lett. 1983. V.64. P. 67–73.
6.Werner R. and Shipboard Party, FS Sonne. 2009. Fahrbericht. Cruise Report SO201-1b. KALMAR.N32.,P.62.http://www.ifm-geomar.de/fileadmin/ifm-geomar/fuer_alle/institut/publikationen/ifm-geomar_rep32.pdf
7. Krasnova E, Portnyagin M, Silantyev S, Hoernle K, Werner R. Two-stage evolution of mantle peridotites from the Stalemate Fracture Zone (NW Pacific). Geochemistry International. 2013. V. 9. N. 759-772.
8. Silantyev S.A., Portnyagin M.V., Krasnova E.A., Hauff F., Werner R., Kuzmin D.V. Petrology and Geochemistry of Plutonic Rocks in the Northwest Pacific Ocean and Their Geodynamic Interpretation. Geochemistry International, 1914, in press.
10. Zolotov M.Yu., Mironenko M.V. Timing of acid weathering on Mars: A kinetic-thermodynamic assessment // J. Geophys. Res. 2007 V. 112. E07006
11. Mironenko M.V., Melikhova T.Yu., Zolotov M.Yu., Akinfiev N.N. GEOCHEQ_M – program package for thermodynamic and kinetic modekking of geochemical processes. Version 2008. Herald of Gescinces Department of Russian Academy of Sciences. 2008. N1(26). URL: http://www.scgis.ru/russian/cp1251/h_dgggms/1-2008/informbul-1_2008/mineral-22.pdf.
12. Hellebrand E., Snow J.E., Muehe R. Mantle melting beneath Gakkel Ridge (Arctic Ocean): abyssal peridotites spinel compositions. Chemical Geology. 2002. V. 182. P.227-235.

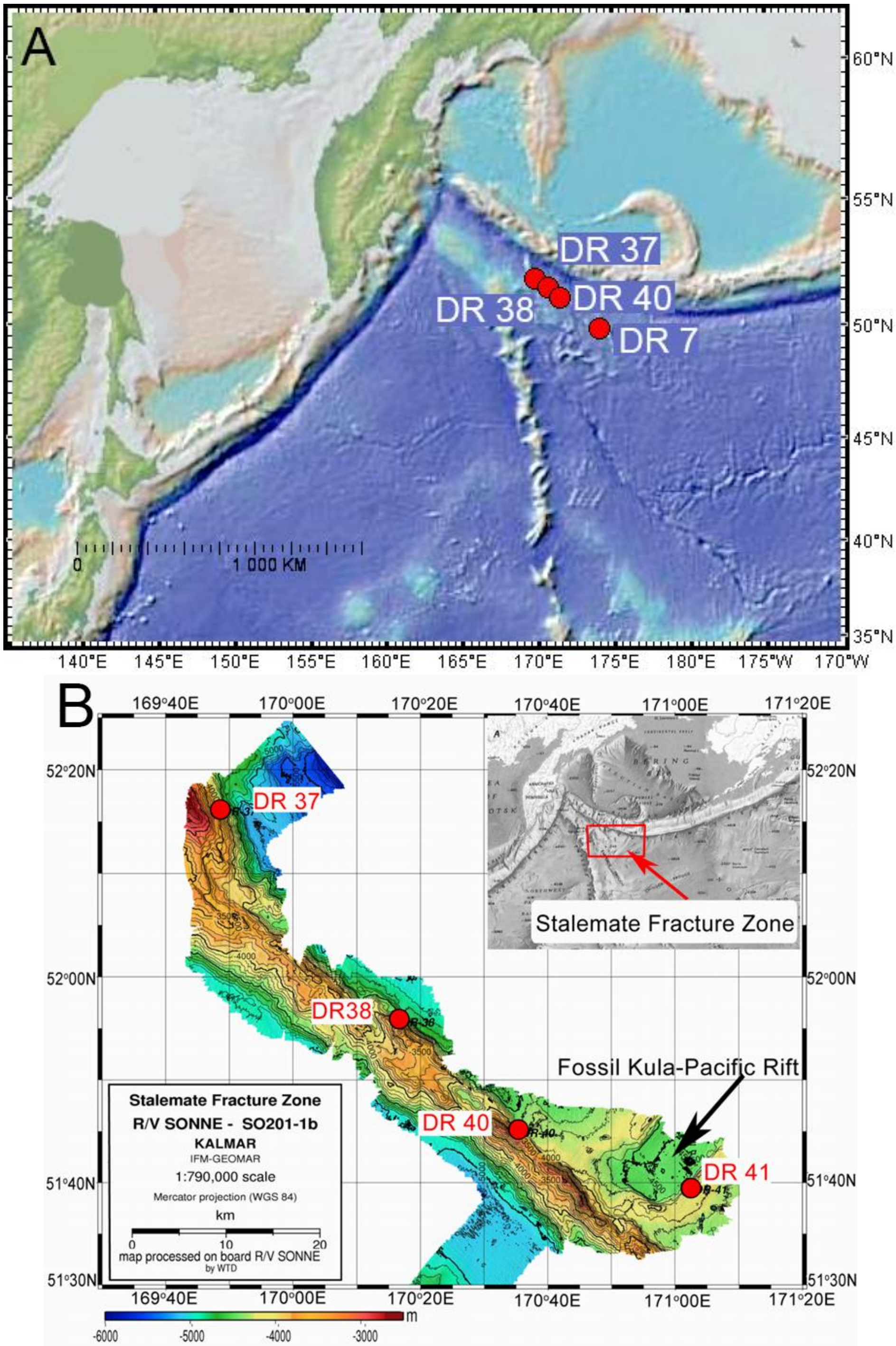

Fig. 1. Overview maps of A: the North West part of Pacific ocean and the Stalemate Fracture Zone, B: the northern part of the Stalemate Ridge; and SO201-KALMAR Leg 1b dredge locations.

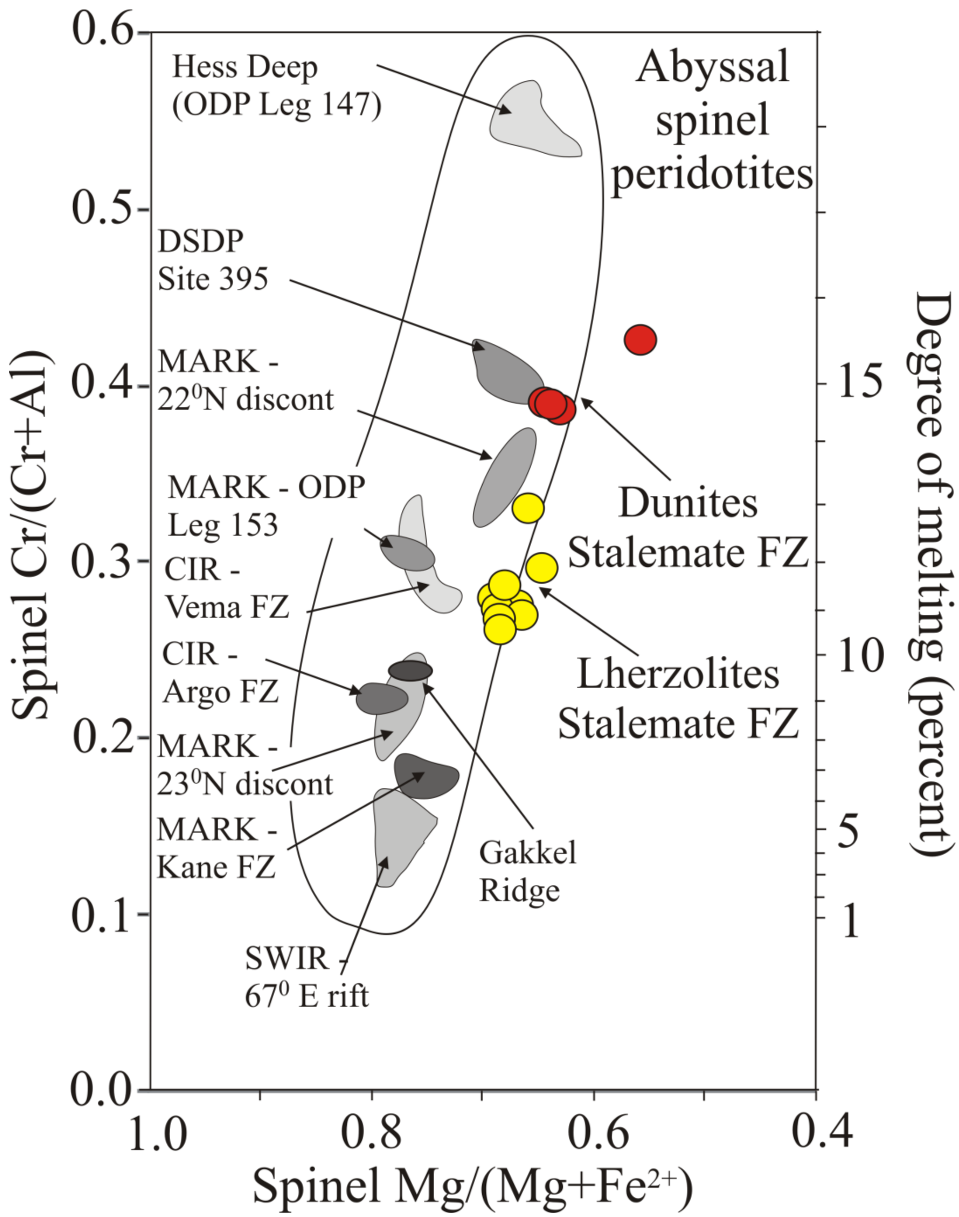

Fig. 2. Composition of Cr# = Cr/(Cr+Al) and Mg# = Mg/(Mg+Al) in Spinel. Spinel compositions from varioys abyssal peridotites are shown after (12).

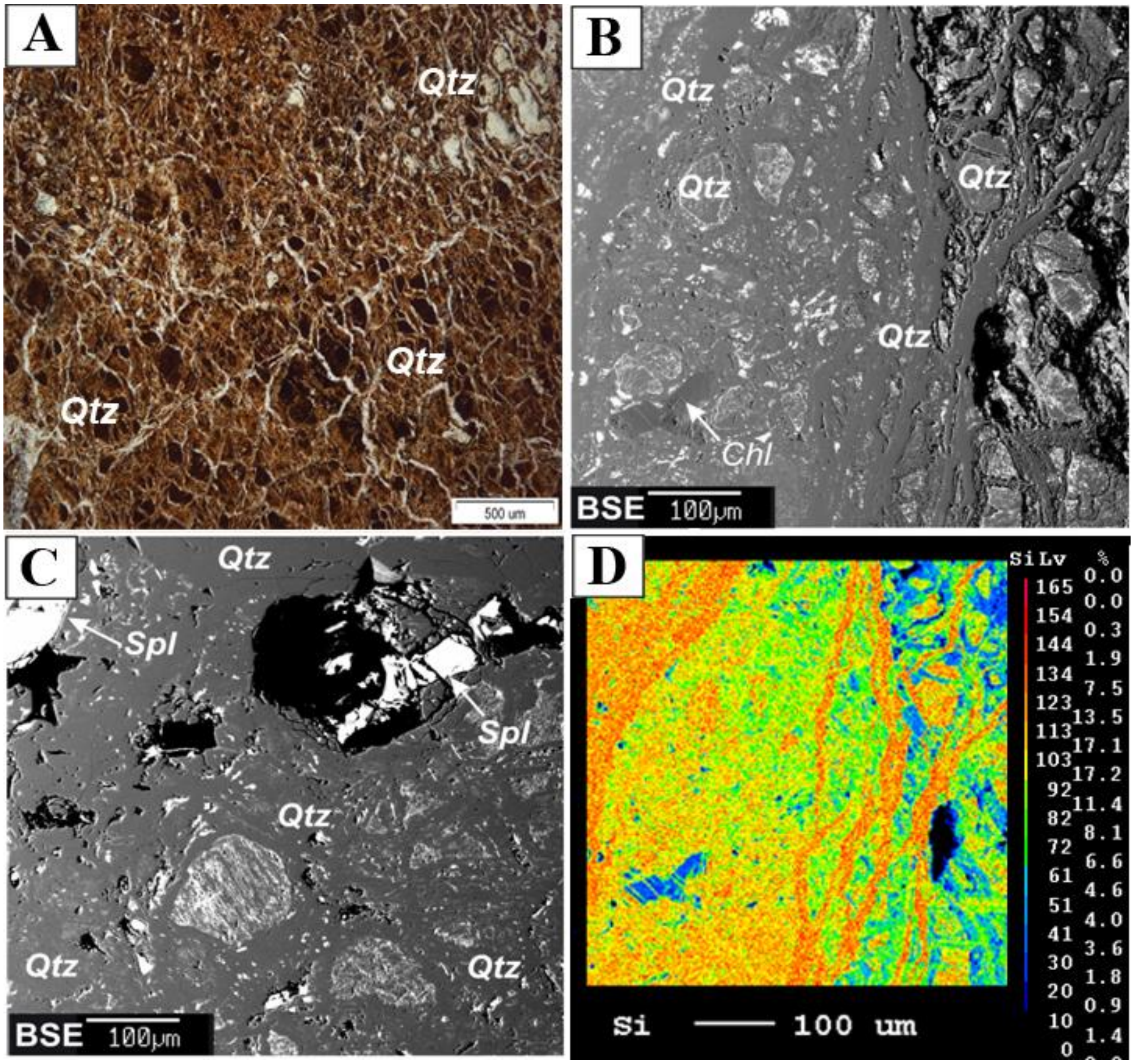

Fig. 3. Silicified dunites from the Stalemate Fracture Zone. (a) Microphoto of a fragment of sample DR37-2. The bulk SiO2 content in this rock is 87 wt %. Olivine cores are replaced by a microcrystalline aggregate of quartz (b)–(d) Fragment of sample DR37-4 from a transition zone between the brecciated (right) and massive (left) zones. (b, c) back-scattered electron image; (d) distribution of Mg contents.

