A Report on

Indian Participation in International Ocean Discovery Program (IODP) 2009 - Present

IODP-India

ESSO

NCAOR

राष्ट्रीय अंटार्कटिक एवं समुद्री अनुसंधान केंद्र
पृथ्वी विज्ञान मंत्रालय, भारत सरकार
NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH
Ministry of Earth Sciences, Government of India

Compiled by:

Ayush Verma, Tejaswini Pakhidde and Dhananjai K Pandey,

IODP-India, NCAOR, Goa.

September 2016

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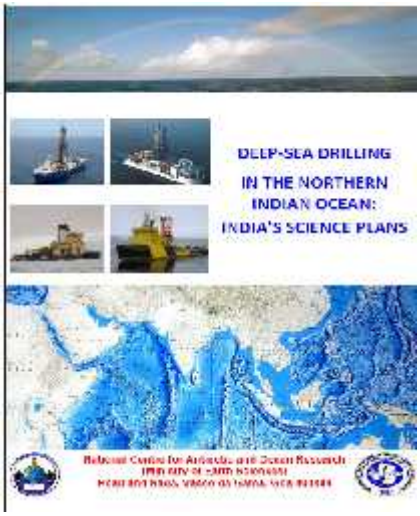
Introduction

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 sub-seafloor environments. Scientific drilling is performed through highly specialised and unique drilling platforms available before the international scientific community namely - JOIDES RESOLUTION (USA), CHIKYU (Japan) and Mission Specific Platform (MSP-Europe). Scientific research on sediment and rock core samples using these drilling platforms is conducted by exclusive access to the scientists from IODP member countries. At present, there are twenty-six representative nations, whose scientists are selected to staff IODP research expeditions conducted throughout the world's oceans. Scientist activities are managed by the IODP Program Member Offices.

IODP builds upon the earlier success of DSDP (1968-1983) and ODP (1985-2003) and Integrated Ocean Drilling program (2003-2013). The current phase of IODP program (2013-23), IODP identified the science plan as 'Illuminating Earth's Past, Present, and Future'.



IODP SCIENCE PLAN 2013-2023

IODP expeditions are developed from hypothesis-driven science proposals aligned with the program's Science Plan *Illuminating Earth's Past, Present, and Future* and are carried out in accordance with the program's principles of scientific investigation. The science plan identifies 14 challenge questions in the four areas of climate change, deep life, planetary dynamics, and geohazards. It was crafted on behalf of earth, ocean, atmospheric, and life scientists at the request of science funding agencies from 24 nations, representing approximately 75% of the world's economy.

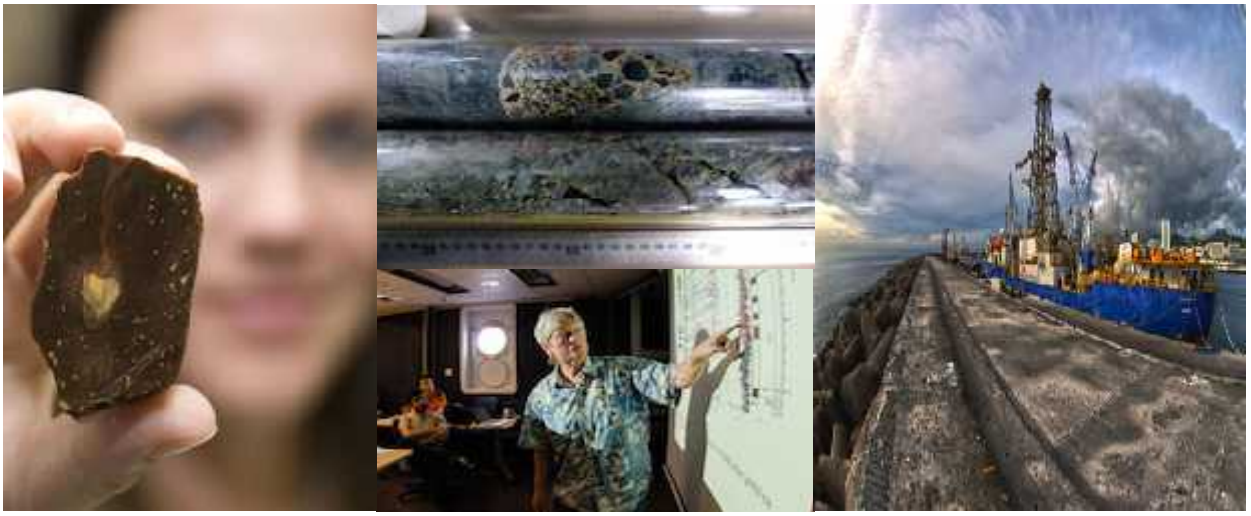


Image Courtesy: www.iodp.org

KEY SPONSORS

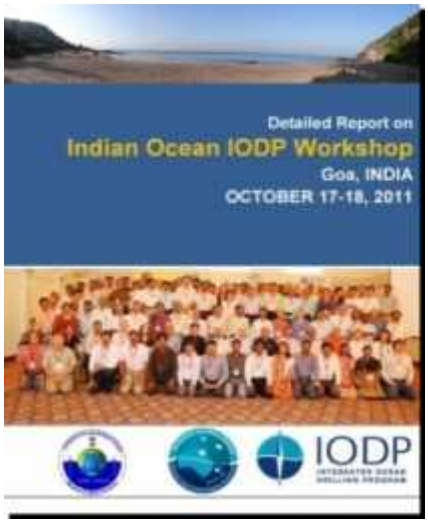
Platform Providers:

- The U.S. National Science Foundation (NSF)
- Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- The European Consortium for Ocean Research Drilling (ECORD)

Additional Funding Partners:

- **Ministry of Earth Science, India (MoES)**
- Ministry of Science and Technology, China (MOST)
- Korea Institute of Geoscience and Mineral Resources (KIGAM)
- Australian-New Zealand IODP Consortium (ANZIC)
- Coordination for Improvement of Higher Education Personnel, Brazil (CAPES)

Indian endeavor towards activities pertaining to the International Ocean Discovery Program (IODP): IODP-India



In order to provide Indian scientists and researchers a unique opportunity to carry out cutting edge geoscientific research using, sediment coring and drilling, India became an Associate member of this consortium through an MoU between Ministry of Earth Sciences (MoES) and National Science Foundation, USA. This MoU enables Indian scientists exclusive access to NSF owned drilling platform JOIDES RESOLUTION. The first phase of the MoU was carried out between 2009-2013. It was subsequently renewed and present phase is in place till 2019.

