IODP Proposal Nurturing Workshop - SPADE
(Scientific Proposals for Andamans Drilling Endeavour)

A workshop to nurture scientific drilling proposals in the Andamans and surrounding regions

Organized by:
IODP-India
at
National Centre for Antarctic and Ocean Research
Goa, India
17-18 September 2018

Supported by

Ministry of Earth Sciences
Government of India

European Consortium for
Ocean Research Drilling

U.S. Science Support
Program (USSSP)

Integrated Ocean Discovery
Program (IODP)

National Centre for Antarctic and
Ocean Research

IODP-India

CONTENTS

IODP Proposal Nurturing Workshop - SPADE

(Scientific Proposals for Andamans Drilling Endeavour)

at National Centre for Antarctic and Ocean Research, Goa

17-18 Sept 2018

Background

The International Ocean Discovery Program (IODP) is an international marine research collaboration that explores Earth's history and dynamics using ocean-going research platforms to recover data recorded in seafloor sediments and rocks and to monitor subseafloor environments. In 2011, an Indian Ocean IODP Workshop was hosted in Goa by The National Centre for Antarctic and Ocean Research (NCAOR) in association with IODP, aimed to build new drilling proposals. With six successful completions of IODP expeditions in Indian Ocean during 2015-2017, it is time to nurture new scientific drilling proposals from Indian Ocean sector with special emphasis to the Andamans and surrounding seas. Initial discussions were held through a joint workshop organized by ANZIC, IODP-India and other agencies on prospective scientific drilling proposals in Indian, Southern Ocean and Antarctic Shelf region at Sydney, 2017. Drilling in the Sumatra Seismogenic Zone (IODP-362) in 2016 to investigate the role of input sediments driving shallow seismogenic slip leading to mega thrusts—stimulated scientific interests in the Andaman sector of the Andaman Sumatra subduction zone. Considering the huge research interests among Indian as well as international geoscientists in the Indian Ocean sector, this international workshop prior to the IODP Forum meeting has been planned. Such an opportunity would provide an ideal forum for in-depth discussions on the scientific issues related to this region. In addition, such a platform could cater to highlight the Indian geo-scientific contributions towards a better understanding of the Indian Ocean sector. The goal of this workshop is to trigger development of new IODP proposals for Indian Ocean sector. The workshop will be an opportunity to entrain a new generation of young scientists to work collaboratively to plan a new phase of ocean drilling.

Importance of ocean drilling in Andamans:

The Andaman-Sumatra Subduction Zone is a convergent plate boundary, formed by subduction of the Indo-Australian plate under the Burmese and Sunda plates. In this perspective, the northern sector of this subduction zone, i.e., the Andaman Subduction Zone, and the adjacent backarc basin, i.e., the Andaman Basin, were formed by subduction of the Indian plate under the Burmese plate. A detailed understanding of geological setting of these areas is important to decipher the plate tectonic evolution of the Andaman Basin and the subduction process at the Andaman Subduction Zone. The distribution of the earthquake epicentres in the Andaman Basin and the forearc regions show that the entire Andaman Subduction Zone is active with abundance of seismicity. Accumulations of volumes of sediments at the trenchward edge of subduction zones (accretionary prisms) are important structures that control processes on the shallow portion of the megathrust. Deep sea drilling in the proximity of forearc high would render enhanced information about the uplift history, thereby, allowing us to explore its evolution through the sediment feeding mechanisms besides seismogenic overview of the underlying plate boundary. Back-thrust is a dominant tectonic structure in the forearc region which controls the surface expression of displacement and ridge-like structures. The spatial and temporal relationship of the back-thrust with respect to subduction will relate to the understanding of slip behaviour. Therefore, the tectonics of forearc structure in the subduction zone will provide constraints regarding Seismogenic behaviour in the subduction thrust faults.

Scope of drilling:

Understanding the slip behaviour and associated earthquakes as well as creation of new oceanic crust through the back arc opening is a high priority challenge for IODP with important societal impacts. It investigates spatial and temporal aspects of physical, hydrological, and chemical properties of the fault zone to elucidate key factors that can control large (and small) slip on the mega-thrusts. These results may be used to explain the past tsunamigenic events along the Andaman sector and surrounding regions. The goal of this workshop is to review results of the recent scientific drilling expeditions in the region; to propose possible paths for an integrated understanding of the role and response of climate in regulating morphology, tectonics, sedimentation, and biogeochemistry. This will lead to building broad scientific teams and collaborative partners for the future. The workshop would provide stimulus for multi-lateral geo-scientific interactions among scientists in the region. It will enable us to discover new frontiers and build on future programs. The workshop would provide an opportunity to develop highly focused proposals for ocean drilling.

Acknowledgments:

1. Ministry of Earth Sciences, Government of India
2. European Consortium for Ocean Research Drilling (ECORD)
3. U.S. Science Support Program (USSSP)
4. International Ocean Discovery Program (IODP)

ABSTRACTS

IODP- Proposal Nurturing Workshop – SPADE

Bay of Bengal circulation and its importance to Monsoon

M Ravichandran
National Centre for Antarctic and Ocean Research, Goa
Email: mravi@ncaor.gov.in

The Bay of Bengal (BoB) has a large influence on the world, since more than 1 billion people depend on rainfall from South Asian monsoon for their livelihood. The presentation covers (i) How the monsoon annual cycle is regulated and modulated inter annually, (ii) What are the atmospheric and ocean circulation in the Bay of Bengal, including local and remote forcing, (iii) When the currents in the Andaman sea is strongest and reason for the same, and (iv) How the BoB responds to important climate modes such as El Nino and Indian Ocean Dipole.

Exploring aspects of monsoon development through ocean drilling: what can we expect from the last Indian Ocean 'mission'?

Dirk Kroon
University of Edinburgh, UK
Email: dick.kroon@ed.ac.uk

Study of the history of Asian and Indian monsoons requires recovery of sediment records contained in nearshore, fan sediments and pelagic sediments in deep basins or carbonate platforms. The IODP Science Plan for 2013-2023 says: IODP drilling strategy has three components. First, by drilling continental margin sediments that contain terrestrial material transported by rivers mixed with marine sediment, it is possible to obtain continuous, well-dated records of both continental and oceanic change. Second, drilling open-ocean sites will be crucial to reconstructing changes in past sea surface temperature gradients. These gradients are essential of cyclone formation and intensification, as well as climate zone size and position. Third, ocean drilling will investigate the character of regional climate change across a range of periods with different mean climatic states, solar forcing and greenhouse gas conditions. During this lecture I will explain how the SEP (Science evaluation Panel) aimed to support and encourage proponents of drilling proposals of the 'last' Indian Ocean Mission. Furthermore, I will show some of the main outcomes of these expeditions so far.

Lithospheric Structure of Andaman Subduction Zone

Virendra M Tiwari* and R Yadav
CSIR- National Geophysical Research Institute, Hyderabad, India
* *Email: virendra.m.tiwari@gmail.com*

We present a lithospheric density model of Andaman subduction zone constructed from joint modeling of gravity and geoid data. Model provides geometry of subducting lithosphere, along axis variation in the geometrical and physical properties of subduction zone, and structure under the aseismic ridge and seamounts. The obtained structural variations are interpreted in the terms of geodynamics of the region. Further, to get a synoptic view of the dynamics of subduction system, a numerical simulation of Andaman subduction zone is set up using FEM method with derived density model. The dynamic model illustrates influences of trench geometry, plate boundary force and rheology on the deformation and stress patterns of the subducting and overriding plates. The high-stress regions show a good correlation with occurrences of the earthquake. However, considering the fact that subduction is a time-dependent phenomenon, a more comprehensive model is needed that incorporates detailed geophysical observations in order to capture small scale deformation in the plate convergence processes particularly oblige convergence.

Tectonic and structural variation along the Andaman Sumatra frontal arc

Vineet K Gahalaut
National Centre for Seismology, Ministry of Earth Sciences, New Delhi, India
* *Email: vk.gahalaut@nic.in*

Andaman Sumatra subduction zone marks the convergent plate boundary between India/Australia and Sunda plates. The relative motion between the two plates is arc normal in the Java Sumatra region and becomes oblique in the Andaman Nicobar region and hyper oblique in the Indo-Burmese arc. The oblique motion is partitioned between the frontal arc and the back arc. In the Sumatra region, the partition appears to be full whereas in the Andaman Nicobar region, it is partial, as the frontal arc motion (as brought out by the plate circuit analysis and the coseismic slip azimuths of the 2004 Sumatra Andaman earthquake) becomes more and more oblique to the trench from Nicobar to Andaman region. The >1200 km long rupture of 2004 Sumatra Andaman earthquake revealed complexities and structural variation along the arc. The rupture was slow and more complex in the Andaman region and did not contribute to tsunami generation. Also, in this region it did not extend up to the trench and the energy released was much smaller than that in the Nicobar and Sumatra region. Whether the subduction of Bay of Bengal sediments and/or ninety east ridge in the Andaman region contributed towards these inferred differences and complexities, remains to be explored. Even the shallow seismic imaging of the trench and accretionary wedge brings out clear differences in the deformation pattern and fault vergences within the wedge from Nicobar Sumatra region to Andaman region. The ongoing GPS measurements in the Andaman Nicobar region highlight dominance of postseismic deformation in the Nicobar region whereas in the northern Andaman region, the postseismic deformation is minimal. These measurements also highlight differences in the deformation pattern between Andaman and Havelock region.

Geochemical evolution of the Andaman Back Arc: A window to the Indian Ocean Mantle

(A proposal for drilling the Central Andaman Outer Rift Valley, Alcock & Sewell Rises, Andaman Sea)

Jyotiranjan S Ray[1*], Kanchan Pande[2], Rajneesh Bhutani[3], Dwijesh Ray[1], Sanjeev Kumar[1] and S Balakrishnan[3]

[1] *Physical Research Laboratory, Navrangpura, Ahmedabad 380009, India*

[2] *Department of Earth Sciences, IIT Bombay, Powai, Mumbai 400076, India*

[3] *Department of Earth Sciences, Pondicherry University, Puducherry 605014, India*

[*] *E-mail: jsray@prl.res.in*

Introduction and Rationale

Understanding chemical evolution of Earth's mantle not only requires knowledge of the changes that occur due to melt extraction but also information about the recycling of crustal material back into the mantle. The former can be directly assessed through the chemistry of Mid-Oceanic-Ridge and Hot Spot lavas, whereas there is no direct means to quantitatively estimate the latter, therefore, we rely heavily on the chemistry of the subduction zone (arc) magmas. The working of the subduction factory in shaping the mantle chemistry is well understood through a collective study of convergent margin magmas such as the suprasubduction zone ophiolites, arc and back arc lavas. The Andaman Subduction Zone (ASZ) in the northeastern Indian Ocean is one such margin which provides a unique opportunity to study all these components in a relatively younger time frame and in a smaller spatial domain.