Crustal thickness variation from gravity signatures of Central Philippines ophiolitic basement complexes

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Abstract

Recent mapping in the Central Philippines revealed ophiolites and ophiolitic units of different ages serving as basement of this region. Acquired geophysical data across the region shows an increasing trend of gravity anomalies to the southeast. Upward continuation of the gridded gravity anomaly data was carried out to isolate the signatures of deep sources. The trend observed in the regional Bouguer anomaly map is found to persist through depth, suggesting that the signatures are caused by the regional structure. Since the basement rocks are of essentially uniform character, the low gravity anomalies to the west of the region are attributed to a deeper high density contrast between the crust and the mantle. High gravity anomalies, on the other hand, are explained by a shallow mantle and a thinner crust. Knowledge on crustal configuration of the region can be used in refining its tectonic history.

Introduction

Our research team has been concentrating on studying the geology of the Central Philippines to identify the effects of the collision of the Palawan Microcontinental Block (PCB) and the Philippine Mobile Belt (PMB) (Dimalanta et al., 2009; Canto et al. 2012; Concepcion et al. 2012). To complement field mapping campaigns carried out in different islands, we gathered significant geophysical information that allows the imaging of subsurface conditions in the region. Integration of the measurements across the Central Philippines provided new and interesting insights on the variation of subsurface characteristics.

Ophiolites of the Central Philippines

The Central Philippines is composed of the islands of Mindoro, Tablas, Romblon, Sibuyan, Panay, Negros, Cebu, Bohol, Leyte, Samar and Masbate. The Negros trench borders the west of the region, along which, the southeast subbasin of Sulu Sea plate is being consumed. To the east of the region lies the Philippine Trench where the Philippine Sea plate is being subducted. Leyte and Masbate are traversed by the strike-slip Philippine Fault Zone, while the Sibuyan Sea Fault lies off-shore and north of the Romblon Island Group.

Regional geologic mapping in these islands (Dimalanta et al., 2006; 2009) revealed ophiolites and dismembered ophiolitic fragments comprising the basement of most of the islands. Previous works have reported a westward younging trend of the age of these ophiolite and ophiolitic units (Tamayo et al. 2004). The ophiolites observed in the region will be briefly discussed subsequently.

The easternmost ophiolite unit in the region is the Samar Ophiolite in southern Samar. It is composed of harzburgites and dunites, isotropic gabbro, sheeted diabase dike/sill complex and basaltic pillow and sheet flow deposits. Vitorfus campbelli pessagno and Sciadiocapsa sp. from the overlying chert gave an Early to Late Cretaceous age for the ophiolite (Dimalanta et al., 2006).

In Northeastern Leyte, a northwest-southeast trending complete ophiolite sequence composed of harzburgites, layered to isotropic gabbros, sheeted diabase and basalt dike complex, and pillowed and massive basaltic lava flow deposits, is collectively named as the Tacloban Ophiolite Complex (Suerte et al. 2005). U-Pb isotopic dating of zircons extracted from a gabbro showing orthocumulate texture gave an Early Cretaceous age for this ophiolite (Suerte et al. 2005).

The southern portion of Leyte is underlain by the Malitbog Ophiolite Complex, which is composed of harzburgites, lherzolites, occasional dunites, pyroxenites, gabbros, diabase dike swarms and pillow lava deposits (Dimalanta et al. 2006). This is believed to be Late Cretaceous in age based on the foraminifera found in the micritic limestones overlying the pillow lava deposits (Florendo 1987).

To the west of southern Leyte lies Bohol island wherein the South East Bohol Ophiolite Complex (SEBOC) is located. It is made up of harzburgites with occasional lherzolites, massive to layered gabbros, sheeted dike complex, basaltic to andesitic sheet flows and pillow lavas (De Jesus et al. 2000). SEBOC is overlain by pelagic chert deposits dated Early Cretaceous based on radiolarians and foraminiferal assemblages (Baretto et al. 2000).

Recent field mapping on Masbate Island revealed a NE-SW trending ophiolitic unit dominantly composed of pillow basalts with minor diabase dikes and isotropic gabbros. Radiolarians extracted from the overlying chert and siliceous mudstones provided an initial Early Cretaceous age.

Further west of Masbate Island lies the Romblon Island Group (RIG) which is composed of the Tablas, Romblon and Sibuyan islands. The RIG is underlain by dismembered units of harzburgites and dunites, isotropic and layered gabbros, dike swarms and volcanic rocks (Dimalanta et al. 2009; Payot et al. 2009a, Payot et al. 2009b, Payot et al. 2011). These units are intercalated with Jurassic to Cretaceous chert (Maac and Ylade, 1988).

To the south of Tablas island, the Antique Ophiolite is exposed along the length of the Antique range. It is composed of serpentinized harzburgites, layered gabbros with thin dunites, isotropic gabbros, rare sheeted dikes, and basaltic pillow lavas and sheet flow deposits (Dimalanta et al. 2006; Tamayo et al. 2001). The volcanic units are overlain by marine clastic and calcareous sediments, which are dated to be Early Cretaceous in age (e.g Rangin et al. 1991).

The Middle Oligocene Amnay Ophiolite is exposed in Mindoro island which lies to the northwest of Panay. It consists of serpentinized harzburgites, dunites, isotropic gabbros, sheeted dike complex and pillow lavas (e.g Perez et al. 2013). The age of the Amnay Ophiolite is taken from the nannoplankton found in the capping pelagic mudstones (Dictyococcites dictyodus, Discoaster deflandrei, Cyclicargolithus abisectus, Sephenolithus moriformis) (Canto et al. 2012; Rangin et al.1985).

Since these ophiolites and ophiolitic units comprises the basement of the Central Philippines, we expect to find regional geophysical signatures in the region which could be attributed to the presence of these suite of rocks.

Geophysical Techniques

Ground gravity data across the Central Philippines were gathered using a Scintrex CG-5 Autograv gravity meter in different geophysical campaigns from 2006 to 2013. Airborne gravity data was taken from JICA (1990) for Leyte Island. The data was integrated with the acquired ground gravity data for the interpretation of the gravity characteristics in the region. The gravity data were subjected to instrumental drift, latitude variations, Free air and Bouguer Spherical cap corrections. After standard data reduction was applied, calculated Bouguer anomalies were gridded using the Kriging algorithm of the Geosoft Oasis Montaj (version 6.3) and a Bouguer anomaly map of the region was then produced. To further investigate the deep characteristics of the subsurface, the gridded Bouguer anomalies were upwardly continued. This filtering technique eliminates signals caused by shallow density contrasts, allowing the interpretation of anomalies caused by deep-seated sources.

Gravity Signatures of the Central Philippines

After standard data correction and reduction, gravity anomalies of the Central Philippines were found to range from -69mGals on Mindoro Island to 134mGals on Southeast Bohol (Figure 3A). An increasing trend of the anomalies to the southeast is evident on the Regional Bouguer Anomaly (RBA) map (Figure 3A). Usually, the differences in gravity signatures can be explained by the density contrasts of the underlying rocks. In this case, however, the composition of the underlying rocks is uniform, when viewed in a regional scale. Deep-seated anomalies that are not explained by the differences in composition and density contrasts of the lithologies may be attributed to the crust-mantle configuration.

In order to isolate gravity signatures that would be used to investigate crustal geometries, RBA is subjected to a mathematical filter that removes short-wavelength gravity anomalies. This filter, called the upward continuation, produces the gravity signature of deep sources, which in turn, characterizes the regional structure of the subsurface.

The increasing trend to the SE of the gravity anomalies observed in Figure 3A is found to persist through depth, as shown in the upward continued map (Figure 3B). The low gravity anomalies over the ophiolites of the western Philippines possibly indicate that the mantle is deeper in that region. High gravity anomalies in the eastern Philippines are interpreted to correspond to a mantle that is closer to the surface, translating to a thinner crust.

Conclusions

The Central Philippines is underlain by ophiolites and ophiolitic basement. Despite the uniformity in their regional composition, there is an observed significant increase of gravity anomalies towards the southeast. This is attributed to the regional crustal structure, where the low gravity anomalies signify deeper mantle and high gravity anomalies translates to a shallow one. The crust in the Central Philippines therefore possibly thins towards the southeast.

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References

Barretto, J.A.L., C.B. Dimalanta and G.P. Yumul Jr. Gravity variations along the Southeast Bohol Ophiolite Complex (SEBOC), Central Philippines: Implications on ophiolite emplacement. The Island Arc 9, pp. 575-583, 2000

Canto, A.P.B., J.T. Padrones, R.A.B. Concepcion, A.dC. Perez, R.A. Tamayo Jr. C.B. Dimalanta, D.V. Faustino-Eslava, K.L. Queaño and Yumul, G.P. Jr. Geology of Northwestern Mindoro and its adjoining islands: Implications for terrain accretion in west central Philippines. Journal of Asian Earth Sciences 61, pp. 78-87, 2012.

Concepcion, R.A.B., C.B. Dimalanta, G.P. Yumul Jr., D.V. Faustino-Eslava, K.L. Queaño, R.A. Tamayo Jr. and A. Imai. Petrography, geochemistry and tectonics of a rifted fragment of Mainland Asia: evidence from the Lasala Formation, Mindoro Island, Philippines. International Journal of Earth Sciences (Geologische Rundschau) 101, pp. 273-290, 2012.

De Jesus, J.V., G.P. Yumul Jr., and D.V. Faustino. The Cansiwang Melange of Southeast Bohol (Central Philippines): Origin and tectonic implications. The Island Arc 9, pp. 566-575, 2000

Dimalanta, C.B., E.G.L. Ramos, G.P. Yumul Jr. and H. Bellon. New features from the Romblon Island Group: Key to understanding the arc-continent collision in Central Philippines. Tectonophysics 479, pp. 120-129, 2009

Dimalanta, C.B., L.O. Suerte, G.P. Yumul Jr., R.A. Tamayo and E.G.L. Ramos. A Cretaceous supra-subduction oceanic basin source for Central Philippine ophiolitic basement complexes: Geological and geophysical constraints. Geosciences Journal 2, pp. 305-320, 2006

Florendo, F.F. The tectonic framework and the Cretaceous to Cenozoic evolution of the East-Central Philippines. M.Sc. thesis, University of Tulsa, Oklahoma, USA, 103 pp.,1987

Japan International Cooperation Agency – Metal Mining Agency of Japan (JICA-MMAJ). Mineral deposits and tectonics of two contrasting geologic environments in the Republic of the Philippines, phase II – Masbate area, Northern Leyte area, Southern Leyte area, Dinagat, Siargao and Palawan I-IV area. Mines and Geosciences Bureau, Philippines, 740pp, 1990

Maac, Y.O. and E.D. Ylade. Stratigraphic and paleontologic studies of Tablas, Romblon. Report of Research and Development Cooperation ITIT Project No. 8319: Research on stratigraphic correlation of Cenozoic strata in oil and gas fields Philippines, pp. 44-67, 1988

Payot, B.D., S. Arai, A. Tamura, S. Ishimaru and R.A. Tamayo Jr. Unusual ultra-depleted dunite from Sibuyan Island: a residue for ultra-depleted MORB? Journal of Mineralogical and Petrological Sciences 104, pp. 383-388, 2009a

Payot, B.D., S. Arai, R.A. Tamayo Jr., G.P. Yumul, Jr. What underlies the Philippine island arc? Clues from Calaton Hill, Tablas island, Romblon (Central Philippines). Journal of Asian Earth Sciences 36, pp. 371-389, 2009b

Payot, B.D., S. Arai, R.A. Tamayo, Jr. Abyssal harzburgite veined by silica-oversaturated melt in the Sibuyan Ultramafics, Romblon, Central Philippines

Perez, AdC., D.V. Faustino-Eslava, G.P. Yumul, Jr., C.B. Dimalanta, R.A. Tamayo Jr., T.F. Yang and M.F. Zhou. Enriched and depleted character of the Amnay Ophiolite upper crustal section and the regionally heterogeneous nature of the South China Sea mantle. Journal of Asian Earth Sciences 65, pp. 107-117, 2013

Rangin, C., J.F. Stephan and C. Muller. Middle Oligocene oceanic crust of South China Sea jammed into Mindoro collision zone (Philippines). Geology 13, pp. 425-428, 1985

Rangin, C., J.-F. Stephan, J. Butterlin, H. Bellon, C. Muller, J. Chorowicz, D. Baladad. Collision neogene d'arcs volcaniques dans le centre des Philippines: Stratigraphie et structure de la chaine d'Antique (ile de Panay). Bulletin of the Geological Society of France 162, pp. 465-477, 1991