Soon after joining the IODP, India became member of various scientific and administrative panels of the IODP. These panels where India is currently nominated include Science Evaluation Panel (SEP) - both Science and Site components, JOIDES RESOLUTION Facility Governing Board and IODP Forum.

The National Centre for Antarctic and Ocean Research, Goa (NCAOR), an autonomous institute under MoES has been designated as the nodal agency to act as IODP-India and the Program Management Office (PMO). IODP-India is responsible for coordinating all Indian scientific activities pertaining to this program.

Under the MoU with NSF, provisions are made for the Indian scientists and researchers to participate in the regular IODP expeditions around the world onboard JOIDES RESOLUTION as well as European Consortium's Mission Specific Platforms (MSP) and get involved in the active research pertaining to the deep sea drilling. In the current phase of IODP (2013-23) India has signed the MoU with NSF, USA, with the following objectives-

1. Deep Sea Drilling in the Arabian Sea, to understand possible tectono-climatic links between Himalayan orogeny and Indian Monsoon as well as nature of crust in the Laxmi Basin.
2. Continue the long-term scientific drilling programs in Indian Ocean, Southern Ocean and Antarctic Ocean and addressing the global and regional issues.
3. Develop the research programs in the frontier area of Ocean sciences using long and continuous marine sediment cores.
4. Capability building through active Indian participation in Deep Ocean Research of IODP.

Expedition wise details of Indian IODP participation:

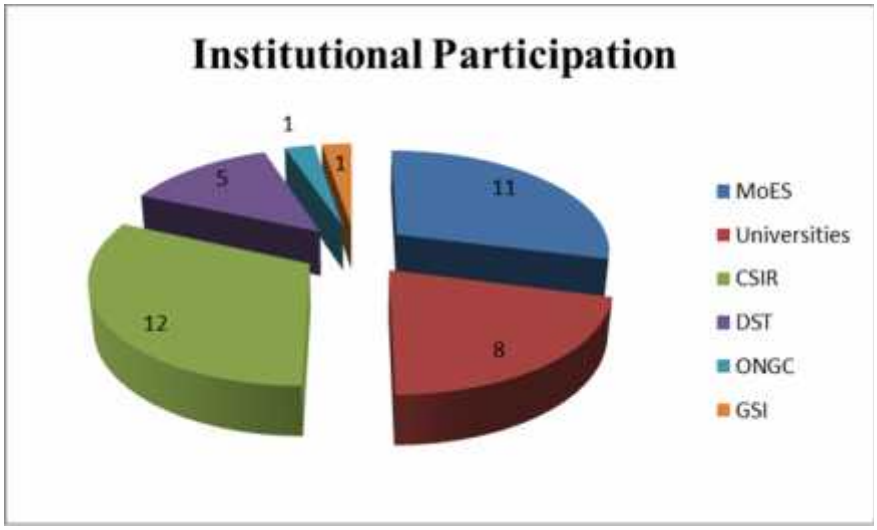
So far 38 Indian scientists from 14 different institutions and a variety of disciplines have taken part since 2009 in various ocean drilling expeditions around the world (the above number includes the two scientists who were also considered for shore based sediment samples).

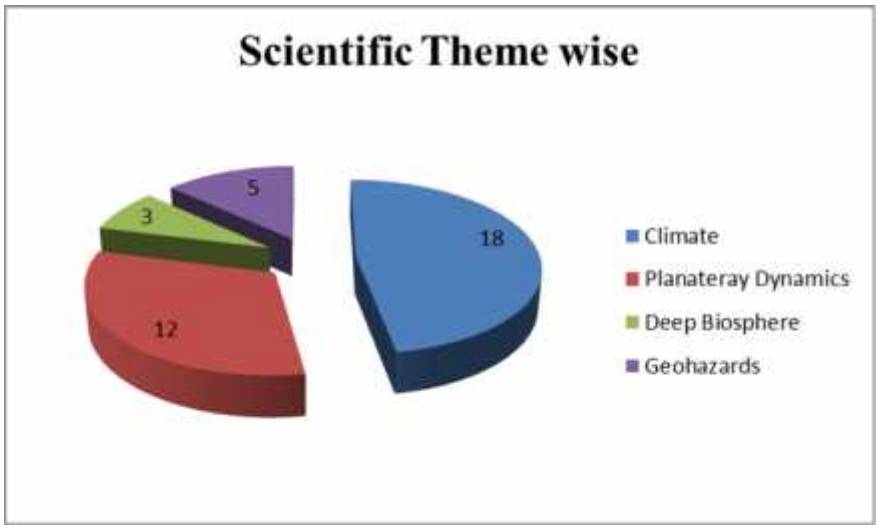
S.No.	IODP Expedition	Name	Organisation	Date
22	IODP-362	Ms.Nisha Nair	NCAOR, Goa	6th August 2016 – 6th October 2016
21	IODP-361	Ms. N Lathika	NCAOR, Goa	30th January 2016 – 31st March 2016
20	IODP-360	Dr. Biswajit Ghosh	Calcutta University	30th November 2015 – 30th January 2016
19	IODP-359	Dr. Nagender Nath	NIO, Goa	30th September 2015 – 30th November 2015
18	IODP-355	Dr. Dhananjai Pandey	NCAOR, Goa	31st March 2015 – 31st May 2015
		Dr. Ravi Mishra	NCAOR, Goa	
		Dr. Manish Tiwari	NCAOR, Goa	
		Dr. Rajeev Saraswat	NIO, Goa	
		Dr. A Ganesh Kumar	NIOT, Chennai	
		Prof. A D Singh	BHU, Varanasi	
		Prof. Girish K Sharma	Kumaun University, Nanital	
		Dr. T Radhakrishna	NCESS, Trivandrum	
		Mr. Anil Kumar	WIHG, Dehradun	
		Mr. G. P Gurumurthy	Manipal University,	