The ASZ represents an ocean-ocean subduction system, where the Indian Plate subducts obliquely beneath the Burma Plate, a sliver of the Eurasian Plate (Fig. 1). The initiation of the subduction dates back to ~98 Ma (Bhattacharya & Ray, 2015). The Andaman volcanic arc, consisting of two known volcanoes (Barren Island and Narcondam; Fig. 1), is a northward extension of the Sunda arc system of Indonesia. Whereas the true spatial and temporal extent of the Andaman arc remains a mystery, our studies reveal that Narcondam became extinct at ~ 0.5 Ma and the currently active Barren Island became subaerial at ~1.5 Ma (Bhutani et al., 2014; Ray et al., 2015). This southwardly fading arc may contain numerous submarine extinct volcanoes as part of the Alcock and Sewell rises (Fig. 1) or may have had a longer and complex evolutionary history compared that generally envisaged. The suggestion that the crust beneath Barren Island volcano is ~106 Ma (Ray et al., 2015) appears to support the latter. Geochemical and isotopic characteristics of the lavas not only show imprint of slab but also hint at possible influence of asthenospheric mantle, particularly in the lavas of Barren Island (Fig. 2; Luhr & Haldar, 2006; Sheth et al., 2011; Streck et al., 2011; Kumar, 2012; Smitha, 2014). The latter could be due to the close proximity of the volcanic arc to the back arc spreading ridge (Fig. 1), which is believed to have started at ~4 Ma (e.g., Curray, 2005). The Andaman and Nicobar Islands are part of an accretionary prism, located on the outer arc of the Andaman fore arc (Fig. 1). The islands are made up of supra-subduction zone ophiolites and Paleogene-Neogene trench-fore arc sediments.

In spite of the existing information, the ASZ remains to be the least studied convergent plate margins. Many important questions about the origin and evolution of various components of the subduction system, particularly those related to volcanic arc and the back arc, are yet to be answered. Also, remains unknown are the links between various sub-oceanic mantle domains in the Indian Ocean and Andaman Sea. Answers to these require a thorough investigation of mantle derived rocks in various regions of the Andaman arc and submarine rises including the spreading ridge. Since most the Andaman Basin is covered with thick Quaternary and older sediments, dredging is cumbersome and many a times futile. Therefore, we propose sampling through drilling; along the proposed transect X-Y in Fig. 1, into the basements in Alcock rise, newly formed ocean crust on either side of the Central Andaman Rift Valley and the Sewell rise. Considering the fact that the Andaman back arc spreading ridge is one of the youngest in the world our study would likely to reveal a great deal about the origin of back arc magmatism and its chemical effect on the arc volcanism.

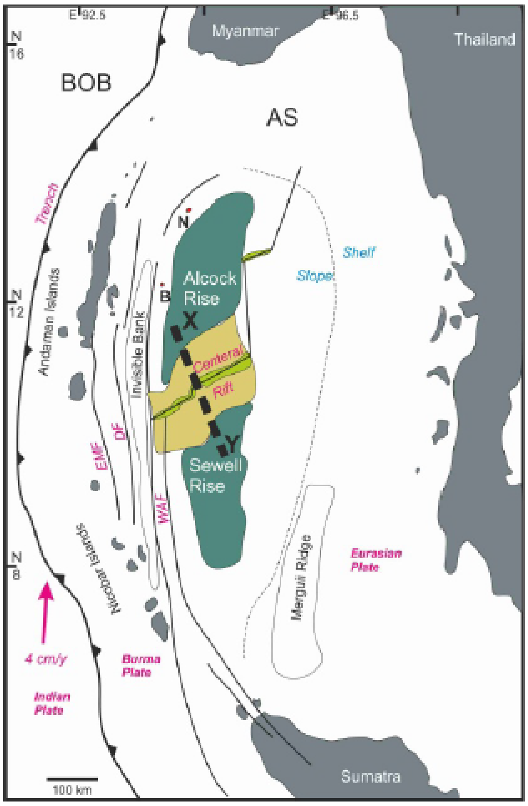

Fig. 1: Schematic map of the Andaman Subduction Zone. Various faults, ridges and basins are marked. N: Narcondam; B: Barren Island. X-Y is the proposed transect for the drilling

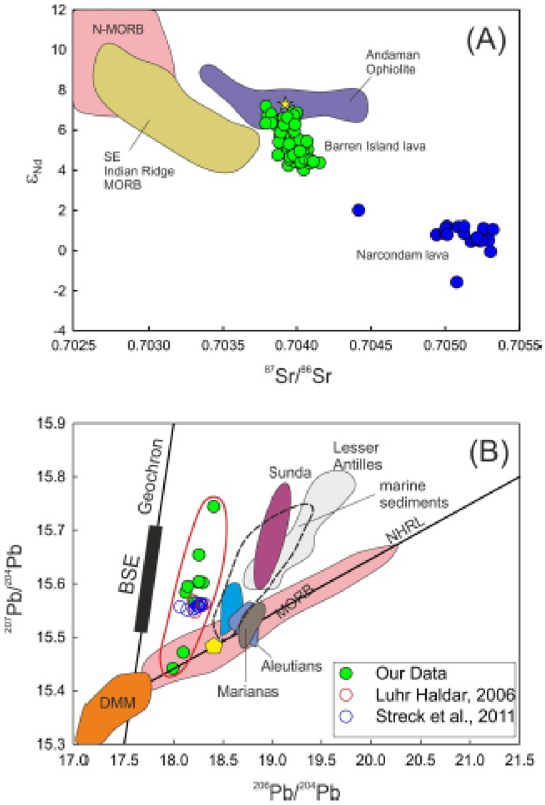

Fig. 2: Isotopic composition of lavas from Barren Island and Narcondam compared with that from other mantle derived rocks and sources in the Indian Ocean region. Data sources: Mahoney et al. (2002), Luhr Haldar (2006); Streck et al. (2011); Kumar (2012); Smitha (2014).

Objectives

The specific objectives of the study would be to understand/determine:

1) Evolution of the Indian Ocean mantle in time and space by comparing geochemistry of Andaman MORB with other MORBs from Indian Ocean region.
2) Timing of initiation of back arc spreading in the Andaman Basin
3) Rate of spreading along the Andaman Ridge (Mid-Oceanic Ridge)
4) Nature and depth of magma chamber below the Andaman Ridge

5) Amount of lithospheric/slab component in the Andaman MORB mantle
6) Effect of back arc rifting on mantle wedge melting/arc magmatism
7) The evolution of the Andaman arc vis-à-vis evolution of the Alcock and Sewell rises
8) The link between the Andaman arc and the Sunda arc

Methodologies

To achieve the above objectives, we propose the following sampling and analytical methodologies.

Sampling:

1) Drilling of at least two cores from surface to the old magma chambers on the newly formed oceanic crust on either side of the active spreading center (Central Andaman Rift valley): length = ~ 3 km each
2) Drilling of two cores, one each on the Alcock Rise and Sewell Rise: length = ~3 km each

Analytical Methods:

1) Petrographic studies: Microscopy; SEM
2) Geochronology: 40Ar-39Ar dating (Gas Mass Spectrometry)
3) Geochemical studied: Major & Trace elements by EPMA; Q-ICPMS/LA-HR-ICPMS
4) Radiogenic isotopic studies (Sr-Nd-Pb: TIMS & MC-ICPMS)
5) Oxygen isotopic studies (LF-IRMS)

Theoretical modelling:

Advance mantle melting models would be employed/ developed to understand the geochemical data in relation to the nature, location and evolution of the Andaman oceanic mantle.

Expertise/Facilities

1) JSR, RB & SB are experts in mantle geochemistry and have LA/Q-ICPMS, MC-ICPMS and TIMS facilities in PRL/PU to carry out the analyses. They also have ample experience with theoretical modelling of geochemical/isotopic data.
2) JSR and DR have prior experience of sampling of seamounts/MORB and their geochemical/isotopic study.
3) KP is an expert in 40Ar-39Ar dating and has a facility of his own at IIT Bombay.
4) DR has EPMA and XRF facilities in PRL.
5) SK is an expert in stable isotopes and has developed Laser Fluorination IRMS in PRL for oxygen isotope studies of silicates.

References

Bhattachrya, S & Ray, JS, 2015, AGU Fall Meeting, Abstract T41E-2950.

Bhutani, R, Pande, K, Ray, JS, Smitha, RS, Awasthi, N, & Kumar, A, 2014, GSA, Abstract 268-9.

Curray, JR, 2005, J Asian Earth Sci, 25, 187-228.

Kumar, A, 2017, PhD Thesis, MS Univ Baroda.

Luhr, JF & Haldar, D, 2006, J Vol Geotherm Res, 149, 177-212.

Mahoney, JJ, Graham, DW, Christie, DM, Johnson, KTM, Hall, L & Vonderhaar, DL, 2002, J Petrol, 43, 1155- 1176.

Ray, JS, Bhutani, R & Pande K., 2015, Bull Vol, 77, 55.

Sheth, HC, Ray, JS, Bhutani, RB, Kumar, A & Awasthi, N, 2011, J Vol Geotherm Res, 202, 73-82.

Smitha, RS, 2014, PhD Thesis, Pond Univ.

Streck, MJ, Ramos, F, Gillam, A, Haldar, D & Duncan RA, 2011, Topics in Igneous Petrology (ed: Ray et al.), 241-272.

Cycling of volatiles and metals through subduction zones: implications for nutrient supply and for mineralisation

Marie Edmonds
Earth Sciences Department, University of Cambridge, UK
Email: marie.edmonds@esc.cam.ac.uk

Subduction zones recycle material from the surface of the Earth back into the mantle. The subduction process, whereby a cold slab descends into the mantle, heating up and releasing water as hydrous minerals break down, fractionates volatile elements from refractory elements. Volatiles (including metals) are transferred, via supercritical fluids, to the overlying mantle wedge and into primary melts which rise up through the overlying lithosphere to form the subarc and backarc igneous crust.

We have recently shown that subaerial subduction zone volcanoes vent a distinct metal assemblage into the atmosphere, compared to mid-ocean ridge (MOR)and hotspot volcanoes[1] and are associated with higher gaseous metal fluxes. The gases and aerosols emitted by subduction zone volcanoes are characteristically rich in Tl, Pb, Bi, W, As, Cu and Zn. These elements are highly *fluid-mobile*, i.e. they partition strongly into aqueous fluids from silicate melt, thereby becoming enriched in the primary melts formed in subduction zones. Furthermore, as the magmas ascend from the melting region to the surface, they partition strongly into a magmatic aqueous fluid, generated during degassing. The metals therefore become concentrated in the magmatic vapour phase at the surface, being vented into the atmosphere directly as gas and aerosol (complexed with chlorine and sulfur).

These results have implications for the flux of nutrients into the oceans from hydrothermal venting, as well as for the modes and mechanisms of mineralization. As the balance between MOR and backarc venting shifted as plate tectonics became established on Earth, the nature of the hydrothermal flux would have altered. It follows (but has not yet been shown) that metal (and metalloids) emissions from backarc submarine vents have a distinct compositional fingerprintcompared to MOR hydrothermal vents, rich in Tl, Pb, Bi, W, As, Cu and Zn. Some of these metals and metalloids are important constituents of proteins in microbes, or act as catalysts or electron donors/acceptors in key microbial reactions. Mineralization is also expected to be distinct in backarc settings compared to MOR, which has been shown by some studies of modern back-arc hydrothermal fluids and mineralized deposits.