Rangin, C., J.-F. Stephan, J. Butterlin, H. Bellon, C. Muller, J. Chorowicz, D. Baladad. Collision neogene d'arcs volcaniques dans le centre des Philippines: Stratigraphie et structure de la chaine d'Antique (ile de Panay). Bulletin of the Geological Society of France 162, pp. 465-477, 1991

Suerte, L.O., G.P. Yumul, Jr., R.A. Tamayo Jr., C.B. Dimalanta, M.-F. Zhou, R.C. Maury, M. Polve and C.L. Balce. Geology, geochemistry and U-Pb SHRIMP age of the Tacloban Ophiolite Complex, Leyte Island (Central Philippines): Implications for the existence and extent of the proto-Philippine Sea Plate. Resource Geology 55, pp. 205-214, 2005

Tamayo, R.A.T., G.P. Yumul, Jr., R.C. Maury, M. Polvé, J. Cotten and M. Bohn. Petrochemical investigation of the Antique Ophiolite (Philippines): Implications on volcanogenic massive sulfide and podiform chromitite deposits. Resource Geology 51, pp.145-166, 2001

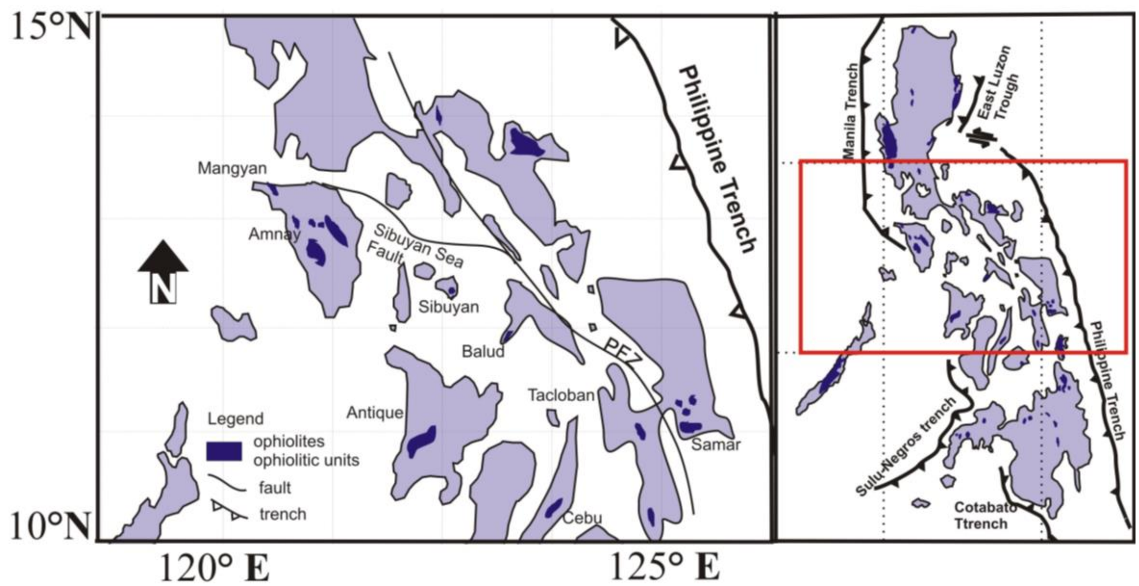

Figure 1: The Central Philippines, composed of the islands of Mindoro, Tablas, Romblon, Sibuyan, Masbate, Panay, Negros, Cebu, Bohol, Leyte and Samar, is bordered by the Negros trench to west and by the Philippine trench to the east. It is underlain by ophiolites and ophiolitic units of different ages.

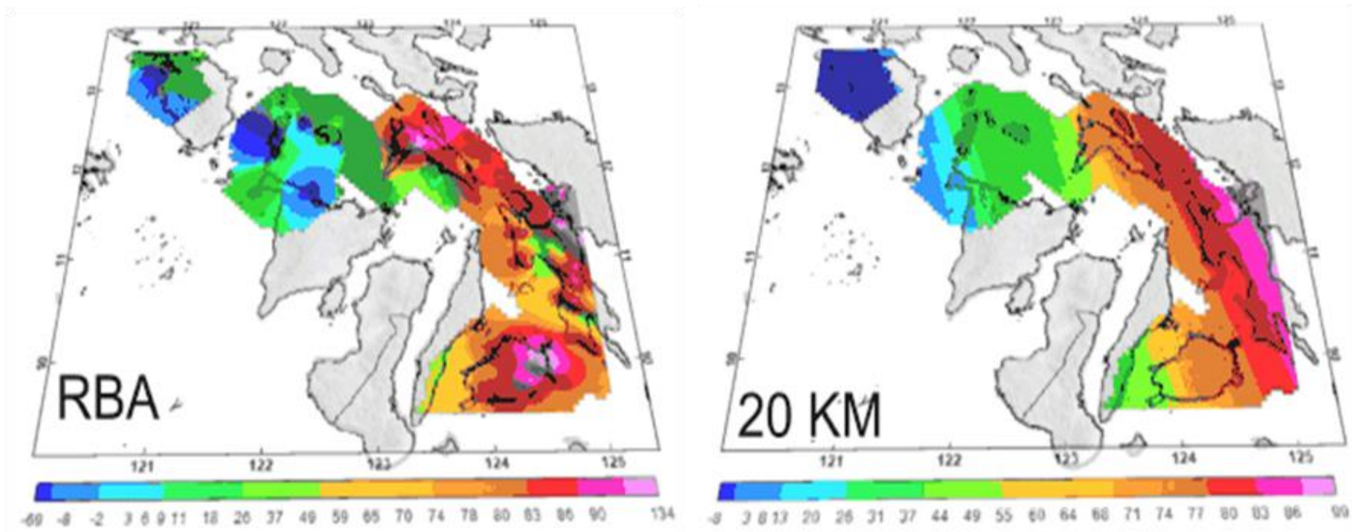

Figure 2: Bouguer anomalies across Central Philippines. A) Regional Bouguer Anomaly (RBA) B) Upwardly continued Bouguer Anomaly map up 20 km.

Table 1. Summary of the ages of different ophiolites and ophiolitic units in Central Philippines

Ophiolite/ Ophiolitic Unit	Dating Techniques	Age	References
Antique	Radiolarians from the overlying chert	Late Cretaceous	Rangin et al. 1991
Malitbog	Foraminifera of overlying limestone	Late Cretaceous	Florendo et al. 1987
Samar	Radiolarians from the overlying chert	Early to Late Cretaceous	Dimalanta et al. 2006
Tacloban	U-Pb isotopic dating of zircons extracted from gabbro	Early Cretaceous	Suerte et al. 2005
SE Bohol	Radiolarians and foraminifers of overlying chert	Early Cretaceous	Barreto et al. 2000
Balud	Radiolarians from intercalated chert	Early Cretaceous	This study
Sibuyan	Radiolarians from intercalated chert	Jurassic to Cretaceous	Maac and Ylade, 1988

MARINER: Seismic Investigation of the Rainbow Hydrothermal Field and its Tectono/Magmatic Setting, Mid-Atlantic Ridge 36° 14'N – A Report from RV *M.G. Langseth* Cruise MGL1305

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SCIENTIFIC MOTIVATION AND PROJECT OBJECTIVES

Hydrothermal systems extract approximately one third of the global Earth's yearly heat loss through mid-ocean ridges (MORs) and are a primary means of chemical exchange between the solid Earth and the oceans. Hydrothermal circulation occurs when seawater penetrating the lithosphere through fractures is heated through its contact with hot rock, undergoing chemical alteration. As it penetrates deeper, its temperature increases and the water becomes buoyant, rapidly rising back to the seafloor. Sections of MORs with greater magma supply, and hence greater heat flux, are thought to host a greater abundance of hydrothermal systems. This simple conceptual model provides a framework within which to understand hydrothermal heat generation and extraction, yet leaves open the question of the nature of heat sources and the physical mechanisms controlling hydrothermal fluid flow [e.g., Wilcock and Delaney, 1996].

Most of our understanding of hydrothermal systems along ridges results from studies of the materials output by this process [e.g., Humphris et al., 1995; Von Damm, 1990]. In contrast, the deeper distributions of melt that may drive these systems and the general tectonic and thermal structure around them are inadequately known and have been studied in only a few locations, most of them along fast and intermediate spreading ridges like the East Pacific Rise and the Juan de Fuca Ridge. In these settings, hydrothermal systems are mainly located within the axial zone of a spreading segment, hosted in basaltic rock, and are primarily driven by heat extracted from crystallization of mid-crustal melt sills [e.g., Canales et al., 2006; Haymon et al., 1991; Singh et al., 1998; Van Ark et al., 2007]. In contrast, hydrothermal systems along slow spreading ridges like the Mid-Atlantic Ridge (MAR) show a great variety of venting styles and host-rock lithology, and are located in diverse tectonic settings like axial volcanic ridges, non-transform ridge discontinuities (NTDs), the foot of ridge valley walls, and off-axis inside corner highs [e.g., German and Parson, 1998; German and Lin, 2004]. Here the relative roles of magmatic heat input, tectonic heat advection, and faulting in controlling ridge thermal structure and hydrothermal circulation are still poorly understood [e.g., Cannat et al., 2004].

The Rainbow hydrothermal field (RHF) is a major high-temperature hydrothermal system that is located within one such setting, a non-transform discontinuity of the MAR [German et al., 1996] (Figure 1). It is hosted in an ultramafic massif, venting methane-, hydrogen- and iron-rich fluids [e.g., Holm and Charlou, 2001] that support diverse macrofaunal and microbial communities [e.g. Desbruyères et al., 2001; O'Brien et al., 1998]. The tectonized setting of the NTD apparently lacks significant volcanic features, yet the RHF vents high-temperature fluids (up to 365 °C) at high flow rates [German et al., 1996], which is difficult to explain without a magmatic heat source. This conundrum stands in the way of our ability to develop a model for the origin and functioning of the Rainbow vent field as well as inhibits development of more general models for the roles of magmatic heat input and tectonic faulting on controlling thermal structure and hydrothermal circulation, particularly for hydrothermal systems in regions dominated by ultramafic lithologies, which are common at slow and ultra-slow MORs [e.g., Cannat et al., 1995; Dick et al., 2003].

Starting in 2013 with funding from the US NSF, we began a multi-faceted geophysical investigation of the MAR region between latitudes 35°50'N and 36°30'N (approx., Figure 1). This section of the MAR includes, from south to north, spreading segments South AMAR, AMAR Minor, and AMAR [German et al., 1996], and the Rainbow NTD, Massif and associated hydrothermal fields. The fundamental question we aim to address in this project is: What are the relationships between magmatism, faulting, substrate lithology, and hydrothermal circulation at the Rainbow hydrothermal field? By addressing this question and investigating the subsurface structure of this unique system, we aim to advance understanding of the relationships between magmatic processes, hydrothermal circulation, and the thermal and tectonic structure of a ridge discontinuity, which will be applicable to other regions. In particular, understanding the mechanisms and processes that result in hydrothermal circulation at Rainbow will allow us to understand how high-temperature hydrothermal fluids can be generated in tectonized, ultramafic terrains (e.g., Logatchev and Ashazde fields in the MAR [Bel'tenev et al., 2005; Krasnov et al., 1996], and to make predictions about how common similar hydrothermal systems (i.e., hosted in ultramafic rocks, venting hydrogen, methane, and iron-rich high-temperature fluids) might be along other slow- and ultra-slow spreading ridges.

We will use geophysical observations to test a specific hypothesis against two alternates:

Hypothesis: The heat driving hydrothermal circulation at Rainbow is provided by a magma body underlying the ultramafic rocks exposed on the massif, and steep normal faults crosscutting the massif provide permeability pathways for fluid circulation. If this hypothesis is correct, then Rainbow may be experiencing a phase of enhanced melt supply from the mantle, therefore providing an excellent opportunity to investigate delivery and emplacement of melt beneath a NTD, where long-term magma supply should be very low [e.g., Cannat et al., 1995; Phipps Morgan and Forsyth, 1988]. In addition, this hypothesis predicts that at least part of the Rainbow massif could be mafic in origin, despite indications suggesting is predominantly ultramafic [e.g., Fouquet et al., 1997].

Alternate 1: The heat driving hydrothermal circulation at Rainbow is extracted from the magmatic system(s) of the neighboring segment(s), and fluids are transported relatively large lateral distances on possibly low-angle fault(s). An alternative to hypothesis 1 is that the NTD is currently magmatically starved, but fluids are taping magmatic heat from the neighboring segments [German et al., 1996], possibly via low-angle faults that provide pathways for fluids to travel from the ends of the neighboring segments to the center of the NTD. Thus, this hypothesis does not require presence of a significant component of mafic lithologies beneath the massif, consistent with seafloor observations and exit fluid chemistry.