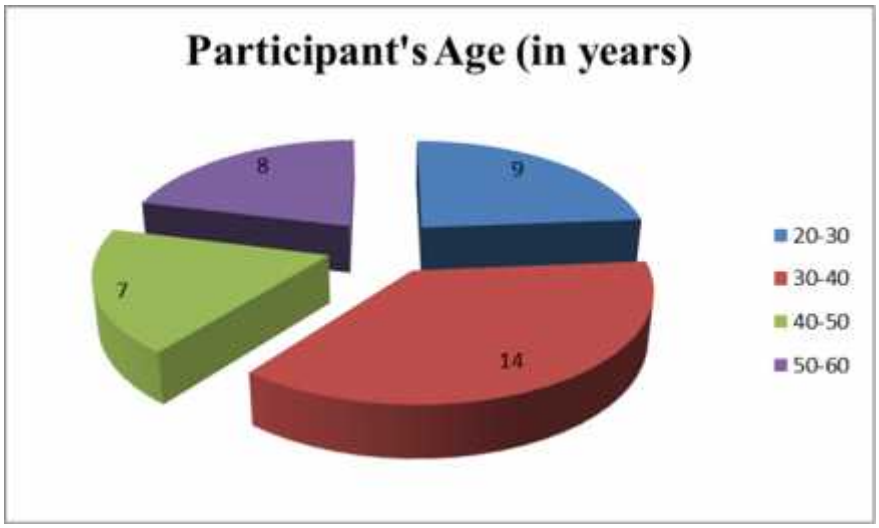
			Manipal	
		Mr Rakesh Sexana	ONGC, Mumbai	
17	IODP-354	Dr. Supriyo Das	Presidency University, Calcutta	29th January 2015 – 31st March 2015
		Dr. Manoj M C	BSIP, Lucknow	
16	IODP-353	Dr. Netramani Sagar	NGRI, Hyderabad	29th November 2014 – 29th January 2015
		Dr. Aditya Paketi	NIO, Goa	
		Mr. Dinesh K. Naik	NIO, Goa	
15	IODP-346	Dr. Raj K. Singh	WIHG, Dehradun	29th July 2013 – 27th September 2013
14	IODP-345	Dr. Abhishek Saha	Calcutta University	11th December 2012 – 12th February 2013
13	IODP-343	Dr. Santanu Bose	Calcutta University	1st April 2012 – 24th May 2012
12	IODP-342	Dr. Amit Kumar Ghosh	BSIP, Lucknow	2nd June 2012 – 1st August 2012
11	IODP-341	Dr. Shyam M Gupta	NIO, Goa	29th May 2013 – 29th July 2013
10	IODP-340	Mr. K.S.V. Subramanyam	NGRI, Hyderabad	2nd March 2012 – 17th April 2012
9	IODP-339	Prof. A D. Singh	BHU, Varanasi	16th November 2011 – 17th January 2012
8	IODP-338	Dr. Ravi Mishra,	NCAOR, Goa	1st October 2012 – 13th January 2013
7	IODP-335	Dr. Parijat Roy	NGRI, Hyderabad	13th April 2011 – 3rd June 2011
6	IODP-334	Dr. Yatheesh V	NIO, Goa	13th March 2011 – 13th April 2011
5	IODP-325	Dr. Manish Tiwari	NCAOR, Goa	2nd July 2010 – 16th July 2010
4	IODP-323	Dr. Maheswar Ojha	NGRI, Hyderabad	5th July 2009 – 4th September 2009
3	IODP-322	Dr. Pawan Govil	NCAOR, Goa	1st Sept 2009 – 10th October 2009
2	IODP-321	Dr. Pawan Devangan	NIO, Goa	5th May 2009 – 22nd Jun 2009

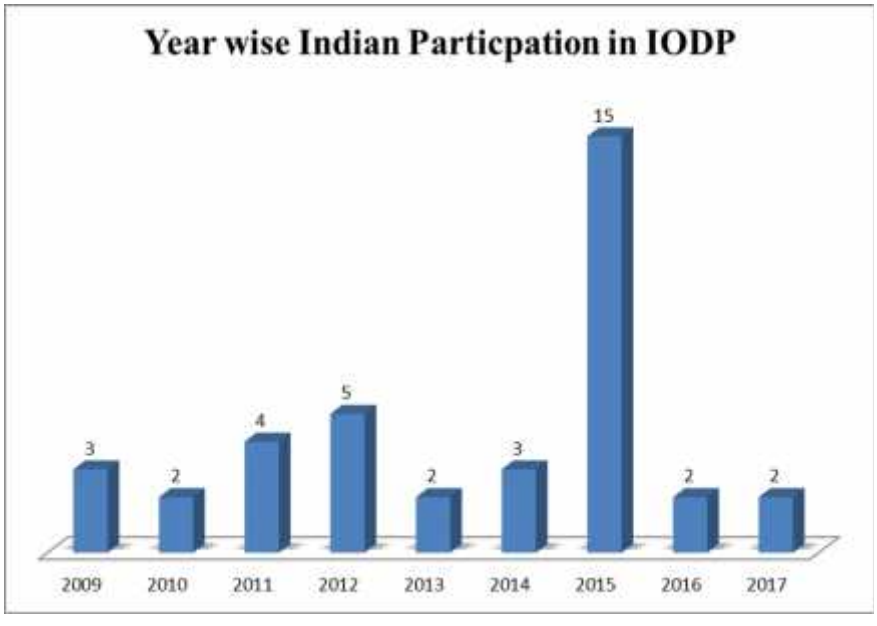
1	IODP-318	Mr. Prakash Srivastava	GSI, Faridabad	4th January 2010 – 8th March 2010

