

InterRidge Workshop  
**“Tectonic and Oceanic Processes along the Indian Ridge System”**

19 – 21 January 2005, N.I.O., Goa

### **Summary**

InterRidge Workshop on “Tectonic and Oceanic Processes along the Indian Ridge System” was held at the National Institute of Oceanography, Dona Paula, Goa, India from 19 to 21 January, 2005. The workshop was well attended with participants from 8 countries and covered all aspects related to the ridge research in eight technical sessions. There were 10 special talks, 24 oral presentations and 18 poster presentations. Besides, a special interactive talk was devoted to the recent seismic event, off Sumatra, that generated a tsunami. On the second day of the workshop a film on “Volcanoes of the deep sea” was screened. Panel discussions were held during the concluding session of the workshop, which brought out opportunities for forging collaboration among the ridge researchers across the world.

The workshop was organized with financial help from the Council of Scientific and Industrial Research, InterRidge and Ridge 2000 Program, USA.

### **Background**

The Council of Scientific & Industrial Research (CSIR), India, in association with the Department of Ocean Development, Government of India, initiated a Network Programme “Tectonic and oceanic processes along the Indian Ridge system and Back Arc Basins”, to investigate the mid-ocean ridge system and the backarc basin in the Indian Ocean. The National Institute of Oceanography, Dona Paula, Goa and National Geophysical Research Institute, Hyderabad, both constituent laboratories of the CSIR, are implementing this interdisciplinary programme. India, an associate member of the InterRidge proposed to organize a workshop on “Tectonic & Oceanic Processes along the Indian Ridge System” to provide a forum for the ridge researchers world over to exchange ideas and results and foster collaborations. The proposal was considered during the InterRidge Steering Committee meeting held at Tokyo, Japan, in 2003. It was decided that an InterRidge Workshop entitled “Tectonic and oceanic processes along the Indian Ridge system and back arc basins” would be hosted by NIO, at Goa, India, from 19-21 January 2005.

### **Workshop objectives**

- To focus on the geological, geophysical, physical, chemical and biological processes at the Indian Ocean spreading centers
- To provide a forum for exchange of ideas and results
- To encourage international collaboration in exploration of Indian Ocean ridge research using latest tools and techniques.

### **Workshop themes**

Scientific contributions were solicited under the following themes:

- Ridge segmentation
- Outcropping mantle and mullion tectonics
- Ridge-hotspot interaction and mantle dynamics
- Hydrothermal processes and ridge biology
- Back arc basins
- Emerging technologies

## Participants

This was one of the well-attended workshops of the InterRidge. A total of 80 participants from 10 countries attended the workshop. Following is the country wise breakup of participation.

France – 5	Japan – 3	Russia – 1	United States of America – 10
Germany – 2	Korea – 1	Spain - 1	
India – 55	Portugal - 1	United Kingdom – 2	

## Inauguration



The inaugural ceremony of the workshop was held in the impressive NIO auditorium named “Cardium” on 19 January 2005 at 9.30 hrs. Dr. Satish Shetye, Director, NIO, in his welcome address underlined the importance of understanding the earth system process and the need to enhance the efforts to study the Indian Ocean. Dr. Colin Devey, InterRidge Chair and Chair of Scientific Organizing Committee of the workshop briefed the future goals of the InterRidge. Dr. Jerome Dymont, Co-chair of the Scientific Organizing Committee explained the objectives of the workshop. Dr. KA Kamesh Raju, National Coordinator of the Indian Ridge programme presented a sketch of Indian Ridge initiative, its past activities and future goals. Dr. H.K. Gupta, Secretary, Department of Ocean Development, Govt. of India, inaugurated the workshop by lighting the traditional lamp. In his inaugural address Dr. Gupta enumerated various initiatives of the Department of Ocean Development and reiterated the support of the Government for oceanographic research. He also mentioned the impact of the recent tsunami that devastated the coasts of Southeast Asian countries, including India, and the plans set in motion to establish capabilities for predicting future events.

## Poster display



Dr. Chuck Fisher, Chair, Ridge2000, inaugurated the poster display. A total of 18 posters were presented, which were grouped as per the scientific themes of the workshop. Few posters with wider scope were displayed as general interest posters. To provide ample opportunity for the participants to interact with the authors, arrangements were made for the display of posters on all the three days of the workshop.

## Technical sessions

The schedule of the workshop consisted of 8 technical sessions besides inauguration and concluding sessions (Annexure –1). Each technical session contained at least one special talk followed by oral presentations. A total of 24 scientific presentations and 10 special talks were given during the workshop.