A drilling program in the Andaman Sea region in the backarc of the Sunda Arc may be used to study volcanic and magmatic processes, hydrothermal venting and microbial life to better understand the geochmical cycling of volatiles and metals through subduction zones and to investigate the larger implications of such cycling for metal bio-utilization and mineralization. Backarc metal systematics are much less well understood than for MOR systems, yet backarc spreading ridges make up ~ 20% of the spreading ridge system on Earth and likely account for a much larger proportion of the hydrothermal flux into the ocean.

1 Edmonds, M., Mather, T. A. & Liu, E. J. A distinct metal fingerprint in arc volcanic emissions *Nature Geoscience* (September 2018, in press).

Subduction complex of Andaman region: current understanding and scope for further study

Tapan Pal
Geological Survey of India, NER, Shillong, India
Email: paltapan62@gmail.com

The main Andaman and Nicobar Islands represent an accretionary prism in an outer-arc setting and turbidites of a forearc setting. The N–S-trending three major thrust slices of dismembered ophiolite (Cretaceous age) along with interleaved Eocene trench-slope sediments constitutes mainly the prism. The emplacements of ophiolite- sediments are controlled mainly by a series of E-dipping thrusts along with some 'out of sequence' thrust and west dipping back trust.

In the ophiolite sequence both crustal and mantle sections are well preserved on the lands. The chemical signatures of the mantle peridotites of ophiolites show its polygenetic MORB–SSZ (Suprasubduction zone) setting. The petrographic and chemical signatures suggest that mantle rocks are dominated by overriding Burma plate but in certain thrust slices especially towards western side of the islands MORB mantle peridotites are preserved suggesting the presence of off scraped Indian plate.

Drilling by oil companies in the forearc region also indicated the presence of thrust slices of ophiolite and sediments, covered by forearc sediments. Towards north, in the Burma (Myanmar), ophiolites occur in two major belts but in Andaman so far, only ophiolite belt is reported which coincides more or less with the western ophiolite belt of Burma. It is not clear whether another ophiolite belt is continued further east within the present day forearc basin or not. Drilling in forearc region by oil companies hints for the existence of ophiolite (higher forearc) in shallower level near EMF (Eastern Margin fault)**.** If it is proved that a separate ophiolite belt (accretionary prism) really exists, then what about the arc of the older accretionary prism. Detailed marine survey can only resolve this issue.

Siliciclastic turbidites (forearc) sediments occurring both towards West and East of the main islands are typical submarine fan deposits. Towards the eastern part of the islands extensive foreacrc sediments represent a well-defined submarine fan sequence as: a) siliciclastic turbidites (upper Eocene-Oligocene?) towards lower part and b) volcaniclastic to carbonate turbidites (Mio-Pliocene) towards upper part of the basin. In the western part of the islands on the other hand only siliciclastic turbidites are present. The paleocurrent pattern of both the western and eastern quartz rich siliclastic turbidites show northerly existing Burma continent as the major provenance.

It is still not clear how forearc sediments occur in both East and West of the main outerarc ophiolites. Some researchers suggest that the siliciclastic turbidites occurring in the western part of the islands are the product of modern subduction, initiated after the roll back of the trench. The turbidites of the eastern part are the product of the older subduction. Some other workers suggest that the turbidites in both the western part and eastern part of the islands could be the Bengal fan sediments. For detailed geometry and interpretation of the forearc

fan sediments especially in between EMF (East Margin Fault) and DF (Diligent fault) marine survey will be required.
Quaternary Narcondam Volcano and Quaternary to Recent Barren volcano show arc signatures. The dormant and dacite-andesite Narcondam volcano is the domal volcano reflecting magma mixing of rhyolite and basalt magma but the end magma members i.e., rhyolite and basalt are yet to be reported from the island. Besides, the Narcondam Island has influences of continental crust. The Barren Volcano, throughout its history ejecting basaltic magma, is quite different from Narcondam Volcano. The ambiguity remains unanswered in the nature of the volcanism in the arc line.

The opening of Back arc Andaman Sea, is still debatable. Some workers suggested a continuous spreading model from Pliocene-Recent whereas others suggested that spreading was done only in Miocene and cast a doubt about the present day spreading. Another group of workers suggest two-phase opening history of the Andaman Sea with of 4–5 and 11 Ma old. First stage of the opening of Andaman Sea perhaps remains concealed in the early–middle Miocene forearc subsidence history.

The nature of the crust in the Alcock and Sewell Rises and western part of East Andaman basin also remains uncertain, and it has been differently explained as oceanic crust and continental crust. Dredged basaltic samples from Alcock rise has been explained as the product of syn-rift volcanic extrusions over the continental crust rather than as a part of oceanic crust. Therefore, deep drilling in the Alcock rise piercing the crust and Central Trough sediments will resolve the long standing debate on the spreading history of back-arc Andaman Sea.

Gas Hydrate activities in India with special reference to Andamans

KK Chopra
Directorate General of Hydrocarbons
Email: kkchopra@dghindia.gov.in

In India, Gas Hydrate research and exploratory activities are being steered by the Ministry of Petroleum & Natural Gas under National Gas Hydrate Program (NGHP). Under NGHP two expeditions have been carried out for the Gas hydrates exploration.

NGHP-Expedition-01 exploration program carried out in 2006 for mapping gas hydrates zones in Krishna-Godavari, Kerala-Konkan, Mahanadi and Andaman offshore and established the physical Presence of gas hydrate in Krishna Godavari, Mahanadi and Andaman Basin in clay dominated complex geologic settings. The preliminary investigation of the seismic data showed a seismic reflection at a depth of ~608 mbsf that possess many of the features of a BSR. Andaman Sea Site NGHP-01-17 Site located in the Andaman Sea along the eastern coast of the Andaman Islands was identified for Gas Hydrates. Hole NGHP-01-17A was drilled, and cored to a total depth of 691.6 mbsf having water depth of ~1,344 m. Gas hydrate was inferred and detected from numerous core IR and pore water Cl- anomalies at Site NGHP-01-17. The highest Gas Hydrate saturation values coincide with IR-inferred are from the ash beds and ash-rich units with peak saturation values exceeding 50%. An offset well NGHP-01-17B was subsequently drilled to 718 mbsf and wireline logged (including a VSP survey) too. Abundant methane was recovered in a pressure core from a depth of 586.3 mbsf (just above the depth of the predicted BSR). An additional pressure core collected from a depth of 672.3 mbsf, which is below the BSR, contained abundant methane and is interpreted to indicate the presence of free gas. Down-hole temperature measurements confirmed that the geothermal gradient at this site is very low, which accounts for the anomalously deep BSR and base of the assumed methane hydrate stability zone. Drilling of wells, wire-line logging and coring done established the presence of Gas hydrate in the region.

NGHP-Expedition-02 was completed in 2015 for Gas Hydrates exploration in the Krishna Godavari and Mahanadi area has discovered two gas-hydrate-bearing sand reservoir systems in the offshore Krishna Godavari basin. Very small saturation of gas hydrate was found in Mahanadi deep water basin. NGHP Expedition-02 results are encouraging and further extensive studies are planned to assess the gas hydrate resource potential, reservoir characterization, reservoir delineation and geo-mechanical modelling for seafloor and wellbore stability and identification of sites for pilot production for testing.

Technology for production of gas from gas hydrate is not yet matured and is at R & D stage. A thorough exploration studies are to be undertaken to discover Gas Hydrates in sand bearing reservoirs of Krishna Godavari, Mahanadi and Andaman areas which will be key parameters for making exploitation strategy before venturing into Expedition-03. KG deep offshore areas contain gas hydrate accumulations seems at present better options for gas hydrate production testing under NGHP Exp-03.

Bay of Bengal Drilling and Monsoon Reconstructions

Steven C Clemens[*] and Kaustubh Thirumalai
Brown University, Providence, RI. USA
[*] *Email: steven_clemens@brown.edu*

A number of IODP-sponsored workshops have been held in the past two years (Sydney, Narragansett Rhode Island, Shanghai) focusing on the next phase of Indian Ocean drilling to commence in 2023. These workshops reflect the strong need to address key targets in the Indian Ocean, including those in the Andaman Sea and Indian Margin. These regions are among the most convectively active regions on Earth and host a trove of paleoclimate information that recent expeditions (353, 354, and 359) barely began to address. In recent workshops (Narragansett, Shanghai) the paleo-monsoon community expressed the need for high-resolution time series reconstructions in the Pliocene and Miocene, similar to that typically produced for the Pleistocene, as well as greater spatial coverage of Pleistocene sites.
Expedition 353 (Indian Monsoon Rainfall in the Core Convective Region) drilled a site that barely reached the latest Miocene on the Indian margin (U1445) and one that reached the middle Miocene in the Andaman Sea (U1447) but had interspersed fine-scale turbidites. Deepening Site U1445, for example, offers an excellent potential for well-preserved Miocene sediments, as would other potential targets.

Beyond deeper-time targets, initial work on Pleistocene materials from the Indian National Gas Hydrates Program (NGHP) sites as well as the more recent IODP sites is beginning to reveal a spatial complexity that was previously unrecognized, including potential differences in the timing of strong monsoon rainfall in the eastern and western sides of the Bay of Bengal. As well, new results from south central Indian speleothem $\delta^{18}O$ records is revealing north-south spatial heterogeneity in the late Pleistocene monsoon signal within India itself. Drilling targets on the southeast Indian margin would provide complimentary ocean sites necessary to better understand differences inland-ocean climate responses.

While 2023 may seem distant, in the drilling world, it's very soon; the community needs to converge soon on funding and accomplishing seismic surveys necessary to identify appropriate targets that will enable the next phase of monsoon research.

Deciphering long-term Monsoon evolution through coring in Andaman Sea

Arun D Singh*, Dinesh Naik, Sayandeep Banerjee
Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi, India
* *Email: arundeosingh@yahoo.com*

The Andaman Sea (AS), a marginal basin in the northeastern Indian Ocean, with a max. water depth of 4200 m is connected with the Bay of Bengal (BOB) and the western Pacific (Austral-Asian) sea via shallow channels between the chain of the Andaman & Nicobar Island and the Malacca Strait, respectively. Surface water hydrography (salinity and temperature) and circulation in both the basins are strongly affected by seasonal variations in monsoon. The hydrographic characteristics and oceanographic processes in both AS and BOB are comparable down to a depth of about 1000 m. The upper water column (up to 1000 m) in BOB is bathed in North Indian High Salinity Intermediate Water (NIHSIW), and seasonal low-salinity water mass dependent on the intensity of seasonal monsoon. Presence of several sills between the Andaman Islands (Prepares channel, Ten degree, and Great Channel), however, inhibit deep water exchanges between these two basins. It is known that the intermediate (~ 1200 -3800 m) and deep water (> 3800) masses in the Indian Ocean originate from the North Atlantic and Southern Oceans. Earlier investigations (including model study) also suggest temporal variations in a connectivity of Indian and Pacific surface waters via the Indonesian Throughflow affecting nutrient supply to the BOB and AS. Numerous studies have been carried out on reconstructions of late Quaternary Indian monsoon history on shorter time scales based on multiproxy records developed from short sediment cores. Recently, the scientific ocean drilling in the Bay of Bengal and southern Andaman Sea has also been conducted by the R/V JOIDES RESOLUTION with a main scientific objective to achieve a long record of Indian monsoon circulation history tracing back to the Miocene at tectonic to centennial scales. Our knowledge on tectonic evolution of shallow passages/sills and its impact on temporal changes in water mass exchanges (between BOB and AS) through time is not sufficient. Additionally, it is essential to better understand; how the entire water column structure across the BOB and AS varied through time, and how the deep circulation affected the nutrient levels, since the evolution of the Andaman Sea? Scientific drilling in the forearc basin from northern end of the ninety-east ridge across the ten degree channel would be ideal for addressing these crucial paleoceanographic issues.