Statistical Analysis of Indian Participation in IODP (2009-2016):




Scientific Theme wise
5
3
18
12
Climate
Planateray Dynamics
Deep Biosphere
Geohazards


Participant's Age (in years)
8
9
7
14
20-30
30-40
40-50
50-60

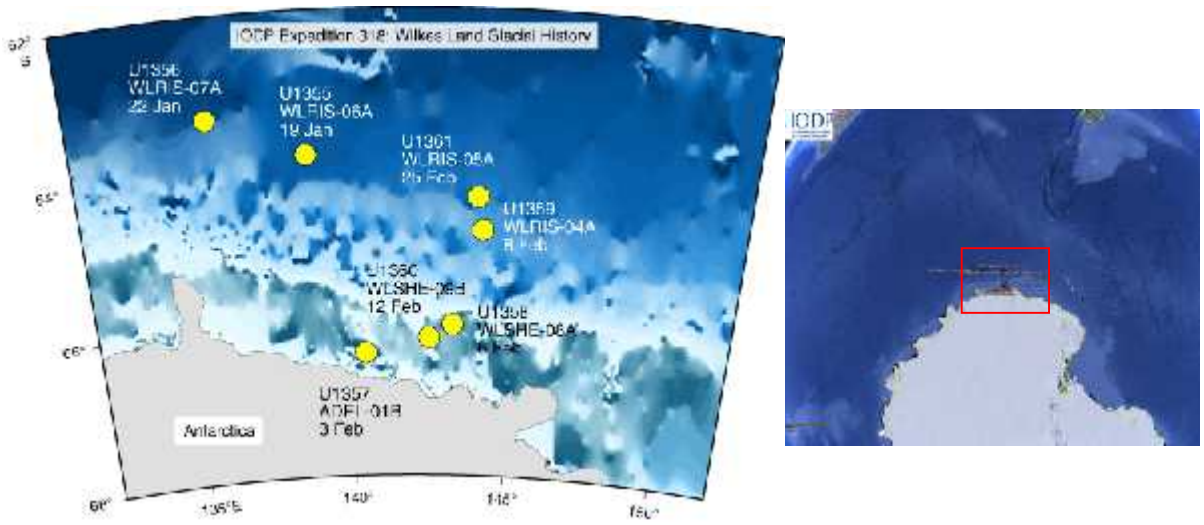

Year wise Indian Particpation in IODP
3
2
4
5
2
3
15
2
2
2009
2010
2011
2012
2013
2014
2015
2016
2017

Integrated Ocean Drilling Program Expedition 318

Cenozoic East Antarctic Ice Sheet evolution from Wilkes Land margin sediments

General Information

Sites: U1355-U1361
Dates: 4 January to 8 March 2010
Ports: Wellington, New Zealand to Hobart, Australia
Co-chief Scientists: Carlota Escutia & Henk Brinkhuis
Staff Scientist: Adam Klaus
Logging Staff Scientists: Annick Fehr & Trevor Williams



Source: http://iodp.tamu.edu/scienceops/maps/exp/318/318_map.jpg

Summary and Objectives

Drilling the Antarctic Wilkes Land margin was designed to provide a long-term record of the sedimentary archives along an inshore to offshore transect of Cenozoic Antarctic glaciation and its intimate relationships with global climatic and oceanographic change. The principal goals were

1. To obtain the timing and nature of the first arrival of ice at the Wilkes Land margin inferred to have occurred during the earliest Oligocene (reflecting Oligocene isotope Event 1),
2. To obtain the nature and age of the changes in the geometry of the progradational wedge interpreted to correspond with large fluctuations in the extent of the East Antarctic Ice Sheet and possibly coinciding with the transition from a wet-based to a cold-based glacial regime,
3. To obtain a high-resolution record of Antarctic climate variability during the late Neogene and Quaternary, and
4. To obtain an unprecedented ultrahigh resolution (i.e., annual to decadal) Holocene record of climate variability.

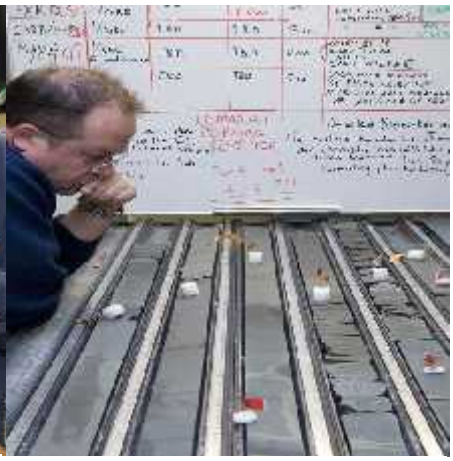
Integrated Ocean Drilling Program Expedition 318, carried out in January–March 2010, occupied seven sites that recovered ~2000 m of high-quality middle Eocene–Holocene sediments at proposed Sites WLRIS-6A, WLRIS-7A, WLRIS-4A, and WLRIS-5A on the Wilkes Land rise and Sites WLSHE-8A, WLSHE-9A, and ADEL-01B (Sites U1358, U1360, and U1357) on the Wilkes Land shelf at water depths between ~400 and 4000 m.