**Session I – Ridge segmentation:** Jerome Dymant initiated scientific presentations with an introductory talk on “Past and present Indian Ocean ridges: exciting targets for mid-ocean ridge studies”. He observed that unlike the Pacific and Atlantic oceans, the Indian Ocean presents a variety of spreading center types, from the ultra-slow Southwest Indian Ridge (SWIR) to the slow Carlsberg (CR) and Central Indian (CIR) ridges to the intermediate Southeast Indian Ridge (SEIR) and geochemically, the Indian ridges represent a window to a distinctive mantle province, emphasized by the Dupal anomaly. He further added that many exciting opportunities await ridge researchers in the Indian Ocean and urged not to miss them!

In the special talk, Charles DeMets described results from a new detailed study of Somalia-India-Australia motion since 20 m.y., based on more than 3000 magnetic anomaly and fracture zone crossings identified from original shipboard, airborne, and satellite data. Segmentation and tectonics of Carlsberg Ridge and the Central Indian Ridge were dealt by Chaubey et. al. and Kamesh Raju et. al. respectively. In another paper, Charles DeMets explained changes in Indian plate motion since 20 Ma and Carlsberg and northern Central Indian ridge spreading kinematics. Peter Rona et al. compared the morphology, petrology, and hydrothermal activity of sections of the Mid-Atlantic Ridge with that of the Carlsberg Ridge in the northwestern Indian Ocean extending from the Owen Fracture Zone (10°N) to the Vityaz Fracture Zone (5°S). Catherine Mével et. al. characterized the variations in thermal regime along the axis of the southwest Indian ridge between the Rodrigues Triple junction and the Andrew Bain fracture zone related to the local influence of hot spots.

**Session II – Outcropping mantle and mullion tectonics:** Robert S White delivered special talk on “Melt production rates under mid-ocean ridges”. He showed that the rate of melt production under mid-ocean ridges is controlled primarily by the temperature of the underlying mantle and by the rate of seafloor spreading. Independent methods of determining the thickness of melt produced can be derived from geophysical measurements of the igneous crustal thickness (wide-angle seismics and gravity) and from geochemical inferences from rare earth element (REE) concentrations in mid-ocean ridge basalts of the total amount of melt generated in the mantle. Both geophysical and geochemical methods give consistent results for the amount of melt generated from the mantle and frozen to form oceanic crust. He added that the Indian Ocean contains a wide range of both spreading rates and of mantle temperatures, including both abnormally hot and abnormally cold regions of mantle, which enables the dependence of melting on both mantle temperature and spreading rate to be investigated.

Abhay Mudholkar described the emplacement of mantle rocks along the Carlsberg Ridge with the help of seafloor topography and petrographic studies. Dwijesh Ray et al. brought out the influence of low temperature hydrothermal alteration during serpentinisation along the north Central Indian Ridge. RK Drolia showed the results of analysis of swath bathymetry from the northern Central Indian ridge. Satish Singh presented some thoughts on seismic imaging of moho, magma chambers and serpentinisation front along Indian Ocean Ridge systems from MAR and EPR experiences.

**Session III – Ridge-hotspot interaction and mantle dynamics:** Henry Dick gave the special talk of the session on the SW Indian Ridge. He observed that long sections of the SW Indian Ridge closely resemble slow-spreading ridges, consisting of linked magmatic segments, small non-transform offsets and transform faults, the crust is generally significantly thinner, and mantle peridotites are more abundant near ridge discontinuities. Elsewhere, long sections of the ultraslow spreading SW Indian Ridge consist of linked amagmatic and magmatic ridge segments without transform or non-transform offsets despite often-extreme ridge obliquity. He also found that in regions of low overall melt productivity, widely spaced volcanoes may erupt transitional or alkaline basalt at the ridge axis rather than N-MORB, though the actual volcanic edifices may be as large as or larger than those found at slow spreading ridges.

Tiwari et al. debated on the nature of isostatic compensation along the Deccan-Reunion hotspot track due to on-axis versus intra-plate volcanism. Christopher Hemond presented two papers – one on recycled Oceanic Crust and Pelagic Sediment, into the Indian Mantle. The Central Indian Ridge (18°-20°S) and the other dealing with Rodrigues Ridge and St Paul-Amsterdam Plateau as examples of ridge-hotspot interactions in the Indian Ocean. YJ Bhaskar Rao et al. presented evidence for northward extension of Indian Ocean - type mantle anomalies based on Sr and Nd isotopic systematics of Indian Ocean MORBs from Central Indian and Carlsberg ridges.

**Special evening talk on the recent seismic event off Sumatra:** The occurrence of severe submarine earthquake (M9.0) off Sumatra and the mega tsunami it generated caused devastation in the coastal areas of Southeast Asian countries is a matter of grave concern to the earth scientists. Satish C. Singh delivered a special talk of the event, its effects and post tsunami research that needs to be undertaken immediately. He also presented a plan of work, which solicits multi-nation and multi-institutional participation.