Targeting Sweetspots and Hotspots for Indian Monsoon Reconstructions

Liviu Giosan
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
Email: lgiosan@whoi.edu

Recent industry and scientific drilling in the northern Indian Ocean accomplished many objectives for reconstructing the longterm history of the Indian monsoon. In the same time, this effort revealed significant gaps that require future drilling investment. First, the paucity of carbonate-rich sequences, most suitable for paleo studies can be addressed by drilling the western peninsular Indian margin. Previous drilling accomplished by the Indian National Gas Hydrates Program (NGHP) in the Kerala-Konkan basin of the eastern Arabian Sea shows the potential for recovering turbidite-free, pelagic foraminifera-rich records into Eocene. In contrast, recently drilled terrigenous-dominated sites extend discontinuously into the mid Miocene.

The Kerala-Konkan target is the unfulfilled objective of Expedition 359 and remains the sweetspot for the paleoclimatology and paleoceanography in the northern Indian Ocean. The objectives include: (1) detect the onset, intensification phases and the complete Cenozoic evolution of the Indian monsoon at a location free of any direct influence from the glaciated Himalaya and Tibet; (2) establish the sensitivity and timing of changes in monsoon circulation relative to external insolation forcing and internal boundary conditions; (3) to deconvolve the effects of tectonics and pre-monsoonal/monsoonal climate change on erosion, weathering, and run-off; and (4) to determine for the first time the expression of the Paleogene-Eocene Thermal Maximum in a foraminifera-rich pelagic setting in the northern Indian Ocean.

In the Andaman Sea, a region that receives the sedimentary input from a hotspot of monsoon rainfall, results from NGHP and Expedition 353 sites indicate the potential for paleo reconstructions. Despite the complex tectonics of the region, strategic drilling of multiple sites on the accretionary prism based on suitable seismic surveys can ultimately lead to paleoclimatic records extending into Oligocene. The advantage of this region is highlighted by recent work in the Irawaddy River basin that attests the relative simplicity of sedimentary sources including for monsoon-controlled vegetation proxies and lithogenic materials. The workshop provides an opportunity to mesh paleo objectives/targets with interests in tectonics/geohazards into a comprehensive proposal to drill the Andaman Sea.

Porosity Preservation in the Andaman Accretionary Wedge: Steady State Diagenesis in a Non-Steady State Geologic Setting

Joel E Johnson[1*] and Stephen C Phillips[1,2]
[1] *University of New Hampshire, Dept. of Earth Sciences, 56 College Rd. Durham, NH 03824, USA*
[2] *University of Texas at Austin, Institute for Geophysics, Jackson School of Geosciences, Austin, TX, 78712*, USA
[*] *Email: Joel.Johnson@unh.edu*

Drill Sites NGHP-01-17 and IODP-U1447 and -U1448 are located in the Andaman accretionary wedge, east of Nicobar Island. Previous work at NGHP-01 Site 17 has shown remarkable porosity preservation (~65%) between ~200 to 685mbsf that is attributed to observed microcrystalline authigenic carbonate precipitation (Rose et al., 2014). In order to preserve the porosity over this interval, the diagenetic carbonate must have been precipitated pre-compaction, while the sediments were unconsolidated and filled with seawater derived porewater. Abundant measured methane and recovered gas hydrate within this core, suggests these authigenic carbonates are likely methane-derived, formed at the sulfate-methane transition (SMT) by the anaerobic oxidation of methane. The relatively constant porosity preservation within this interval suggests steady state diagenesis that is driven by both a consistent sedimentation rate and source of methane. Because authigenic carbonate produced at the SMT requires sulfate, this diagenesis is considered early phase, in close proximity to the sediment-water interface (upper 40 mbsf), consistent with precipitation at pre-compaction sediment depths. Examination of porosity depth profiles at nearby IODP sites U1447 and 1448, reveals similar porosity preservation, likely driven by the same process. All three sites show linear sedimentation rates across this interval and the consistent porosity profiles imply uniform authigenic carbonate formation from a consistent supply of methane. Although some intervals show elevated diatom and biosiliceous fragment abundance that may also help preserve porosity, the uniformity of the porosity profiles through variable biosilica content at all three sites, suggests uniform authigenic carbonate precipitation is promoting porosity preservation. The microcrystalline authigenic carbonates (<3 µm diameter) at Site 17 are not visible in smear slide or coarse fraction observations, instead only through SEM imagery, making their presence difficult to detect. Their potential effect on the physical properties of sediments may be the best way to initially infer their presence. Seafloor environments with consistent sedimentation rates and methane fluxes are likely to precipitate these microcrystalline authigenic carbonates. Steady-state environments include pelagic and hemipelagic settings void of sediment gravity flows or large changes in sedimentation rate, which are not typical in accretionary wedge settings, but are favorable for paleoceanographic reconstructions. Here, isolation of the Andaman wedge from significant sources of terrigenous sediment and oblique subduction that promotes trench parallel deformation-minimizing thrust ridge deformation- allows for such a steady state setting.

Investigating Indian Monsoon variability on a warmer Earth: Preliminary results from IODP Expedition 353 sites drilled in the Andaman Sea and Bay of Bengal

Ann Holbourn* and Wolfgang Kuhnt
Institute of Geosciences, Christian-Albrechts-University, D-24118 Kiel, Germany
* *Email: ann.holbourn@ifg.uni-kiel.de*

Extended, well-preserved sedimentary archives recently recovered from the Andaman Sea and Bay of Bengal during IODP Expedition 353 enable reconstruction of Indian Monsoon variability and of surface- and deep-water circulation in unprecedented time resolution over the Neogene. Site U1443 (2925 m water depth), drilled on the crest of the Ninetyeast Ridge at the southern end of the Bay of Bengal, provides a first complete record of deep water paleoceanography extending back to the early Miocene. High-resolution benthic oxygen (δ^{18}O) and carbon (δ^{13}C) isotopes in combination with X-ray fluorescence (XRF) scanner elemental data track the abrupt onset and development of the Miocene Climatic Optimum (MCO, 16.9-14.7 Ma)These new records show that transient carbonate dissolution events during warmer phases of the MCO were pervasive through the Pacific and Indian Oceans. Following global cooling at ~13.8 Ma, a prolonged and intense episode of carbonate dissolution occurred between ~13.2 and ~8.5 Ma, whichwe relate to the Carbonate Crash, originallyidentified in the Equatorial Pacificand Caribbean regions. The recovery from the Carbonate Crashand the early onset of the Biogenic Bloom in the tropical eastern Indian Oceanwere coupled to a marked increase in biological productivityat ~11 Ma,likely associated with a strengthening of monsoonal winds and upper ocean mixing.

Sediment archives recovered in the Andaman Sea at Sites U1447(1392 m water depth) and U1448 (1098 m water depth) provide outstanding records of monsoonal run-off from the Irrawaddy River extending back to ~10 Ma. XRF-scanning elemental data and temperature/salinity reconstructions from paired stable isotope and Mg/Ca records reveal intense coolingpulses of surface and intermediate waters between ~6 and ~5.5 Ma,associated with changes in monsoonal discharge from the Asian continent into the Andaman Sea. Site U1448 also recovered pelagic middle Miocene sediment below the distinct seismic reflector at 1.865 sec TWT on seismic line AN01-26A. This reflector represents a major unconformity between upper Miocene (oldest biostratigraphic datum just above the unconformity is 5.94 Ma, LO of *Reticulofenestra rotaria*) and middle Miocene (14.53 Ma, LO of *Praeorbulina sicana* just below the unconformity) sedimentation. The middle Miocene pelagic succession below the unconformity is comprised of carbonate-rich biosiliceous sediments recovered with XCB coringfrom a single hole. Although this succession provides some initial insightsinto monsoonally-influenced biogenic sedimentation patterns during the MCO, it does not allow the establishment of a precise, orbitally tuned isotope stratigraphyto constrain the temporal sequence of climate events and to elucidate relationships to high-latitude climate evolution.

Time constraints during IODP Expedition 353 and the lack of further seismic coverage prevented the recovery of a continuous sedimentary archive ofMiocene monsoonal history in the Andaman Sea. This archive would be crucial to better understand (1) the history of the Irrawaddy River sedimentary discharge into the Andaman Sea, (2) the evolution of the Indian

Monsoon and its relation to the uplift history of the eastern part of the Himalayas,(3) the impact of major global climatic and paleoceanographic events (MCO, Antarctic ice expansion, Carbonate Crash, Biogenic Bloom, and latest Miocene cooling associatedwithfirstNorthern Hemisphere glaciations) on the Indian Monsoon system, and (4) the primary controls on monsoonal climate dynamics during wamer periods of Earth's climate history. Although the seismic structures at the western end of line AN01-26A,to the west of Sites U1447 and U1448,show high potential for recovering such a complete sedimentary succession in the Andaman Sea, North-South crossing seismic lines and extended East-West seismic lines are currently missing.

Understanding the nature and structure of the shallow portion of a subduction zone: IODP Drilling of the IndoBurma Subduction Zone

Cecilia M McHugh[1,2*], Michael Steckler[2], Leonardo Seeber[2], Paul Betka[2], Syed Humayun Akther[3], Volkhard Spiess[4], Tilmann Schwenk[4]

[1] *School of Earth and Environmental Sciences, Queens College, City University of New York, Flushing, NY, USA*

[2] *Marine Geology and Geophysics, Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, USA*

[3] *Department of Geology, Dhaka University, Bangladesh*

[4] *Faculty of Geosciences, University of Bremen, Germany*

[*] *Email: Cecilia.Mchugh@qc.cuny.edu*

Recent earthquakes, such as the 2004 Sumatra-Andaman Mw9.3 and the 2011 Tohoku-oki, Japan Mw9.0 earthquakes have highlighted the importance of seismogenic motion at the updip end of subduction zones. Earthquakes at this updip zone are responsible for tsunami generation. The nature and structure of the shallow portion of the subduction zone likely changes with variations in the amount of incoming sediment and whether the region is undergoing accretion or subduction erosion. Recent analyses have concluded that the largest subduction earthquakes preferentially occur at heavily sedimented (>1 km) subduction zones. One interpretation is that the lack of asperities and higher compliance at heavily sedimented subduction zones may allow great strain to build up prior to failure.