Source of above information: http://publications.iodp.org/preliminary_report/318/318pr_4.htm

Indian Participation

Mr. Prakash Kumar Shrivastava
Sedimentologist
Antarctica Division, Geological Survey of India

Mr. Prakash Shrivastava at the Core Description table. (Credit John Beck, IODP/TAMU)



The core sampling table (Credit John Beck, IODP/TAMU)

Contribution:

Publication(s):

1. Escutia, C., Brinkhuis, H., Klaus, A., and the Expedition 318 Scientists, 2011.*Proc. IODP*, 318: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.318.2011

1. Pant N.C., P. Biswas, Shrivastava, Prakash., Bhattachaya S. and Verma Kamlesh, Pandey Mayuri and IODP Expedition 318 Scientific Party, 2013, Provenance of Pleistocene sediments from Site U1359 of the Wilkes Land IODP Expedition- evidence for multiple sourcing from east Antarctic craton and Ross orogen, Geological Society, London, v. 381, p. 277-297, First published online, July 1, 2013, doi:10.1144/SP381.11

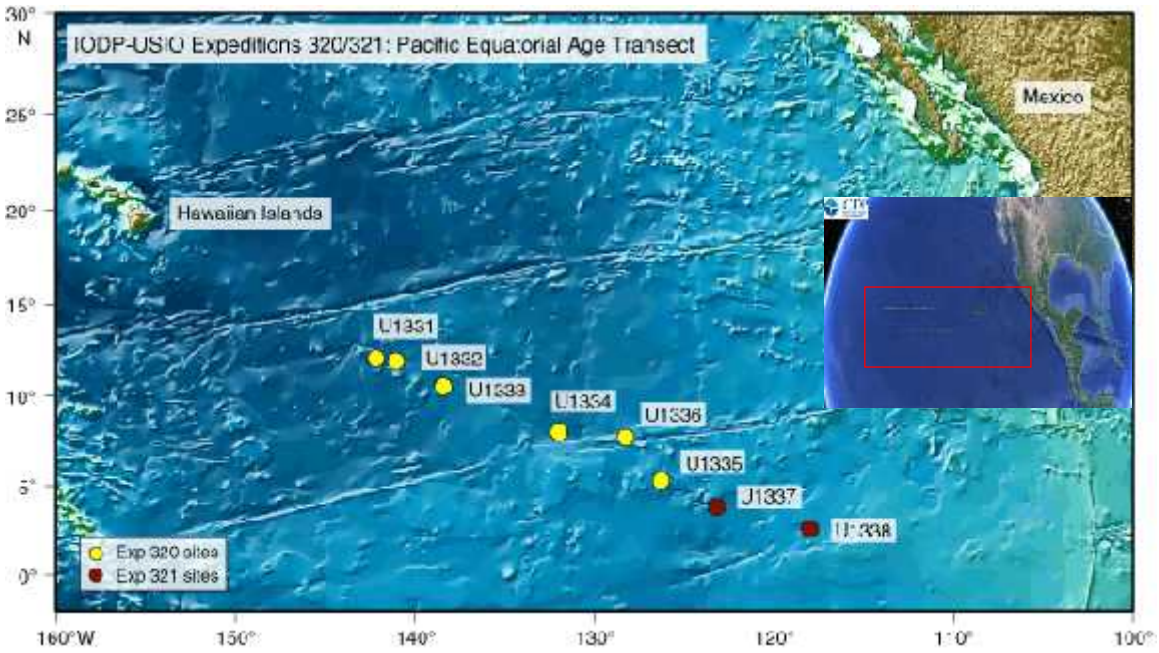
2. Verma, Kamlesh, Bhattacharya, Sanjeeb, Biswas, P., Shrivastava, Prakash., Pandey, Mayuri, Pant, N. and IODP Expedition 318 scientific party, 2014, Clay mineralogy and carbon content record of the ocean sediments from the Wilkes Land margin, East Antarctica: implications on the palaeoclimate, provenance and sediment dispersal pattern, International Journal of Earth Sciences . Nov2014, Vol. 103 Issue 8, p2315-2326.

Integrated Ocean Drilling Program Expedition 321

Pacific Equatorial Age Transect

General Information

Sites: U1337-U1338
Dates: 5 May to 22 June 2009
Ports: Honolulu, Hawaii to San Diego, California
Co-chief Scientists: Mitch Lyle & Isabella Raffi
Staff Scientist: Kusali Gamage
Logging Staff Scientist: Alberto Malinverno



Source: http://iodp.tamu.edu/scienceops/maps/exp/320321/320321_map.jpg

Summary and Objectives

Integrated Ocean Drilling Program Expedition 320/321, "Pacific Equatorial Age Transect" (Sites U1331–U1338), was designed to recover a continuous Cenozoic record of the equatorial Pacific by coring above the paleoposition of the equator at successive crustal ages on the Pacific plate. These sediments record the evolution of the equatorial climate system throughout the Cenozoic. The Pacific Equatorial Age Transect (PEAT) program cored eight sites from the sediment surface to basement, with basalt aged between 53 and 18 Ma, covering the time period following maximum Cenozoic warmth, through initial major glaciations, to today. The PEAT program allows the reconstruction of extreme changes of the calcium carbonate compensation depth (CCD) across major geological boundaries during the last 53 m.y. Expedition 321, the second part of the PEAT program, focused on the time period roughly from 25 Ma forward. During Expedition 321 two major Neogene equatorial Pacific sediment sections were recovered at Sites U1337 and U1338.