**Session IV – Hydrothermal processes and ridge biology:** In the special talk, John Lupton gave a detailed account of <sup>3</sup>He in the Indian Ocean. He explained that, in the Indian Ocean, the <sup>3</sup>He distribution is the result of a complex mix of sources, including input from a variety of hydrothermal sites, intrusion of Antarctic Bottom Water from the south, and a tongue of <sup>3</sup>He-rich Indonesian through flow water intruding from the east. While it might be expected that hydrothermal sources are distributed throughout the mid-ocean ridge system, only a portion of the Indian Ocean ridges have been explored. Based on the <sup>3</sup>He distribution, the principal hydrothermal sources appear to

be in the Gulf of Aden, in the central Indian Ocean near the Rodriguez Triple Junction, and a source near the convergent margin in the far northeast.

Marvin Lilley et al. dealt with the chemistry of the Kairei and Edmond vent fields, Central Indian Ridge. They interpreted that fluids from both fields appear to have phase separated at supercritical conditions, and only fluids with chloride concentrations greater than local ambient seawater were found at both sites. The composition of the hydrothermal fluids from each of these sites is distinct. Bramley Murton et al., presented results of their cruise to Carlsberg Ridge, organized during August 2003, and detection of a mega-plume and insights into volcanic events and hydrothermal processes. The paper by Bibhuranjan Nayak dealt with Hydrothermal Mineralization at Mount Jourdanne, Southwest Indian Ridge (SWIR) and mineralogical associations that indicate different thermal episodes that range from conditions under which black smokers form to the ceasing of the hydrothermal activity through white smoker activity. BR Rao et al., showed recent field observation of methane anomalies over ridge segments along the Central Indian and Carlsberg Ridges and inferred that the source of the methane signal may be located in the vicinity of the southern segment.

**Session V – Hydrothermal processes and ridge biology:** Charles Fisher delivered special talk on “Adaptations of hydrothermal vent animals to their habitat, with special reference to the currently known fauna of the Central Indian Ocean Ridge”. He showed with examples that almost all of the animals found during dives to the Central Indian Ocean Ridge are new species. Many of these new species, like the abundant mussels and shrimp, are closely related to other well-studied species of mussels and shrimp found at other vent sites around the world.

PA Loka Bharathi reviewed the current status of microbiological studies of the Indian ridge systems. The recent work include the discovery of extremely active vent sites with biological communities close to the Rodriguez Triple Junction by Japanese scientists and microbiological studies at the Edmond deep-sea Hydrothermal vent field in CIR which is dominated by  $\epsilon$ -proteobacteria comprising nearly 75 %. Baban Ingole presented a paper on “Biological communities of the Indian Ridge System”. Y. V. B. Sarma et al., discussed signals from Light Scattering Sensors (LSS) in conjunction with potential temperature anomaly ( $\Delta\theta$ ) and methane ( $\text{CH}_4$ ) and silicate ( $\text{SiO}_4$ ) as physical and chemical proxies to identify deep sea hydrothermal activity over the Carlsberg Ridge (CR) and Central Indian Ridge (CIR) regions. They have shown encouraging signals in chemical proxies such as  $\delta^3\text{He}$  and Fe in the Carlsberg ridge region. Geochemical aspects of the sediments from Carlsberg Ridge were dealt by AB Valsangkar.

**Session VI –Back arc basins:** In the special talk, Sang-Mook Lee elaborated on the diverse tectonic and magmatic interactions at backarc spreading centers with examples from the Bismarck Sea, western Pacific. He noted that an important aspect that distinguishes backarc spreading centers from mid-ocean ridges is the diversity of tectonics and magmatism which can be observed within short along-axis distance. Unlike mid-ocean ridges which are fixed relative to the underlying mantle, many backarc spreading centers are relatively young features which have undergone rapid deformation over the geological timescale, and therefore, the present-day backarc basins may well represent different snapshots of a few end members of a dynamical system.

B.N. Nath presented a paper by Siby Kurian et al. about the geochemical evidence of hydrothermal component in Andaman Backarc basin sediments. Their interpretation using geochemical data of the significant detrital component in the sediment cores is consistent with the published seismic data that shows sediment infilling in the northeastern part of the neotectonic spreading ridge. The large detrital component in these sediments may be diluting hydrothermal signatures.

**Session VII –Special Talks:** Charles Langmuir delivered special talk on “Mantle domain boundaries in the Indian Ocean and the nature of mantle heterogeneity.