Alternate 2: Detachment faulting controls hydrothermal circulation and uplift of the Rainbow massif. There is increasing evidence that a variety of hydrothermal venting styles are intimately linked to detachment faulting and formation/evolution of oceanic core complexes [McCaig et al., 2010]. It has been proposed that the RHF sits on the footwall of a detachment fault [Gràcia et al., 2000], and some of the geological characteristics of the massif are consistent with this hypothesis [Gaill et al., 2007; Ildefonse et al., 2008]. In this scenario fluids could extract heat from the hot (and possibly partially molten) deep region of the mantle where a detachment fault roots, and/or from the exhuming footwall. If uplift of the massif is not the result of detachment faulting, then buoyant diapirism driven by serpentinization is a possible alternative [e.g., Bonatti, 1976], as substantial hydration of the mantle beneath the massif would be accompanied by volumetric expansion and reduced density.

REPORT

To test these hypotheses we conducted in April-May, 2013 a geophysical survey of the Rainbow area onboard the US RV Marcus G. Langseth (cruise MGL1305). The acquired data will allow us to carefully image the subsurface architecture (which is intimately linked to hydrothermal flow processes) around and beneath the RHF and map, in 3D, the seismicity associated with the vent field and the NTD. Our geophysical survey of the Rainbow area consisted of:

(1) A large-scale 3D high-resolution active-source seismic tomography experiment using 46 ocean bottom seismometers (OBSs) and airgun sources (36-element, 6,600 cu.in. total volume) (Figure 1). This dataset will be used for determining the 3D seismic velocity structure of the crust and upper mantle. About 3,800 shots were triggered along ~1,700 km of profiles with a nominal shot spacing of 450 m. Airgun sources were towed at a nominal depth of 12 m. OBS had 4 components (geophone plus hydrophone) and recorded at a sampling rate of 200 Hz, and were provided and operated by the US Ocean Bottom Instrumentation Pool (OBSIP).

(2) Twenty-one 2D multichannel seismic (MCS) reflection profiles using one 8-km-long hydrophone streamer and airgun sources (36-element, 6,600 cu.in. total volume) (Figure 1). This dataset will be used for high-resolution 2D tomography of the shallowmost lithosphere as well as for depth imaging of faults, melt bodies, and other major structural discontinuities. About 1,300 km of MCS profiles consisting of ~35,000 shots at a nominal spacing of 37.5 m were acquired. Each shot was recorded in 636 channels (12.5 m group spacing) in 12-second-long records at 2 ms sampling rate. Both, hydrophone streamer and airgun sources were towed at a nominal depth of 12 m.

(3) Deployment of a network of 15 OBSs for long-term monitoring (~7-8 months) of the microseismicity of the Rainbow Massif and NTD (Figure 2). This dataset will be used for locating active faults and determine their 3D geometry, and for investigating hydrothermal processes along fluid flow paths. Recovery of this OBS network is scheduled for January 2014.

(4) Multibeam bathymetry and backscatter echosounding data were acquired with full coverage within a 65km x 100km area centered on the Rainbow Massif, encompassing the seismic survey area (Figure 1). This dataset will provide the morphological context within which the other datasets can be interpreted. We used a hull mounted 1ºx1º Kongsberg EM-122 multibeam system with 432 soundings per swath and two swaths per ping cycle for up to 864 soundings, transmitting at a frequency of 12.0 kHz with maximum angular coverage of 150°. For this cruise the system was run with an angular swath width of 124˚ to 130˚ in an equal area mode, where the beamformer projects beams of varying angle across the swath to create equal size sonar footprints on the seafloor, resulting in a footprint of roughly 20 m in 2500m of water. The resulting swath width is between 2.5 and 3.5 times the water depth, corresponding to 1000-12,000 m in our survey area.

(5) Underway potential fields (gravity and magnetics) data were acquired along profiles coincident with both the OBS and MCS shooting profiles. These datasets will contribute towards improving our knowledge on variations in sub-surface density and magnetization (and therefore structure) of the study area, and age of the morphological features. Gravity data were acquired with a Bell Aerospace BGM-3 marine gravimeter. Surface magnetic data were acquired with a Geometrics 882 magnetometer, towed at a distance of 140 m from the ship, with a frequency of 10 samples per second.

In addition to the geophysical measurements described above, we conducted 35 XBT vertical profiles, and we collected a few sediment samples of opportunity from OBSs that returned to the surface with enough seabed material preserved in their frames.

MARINER Cruise Science Party consisted of a multi-disciplinary team of scientists from institutions and universities from several countries, and included two postdoctoral researchers, three Ph.D. graduate students, and three undergraduate students. We will be working together over the next couple of years towards developing a consistent model of the architecture, heat supply and tectonics of a ridge NTD. Data processing and modeling is currently underway. Data and results will be reported at international scientific meetings and publications in the coming months. More details about this project and cruise achievements can be found at: http://www.whoi.edu/sites/rainbow. Questions about this project should be directed to the co-PIs R.A. Dunn (dunnr@hawaii.edu), J.P. Canales (jpcanales@whoi.edu), and R.S. Sohn (rsohn@whoi.edu).

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REFERENCES

Bel'tenev, V., V. Ivanov, A. Shagin, M. Sergeyev, I. Rozhdestvenskaya, V. Shilov, I. Dobretzova, G. Cherkashev, M. Samoravov, and I. Poroshina (2005), New hydrothermal sites at 13oN, Mid-Atlantic Ridge, InterRidge News, 14, 14-16.

Bonatti, E. (1976), Serpentinite protrusions in the oceanic crust, Earth Planet. Sci. Lett., 32, 107-113.

Canales, J. P., S. C. Singh, R. S. Detrick, S. M. Carbotte, A. J. Harding, G. M. Kent, J. B. Diebold, J. Babcock, and M. R. Nedimović (2006), Seismic evidence for variations in axial magma chamber properties along the southern Juan de Fuca Ridge, Earth Planet. Sci. Lett., 246, 353-366.

Cannat, M., J. R. Cann, and J. MacLennan (2004), Some hard rock constraints on the supply of heat to mid-ocean ridges, in Mid-ocean ridges: Hydrothermal interactions between the lithosphere and the oceans, edited by C. R. German, J. Lin and L. M. Parson, pp. 111-149, AGU, Washington, D.C.

Cannat, M., C. Mével, M. Maia, C. Deplus, C. Durand, P. Gente, P. Agrinier, A. Belarouchi, G. Dubuisson, E. Humler, and J. R. Reynolds (1995), Thin crust, ultramafic exposures, and rugged faulting patterns at the Mid-Atlantic Ridge (22°-24°N), Geology, 23, 49-52.

Desbruyères, D., M. Biscoiti, J.-C. Caprais, and et al. (2001), Variations in deep-sea hydrothermal vent communities on the Mid-Atlantic ridge near the Azores plateau, Deep Sea Res. Part I, 48, 1325-1346.

Dick, H. J. B., J. Lin, and H. Schouten (2003), An ultraslow-spreading class of ocean ridge, Nature, 426, 405-412.

Dyment, J., D. Bissessur, K. Bucas, V. Cueff-Gauchard, L. Durand, Y. Fouquet, F. Gaill, P. Gente, E. Hoisé, B. Ildefonse, C. Konn, F. Lartaud, N. LeBris, G. Musset, A. Nunes, J. Renard, V. Riou, A. Tasiemski, R. Thibaud, P. Torres, V. Yatheesh, I. Vodjdani, and M. Zbinden (2009), Detailed investigation of hydrothermal site Rainbow, Mid-Atlantic Ridge, 36o13'N: Cruise MoMARDream, InterRidge News, 18, 22-24.

Fouquet, Y., J. L. Charlou, H. Ondreas, J. Radford-Knoery, J. P. Donval, E. Douville, R. Apprioual, P. Cambon, H. Pelle, J. Y. Landure, A. Normand, E. Ponzevera, C. German, L. Parson, F. J. A. S. Barriga, I. Costa, J. Relvas, and A. Ribeiro (1997), Discovery and first submersible on the Rainbow

hydrothermal field on the MAR (36o14'N), Eos Trans. AGU, 78, 832.
Gaill, F., V. Ballu, M. Cannat, W. C. Crawford, J. Dyment, J. Escartín, T. Fouquet, J. Goslin, G. Reverdin, P.-M. Sarradin, P. Tarits, M. Andreani, E. Bonnivard, K. Bucas, G. Burgaud, M. A. Cambon, V. Cueff, C. Durand, O. Gros, G. Hamel, M. Henriques, E. Hois, B. Ildefonse, C. Konn, N. Le Bris, H. Le Guyader, J. Ravaux, B. Shillito, J. Y. Toullec, and M. Zbinden (2007), Cruise MoMARDREAM-Naut and other MoMAR experiments at Rainbow and Lucky Strike in Summer 2007, InterRidge News, 16, 15-16.
German, C. R., and L. M. Parson (1998), Distributions of hydrothermal activity along the Mid-Atlantic Ridge: interplay of magmatic and tectonic controls, Earth Planet. Sci. Lett., 160, 327-341.
German, C. R., and J. Lin (2004), The thermal structure of the oceanic crust, ridge-spreading and hydrothermal circulation: how well do we understand their inter-connections?, in Mid-Ocean Ridges: Hydrothermal Interactions Between the Lithosphere and Oceans, edited by C. R. German, J. Lin and L. M. Parson, pp. 1-18, AGU, Washington, D.C.
German, C. R., L. M. Parson, and H. S. Team (1996), Hydrothermal exploration near the Azores Triple Junction: tectonic control of venting at slow-spreading ridges, Earth Planet. Sci. Lett., 138, 93-104.
Gràcia, E., J.-L. Charlou, J. Radford-Knoery, and L. M. Parson (2000), Non-transform offsets along the Mid-Atlantic Ridge south of the Azores (38oN-34oN): ultramafic exposures and hosting of hydrothermal vents, Earth Planet. Sci. Lett., 177, 89-103.
Haymon, R. M., D. J. Fornari, M. H. Edwards, S. M. Carbotte, D. J. Wright, and K. C. Macdonald (1991), Hydrothermal vent distribution along the East Pacific Rise crest (9°09'-54'N) and its relationship to magmatic and tectonic processes on fast-spreading mid-ocean ridges, Earth Planet. Sci. Lett., 104, 513-534.
Holm, N. G., and J. L. Charlou (2001), Initial indications of abiotic formation of hydrocarbons in the Rainbow ultramafic hydrothermal system, Mid-Atlantic Ridge, Earth Planet. Sci. Lett., 191, 1-8.
Humphris, S. E., P. M. Herzig, D. J. Miller, J. C. Alt, K. Becker, D. Brown, G. Brügmann, H. Chiba, Y. Fouquet, J. B. Gemmell, G. Guerin, M. D. Hannington, G. J. Iturrino, R. Knott, R. Ludwig, K. Nakamura, S. Petersen, A.-L. Reysenbach, P. A. Rona, S. Smith, A. A. Sturz, M. K. Tivey, and X. Zhao (1995), The internal structure of an active sea-floor massive sulphide deposit, Nature, 377, 713-716.
Ildefonse, B., Y. Fouquet, E. Hoise, J. Dyment, P. Gente, R. Thibaud, D. Bissessur, and V. Yatheesh (2008), Geological mapping of the Rainbow Massif, Mid-Atlantic Ridge, 36o14'N, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract T43B-2028.
Krasnov, S., G. Cherkashev, I. Poroshina, Y. Fouquet, D. Prieur, and A. Ashadze (1996), 15oN Mid-Atlantic Ridge Logatchev hydrothermal field, paper presented at FARA-InterRidge Mid-Atlantic Ridge Symposium.
McCaig, A. M., A. Delacour, A. E. Fallick, T. Castelain, and G. Frueh-Green (2010), Detachment Fault Control on Hydrothermal Circulation Systems: Interpreting the Subsurface Beneath the TAG Hydrothermal Field Using the Isotopic and Geological Evolution of Oceanic Core Complexes in the Atlantic, in Diversity of Hydrothermal Systems on Slow Spreading Ocean Ridges, edited by P. Rona, C. W. Devey, J. Dyment and B. Murton, pp. 207-239, AGU, Washington, D.C.
O'Brien, D., M. Carton, D. Eardly, and J. W. Patching (1998), In situ filtration and preliminary molecular analysis of microbial biomass from the Rainbow hydrothermal plume at 36°15'N on the Mid-Atlantic Ridge, Earth Planet. Sci. Lett., 157, 223-231.
Phipps Morgan, J., and D. W. Forsyth (1988), Three-dimensional flow and temperature perturbations due to a transform offset: Effects on oceanic crustal and upper mantle structure, J. Geophys. Res., 93(B4), 2955-2966.

Singh, S. C., G. M. Kent, J. S. Collier, A. J. Harding, and J. A. Orcutt (1998), Melt to mush variations in crustal magma properties along the ridge crest at the southern East Pacific Rise, Nature, 394, 874-878.

Van Ark, E., R. S. Detrick, J. P. Canales, S. M. Carbotte, A. J. Harding, G. M. Kent, M. R. Nedimović, W. S. D. Wilcock, J. B. Diebold, and J. Babcock (2007), Seismic structure of the Endeavour segment, Juan de Fuca Ridge: Correlations with seismicity and hydrothermal activity, J. Geophys. Res., 112, B02401, doi:10.1029/2005JB004210.

Von Damm, K. L. (1990), Seafloor hydrothermal activity: black smokers and chimneys, Ann. Rev. Earth Planet. Sci., 18, 173-204.