The overall aim was to obtain a continuous well-preserved equatorial Pacific sediment section that addresses the following primary scientific objectives:

1. To detail the nature and changes of the calcium carbonate compensation depth (CCD) over the Cenozoic in the paleoequatorial Pacific.

2. To determine the evolution of paleoproductivity of the equatorial Pacific over the Cenozoic.

3. To validate and extend the astronomical calibration of the geological timescale for the Cenozoic, using orbitally forced variations in sediment composition known to occur in the equatorial Pacific, and to provide a fully integrated and astronomically calibrated bio-, chemo-, and magnetostratigraphy at the Equator.

4. To determine temperatures (sea surface and bottom water), nutrient profiles, and upper water column gradients.

5. To better constrain Pacific plate tectonic motion and better locate the Cenozoic equatorial region in plate reconstructions, primarily using paleomagnetic methods.

6. To make use of the high level of correlation between tropical sedimentary sections and existing seismic stratigraphy to develop a more complete model of equatorial circulation and sedimentation.

Scientific team samples a core. (Credit John Beck, IODP/TAMU)

Indian Participation

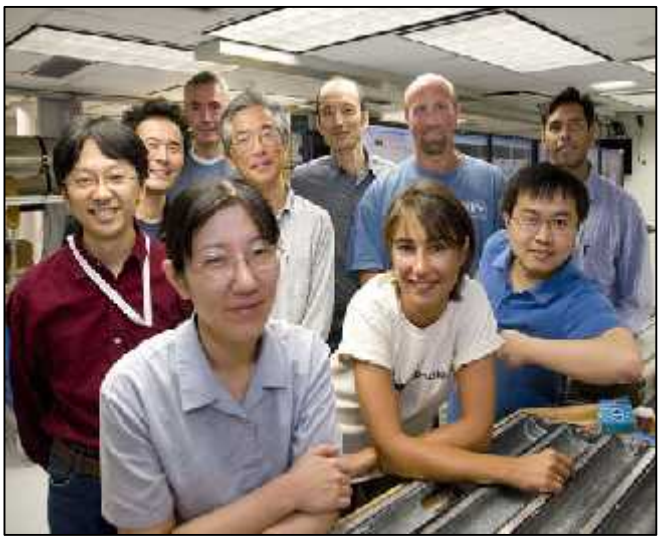
Dr. Pawan Devangan
Physical Properties/Downhole Tools Specialist
Scientist, National Institute of Oceanography
Goa, India

Contribution:

Publication:

1. Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, 2010. *Proc. IODP*, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.).

2. Pälike et al (including Dewangan Pawan) (2012): A Cenozoic record of the equatorial Pacific carbonate ; IODP Expedition 321 (ARTICLE doi:10.1038/nature11360) 30 AUGUST 2012 | VOL 488 | NATURE| 609.



Noon to midnight science group including Dr. Pawan Dewangan

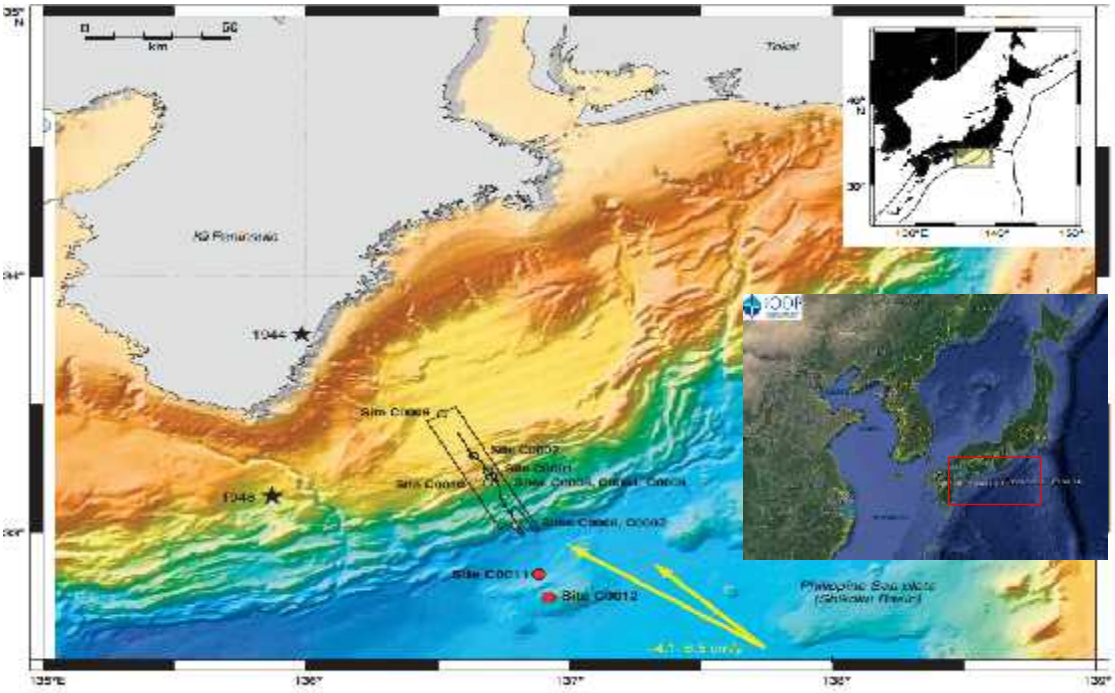
Integrated Ocean Drilling Program Expedition 322

Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE)

Characterization of composition, architecture, and state of pre-subduction sediments transported to the seismogenic zone.