**Screening of film “Volcanoes of the Deep Sea” (courtesy Peter Rona):** An excellent digital movie, which was produced using Hollywood’s latest technology (IMAX) working closely with

Woods Hole scientific team was screened. The movie was a visual delight of the deep sea and presented a good account of under water volcanism, hydrothermal venting and associated biological activity.

**Session VIII –Emerging technologies:** “Japanese expeditions on the Indian Ridges: the past achievements and future plans” was the special talk of the session which was delivered by K. Tamaki. He has presented the details of previous expeditions and plans of future cruises and the latest tools that are being used. He also explained the Japanese initiative under ODP to undertake drilling in the Indian Ocean and the possible scientific problems that can be addressed.

Jean-Yves Royer et al., presented a scheme for monitoring the Indian Ocean ridge seismicity with a hydrophone network. The objective was to monitor the low level seismic activity (magnitude < 2) associated with the Indian Ocean ridge system, using a network of 3 temporary hydrophones combined with the 3 permanent hydro-acoustic stations of the Comprehensive nuclear-Test-Ban Treaty Organization (CTBTO) deployed in the SOFAR channel of the Indian Ocean (Crozet Island, Diego Garcia Island and Cape Leeuwin) and the seismicity associated with the deformation of the Indo-Australian composite plate. Similar experiments have been successfully conducted in the Atlantic and Pacific oceans. Sanjeev Afzulpurkar reviewed the current status of instrumentation used for ridge studies and outlined future needs.

### **Panel discussion**

The panel discussion was initiated by the InterRidge Chair, Dr. Colin Devey by giving an overview of the deliberations that took place during the technical presentations. The presentations covered all the segments of the Indian Ridge system, with the exception of South East Indian Ridge, due to the last minute cancellation of the participants. Outstanding aspects that required attention are the coverage along the Central Indian and Carlsberg Ridge segments, more dense sampling along the segments to characterize the geochemical signatures, emphasis on vent exploration and use of modern tools. Dr. Langmuir suggested use of the protocols followed in SWIR and in the Pacific for the Vent exploration, these deal with integration of tectonics with the water column signatures. Dr. Jerome Dyment stressed on the need for more exchanges to take place between the Indian Ridge scientists and the groups working in the Atlantic and Pacific. He opined that such exchanges facilitate sharing of expertise gained. Dr. Drolia suggested the need to form a CR-CIR working group on the lines of SWIR working group. In response to this, Dr. Dyment suggested that the interactions can be achieved through the existing working groups, and the present working groups are primarily process oriented rather than the geographical area. These working groups will have scope for wider interactions cutting across the geographical boundaries. The other point that came into focus is the biogeography of the benthic species in the Indian Ocean, highlighted by Dr. Ingole and others. Dr. Subrahmanyam suggested the need to have the off-axis coverage over the CIR segment to capture the signature of intra-plate deformation processes east of CIR, Dr. Drolia mentioned the need to look into the incipient triple junctions east of the CIR segment. Highlighting the immediate requirement of the Indian Ridge program to have modern tools such as deep-tow, ROV and in-situ sensors, Dr. Kamesh Raju solicited the participation of the Ridge researchers in the forthcoming second phase exploratory efforts of the Indian Ridge program along with modern tools and methods. He also indicated that exchange of technicians would be useful. Responding to the suggestions for the off-axis coverage along the CIR segments, Dr. Kamesh, indicated, this can be taken up as an activity of the future investigations of the CIR segment. Dr. Tamaki, offered berths for the Indian participants in the future Indian Ocean cruises of Japan using AUV. Dr. Chaubey suggested bringing out a special issue on “Tectonic and oceanic processes along the Indian Ridge system”. He also informed that the Marine Geophysical Researches, an international journal for the study of the earth beneath the sea, agreed to publish a special issue containing 10-12 good research papers. Dr. Colin Devey, InterRidge Chair and Chair of Scientific Organizing Committee of the workshop welcomed the suggestion and promised to provide support to this endeavor. There was a brief discussion on the IODP proposals in the Indian Ocean, Dr. Tamaki, who is closely involved with the IODP program coordination from Tokyo, clarified that proposals are welcome from the individuals or a group of scientists, membership in IODP is not a pre-

requisite. Discussions ended with a recommendation to have more exchange of scientists, tools and expertise to explore the Indian Ocean ridge segments. The panel discussion concluded with a formal vote of thanks by Dr. C. Subrahmaniam.

### **Student awards**

As per the tradition of the InterRidge to encourage young researchers and attract bright students towards ridge research, student awards were announced for best student poster presentation. In view of several meritorious posters from the students, the award was shared among three young researchers Mr. KV Anoop (Geophysics), Mr. Dwijesh Ray (Geology) and Ms. Sheryl Fernandez (Biology).