Along the Indian Ocean subduction system, the incoming sediment thickness greatly increases from south to north due to the thick sediments of the Bengal Fan. While incoming sediments are ~2 km thick offshore Sumatra, at the IndoBurma subduction zone, off the Arakan coast of Myanmar, the incoming sediment thickness reaches as much as 8-11 km. Further north, where the IndoBurma subduction zone encounters the Ganges-Brahmaputra Delta off the coast of Bangladesh and Myanmar, the incoming plate has up to 16-19 km of sediment. The accretionary prism north of its intersection with the delta widens and it is composed of a series of anticlines forming the IndoBurma ranges. The region spanning the transition ruptured in a large subduction earthquake in 1762 estimated to be Mw8.5-8.8. The occurrence of a similar event would be catastrophic for the heavily populated regions along the coasts of Myanmar and Bangladesh.

The goals for a proposal drilling would be to investigate the change in deformation style at the IndoBurma subduction zone. In the south, offshore Myanmar it is a typical accretionary prism with a deformation front at the base of the continental slope, but it changes to a broad blind foldbelt over a shallow detachment to the north after encountering the GBD. What are the lithological changes, rates and timings of deformation in both parts of the accretionary prism? Are there multiple detachments levels that may be lithologically controlled due to changes between porous sands and overpressured shales? What is the nature of the detachments and how are they affected by the incoming sediment thickness? An alternative view proposes that subduction at the IndoBurma Ranges has stopped and the plate boundary is dominated by dextral shear. This view highlights submarine landslides at the shelf break offshore of southern Bangladesh and western Myanmar to argue that the E-W shortening across the outer and blind belts is driven by gravity collapse. The workshop will provide an opportunity to further expand interest in heavily sedimented subduction zones and the risk they pose. The workshop will also raise awareness of potential geohazards along the northern portion of the IndoBurma subduction zone and discuss the alternative interpretations of the tectonics and their implications for earthquake hazard in the region.

Freshwater flux in the Bay of Bengal during Holocene

Prosenjit Ghosh
Centre for Earth Sciences, Indian Institute of Science, Bangalore, India
Email: pghosh@iisc.ac.in

The excess river discharge (Ganges–Brahmaputra–Irrawadi rivers) drive the suspended sediment flux and salinity of surface water in the Northern Bay of Bengal in modern day (Schott and McCreary, 200). The isotopic signature of freshwater is spatially restricted to the continental margin, where productivity of surface-dwelling phytoplankton during the post-monsoon period is dependent on the amount of nutrient supply (Kumar et al.,2010) or freshwater fluxes. The presentation aims at understanding the ISM freshwater fluxes and productivity during last 33kys analysing the stable oxygen and carbon isotope ratios in Globigerinoides ruber from a well-dated sediment core from the region close to the northern Bay i.e. Kakinada.

Scientific Drilling in the Northern Andaman Sea

Hongbo Zheng[1], Peter D Clift[2] and **P Saravanan[1*]**
[1] *Research Center for Earth System Science, Yunnan University, Kunming, 650500, China*
[2] *Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803, USA*
[*] *Email: geosaran.jan26@gmail.com*

We propose to drill a single deep site at the foot of the continental slope on the northern margin of the Andaman Sea close to the continent-ocean boundary between the rifted southern margin offshore the Irrawaddy Delta and the Alcock Rise. This site which will be located over previously identified oceanic or hyper extended continental crust is aimed at recovering a full sequence of sediments dating back to the onset of extension, as well as recovering a clastic erosional record delivered from the Irrawaddy River. Debate continues concerning the age of extension and seafloor spreading in the Andaman Sea, and our drill site is designed in order to document the onset of seafloor spreading. The timing of extension is important as it is linked to strike-slip motion along the Sagaing Fault, westernmost continental structure related to extrusion tectonics in Southeast Asia. The timing of motion and this is critical to understanding the role that extrusion has taken in accommodating the convergence between India and Eurasia during the Cenozoic. Sampling the sedimentary cover is designed to date the onset and development of the Irrawaddy River and to assess whether the catchment was ever part of a wider drainage system, as has been proposed by models which link uplift of the south-eastern flanks of the Tibetan plateau with the process of headwater capture between the major river systems of Southeast Asia. The timing of any drainage capture and its relationship with a topographic uplift in south-east Tibet is an important test of the drainage capture hypothesis. The same sediments can also be used to reconstruct the evolving environmental conditions, intensity, and rates of chemical weathering and evolving vegetation of Myanmar. In doing so we can use these data to better constrain the development of environment and links to the changing intensity of the South Asian monsoon.

High-resolution records of the monsoonal history in the northern Bay of Bengal - Drilling Proposal for the Swatch of No Ground Shelf Canyon and the upper Bangladesh Slope

Volkhard Spiess[1*], Tilmann Schwenk, Hermann Kudrass and the Magellan Plus workshop participants (L. Palamenghi, H. Akhter, S. Berne, Z. Chen, P. Clift, C. France-Lanord, V. Galy, S. Goodbred, C. Hein, B. Jørgensen, A. Lückge, M. Lupker, H. Pälike, P. Puig, E. Schefuß, M. Strasser, B. Machalett)

[1] *Department of Geosciences, University of Bremen*

[*] *Email: vspiess@uni-bremen.de*

We propose to investigate the world`s largest sedimentary system, which is sustained by drainage from the Himalayas by the Ganges and Brahmaputra rivers. We will use three rapidly accumulated archives from the northern Bay of Bengal to reconstruct at high resolution the variability of the Indian Summer Monsoon, the Holocene record of tropical cyclones and the response of the deep biosphere to extreme conditions. These archives will be collected from three contrasting settings (1) a shelf canyon, (2) the shelf-edge, and (3) the upper continental slope.

The shelf canyon intersects active deltaic clinoforms and receives most of the sediment delivered by the rivers through gravity flows, mainly initiated by frequent tropical cyclones. These have deposited graded beds, resulting in extremely high sedimentation rates of up to 30 cm/year. The 500-m thick Holocene to late Pleistocene beds are well preserved in the anoxic environment of the canyon and present an opportunity to produce several independent contemporaneous proxy records of the Indian Summer Monsoon. Terrestrial vegetation biomarkers, pollen, and isotopic signatures of terrigenous sediments record

variations in monsoonal precipitation, weathering, and sediment provenance. Furthermore, marine biomarkers, marine diatoms, and pore water can be used to reconstruct the paleoceanographic conditions. In addition, the frequency of graded beds can be used to investigate Holocene cyclone activity. Finally, cores from the canyon will allow to assess anthropogenic impacts caused by expanding agriculture and vanishing forest cover.
Sedimentation in the canyon is challenging for microbial life, and thus provides an opportunity to address a primary objective for deep biosphere research, the microbial response to extreme conditions, such as anoxic environments and rapid and frequent burial events. The extremely high accumulation rates in the northern Bay of Bengal provide an end-member example of deep organic carbon burial and offer unique opportunities to study microbial controls on carbon sequestration. These high-resolution records in the canyon are complemented by glacial records of the paleo environmental changes preserved near the shelf edge, where stacked low-stand submarine deltas can also provide constraints on long-term subsidence. Finally, the hemipelagic deposits on the upper slope contain millennial-scale records of the monsoon evolution back into the Miocene.

The combined results of these three distinct high-resolution archives in conjunction with other IODP projects in the Bay of Bengal will provide a comprehensive reconstruction of the Indian Monsoon, which is a main goal of the 'Climate and Ocean Change' theme of the IODP Science Plan.

Three distinct depositional settings with annual sedimentation rates of 30 cm to 0.1 mm/a are targeted in the northern Bay of Bengal. These sedimentary archives contain coupled high-resolution records of the onshore environmental and the offshore paleoceanographic responses to monsoon variation. The following main objectives are addressed:

- Quantify and exactly date changes in monsoonal precipitation using contemporaneous Holocene/Pleistocene/Upper Miocene records of vegetation, weathering intensity and paleoceanographic changes.
- Define the shifting source areas and transport pathways for Himalayan detrital sediment through the Quaternary, as controlled by the positions of the ITCZ and the main areas of monsoonal precipitation.
- Establish the relationship between tropical cyclone frequency, ENSO, and other Holocene global and regional climatic variations through the reconstruction of a detailed record of cyclone-generated deposits.
- Reconstruct the history of Late Quaternary low-stand deltas to determine glacial climate, water and sediment discharge, and to constrain long-term subsidence rates of the Bengal shelf.
- Define the strategies of microbial life in rapidly accumulating anoxic marine sediments and the microbial controls on preservation of buried organic carbon.
- Investigate the anthropogenic impacts of deforestation and expanding agriculture within the catchment area of the Ganges and Brahmaputra, particularly on the composition and quantity of organic carbon and sediment exported to the offshore

Scientific results from a passive OBS experiment in the Andaman-Nicobar region

P Dewangan*, P Singha, R Reddy, and KA Kamesh Raju
CSIR-National Institute of Oceanography, Dona Paula, Goa, India
* *Email: pdewangan@nio.org*

We deployed a temporary passive ocean bottom seismometer (OBS) network from 25th December 2013 to 15th May 2014 to understand the local seismicity pattern in the Andaman region. A total of 559 local earthquakes are identified from the OBS network. The OBS data are integrated with the available earthquake data from the Andaman ISLANDS network and a few global seismological stations. The joint hypocenter determination (JHD) is carried out for the local earthquakes using the minimum 1D velocity model and station corrections.

The configuration of Wadati-Benioff zone is clearly observed from the intermediate-depth earthquakes, and the dip of the subducting Indian plate increases from 26º in the Nicobar segment to 53º in the Andaman segment. A seismic gap is observed in the subducting Indian plate between 7.5º N and 9.5º N at depths exceeding 60 km which may be attributed to partial subduction of Ninetyeast ridge (NER). The shallow-depth local seismicity is similar to that observed after the 2004 Aceh earthquake. A prominent trend is observed at 8º N which abruptly terminates the local seismicity along the trench. We propose that the reactivation of the NE-SW trending fault of NER may be responsible for this barrier. We also observed harmonic tremors (HT) with fundamental frequencies ranging from 0.5 to 2.5 Hz with more than 14 overtones in the OBS deployed in the vicinity of the volcanic arc in the Nicobar region. The sharp spectral peaks suggest that the source of HT could be due to the resonance of oscillating fluid/gas within a small reservoir possibly linked to the activities of submarine volcanoes in the Nicobar region. An important characteristic of HT is that the fundamental frequency is not constant but varies temporarily. The increase or decrease of fundamental frequency with time is known as upward or downward gliding which occurs due to change in the dimension of the source or due to the variation of the sound speed of the magma or hydrothermal fluid with gas content.