General Information

Sites: C0011, C0012
Dates: 1 Sep to 10 Oct 2009
Location: Shikoku Basin, the back-arc basin of the IZU-Bonin volcanic chain, where the Philippine Sea plate dives down at Nankai Trough.
Co-chief Scientists: Michael B. Underwood, Saneatsu Saito



IODP Expedition 322 Site Map

Source: http://publications.iodp.org/proceedings/322/MAPS/322_MAP.PDF

Summary and Objectives

Integrated Ocean Drilling Program (IODP) Expedition 322 was designed to document characteristics of incoming sedimentary strata and upper igneous basement prior to their arrival at the subduction front. To accomplish these objectives, coring was conducted at two sites in the Shikoku Basin on the subducting Philippine Sea plate. Site C0011 is located on the northwest flank of a prominent bathymetric high (the Kashinosaki Knoll), whereas Site C0012 is located near the crest of the knoll. The resulting data, which include logging while drilling during IODP Expedition 319, provide a wealth of new information on presubduction equivalents of the seismogenic zone. Key Scientific Objectives were:

1. How does the physical hydrogeology of Shikoku Basin respond to variations in primary lithologic architecture and basement structure?
2. How do fluids in the igneous basement affect subduction processes?
3. How have system-wide patterns of sediment dispersal affected composition within the Shikoku Basin, particularly on the northeast side of the fossil spreading ridge?
4. How do thermal structure and primary sediment/rock composition modulate diagenesis and fluid-rock interactions prior to subduction?
5. Which factor(s) control(s) the décollement's position near the prism toe and at greater depths, together with the fault's mechanical behavior throughout?

Source of above information:
http://publications.iodp.org/proceedings/322/101/101_4.htm#wp1013162

Dr. Pawan Govil taking samples (Credits IODP)

Indian Participation

Dr. Pawan Govil
Micropaleontologist
Scientist, Birbal Sahni Institute of Paleobotany,
Lucknow, India.

Contribution:

Publication(s):

1. Saito, S., Underwood, M.B., Kubo, Y., and the Expedition 322 Scientists, 2010.*Proc. IODP*, 322: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.322.2010
2. Hayashi Hiroki, Yamashita Kazuki, Govil Pawan, Idehara Yuki, Tanaka Takayuki and Nishi Hiroshi (2012). "Data report: middle Miocene to Pliocene planktonic foraminiferal biostratigraphy of the northern part of the Shikoku Basin, IODP Exp. 322 Site C0012". Paper accepted for scientific results of IODP Expedition 322. doi:10.2204/iodp.proc.322.206.2014

Boundary of sedimentary rock (upper half) and basaltic basement (lower half) obtained at C0012

Abstracts:

1. Naruse. H. et al (including Govil P.), 2010. Abrupt change in the rate of hemipelagic sedimentation at the late Miocene (~11 Ma) in the Shikoku Basin: implications for the tectonic history of the southwestern Japan [presented at the 2010 American Geophysical Union Fall Meeting, San Francisco, CA, 13–17 December 2010]. (Abstract T13A-2142) http://www.agu.org/meetings/fm10/waisfm10.html

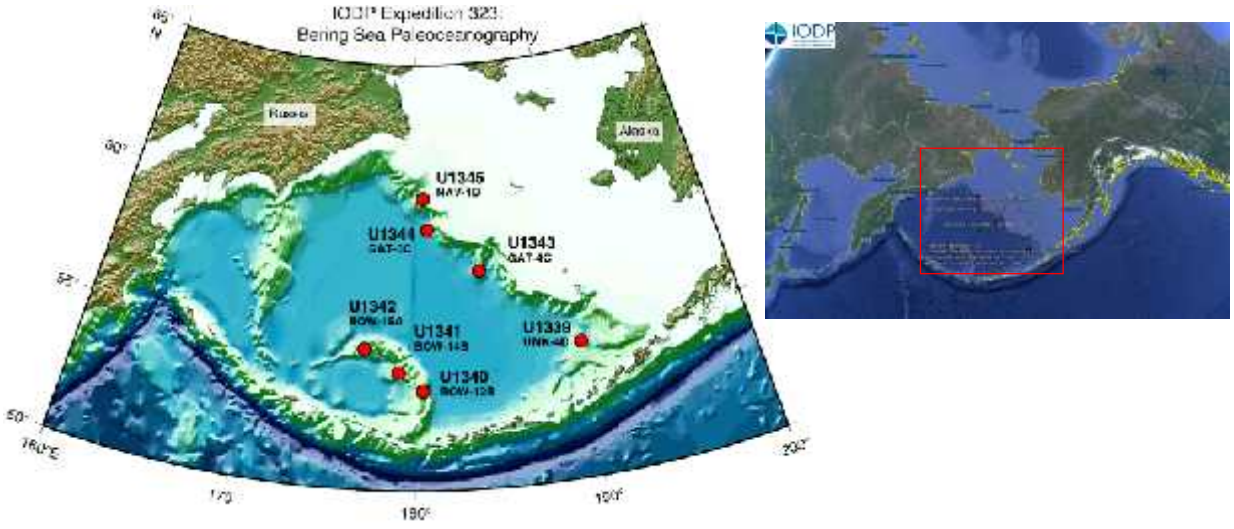
Integrated Ocean Drilling Program Expedition 323

Bering Sea Paleoceanography

Pliocene–Pleistocene paleoceanography and climate history of the Bering Sea

General Information

Sites: U1339-U1345
Dates: 5 July to 4 September 2009
Ports: Victoria, Canada to Yokohama, Japan
Co-chief Scientists: Christina Ravelo & Kozo Takahashi
Staff Scientist: Carlos Alvarez-Zarikian
Logging Staff Scientist: Gilles Guerin



Source: http://iodp.tamu.edu/scienceops/maps/exp/323/323_map.jpg

Summary and Objectives

Integrated Ocean Drilling Program (IODP) Expedition 323 was dedicated to examining subseafloor biomass and microbial processes in high-productivity regions for the first time.