Wilcock, W. S. D., and J. R. Delaney (1996), Mid-ocean ridge sulfide deposits: Evidence for heat extraction from magma chambers or cracking fronts?, Earth Planet. Sci. Lett., 145, 49-64.

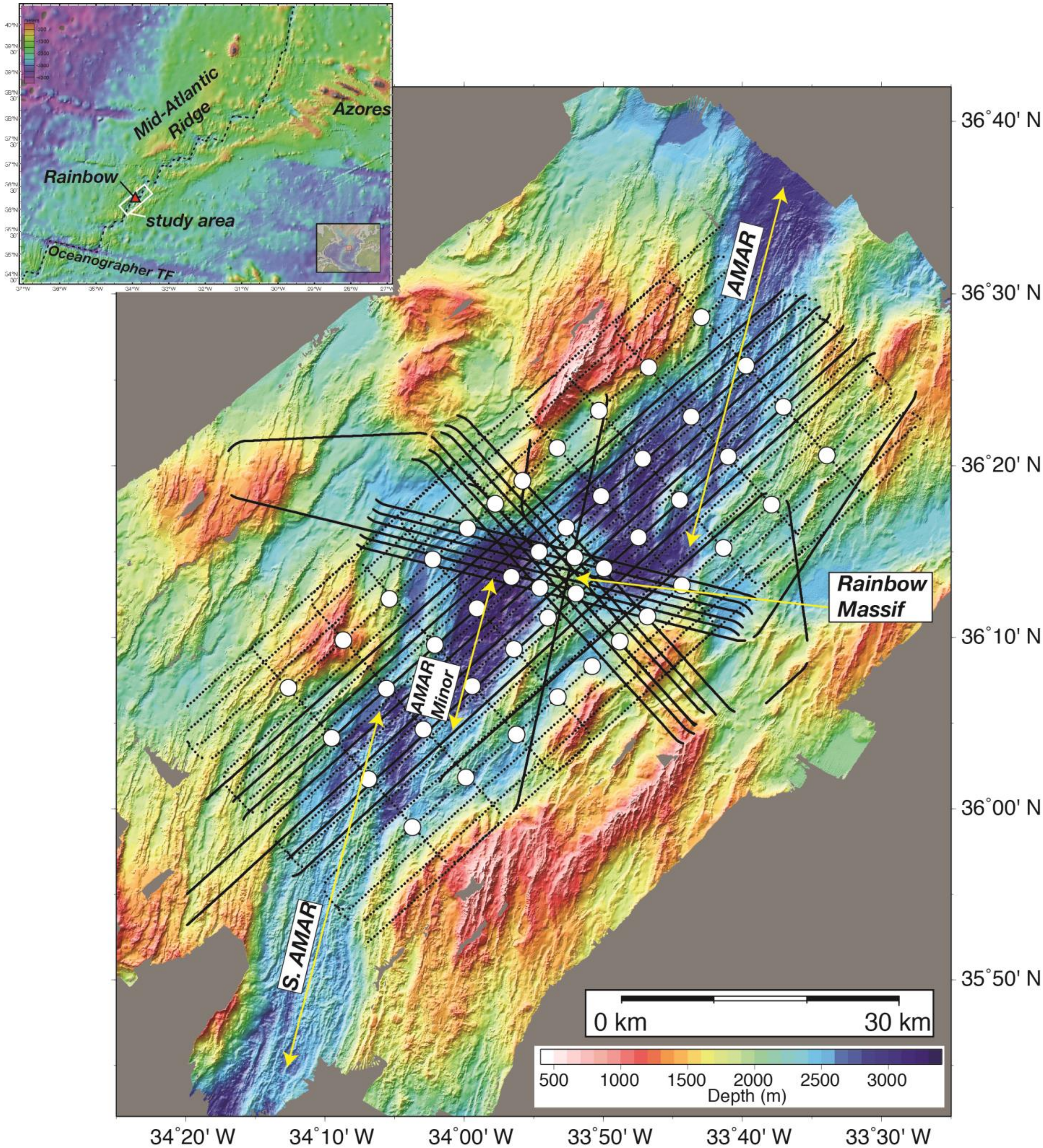

Figure 1. Shaded bathymetry map of the MAR at the Rainbow NTD (data from cruise MGL1305). Open circles and dots are OBS and shot locations, respectively, for the 3D active-source tomography experiment. Solid lines are MCS profiles. Top-left inset shows location of the study area in the MAR south of the Azores.

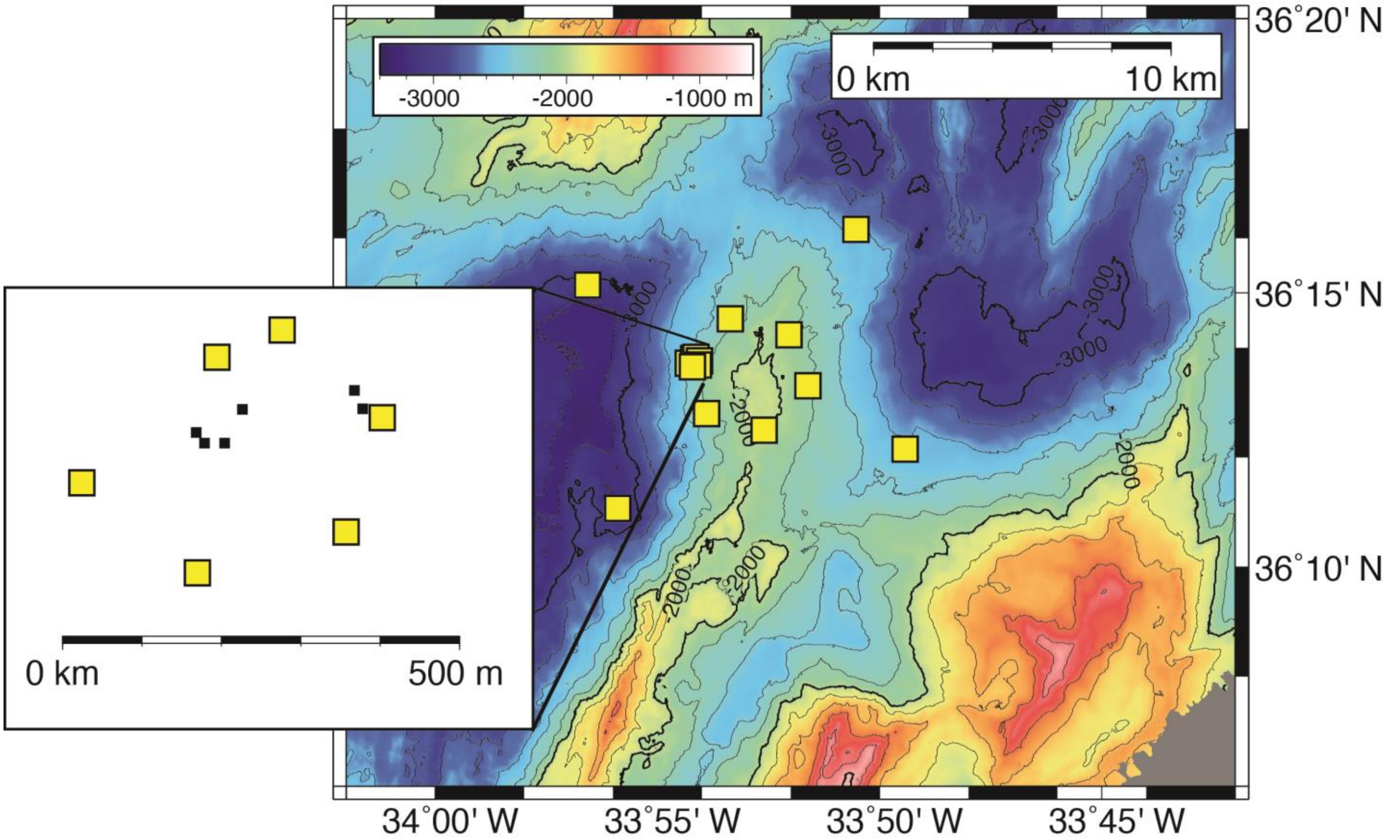

Figure 2. Bathymetry map of the Rainbow NTD and OBS network for passive seismic monitoring. Yellow squares are OBS drop positions. Black squares in inset are location of active hydrothermal vents from Dyment et al. [2009]

Preliminary report on the COLMEIA Cruise, Equatorial Atlantic Recife, January 24 - Recife, February 28, 2013

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Abstract

The COLMEIA cruise, held in the Equatorial Atlantic, in the area of the St. Paul transform system, is part of a joint effort between France and Brazil for the study of the Mid-Atlantic ridge near the St. Peter St. Paul's Rocks. During the cruise we acquired multibeam echosounder bathymetry, backscattering, water column acoustic data, gravity, magnetics and seismics. Thirty-one successful dredges returned a wide variety of rocks, including gabbros and peridotites. Fifteen CTD stations with nephelometric profiles were cast and a hydrothermal plume signal was found, with a source probably located in the Mid-Atlantic Ridge segment south of the St. Paul transform system. Both the bathymetry data and the rocks recovered by dredging suggest that the image of a regional amagmatic Mid-Atlantic ridge is a simplistic view of the processes active in the St. Paul system. Significant variations in the spreading style were recognized, with a more magmatic northern segment and comparatively less magmatic central and southern segments where long-lived asymmetric core complexes were found. A most important result is the evidence for compressive stresses across the area, which can be linked to the uplift of the Saint Paul mylonitic massif.

Introduction

The COLMEIA Cruise was held between January 24 and February 28, 2013 on board the research vessel L'Atalante, in the area of the Saint Paul fracture zone in the Equatorial Atlantic. The scientific objective of the cruise was to study in detail the temporal evolution of the complex Saint Paul transform plate boundary, and the origin of the St. Peter -St. Paul mylonitic massif. We carried out a complete survey of the area with multibeam echosounder bathymetry, backscattering, water column acoustic data, gravity, magnetics and seismics. We also performed thirty-one successful dredges and fifteen CTD stations. Five autonomous hydrophones were moored in the SOFAR channel around the study area in order to monitor the seismic activity and will be recovered mid-2014 (Figure 1).

The Equatorial Atlantic is characterized by the presence of major transform faults that offset the Mid-Atlantic Ridge axis for hundreds of kilometers. The most peculiar feature of this region is probably the tiny archipelago of St Peter-St Paul Rocks, located inside the St Paul transform and fracture zone system. On these islands, stronlgy mylonitized peridotites emerge above sea level, a unique feature in the world's ocean. The St. Paul transform and FZ system is a complex, multi-fault transform boundary displaying three small accreting segments, less than 20 km long, separated by large offset transform faults, forming an « intra-transform » ridge geometry (Schilling et al., 1995; Hékinian et al., 2000).

This area of the Mid-Atlantic ridge has long been recognized as a mantle "cold spot" (e.g. Bonatti, 1990; Bonatti et al., 1993; Schilling et al., 1995). The ridge axis reaches its deepest values along the St Paul intra-transform ridge segments. Basalts dredged along the ridge axis revealed low degrees of melting and temperatures (Schilling et al., 1995). Peridotites dredged at different locations along the equatorial transforms (Bonatti et al., 1993, 2001; Seyler and Bonatti, 1997) also revealed low mantle melting regimes. Thus, petrology and geochemical data suggest that the melting regime in the Equatorial Atlantic is lower than the nearby ridge regions. The source of the anomalously low melting rates beneath the equatorial MAR is supposed to be linked to a thermal and/or compositional anomaly in the mantle beneath the Equatorial Atlantic (Bonatti, 1990; Bonatti et al., 1993; 2001; Schilling et al., 1995). Bonatti (1990) proposed that the delamination of continental lithosphere during the opening of the Equatorial Atlantic, could explain the chemistry of the samples and the inferred low degree of melting, while Sichel et al. (2007) suggest that the anomalous mantle results from fragments of a subducted slab in the upper mantle. Recent work suggests that the mantle beneath the Equatorial MAR may have already experienced some amount of melt extraction before the present times (Brunelli and Seyler, 2010), which is in agreement with the high Os model ages (Esperança et al., 1999).

The main objectives of the COLMEIA cruise were:

1. To verify whether the Equatorial Mid-Atlantic ridge segments are undergoing a cold accretion regime, thus explaining the emplacement of deep crust and mantle rocks at the seafloor and in the St Peter St Paul Rocks;
2. To understand the exhumation processes of these deep rocks;
3. To understand the processes at the origin of the peridotite massif and its connection with the ridge segments;
4. To understand the nature of the equatorial upper mantle;
5. To map and characterize hydrothermal active areas in the active parts of the system.

Preliminary results

Multibeam bathymetry data collected during the COLMEIA cruise confirm the existence of three small intra-transform ridge segments at the St. Paul system. The segments are short and narrow, with deep axial valleys. Axial depths are below 4000 m on average, and reach 5400 m in some nodal basins. There is no evidence for a clearly defined neo-volcanic ridge on the axial valley floors, but a few round volcanoes were observed in the axial valley of the central segment. The pattern of off-axis abyssal hills is highly variable from one segment to another. The northern segment displays a long sequence of magmatic abyssal hills. The central segment shows both hummocky ridges probably of magmatic origin, but also ridges where peridotites have been dredged. The southern segment shows few short, symmetric ridges made of peridotite and gabbros. Both the central and the southern segments display asymmetric core complexes nucleating at segments ends. This variety of off-axis morphologies suggest that accretionary processes along the intra-transform segments are unstable and highly variable in space and time. Two remarkably long-lived core complexes were observed on the western flanks of the central and southern segments.