Indian Ocean circulation timing and connections: Opportunities to test hypotheses developed from continental margin drilling

Beth Christensen[1*], Gerald Auer[2], David DeVleeschouwer[3], Jeroen Groeneveld[3], Stephen Gallagher[4], Jorijntje Henderiks[5], Cecilia McHugh[6], Willem Renema[7]
[1] Rowan University, NJ, USA; [2] JAMSTEC, Japan; [3] MARUM, University of Bremen, Germany; [4]Melbourne University, Australia; [5] Uppsala University, Sweden; [6] Queens College, NY, USA; [7]Naturalis Biodiversity Center, the Netherlands
* *Email: christensenb@rowan.edu*

Expedition 356 established that Australian climate changed from arid to humid at 5.5 Ma, and starting 3.3 Ma, gradually became more arid until 2.4 Ma (Christensen et al., 2017). This occurred in concert with the uplift and constriction of the Indonesian Throughflow, and we hypothesized that this resulted in the establishment of modern Indian Ocean circulation around 2.4 Ma. To test this hypothesis, as well as a newer idea that another restriction occurred at 1.7 Ma, additional records spanning the 6-1.5 Ma time interval are needed. By using existing and drilling additional holes we propose to pinpoint the timing of the initiation of major current systems in the Indian Ocean.

Much of what we know about Indian Ocean circulation comes from previously drilled sites. These expeditions have produced exciting scientific discoveries, but they have also highlighted how little we know about the Indian Ocean. Analyses of the most recent cores drew upon knowledge primarily acquired early in the DSDP phase (Sites 211- 264) and throughout the ODP phase (Sites 705-719; 732-735; 757-766; 1104-1106; 1141-1142). These older cores provided tantalizing windows into the system, but data quality is limited by the >20-year-old technology and generally discontinuous or lower resolution cores. For example, Bay of Bengal benthic foraminifera (Site 758) suggest changes either in deep water mass or surface water productivity, but the lower core quality limits age control and the ability to make basin-wide comparisons between our new and the old cores. Revisiting some of the more distal regions such as the ninety- east ridge (Legs 26, 121) or the deeper Bay of Bengal would resolve this.

Furthermore, much of the recent drilling is focused on continental margins and is greatly influenced by the terrestrial system. Although these expeditions recovered exceptional archives often superior to those available on land, it is not always a simple matter to tie them into global ocean histories. Additional drilling on ridges in the Indian Ocean, distal to, for example, the NW Australian continental margin (Exp. 356, 363) would allow us to address regional questions raised on Exp. 356, e.g., assessment of organic geochemical proxies for water temperatures, continental climate history from dust pathways, timing of gateway restrictions, and ocean circulation at surface, intermediate and deep water depths. Similarly, the Neogene continuous records in the Arabian Sea and Bay of Bengal (e.g., Exp. 353-355) would benefit from but additional drilling in deeper settings of the Indian Ocean and enhance the spatial and temporal data distribution, allowing us to place our regional questions in a broader framework.
Basin-wide drilling will also help resolve questions of global significance. For example, Exp. 356 sediments reveal a (sub)tropical influence of Antarctic ice sheet expansion in the Miocene (Di Nizio et al., 2016; Groeneveld et al., 2017). This exciting hypothesis can be tested with drilling on the ridges enabling basin-wide reconstruction of surface water temperature, or African dust transport, at resolution consistent with northern hemisphere (NH) data. The resulting detailed northern/southern hemisphere comparisons would reveal the effectiveness of the maritime continent at modulating tropical and high latitude climate systems, and to test ideas about Pliocene productivity (Lawrence et al., 2013). Hypotheses supporting a teleconnection to the Mediterranean (e.g., Sarnthein et al., 2017) or Antarctic control on monsoons could also be tested. Changes in seasonality from the Miocene to the present could be reconstructed on a global scale. Finally, it would allow us to test the hypothesis that the SH oceans operate in concert and are more tightly linked with monsoon systems than NH glaciation (Christensen et al. 2017)

Scientific drilling in the Sumatra forearc: IODP Expedition 362

Nisha Nair
ESSO-National Centre for Antarctic and Ocean Research, Goa, INDIA
Email: nishanair@ncaor.gov.in

The International Ocean Discovery Program (IODP) Expedition 362, Sumatra Seismogenic Zone, aimed to collect core and log data of the incoming oceanic plate section to help understand the nature of seismogenesis in North Sumatra, with a longer term goal of understanding seismogenic processes on related margins. More than 2000m long sediment cores were collected from two primary sites in water depths of more than 4000m about ~225 km seaward of the North Sumatran deformation front. This expedition also aimed to investigate how input materials drive shallow seismogenic slip and influence forearc morphology. Preliminary analysis of the depositional history of the Nicobar Fan sediment records showed a net increase in flux to the eastern Indian Ocean at 9.5–9 Ma, representing the onset of a new sedimentary regime in the East Indian Ocean. Sediment geochemical analyses and thermal modeling provided evidences that diagenesis before subduction may have driven shallow slip which might have resulted in one of the major earthquakes in Sumatra.

The Indian Ocean Dipole and Monsoon: pre-proposal for IODP drilling

Sushant S Naik[1*], P Divakar Naidu[1], Dhananjai K Pandey[2]
[1] *CSIR-National Institute of Oceanography, Goa, India*
[2] *ESSO-National Centre for Antarctic and Ocean Research, Goa, India*
[*] *Email:sushant@nio.org*
Brandon Dugan
Colorado School of Mines, USA

Indian Ocean Dipole (IOD) involves reversal of the sea surface temperature (SST) gradient and winds, across the equatorial Indian Ocean from their climatological state. This proposal aims to recover sequence of sediments from the Miocene to recent from the eastern equatorial Indian Ocean primarily to study the history of IOD on annual to tectonic timescales. The objectives of the drilling are to understand 1) the evolution of SSTs in the eastern Indian Ocean since the Miocene; 2) the long term relation between the eastern Indian Ocean SSTs/ and strengthening/weakening of the Indian monsoon; 3) the response of the eastern Indian Ocean SSTs/IOD to atmospheric CO_2 forcing; and 4) the influence of constricted ITF gateway at ~3-4 Ma on IOD. We propose drilling at a latitudinal transect ~ 5°S (~90-110°E) to obtain longer timescale records (going back to early Miocene), in order to understand the evolution of SSTs and the effect of ITF gateway closure on IOD. Secondly, we propose drilling off the west coast of Sumatra (or high sedimentation rate sites in international waters) which would be helpful in obtaining high-resolution sediment cores to understand variations in IOD at decadal to centennial time-scales. This proposal will be amalgamated with an earlier plan which aims to understand the Nicobar fan evolution, relation to monsoon intensity and Himalayan uplift and the stress state in oceanic crust and relation to seismicity. The site survey is available in the core region of the IOD and we further need to identify high-sedimentation sites.

Keywords: Indian Ocean Dipole, monsoon, Nicobar fan, seismicity, SST

Reconstruction of paleoseismic record in Andaman Basin using lipid biomarker

Supriyo Kumar Das
Department of Geology, Presidency University, Kolkata, India
Email: sdas.geol@presiuniv.ac.in

The subduction zone consisting of the Sumatra–Nicobar–Andaman arc has long been known for causing catastrophes. The massive Toba volcanic eruption that took place approximately 74,000 years ago, for example, had a profound impact on the Earth's climate (Rampino and Self 1992). The eruption of Krakatoa and associated tsunami in 1883 were considered as one of the first human recorded modern global catastrophes (Winchester 2003). However, the subduction zone has received relatively less attention prior to the 2004 earthquake and tsunami caused by a shallow thrust event occurred along the entire arc segment (Stein and Okal 2005). Shallow and intermediate depth earthquakes are caused by the energy release due to obliquely convergent plate motion in subduction zones (Yeats et al. 1997; Sieh and Natawidjaja 2000; Kennett 2001; Kennett and Cummins 2005).

Interestingly, identifying geological record of paleoseismic events in subduction zones, which is considered as birthplace of most of the great earthquakes, is scarce, challenging and limited to the measuring of the frictional heating on faults relative to the surrounding rock or pseudotachylyte (Solidified frictional melt) albeit such evidences are proven elusive (Cowan 1999; Sibson and Toy 2006; Bjørnerud 2009; Kirkpatrick and Rowe 2013; Savage et al. 2014). Trace element partitioning, thermal decarbonation, dehydration reactions, and vitrinite reflectance have also been used to detect fault heating (Hamada et al., 2009; Han et al., 2007; Ishikawa et al., 2008; Sakaguchi et al., 2011). Unfortunately, these methods have limitations, such as vitrinite reflectance is only measurable in sediments containing woody organic matter (Mastalerz et al. 1993) which may not be common in subduction zone sediments. Savage et al. (2014) demonstrated used the thermal maturity of biomarkers (geolipids), by measuring the ratio of thermally stable to thermally unstable biomarker compounds (diamondoids/*n*-alkanes), to estimate the maximum frictional heating experienced by the fault (Peters et al. 2005; Polissar et al. 2011). The authors tested the utility of the method on an ancient, pseudotachylyte-hosting megathrust at Pasagshak Point, Alaska, and showed that the melt-bearing rocks have higher thermal maturity than surrounding rocks. Diamondoids (tricyclo [3,3,1,1,(3,7)] decane), a cage hydrocarbon with a molecular formula of C4n+6H4n+12, is a common biomarker in fossil fuels (Ma et al. 2016). Although the presence of the biomolecule has not been reported from the Andaman Basin and Bay of Bengal, Middle Bengal Fan sediment, collected during the International Ocean Discovery Programme (IODP) Expedition 354, shows ubiquitous presence of *n*-alkanes (unpublished data). The hemipelagic and turbidity sediments in Middle Bengal Fan are immature and show evidence of resuspension due to turbidity current activities which may be related to paleoseismic activities in this region. It may be worth testing the usefulness of biomarkers as a tool to identify ancient seismic activities recorded in the Andaman Basin.

References

Bjørnerud M. (2009) Rethinking conditions necessary for pseudotachylyte formation: Observations from the Otago schists, South Island, New Zealand. Tectonophysics 490:69–80.
Cowan D.S. (1999) Do faults preserve a record of seismic slip? A field geologist's opinion: Journal of Structural Geology 21:995–1001.
Hamada Y., Hirono T., Tanikawa W., Soh W., Song S.-R. (2009) Energy taken up by coseismic chemical reactions during a large earthquake: An example from the 1999 Taiwan Chi-Chi earthquake: Geophysical Research Letters 36:L06301.
Han R., Shimamoto T., Ando J.-i., Ree J.-H. (2007) Seismic slip record in carbonate-bearing fault zones: An insight from high-velocity friction experiments on siderite gouge: Geology 35:1131–1134.
Ishikawa T., Tanimizu M., Nagaishi K., Matsuoka J., Tadai O., Sakaguchi M., Hirono T., Mishima T., Tanikawa W., Lin W., Kikuta H., Soh W., Song S-R. (2008) Coseismic fluid rock interactions at high temperatures in the Chelungpu fault: Nature Geoscience 1:679–683.
Kennett B.L.N. (2001) Representations of seismicity, Geochemistry Geophysics Geosystems 2:2000GC00140.
Kennett B.L.N., Cummins P.R. (2005) The relationship of the seismic source and subduction zone structure for the 2004 December 26 Sumatra–Andaman earthquake. Earth and Planetary Science Letters 239:1–8.
Kirkpatrick J.D., Rowe C.D. (2013) Disappearing ink: How pseudotachylytes are lost from the rock record: Journal of Structural Geology 52:183–198.
Ma A. (2016) Advancement in application of diamondoids on organic geochemistry. Journal of Natural Gas Geoscience 1:257-265.
Mastalerz M., Wilks K.R., Bustin R.M., Ross J.V. (1993) The effect of temperature, pressure and strain on carbonization in high-volatile bituminous and anthracitic coals: Organic Geochemistry 20:315–325.
McCaffrey R. (2009) The tectonic Framework of the Sumatran Subduction Zone. Annual Review of Earth and Planetary Sciences 37:345-66.
Peters K.E., Walters C.C., Moldowan J.M. (2005) The Biomarker Guide, 2nd ed.: Cambridge, UK, Cambridge University Press, 492 p.
Polissar P.J., Savage H.M., Brodsky E.E. (2011) Extractable organic material in fault zones as a tool to investigate frictional stress: Earth and Planetary Science Letters 311:439–447.
Rampino MR, Self S. (1992) Volcanic winter and accelerated glaciation following the Toba supereruption. Nature 359:50–52.
Sakaguchi A., Chester F., Curewitz D., Fabbri O., Goldsby D., Kimura G., Li C.-F., Maskai Y., Screaton E.J., Tsutsumi A., Ujiie K., Yamaguchi A. (2011) Seismic slip propagation to the updip end of plate boundary subduction interface faults: Vitrinite reflectance geothermometry on Integrated Ocean Drilling Program NanTro SEIZE cores: Geology 39:395–398.
Savage HM, Polissar PJ, Sheppard R, Rowe CD, Brodsky EE (2014) Biomarkers heat up during earthquakes: New evidence of seismic slip in the rock record. Geology 42:99-102.
Sibson R.H. Toy V.G. (2006) The habitat of fault-generated pseudotachylyte: Presence vs. absence of friction-melt, in Abercrombie R., McGarr A., Di Toro G., Kanamori H. (eds.) Earthquakes: Radiated Energy and the Physics of Faulting: American Geophysical Union Geophysical Monograph 170:153–166.

Sieh K., Natawidjaja D. (2000) Neotectonich of the Sumatran fault, Indonesia. Journal of Geophysical Research 105:28295-28396.
Stein S., Okal E. (2005) Speed and size of the Sumatra earthquake, Nature 434:581– 582.
Winchester S. (2003) Krakatoa: The Day the World Exploded: August 27, 1883. New York: HarperCollins. 432 pp.
Yeats R., Sieh K., Allen C. (1997) The Geology of Earthquakes, 568 pp., Oxford Univ. Press New York.

Late Cenozoic climate variability and Himalayan weathering: IODP drilling in the Andaman Sea

Prakasam M[1*], Sarkar S[1], Rai SK[1], Mohan K[2]
[1] *Wadia Institute of Himalayan Geology, Dehradun-248001, India*
[2] *School of Mechanical and Building Sciences, Vellore Institute of Technology, Chennai, India*
[*] *Email: geoprakash783@gmail.com*

The Late Cenozoic is marked by a switching from warm to ice house world and it also imparted substantial variations in the paleoclimate, paleoceanography and the continental collisions. The Himalaya is the world's youngest and important orographic barrier which led to major strengthening of the Asian monsoon, and it acts as a watershed of the South Asian countries and it gives birth of the major rivers like the Ganges, Brahmaputra and Irrawaddy. These rivers not only save the billion people's lives in the south Asian region but also preserve climatic records in the Bay of Bengal. The Himalaya has experienced several phases of upliftment and chemical weathering during the Cenozoic. According to previous studies, the paleoclimate and Himalayan weathering history has been well established in the northern Arabian Sea, but in the Andaman Sea and the northern Bay of Bengal the high resolution Late Cenozoic paleoclimatic and Himalayan weathering studies are deficient. In this IODP cruise, we propose to drill couple of sites on the Northern margin of the Andaman Islands and northern part of the Ninety-East Ridge to recover deep and longer sea sediment cores. These sites will mirror the paleoclimatic history of the south Asian region as well as the chemical weathering of the Himalaya during the Late Cenozoic. In these proposed drill sites we expect to achieve the following scientific research goals: (1) High resolution planktic and benthic foraminiferal faunal study to be carried out to understand the paleoclimatic and paleoceanographic changes of the northern Andaman Sea and the northern Bengal basin during the Late Cenozoic; (2) The high resolution stable isotope and δ13C biomarker studies to be carried out to reconstruct the South Asian Monsoon variability and vegetation changes during the Late Cenozoic era; and (3) The geochemical analysis like Mg/Ca, 87Sr/86Sr, 143Nd/144Nd and Li isotope analysis on the foraminiferal species and core sediments to be carried out to find the weathering rates and riverine input of the Himalaya, and its linkage with the South Asian monsoon.

Nature of the crust beneath the Andaman Volcanic Arc

Rajneesh Bhutani[1*], Jyotiranjan S Ray[2], S Balakrishnan[1]
[1] *Department of the Earth Sciences, Pondicherry University, Puducherry, India*
[2] *Physical Research Laboratory, Navarangpura, Ahmedabad, Gujarat, India*
[*] *Email: rbhutani@gmail.com*

Two volcanic islands in the Andaman Sea, the Barren Island and the Narcondam Island are related to the Andaman-Indonesian subduction zone magmatism. These, though part of the same volcanic arc, show contrasting geochemical signatures. The lavas of Narcondam are geochemically more evolved as observed in its diverse rocks types, ranging from basaltic andesite to rhyolite (Bhutani et al., 2014). On the contrary, the lavas of Barren Island are predominantly basaltic and possess the most pristine Nd, Sr and Pb isotopic ratios in this subduction system (Kumar, 2012; Smitha, 2014). Geochemical variations along a volcanic arc are generally attributed to 1) varying degrees of input from subducting trench sediments to the mantle wedge, 2) variation in the nature and thickness of the crust of the overriding plate, or 3) heterogeneity in the mantle source of the magmas. Such variations in the lavas of the Indonesian arc volcanoes have been attributed to both the contributions from subducted sediments and shallow level crustal assimilation (Handley et al. 2014). However, such inferences are difficult to make in the case of Andaman volcanic arc in the absence of any knowledge of the nature and extent of the crust beneath the entire chain. Although geophysical evidence on the southern section of the arc points to presence of a continental crust at the leading edge of the overriding Burma Plate (e.g., Singh et al., 2013), there exists ample petrological evidence to suggest presence of a normal oceanic crust below the arc (e.g., Curray, 2005; Ray et al., 2015). Therefore, it remains a challenge to understand the true reason for the geochemical differences observed in lavas of the southerly volcano Barren Island and the northerly Narcondam. Resolution of this issue therefore requires a thorough understanding of the nature of the crust beneath the leading edge of the overriding plate along the entire Andaman volcanic arc. This can only be achieved by sampling the arc basement through drilling along the Barren-Narcondam ridge.

References:

Curray, JR, Journal of Asian Earth Sciences 25 (2005) 187–232
Bhutani, R, Pande, K, Ray, JS, Smitha, RS, Awasthi, N, & Kumar, A, 2014, GSA, Abstract 268-9
Kumar, A, 2012, PhD Thesis, MS Univ Baroda.
Handley, H. K., Blichert-Toft, J., Gertisser, R., Macpherson, C. G., Turner, S. P., Zaennudin, A., & Abdurrachman, M. 2014. Geochimica et Cosmochimica Acta. http://dx.doi.org/10.1016/j.gca.2014.04.025
Ray, JS, Bhutani, R & Pande K., 2015, Bull Vol, 77, 55.
Singh, C. S., Raphaele Moeremans, Jo McArdle, and Kjell Johansen, 2013. J. Geoph. Res. Solid Earth, 118, 5208–5224.
Smitha, RS, 2014, PhD Thesis, Pond Univ

Drilling in the southern Alcock Rise complex, Andaman Sea for interpreting Neogene paleomonsoon and paleo-weathering changes in the Myanmar watersheds

Pavan Miriyala[1*], and B Nagender Nath[2]
[1] *CSIR – National Geophysical Research Institute, Uppal Road, Hyderabad, India*
[2] *CSIR- National Institute of Oceanography, Dona Paula, Goa, India*
[*] *Email: pavanmiriyala@ngri.res.in*

Andaman Sea attained a special scientific interest not just because of its complex tectonic scenario, but also for it's potential as an archive of paleoclimatic information. Being a depo-centre of the Myanmar river sediments and fresh water, this marginal sea provides an excellent opportunity to reconstruct past environmental, climatic, productivity patterns recorded in the sedimentary archives. Well-constrained and limited number of sediment sources to this basin is an additional advantage than neighboring Bay of Bengal and Arabian Sea. The central Andaman basin (CAB) mainly comprises of Alcock and Sewell rise complexes is known to be the best place to study past climatic studies that mainly records the climatic and geochemical changes taken place in Myanmar watersheds. Here we propose southern Alcock Rise complex at a water depth of ~2 km (SK168/GC01 location) for drilling during the upcoming drilling campaign, where the previous studies have provided one of the best late Pleistocene records of water column-productivity, salinity, temperature in the Andaman Sea as well chemical weathering changes in Myanmar mainland (Sijinkumar et al., 2010, 2011, 2015, 2016; Miriyala et al., 2017). In general, the central Andaman Sea (CAS) is an ideal location for assessing the climatic and geochemical changes taken place in Indo-Burman and Arakan mountain ranges. The high resolution geochemical study (Miriyala et al., 2017) has shown the study area records small changes in provenance of sediments that are affected by shifting glacial-arid-northeast monsoon to interglacial-humid-southeast monsoon, but their study is limited only to last 54kyr.

While the depocenters of Himalayan-Tibetan plateau sediment products are studied more rigorously (DSDP 218, ODP Legs 116 and 121, IODP Expeditions 353 and 354), the proposed drilling will provide much needed information on Neogene monsoonal changes, erosion and silicate weathering patterns in Myanmar watersheds The proposed drilling would provide an opportunity to address the questions such as, 1) how were the past interglacials climates modified since the late Miocene strengthening of Indian summer monsoon; 2) how is the present human- influenced interglacial period (Holocene) different from earlier interglacials, say since mid-Pliocene warming period (MPWP) when the glacial-interglacial cyclicity has strengthened; 3) how the climate will modify with 1ºC, 1.5ºC and 2ºC temperature rise in global warming context through modeling; and 4) how has the chemical weathering process responded to extreme warming periods such as Miocene climatic optimum (MCO) and MPWP.