The new bathymetry data also provide insights into the tectonic setting of the St Peter-St Paul peridotite massif. The massif is currently located on the western flank of the northern intra-transform segment, near the northern transform limit of the system, on the south-American plate. It probably corresponds to a transverse ridge, such as observed in other fracture zones, especially in the Central Atlantic (Hékinian et al., 2000). Evidence for compressive features is observed along the base of the massif, suggesting that uplift is linked to a regional compressive field, consistent with the compressive focal mechanisms reported for this area (Wolfe et al., 1993). Seismic reflexion data show the existence of thick sedimentary layers deposited in the discontinuities between the short ridge segments. Several profiles suggest a highly fractured basement beneath the sediments, suggestive of deformation during the tectonic evolution of the system.

Rock samples were collected by dredging at the axis and flanks of the intra-transform segments, and on the submersed base of St Peter-St Paul massif. A wide variety of rock types, have been recovered. A few structures yielded peridotite with different degrees of serpentinization and deformation. Fresh basalt were recovered from all segments along with gabbros particularly associated to some off-axis features. The abundance of magmatic rocks may lead to re-evaluate the idea that mantle rocks are dominant in the area and suggest that the Mid-Atlantic ridge inside the St. Paul system may not correspond to a near-amagmatic regime with regional mantle exhumation.

Fifteen CTDs with nephelometric profiles were cast at the axial valleys and transform faults of the area but no signal suggestive of a hydrothermal plume was detected on the ridge segments inside the St. Paul system. Three stations yielded a weak nephelometric signal, confirmed by both methane and manganese analyses performed on board, but the signal distribution suggests a source located close to the northern end of the Mid-Atlantic ridge segment immediately south of the St. Paul system.

The five hydrophones moored in the area form a local network aiming to monitor the seismic activity, which is intense in the large offset equatorial transforms. The instruments will be recovered in May 2014 with a Brazilian ship.

During the Expedition three Marine Mammal Observers (MMO) searched for marine mammals. The observations started at sunrise and continued until the sundown on the basis of two hours watches, always with two MMOs on duty. The observers used binoculars (7x50) calibrated for distance evaluation to search for the animals and photographs were taken using a 70-300mm lens. The species was identified using field guides whenever possible or else by exchanges of photographs with other marine mammal researchers. Over a period of 29 days 330.68 hours of observations were made (117.27 hours with the air guns on operation). Fourteen groups of cetaceans were observed (0.04 groups per hour of effort). Nine groups could not be identified at species level because of the distance of the sighting. There were four groups of Pilot Whales and one group of five Sperm Whales (Physeter macrocephalus). Given the occurrence area it is probable that the pilot whales were of the species Globicephala macrorhynchus.

General conclusions

The preliminary results of the COLMEIA cruise revealed that the image of a regional amagmatic mid-Atlantic ridge is a simplistic view of the processes active in the St. Paul system. Instead, significant variations in the spreading style were recognized, with a more magmatic northern segment and comparatively less magmatic central and southern segments. However, the existence of long-lived core complexes at the western flanks of these latter segments suggests that, instead of an amagmatic regime with mantle exhumation, we are observing a reduced melt extraction regime probably controlled by a cold, thick lithosphere where magma is retained in the crust to create large gabbro bodies. Another striking result is the evidence for compressive stresses across the area, which can be linked to the uplift of the Saint Paul mylonitic massif.

Acknowledgements

The COLMEIA cruise is part of the collaboration between France and Brazil for the study of the Equatorial Mid-Atlantic ridge. We thank Captain Gilles Ferrand and his crew as well as the technical staff from GENAVIR-IFREMER for their invaluable assistance during the cruise. The cruise was funded by the French Government through grants to IFREMER, Flotte Océanographique. The project also benefitted from grants from CNRS-INSU, LABEX MER, IFREMER and Laboratoire Domaines Océaniques on the French side and from CPRM and Universidade Federal Fluminense on the Brazilian side.

References

Bonatti, E. 1990. Subcontinental mantle exposed in the Atlantic Ocean on St. Peter-Paul islets, Nature, 345, 800

Bonatti E., Seyler, M. and Sushevskaya, N., A cold suboceanic mantle belt at the Earth's Equator, Science, 261,1993

Bonatti, E., Brunelli, D., Fabretti, P., Ligi, M., Portaro, R. and Seyler, M., Steady state creation of crust-free lithosphere at cold spots in mid-oceanic ridges, Geology, 29, 11, 2001

Brunelli D. and Seyler, M., Asthenospheric percolation of alkaline melts beneath the St. Paul region (Central Atlantic Ocean) Earth and Planetary Science Letters 289, 393–405, 2010

Esperança, S., Sichel, S.E., Horan, M.F., Walker, R.J., Juteau, T., Hekinian, R., 1999. Some Abyssal Peridotites Are Old! Ninth Annual V. M. Goldschmidt Conference, August 22–27, Abs. No. 7389

Hekinian, R., T. Juteau, E. Gracia, B. Sichler, S. Sichel, G. Udintsev, R. Apprioual & M. Ligi, Submersible observations of Equatorial Atlantic mantle: The St. Paul Fracture Zone region. Marine Geophysical Researches 21: 529-560, 2000

Schilling J-G, Ruppel C, Davis AN, Mccuiiy B, Tighe SA, Kingsley RH. & Lin, J. Thermal Structure of The Mantle Beneath The Equatorial Mid-Atlantic Ridge: Inferences From The Spatial Variation Of Dredged Basalt Glass Compositions. Journal Of Geophysical Research, 100(B6): 10057-10076, 1995.

Sichel, S. E., Esperanca S., Motoki , A., Maia, M. , Horan M.F., Szatmari, P. , Alves, E.C. and Mello, S. Geophysical and geochemical evidence for cold upper mantle beneath the Equatorial Atlantic Ocean. Revista Brasileira de Geofisica (2008) 26(1): 69−86

Wolfe C., Bergman, E. and Solomon, S., Oceanic Transform Earthquakes With Unusual Mechanisms or Locations: Relation to Fault Geometry and State of Stress in the Adjacent Lithosphere, J. Geophys. Res, 98, B9, 16187- 16211,1993

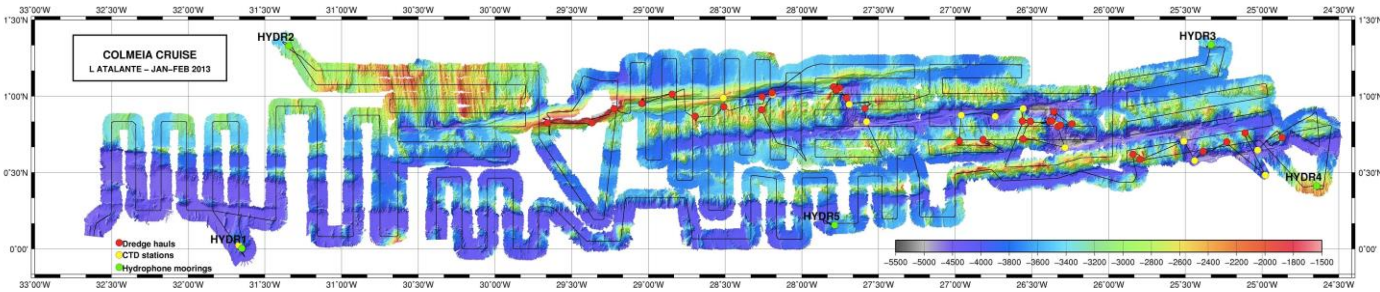


Figure 1. Multibeam bathymetry of the study area with location of the dredge sites in red, the CTD sites in yellow and of the five hydrophone moorings, in green. Scale en meters.

Work Group Updates

Vent Ecology

Co-Chairs: Stephane Hourdez (France) and Yoshihiro Fujiwara
Group Members (Austria, Canada, China, Germany, Japan, Korea, Portugal, Russia, UK, USA) - Maria Baker, Monika Bright, Ana Colaço, Nicole Dubilier, Sergey Galkin, Peter Girguis, Jung-Ho Hyun, Crispin Little, Anna Metaxas, Katsu Fujikura, Xiang Xiao.

Third decadal plan
The Vent Ecology WG has been active in drafting the InterRidge third decadal plan (2014-2023). The contribution of the WG is entitled 'Past, present, and future of vent ecosystems'. Exploration rights granted to different mining companies has raised concerns in our community. A lot remains to be learned about these ecosystems and the species that are part of it to better understand their susceptibility to perturbations. The third decadal plan therefore focuses on the history and the resilience of the vent communities. The primary questions on which the plan focuses are:
1) What are the molecular bases for physiological and life history adaptations to hydrothermal vent conditions? When did these adaptations occur?
2) How did these adaptations affect and yield the diversity of vent organisms?
3) How did past global environmental changes (e.g. global deep-sea anoxia) affect the evolution of vent species?
4) How does the dynamic nature of hydrothermal vents affect the evolution of species?
5) How resilient are vent species/communities and how may they be affected by deep-sea mining?
6) Could global change affect vent species and their function in the ecosystem? On what time scales?
The whole decadal plan can be found at this address
http://www.interridge.org/thirddecade

Deep-sea Mining
In November 2012, Nautilus has announced that the construction of its seafloor production system was terminated as a result of a commercial dispute with the government of Papua-New Guinea (see http://www.nautilusminerals.com/s/Projects-Solwara.asp for a statement from Nautilus Minerals). Other Nations in the Western Pacific may still proceed with hydrothermal vent minerals mining.

High-throughput
The high-throughput page is dedicated to sequencing efforts on hydrothermal vent species, and includes species of invertebrates and bacteria (free-living and symbiotic), for a total of 23 entries. To have a look at the list of projects, go to http://www.interridge.org/highthroughput, and if you would like to add to the list, go to http://www.interridge.org/node/add/highthroughput. The goal is to promote exchanges between researchers in the community and to avoid duplicating efforts.

Meetings
Two main meetings to which the vent biology community participates take place this year.

The 13th International Deep-Sea Biology Symposium was held in Wellington, New Zealand 3-7 December 2012. Held every 3 years, this general deep-sea meeting includes presentations on hydrothermal vents and cold seeps. The vent biology community was well represented.

The 5th International Symposium on Chemosynthesis-Based Ecosystems will be held in Victoria, BC Canada August 18-23, 2013. For more details, see http://www.neptunecanada.ca/cbe5/

Hydrothermal Energy and Ocean Carbon Cycles

Co-Chairs - Nadine Le Bris (IFREMER, France), Christopher R. German (WHOI, USA)

Group Members - Wolfgang Bach (Univ. Bremen, Germany); Loka Bharathi (National Institute of Oceanography, India); Nicole Dubilier (Max Planck Institute Marine Microbiology, Germany); Katrina Edwards (Univ. Southern California, USA); Françoise Gaill (CNRS, Paris, France); Toshi Gamo (Univ. Tokyo, Japan); Peter Girguis (Harvard Univ., USA); Xiqiu Han (Second Institute of Oceanography, SOA, China); Julie Huber (Marine Biological Laboratory, Woods Hole, USA); Louis Legendre (LOV-UPMC, Villefranche, France); George W. Luther III (University of Delaware, USA); William E. Seyfried Jr. (Univ. Minnesota, USA); Stefan Sievert (WHOI, USA); Ken Takai (JAMSTEC, Japan); Andreas Thurnherr (Columbia Univ., USA); Margaret K. Tivey (WHOI, USA).

The WG had no meeting activities this year. The organisation of a larger event, a workshop to bridge with the oceanograph community, was postponed as well, as a consequence of major commitments of the two cochairs. Nevertheless the synthesis and writing phase is progressing. Modelling has been more advanced on the issue of organic carbon and iron export from vents to the water column and two related communication are presented at Goldschmidt 2013 (German et al. 2013, Legendre et al. 2013). A first approach to the quantitative modelling of the seafloor vent ecosystem chemosynthetic carbon production emphasized the need for a better assesment of the constraints and drivers of C-fixation in these environments. A review paper discussing these controls is now under progress, and will be integrating insights from recent experimental approaches and further exploration of chemoautotroph habitats, some of which lead by group members. We may also mention a session at ASLO last Aquatic Science meeting (New Orleans, Feb. 2013) that was convened by one of the WG member on chemoautotrophy in the ocean, though not stricticly organized by the WG.

Coupled Cycling of Fe and Corg in Submarine Hydrothermal Systems: An Ocean Biogeochemistry Perspective. German C, Legendre L, Sander S, le Bris N and the SCOR InterRidge WG135. Mineralogical Magazine, 77(5) 1158
Coupled Cycling of Fe and Corg in Submarine Hydrothermal Systems: Modeling Approach. Legendre L, German CR & Sander SG (0) Mineralogical Magazine, 77(5) 1576

Education and Outreach

Introduction

In its second decade plan, IR pledged its commitment to education, outreach, and capacity building. By investing the time, energy and resources necessary to build a successful E&O program, InterRidge will ensure that its message of responsible exploration and discovery of the world's deep ocean is heard by students, the future stewards of the environment worldwide; policy-makers; and other members of the general public. The hope is that reaching out, educating and motivating people to learn more about the mysteries of the deep sea - a place few will ever see in person - will engender a healthier respect for the Earth system at large.

InterRidge Student and Postdoctoral Fellowship Program

As part of InterRidge's mission to promote international, collaborative, and interdisciplinary studies of oceanic spreading centers, we invite proposals for InterRidge Student and Postdoctoral Fellowships of up to $5000 US each. These Fellowships are designed to encourage international collaboration on any aspect of ridge-crest science by graduate students or postdoctoral researchers, fostering long-standing partnerships for their future careers. The Fellowships can be used for any field of ridge-crest science. In particular these awards are encouraged to be used for international cruise participation, international laboratory use, and adding an international dimension to the Fellow's research. We expect to offer a number of Fellowships each year. Fellowships funded by InterRidge are open to graduate students or postdocs from any nation. Two Fellowships per year are funded by the International Seabed Authority (ISA) Endowment Fund, with the requirement that the graduate student or postdoc is either from a developing country or will assist in training those of a developing country. The ISA Endowment Fund is a new program for collaborative marine scientific research, with details and brochure available at: http://www.isa.org.jm/en/efund/. The mission of the ISA Endowment Fund is to support the participation of qualified scientists and technical personnel from developing countries in marine research activities and to provide opportunities for collaboration by these persons. For more information on the partnership with the ISA for the InterRidge Student and Postdoctoral Fellowship Program, please see: http://www.interridge.org/isapartnership.

InterRidge fellow 2013

Lily Muller

Lily Muller is a second year phD student in University of Oxford. Her primary research involves the ultraslow spreading Southwest Indian Ridge. I am currently using multibeam SWATH bathymetry and shipboard gravity data to characterise the geomorphology, evolution and lithospheric flexure at seamounts on the southwest Indian Ridge for the first time. In addition backscatter data and seafloor video are used to characterise the geology and structure of the axial crest region including faulting and collapse features. I am also using satellite gravity and bathymetry to assess the large scale variations in mantle and surface processes along the length of the ridge. My aim is to gain insight into the small scale (seamounts) and large scale (ridge) processes and the relationship between them. This work collaborates with Professor Alex Rogers who is studying the biology of these seamounts.

Phillipp Nasemann

Philipp Nasemann is a PhD student at the Centre for Chemical and Physical Oceanography -Department of Chemistry at the University of Otago in New Zealand and is supervised by Drs. Sylvia Sander and Claudine Stirling.

He just returned from a research voyage on RV Sonne to the New Hebrides island arc in Vanuatu where a new hydrothermal vent field was studied and sampled. His participation has been sponsored by Prof. Andrea Koschinsky from Jacobs University in Bremen, which he will visit as well to carry out further analyses.

According to his proposal "Fractionation of iron isotopes in Island Arc and Backarc Hydrothermal Systems" focus of the research will be on the alteration of the isotopic signature of iron along its transport from hot vent fluid to the open ocean. Therefore a comprehensive set of samples was collected to determine the initial iron isotopic compositions of host rock and hot vent fluid in this new vent field, and to monitor iron through the buoyancy process all the way into open ocean seawater. Studying iron isotopes and parameters such as iron/sulphur ratios will allow investigating whether significant amounts of iron are actually being exported from hydrothermal vent sites. The results will bring us one step closer to our goal of using iron isotopes as a tool to fully explain importance of different iron sources and the effect they have on the oceanic iron budget.

"I am doing a PhD in isotope geochemistry and marine biogeochemistry of iron. My main aim is to investigate the potential iron isotopes provide as a tracer for marine biogeochemical processes. This InterRidge Fellowship gives me the opportunity to expand my understanding of the biogeochemistry of iron into the field of hydrothermal processes and broaden my knowledge of oceanic iron cycling in general. This is crucial for my PhD and will enhance my ability to develop a career in marine geochemistry."

Szitkar Florent

Florent Szitkar is working with deep-sea, high-resolution magnetic data collected on hydrothermal sites along oceanic ridges worldwide. During his PhD at Institut de Physique du Globe de Paris (IPGP), he became familiar with different methods to process and interpret these data. His work reveal that ultramafic-hosted hydrothermal sites are characterized by a high magnetization resulting from chemical processes during serpentinization, whereas alteration is the main cause of the low magnetization observed at basalt-hosted sites. He successfully used this knowledge to help locating hydrothermal deposits during two cruises in the French exclusive economic zone in the Pacific Ocean.

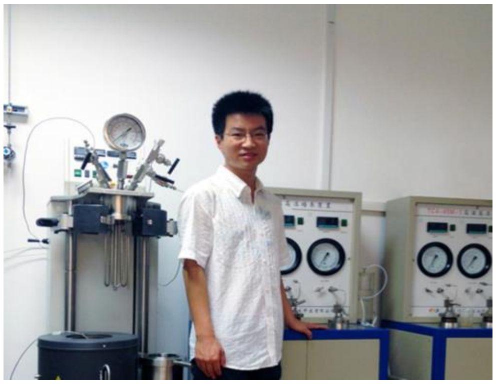
After his PhD defense in May 2013, he continued his work as a post-doc in IPGP to prepare several articles while maintaining international collaborations with prestigious research institutes around the world, including WHOI (USA), GNS Science (New Zealand), and AORI (Japan). He is presently looking for a post-doctoral position starting at the beginning of 2014.

The Inter Ridge project aims to widen his expertise by applying a new inversion scheme developed by Dr. Chie Honsho from AORI (The University of Tokyo, Japan) which avoids the upward-continuation (i.e. the loss of resolution) of other methods. He plans to compute high-resolution magnetization maps over several hydrothermal sites of the Mid Atlantic Ridge, taking full advantage of the near-seafloor measurements and allowing a precise interpretation.

" I have always been interested in Earth Sciences. Even if it's not easy to choose the research topic, the best choice I did was to apply for this thesis project, not only because it's really exciting but also because I have always enjoyed really friendly and warm relationships with my supervisor, Dr. Jérôme Dyment. Under his supervision, I had the opportunity to learn how to become a scientist and prepare papers for prestigious journals. With the professional skills he gave me, I'm now ready to hug a really interesting scientific career! ".

Xinxu Zhang

I have always been fascinated by the microbial life inhabiting oceanic crust since I started my PhD in oceanic crust microbiology and biogeochemistry. This fellowship gives me a great opportunity to investigate the microbial diversity and mineral-microbe interactions of North Atlantic crustal biosphere with top scientists and state-of-the-art technologies. The result will help on understanding the roles of microbes in ocean crust weathering and I will gain extensive experience in studying microbial transformations of earth materials which is crucial for my future research.



R. Rajasabapathy

"Knowledge on Methanotrophic bacterial diversity in the vent regions is of foremost significant because of the chemotropic mode of adaptation. But the diversity of these groups in the vent sites has been complicated to identify due to its limitation in the phenotypic and chemotaxonomic properties. I have always been interested in studying the diversity of marine bacteria especially identifying the functional groups from the shallow water hydrothermal vents. The IR/ISA fellowship will give me an opportunity to explore the methanotrophic bacteria from shallow hydrothermal vent in Azorean Island through methane monooxygenase genes (sMMO)".

Rajasabapathy is currently doing his Ph.D on "Molecular diversity of shallow water hydrothermal vent (Azores) bacteria, their adaptation and biotechnological potentials" under the guidance of Dr. C. Mohandass at CSIR-National Institute of Oceanography, Goa, India. He will visit IMAR- Dept. Oceanography and Fisheries-University of Azores to work on "Forecasting of Methanotrophs by methane monooxygenase genes (sMMO) from the shallow water vent Espalamaca" under the supervision of Dr. Ana Colaco.

Former InterRidge Fellowship reports

INTERRIDGE POSTDOCTORAL FELLOWSHIP: REPORT 2012

Name	:	Baby Divya
Year of award of fellowship	:	2010
Institution	:	National Institute of Oceanography (NIO), Goa, India
Host Institution	:	Institute of Marine Research (IMAR), University of Azores, Portugal
Period of Visit	:	24th January 2012 - 10th July 2012
Supervisor in India	:	Dr.Shanta Achuthankutty Microbiology Laboratory, NIO, Goa, India
Supervisor in Portugal	:	Dr.Raul Bettencourt Genetics Laboratory, IMAR, University of Azores, Portugal

Report on the visit to IMAR, University of Azores, Portugal
Under the InterRidge fellowship, I studied the bacterial gene expression kinetics in the hydrothermal vent bivalve Bathymodiolus azoricus at the University of Azores, Portugal. B. azoricus mussels are found as large animal communities in the hydrothermal vents around the Azores region and are considered as model organism to study the physiological adaptation to extreme physical and chemical conditions. These animals from the shallowest hydrothermal vent, Menez Gwen are maintained in controlled aquarium system, called LabHorta, for monitoring physiological characteristics in seawater.

My study involved the understanding of the variation of bacterial symbiont gene expression in the host gills tissues during their maintenance in the laboratory. Initially, about 20 genes involved in the bacterial metabolism were screened at 12 hour intervals and also after seven days. Out of these bacterial genes, those involved in the chemoautotrophic metabolism such as SOX (sulphur oxidation), MMO (methane oxidation) and Cbb (carbon fixation) were selected for the expression analysis using qPCR. Quantitative gene expression was pursued to understand the individual variation in expression in animals at different time points and between different time points. The salient findings were 1) the expression of SOX (sulphur oxidation), MMO (methane oxidation) and Cbb (carbon fixation) genes varied significantly between individuals and 2) this variation was time dependant and decreased within hours of maintenance of the host animals in sea water. The presence of the expression of genes in the different sections of the gill were confirmed by Fluorescence in situ hybridization (FISH) suggesting their obligate relationship by way of chemosynthesis.

My work under the guideship of Dr. Raul Bettencourt, the eminent geneticist and invertebrate immunology specialist at the University of Azores helped me in getting an exposure to the latest state-of-art techniques at the cellular and molecular level techniques for symbiotic studies. Moreover, I got hands on training with the various instruments within the University of Azores, Horta. My scientific concepts were honed by my constant interaction with my host supervisor, scientists and researchers who were the team members of the shallow water missions. This scientific interaction would help me in my future research and has also enabled me in fostering future collaborative work between my institute, National Institute of Oceanography, India and University of Azores, Portugal. It is my greatest pleasure to thank my supervisor and Project Leader at NIO, Dr. Shanta Achuthankutty, a distinguished marine microbiologist and ecologist, for her untiring help, guidance, encouragement and support throughout the course of the work. I would also like to take this opportunity to thank the InterRidge Coordinator of Initiative for International Cooperation in Ridge Crest Studies for considering me for the award of this fellowship which enabled me to conduct this fascinating piece of work on symbiotic association between higher organism and bacteria.

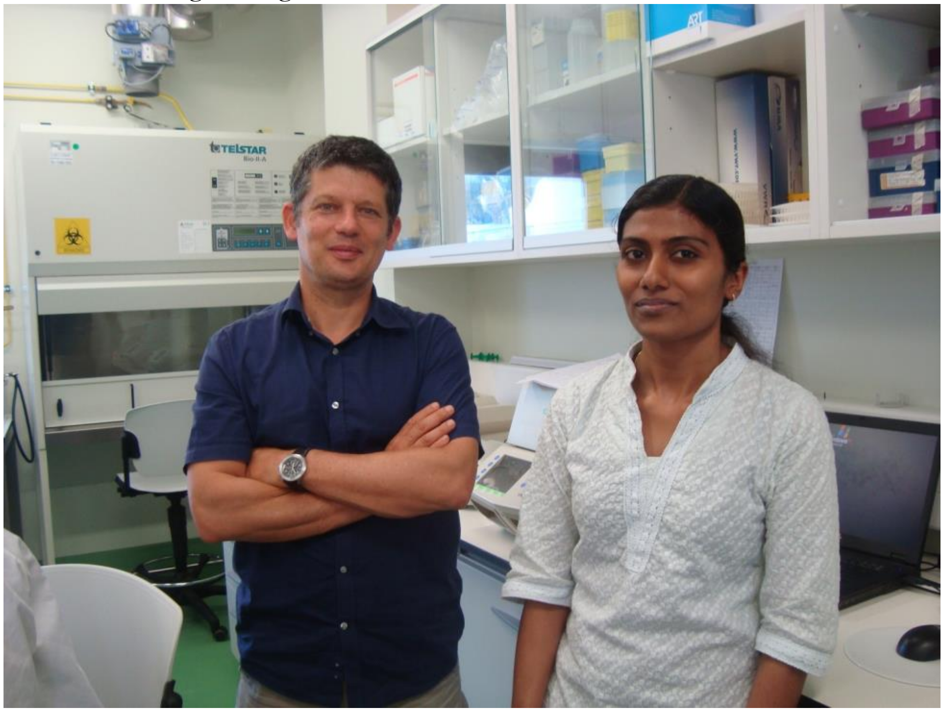


Photo: Drs. Raul Bettencourt and Baby Divya at Genetics Laboratory, University of Azores, Horta

Srinivas Rao Arvapalli, 2011 InterRidge student fellow

National Institute of Oceanography (CSIR), Goa, India.