Reconstruction of sea surface temperature variations in the Andaman Sea during Pliocene using carbonate clumped isotope paleothermometer

K Mohan[1*], K Saravanan[1] and M Prakasam[2]
[1]*School of Mechanical and Building Sciences, VIT Chennai, Vandalur-Kelambakkam Road, Chennai, India*
[2]*Wadia Institute of Himalayan Geology, Dehradun-248001, India*
[*] *Email: mohan.kuppusamy@vit.ac.in*

In the intervening decade, there has been a great deal of progress in a number of areas within the field of elemental and isotopic proxies of temperature, among them development of the clumped isotope approach in biogenic carbonates, refinements of the foraminiferal Mg/Ca proxy, and application of both oxygen isotopes and Mg/Ca to high-resolution paleoclimate sequences of the last few millennia. High-resolution climate reconstructions over the past few millions of years are important to understand and verify natural and human-induced climate forcing factors. This propose studies will provides a first examination of the applicability of 'clumped isotopes' thermometry to reconstructing the growth temperatures of foraminifera in Andaman Basin, Bay of Bengal, by examining the glacial/interglacial variations of the Δ_{47} values of foraminifera carbonates from the Bay of Bangal. The goal is to recover a continuous and high-resolution record since the Pliocene to reconstruct the paleo sea surface temperature (SST) variations and paleoceanographic evolution of Andaman Sea/ Ninety-East Ridge, have been utilize selectively picked planktic and benthic foraminifera from proposed study area. The main aims of this proposal are to produce a high-resolution climate reconstruction over the Pliocene period based on isotope stratigraphy and to refine our understanding about the climate variations in the Arabian Sea and Indian Ocean leave its imprint to all ocean basins and its links to Indian Ocean monsoon suggested by foraminifera isotope records. In these proposed drill sites we expect to achieve the following scientific research goals: (i) To correlate clumped isotope paleo-temperatures of planktic foraminifera with conventional $\delta^{18}O$ values to determine the seawater $\delta^{18}O$ changes during the Pliocene warm period; (ii) Resolving benthic foraminiferal clumped isotope values to understand Miocene – Pliocene deep water changes and variations in NADW inflow to Andaman Sea and Bay of Bengal; (iii) To understand the assessment of vertical temperature gradient during glacial/interglacial intervals from the clumped isotope record of surface and deep dwelling planktonic foraminifera sediments from the Andaman Sea, Bay of Bengal; and (iv) Prospects for the large scale reconstructions of past ocean circulation link Global Climate Change: evidences from foraminiferal assemblages combined with stable isotope data.

Keywords: Clumped Isotope thermometry, Pliocene, Planktic foraminifera, Bay of Bengal

Tectonic configuration and structural architecture of the Andaman Sea: Constraints from Magnetic susceptibility, Palaeomagnetism, Seismic and Marine Magnetotelluric methods

Sayandeep Banerjee* and Arkoprovo Biswas
Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi, India
* *Email: sdbanj87@gmail.com*

In established models, the evolution of the Andaman Sea is considered as a result of combined tectonic phenomenon, encompassing extension dominated to strike slip dominated tectonic processes through ages. The initial process of extension leading to the opening of the basin started in the Late Palaeogene in a back arc setting related to the subduction of the Indian plate under the Sunda plate. In the Neogene, the extensional setting of the Andaman Sea was modified into a NNW–SSE highly oblique extension. Later, during late Miocene it changed into ~N–S strike-slip dominated tectonic regime leading to the development of an axial trough between the Alcock and Sewell rises, resulting in a zone of high magnetic anomalies. However, the driving mechanisms behind the shift of this tectonic setup from extensional to strike-slip dominated tectonics, and the processes involved in it are still unknown. The axial trough between the rises hosts a number of faults with unknown orientations till now. In addition, it is still controversial that whether the East Andaman Basin (EAB) is underlain by continental or oceanic crust. Evidence of both volcanic and non-volcanic margins are present in the EAB. The causes of necking of continental crust and its extension are not yet explored in EAB, which may contribute to the understanding of crustal thinning geometries. Apart from that, the Central Andaman Basin feature several other issues viz. crustal type, age of formation and timing of the igneous activities. Among other lacunae in understanding the structural architecture of the basin, the presence of ridge systems and back-thrust structures (e.g. Diligent fault) related to the Andaman forearc must be explored. While, unravelling the structural architecture of the Andaman Sea region should be the focus of future studies, the role of the Ninety-East Ridge (NER) in modifying the seismogenic behaviour of the subduction zone should not be avoided to decipher the regional tectonic configuration.

To address this issues, a comprehensive study encompassing Magnetic susceptibility, Palaeomagnetism, Seismic and Marine Magnetotelluric (MMT) investigations is needed. The Palaeomagnetism and Magnetic Susceptibility studies coupled with Environmental magnetism and Magnetic mineralogy studies from drill cores will help in the understanding rotations of terrains, microplates and thus, contribute to evaluate the tectonic framework of the Andaman Sea. On the other hand, the extent of the decollement surface, orientation and dip of the faults, reactivation of fracture zones on the subducting plate, thrusts and bivergent structures in accretionary prism could be resolved with the help of seismic profiles. Moreover, MMT method will help in deciphering the deep crustal structure beneath the Andaman Sea as well as the structure of the NER. It will also help to delineate the trend of the suture zones, resistivity-conductivity variation, dip and direction of the fault movement, nature of crustal movement as well as regional tectonic settings. Combining Seismic and MMT can help in identifying the fluid distribution zones of active tectonics in Andaman sea.
Bibliography

Bandopadhyay, P. C. and Carter, A. (eds.), 2017. The Andaman–Nicobar Accretionary Ridge: Geology, Tectonics and Hazards. Geological Society, London, Memoirs, 47, 243p.
Gokarn, S. G., Gupta, G., Dutta, S., and Hazarika, N., 2006. Geoelectric structure in the Andaman Islands using magnetotelluric studies. Earth, planets and space, 58, p. 259-264.

Drilling the Palaeogene in the Indian Ocean

Peter D Clift
Louisiana State University, Baton Rouge, LA 70803, USA
Email: pclift@lsu.edu

Although it has become clear that the South Asian Monsoon became much stronger in terms of rainfall around the start of the Miocene (~24 Ma) and that wind strength increased sharply in the Mid Miocene (~13 Ma) it is less clear when this climatic system first came into being. Sparse evidence from NE Tibet, SW China and Myanmar now suggest that a monsoon of some sort existed in the Late Eocene although evidence is limited. It is further debated whether tropical rainfall reduced as the Oligocene began, linked to global cooling. Testing whether this was a truly regional change is made difficult because of the absence of Upper Eocene-Oligocene rocks in much of the Himalayan foreland. DSDP and ODP drilling on the Owen Ridge did recover some Oligocene-Eocene but the existing core is small in volume and poorly dated. If we are to understand how the monsoon responded to the start of India-Eurasian collision and how the erosion and weathering of the Himalaya changes as a result, we must drill strata of this age in the Indian Ocean. This is difficult because most sediments are deeply buried under the thick Neogene turbidites of the Indus and Bengal Fans. These Palaeogene sediments are accessible at the toes of these fans but there the sequence is reduced and in deep water without good calcareous microfossil age control. Drilling of the Eocene-Oligocene on the Murray Ridge where a significant sequence is uplifted and exposed close to the seafloor provides the best chance to recover this critical time interval. The region also gives the chance to date the base of the Indus Fan and constrain the timing of onset of the India-Eurasia collision.

The Paleogene- Neogene Radiolaria from The Andaman- Nicobar Region: Taxonomy, Biostratigraphy and Paleoceanography

Girish Sharma
Kumaun University, Nainital, Uttarakhand, India
Email: gksharma61@yahoo.com

The archipelago Andaman–Nicobar is located in the western part of the Andaman Sea. It forms a sediment-dominated wedge shaped convergent margin. The Andaman ridge is made up of two stratigraphically and structurally distinct terranes - north–south-trending high-relief folded-thrust belt formed with obliquely subducting eastern part of the Indo-Australian

oceanic plate. The geology of the ridge mainly consists of three types of rocks - Pre-Cretaceous meta-sedimentary rocks, Upper Cretaceous ophiolites and Palaeogene–Neogene sedimentary formations.

Based on my Doctoral work and published papers on Late Cenozoic Radiolaria of Neill Island, Andaman Sea, I think further rigorous work on Andaman –Nicobar region will definitely throw more light on the Stratigraphy and paleoceanography of the region based on the Radiolaria.

Correspondence list

S. No.	Participant	Correspondence
1	Sean Gulick	sean@ig.utexas.edu
2	James Austin	jamie@ig.utexas.edu
3	Dirk Kroon	dick.kroon@ed.ac.uk
4	Virendra M Tiwari	virendra.m.tiwari@gmail.com
5	Vineet K Gahalaut	vk.gahalaut@nic.in
6	Sunil Singh	sunil@nio.org
7	Jyotiranjan S Ray	jsray@prl.res.in; jsray2012@gmail.com
8	Marie Edmonds	me201@cam.ac.uk
9	Tapan Pal	paltapan62@gmail.com
10	KK Chopra	kkchopra@dghindia.gov.in
11	Steven Clemens	steven_clemens@brown.edu
12	Arun D Singh	arundeosingh@yahoo.com
13	Liviu Giosan	lgiosan@whoi.edu
14	Joel Johnson	Joel.Johnson@unh.edu
15	Ann Holbourn	ann.holbourn@ifg.uni-kiel.de
16	Cecilia M McHugh	Cecilia.Mchugh@qc.cuny.edu
17	Prosenjit Ghosh	pghosh@iisc.ac.in
18	P Saravanan	geosaran.jan26@gmail.com
19	Volkhard Spiess	vspiess@uni-bremen.de
20	Pawan Dewangan	pdewangan@nio.org
21	Nisha Nair	nishanair@ncaor.gov.in
22	Beth Christensen	christensenb@rowan.edu
23	Sushant Naik	sushant@nio.org
24	Supriyo K Das	sdas.geol@presiuniv.ac.in
25	M Prakasam	geoprakash783@gmail.com
26	Rajneesh Bhutani	rbhutani@gmail.com
27	Pavan Miriyala	pavanmiriyala@ngri.res.in
28	K Mohan	mohan.kuppusamy@vit.ac.in
29	Sayandeep Banerjee	sdbanj87@gmail.com
30	Peter D Clift	pclift@lsu.edu
31	Girish Sharma	gksharma61@yahoo.com

Dr M Ravichandran
Chair – IODP-India
National Centre for Antarctic and Ocean Research, Goa, India
mravi@ncaor.gov.in

Dr Brijesh K Bansal
Ministry of Earth Sciences, New Delhi, India
bansalbk@nic.in

Dr Mithila Verma
Ministry of Earth Sciences, New Delhi, India
mverma.moes@gmail.com

Dr Dhananjai K Pandey
National Centre for Antarctic and Ocean Research, Goa, India
pandey@ncaor.gov.in

Geosciences Group
@ NCAOR

Anju Pandey
Scientist

Ajeet Kumar
Scientist

N Lachit Singh
Scientist

Nisha Nair
Scientist

Prerna Ramesh
Scientist

Rajeev Yadav
Scientist

S Khogenkumar
Scientist

Sanjay Singh Negi
Scientist

Dhananjai K Pandey
Program Officer—IODP India
Group Director Geosciences

Tejaswini Pakhidde
Co-ordinator

Amarja V Devkar
Office Assistant

The JOIDES Resolution at sunset. (Credit Shuhao Xie & IODP)

Contact us:

IODP-India, National Centre for Antarctic and Ocean Research
Ministry of Earth Sciences, Government of India
Headland Sada, Vasco-da-Gama, Goa-403804, India
Ph: 0832-2525569/580
Email: iodp.india@ncaor.gov.in
www.ncaor.gov.in