Deputation Report of visit to University of Bremen, Bremen, Germany.
I carried out the proposed research project entitled "Distribution of hydrothermal sources over the slow spreading Indian mid oceanic ridges" under the supervision of Dr. Maren Walter, at University of Bremen, Bremen, Germany, as an InterRidge student fellow. The objective of my proposal of study is to 'Identify the hydrothermal source using the water column physical data collected under the Indian Ridge program on hydrothermal exploration. The data was collected in various cruises with CTD (Conductivity, temperature and depth), MAPR (Miniature Autonomous Plume Recorder with Eh sensor) and AUV (Autonomous Under water Vehicle) over the Carlsberg and Central Indian Ridges in Indian Ocean.
"Indian ridge program 2010" selected a 40 mile segment at 10°S, to explore hydrothermal activity on central Indian ridge. We conducted expedition onboard RV Sagar Nidhi (SN-48) to acquire the hydrographic data in water column using CTD, turbidity sensors and AUV. CTD hydrocasts were planned based on the tectonic and geo-morphological features observed in the bathymetric map of the study area. From Continuous observations of turbidity signatures from the back scatter sensors, we conducted AUV dives to find the location of the provenance of hydrothermal signatures.

During my visit I learned the techniques for processing and analysis of hydrographic data. First I started work on AUV data. The deltaE values along the AUV tracks and vertical profiles of MAPRs have been calculated from Eh (Oxidation and Redox Potential) data. Significant ΔE anomaly values are important to understand and find the possibility of source locations of the hydrothermal vents. Similar procedure I applied to calculate the temperature anomaly ($\Delta\Theta$) for AUV tracks data. Only minor ΔE&$\Delta\Theta$ values are observed in the tracks on AUV apart from there are no significant variations in the data. Lupton (1985) method was used to find out the hydrographic (CTD-potential temperature and salinity) anomalies in all the observed hydrothermal plume depth stations. The results of these hydrography anomalies revealed an idea of the physical properties of this plume. I estimated the heat flux of volume of possible source in this study area by using MTT model (Morton et al 1956). I also acquired knowledge on data visualization (AUV and CTD data) and interpretation of the results. The hydrothermal plume spreaded up to 15km in the water column observed through the turbidity data with constant potential density. From the results of heat flux and spreading distance values are cross checked with the other known vents data, we presumed to be a large vent field existence in this slow spreading central Indian ridge, Indian ocean. We found the results are very interesting from this work.

Acknowledgment
I am indebted to Dr. Maren Walter, my dissertation mentor for her guidance and providing support and first- rate resources for this dissertation project Dr. Maren, in particular has been exceedingly generous with her time, laboratory space and equipment. Her expertise in hydrothermal vent studies was an asset to my project. I am also grateful to Dr. Christian Mertens for providing many useful insights into my project and directions to conduct the further research and have always been a good friend. Particularly, I extend my sincere thanks to my Ph.D guide and project leader Dr. K. A. Kamesh Raju for his long-lasting source of support, encouragement and advice throughout my time. I would like to thank Dr. Debbie Milton, InterRidge coordinator for her kind assistance throughout the process. I want thank many of my friends, colleagues and teachers from NIO and University of Bremen who offered me lot of help and support, this work would not has been possible without help from them. This research was supported by "Interridge/ISA fellowship program" and I am very thankful to Interridge/ISA fellowship program for giving me this wonderful opportunity for the advancement of my research career. This experience and knowledge is very useful to upcoming Indian Ridge program on hydrothermal studies.

Call for proposals 2014

InterRidge Student and Postdoctoral Fellowship Programme 2014

http://www.interridge.org/fellowship

All application materials are to be submitted electronically to the InterRidge Coordinator (interridge@gmail.com;coordinator@interridge.org) by 31 March 2014

The InterRidge Office at Peking University, China, is pleased to announce the launch of the 2014 Student and Postdoctoral Fellowship Programme. As part of InterRidge's mission to promote international, collaborative, and interdisciplinary studies of oceanic spreading centers, we invite proposals for InterRidge Student and Postdoctoral Fellowships of up to $5000 US each. These Fellowships are designed to encourage international collaboration on any aspect of ridge-crest science by graduate students or postdoctoral researchers, fostering long-standing partnerships for their future careers. The Fellowships can be used for any field of ridge-crest science. In particular these awards are encouraged to be used for international cruise participation, international laboratory use, and adding an international dimension to the Fellow's research.

We expect to offer a number of Fellowships in 2014. Fellowships funded by InterRidge are open to graduate students or postdocs from any nation. There are also four Fellowships being funded by the International Seabed Authority (ISA) Endowment Fund, with the requirement that the graduate student or postdoc is either from a developing country or will assist in training those of a developing country. The ISA Endowment Fund is a programme for collaborative marine scientific research, with details and brochure available at:http://www.isa.org.jm/en/efund/. The mission of the ISA Endowment Fund is to support the participation of qualified scientists and technical personnel from developing countries in marine research activities and to provide opportunities for collaboration by these persons. For more information on the partnership with the ISA for the InterRidge Student and Postdoctoral Fellowship Programme, please see: http://www.interridge.org/isapartnership

Cruise Travel Bursaries

Purpose

- To encourage new collaborations across the InterRidge member nations.
- To enable early-career, ridge-crest scientists to participate in mid-ocean ridge research cruises.
- To develop new research directions.

The award

Up to $2000 USD will be awarded for travel and subsistence costs to facilitate cruise participation. Successful applicants will be asked, on their return, to:

- Produce a report for the IR website in **English**
- Deliver an ambassadorial seminar in their institution, explaining the enabling role of the InterRidge bursary in their work

How it works

There are two possible routes:

A) Initiated by early-career scientist

1. Identify a cruise on which you wish to participate, and a scientist onboard (host) with whom you would like to collaborate.

2. Contact host by email, asking if there is a spare berth.

3. Host scientist checks with the cruise Chief Scientist.

4. If all are in agreement, download the bursary application form (see bottom of page - to be completed by host scientist / applicant), and submit it to the InterRidge Office as an email attachment, together with your CV and letter of support from your manager/university/laboratory.

B) Initiated by host scientist

1. If you are interested in establishing new collaborations relating to the cruise on which you are participating, contact your Chief Scientist for information on spare berths, and permission to open discussions with interested parties. Send information on spare berths into the InterRidge Office and we will put it on the website.

2. Early-career scientists - check the InterRidge website (http://www.interridge.org/berths) to see which cruises have spare berths and contact the host scientist. OR

A host scientist may already know of an eligible applicant, in which case they may proceed with the application, subject to approval by the Chief Scientist.

3. If all (Chief Scientist, host scientist (if different), and early-career scientist) are in agreement, download the bursary application form (see bottom of page - to be completed by host scientist / applicant) and submit it to the InterRidge Office as an email attachment,together with the applicant's CV and letter of support from his/her manager/university/laboratory.

What will you do onboard?

Participate in the planned science programme.

Carry out your collaborative research.

(Preference will be given to applicants from InterRidge member countries, who have a clear role on the research cruise and who are not part of the original research team. We especially favour applicants from countries other than those of the host scientist).

Call for spare berth for early career scientists

In 2014, InterRidge office will continue provide cruise bursaries for early career scietists to participate in mid-ocean ridge research. We encourage chief scietists to provide information of spare berth to our office.

UPCOMING CRUISES

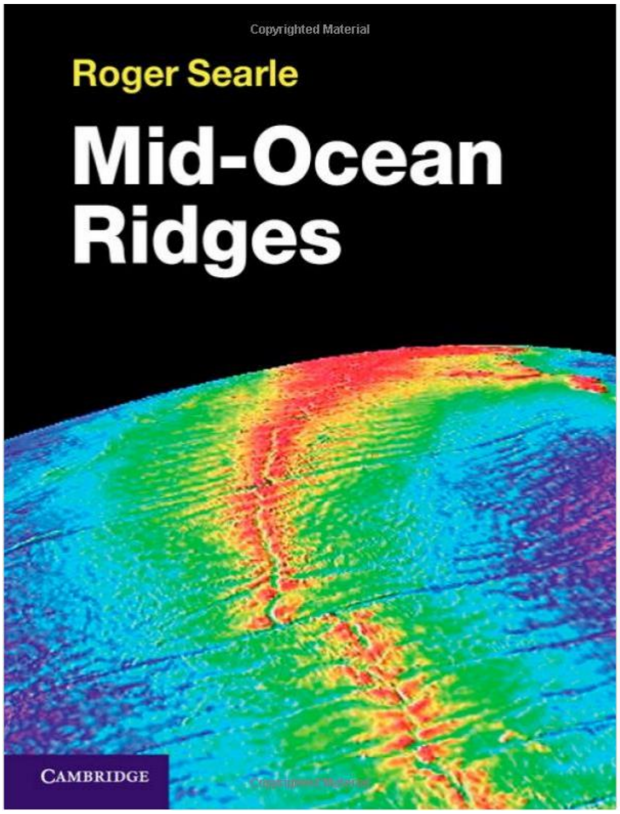
Country	Cruises	Time	Location	Berth availability
France	BICOSE	Early 2014	Pourquoi Pas ?	
France	MOMARSAT 2014, SISMOSMOOTH, HYDROBSMOMAR 2, OHASIS-BIO, STORM	Expected in 2014-2015		
Japan	KY14-01	08/01/2014-31/01/2014	Okinawa Trough	
Austrailia		04/10/2014-08/11/2014	offshore western Australia	Yes, Contact Jo Whittaker <Jo.Whittaker@utas.edu.au>
United Kindom	James Cook	January/February 2015	Costa Rica	

Upcoming events

Event	Time	Location	Website
Deep-Ocean Industrialization: A New Stewardship Frontier	16 February 2014	Chicago, USA	http://aaas.confex.com/aaas/2014/webprogram/Session7092.html
2014 Ocean Science Meeting	23-28 February 2014	Honolulu, USA	http://www.sgmeet.com/osm2014/default.asp
Lyell Meeting 2014	12 March 2014	London UK	http://www.geolsoc.org.uk/lyell14
Deep–Sea Mining Summit 2014	17-28 March 2014	London, UK	http://deepsea-mining-summit.com/
Sea Bed Mining 2014	24-26 March 2014	London,UK	http://www.seabedminingsummit.com/
VentBase meeting	2-4 April 2014	Wellington, NZ	http://www.niwa.co.nz/coasts-and-oceans/ventbase/2014
European Geosciences Union General Assembly 2014	27 April-02 May 2014	Vienna, Austria	http://www.egu2014.eu/
2014 Goldschmidt Conference	8-13 June 2014	Sacramento, USA	http://goldschmidt.info/2014/
IMBER Open Science Conference	23-27 June 2014	Bergen, Norway	http://www.imber.info/index.php/Meetings/IMBER-OSC-2014
Underwater Mining Institute 2014	21-27 September 2014	Lisbon, Portugal	
The World Conference on Marine Biodiversity 2014	12-16 October 2014	Qingdao,China	http://wcmb2014.csp.escience.cn
AGU Fall meeting 2014	15-19 December 2014	San Francisco, USA	http://fallmeeting.agu.org/2014/

New Publications

Mid-Ocean Ridges by Roger Searle



Editoral Review

"This volume provides a comprehensive, up-to-date and authoritative account, extensively illustrated and referenced, of the geology, the morphology, the tectonics and the chemistry of the ridges, relating these to the underlying mantle movements. It also describes in detail the techniques used in these studies. Professor Searle has been at the forefront of research on the mid-ocean ridges throughout his career, and has produced an ideal textbook both for students and those currently researching the geology of the ocean floor." - Sir Anthony Laughton, FRS, formerly Director of the Institute of Oceanographic Sciences, UK

"Professor Searle has done a superb job of summarizing and analyzing the history of, and the latest insights into, mid-ocean ridges, ranging from ultra-slow to fast spreading rates and including the tectonics, geophysics, geochemistry, volcanism and hydrothermal activity of this "longest mountain range in the world." This is an essential volume for any student or researcher studying mid-ocean ridges, both those in the Earth sciences and those with backgrounds in marine biology, chemistry oceanography, physical oceanography and other related fields." - Ken C. Macdonald, Emeritus Professor of Marine Geophysics, University of California at Santa Barbara

Book Description

This coursebook presents a multidisciplinary approach to the science of mid-ocean ridges - essential for a complete understanding of global tectonics and geodynamics. An ideal introduction to a key global phenomenon for graduate and advanced undergraduate students and professionals working in marine geology, plate tectonics, geophysics, geodynamics, volcanism and oceanography.

About the Author

Roger Searle is Emeritus Professor of Geophysics at Durham University. He has spent forty years studying mid-ocean ridges, and was a pioneer in the use of side-scan sonar to study their geodynamic, tectonic and volcanic processes. In his research he also uses topographic analysis and gravity and magnetic modelling to understand ridge structures. He was awarded the Royal Astronomical Society's Price Medal in 2011 and elected a Fellow of the American Geophysical Union in 2012. Searle has worked in many of the world's major oceanographic institutions, participated in thirty-seven research cruises and led eighteen. He was first full chairman of the international research organisation InterRidge, and has served on national and international committees including chairing the International Ocean Drilling Program's Site Survey Panel.

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