The major objectives of Expedition 323 in the Bering Sea were

1. To elucidate a detailed evolutionary history of climate and surface ocean conditions since the earliest Pliocene in the Bering Sea, where amplified high-resolution changes of climatic signals are recorded.
2. To shed light on temporal changes in the origin and intensity of NPIW and possibly deeper water mass formation in the Bering Sea.
3. To characterize the history of continental glaciation, river discharges, and sea ice formation in order to investigate the link between continental and oceanic conditions of the Bering Sea and adjacent land areas.
4. To investigate linkages through comparison to pelagic records between ocean/climate processes that occur in the more sensitive marginal sea environment and processes that occur in the North Pacific and/or globally.

This objective includes an evaluation of how the ocean/climate history of the Bering Strait gateway region may have affected North Pacific and global conditions.

5. To constrain global models of subseafloor biomass and microbial respiration by quantifying subseafloor cell abundance and pore water chemistry in an extremely high productivity region of the ocean. We also aim to determine how subseafloor community composition is influenced by high productivity in the overlying water column.

During Expedition 323 in the Bering Sea, 5741 m of sediment (97.4% recovery) was drilled at seven sites covering three different areas: Umnak Plateau, proximal to the modern Alaskan Stream entry; Bowers Ridge, proximal to the glacial Alaskan Stream entry; and the Bering Sea shelf region, proximal to the modern sea ice extent. Four deep holes were drilled that ranged in depth from 600 to 745 m below seafloor, spanning 1.9 to 5 Ma in age.

Source of above information:

http://publications.iodp.org/preliminary_report/323/323pr_4.htm
http://iodp.tamu.edu/scienceops/expeditions/bering_sea.html

Indian Participation

Dr. Maheshwar Ojha
Downhole Tools/Physical Properties Specialist
Scientist, Gas Hydrate Group,
National Geophysical Research Institute (NGRI),
Hyderabad, India.

Dr. Maheshwar Ojha enters data from the multisensor track into the database. (Credit William Crawford, IODP/TAMU)

Contribution:

Publication(s):

1. Takahashi, K., Ravelo, A.C., Alvarez Zarikian, C.A., and the Expedition 323 Scientists, 2011. *Proc. IODP*, 323: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.323.2011

2. Ojha Maheswar, Maiti Saumen, 2016, Sediment classification using neural networks: An example from the site-U1344A of IODP Expedition 323 in the Bering Sea; IODP Expedition-323. Deep-Sea Research II 125-126 (2016) 202 213; Science Direct journal homepage: www.elsevier.com/locate/dsr2 Deep-Sea Research II. http://dx.doi.org/10.1016/j.dsr2.2013.03.024.

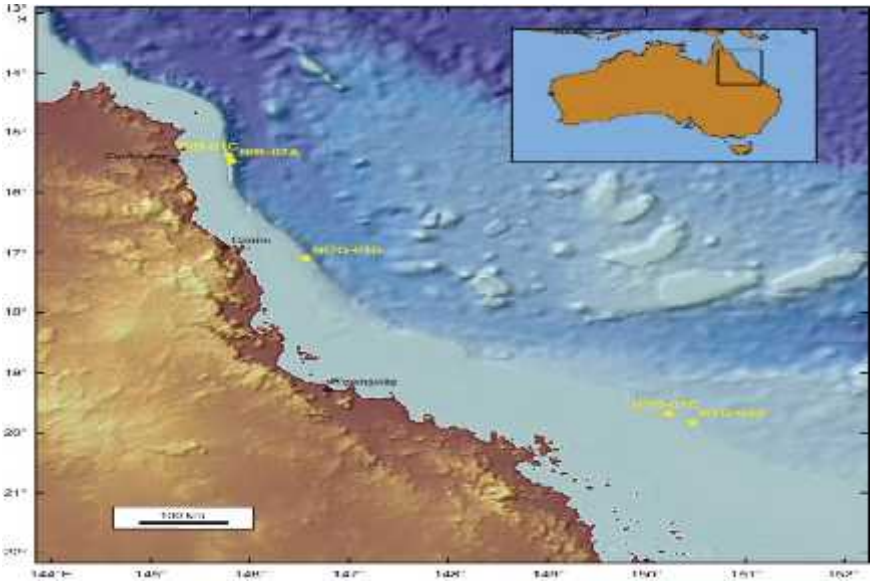
Basalt core samples collected at Site U1342 in the Bering Sea. (Credit Tatsuhiko Sakamoto & IODP)

Integrated Ocean Drilling Program Expedition 325

Great Barrier Reef Environmental Changes

General Information

Sites: Ribbon Reef 5 (RIB-01C) - 5 sites
Ribbon Reef 3 (RIB-02A) - 4 sites
Noggin Pass (NOG-01B) - 8 sites
Hydrographer's Passage (HYD-01C) - 11 sites
Hydrographer's Passage (HYD-02A) - 12 sites
Dates: 11 February - 6 April 2010
Ports: Townsville, Queensland, Australia
Co-chief Scientists: Dr Jody Webster (School of Geosciences, University of Sydney, Australia) and Dr Yusuke Yokoyama (Ocean Research Institute, University of Tokyo, Japan).
Petrophysical Staff Scientist: Louise Anderson



Source: http://publications.iodp.org/preliminary_report/325/325_f2.htm

Summary and Objectives

In the Integrated Ocean Drilling Program (IODP) Expedition 325, designed to investigate the fossil reefs on the shelf edge of the Great Barrier Reef, a succession of fossil reef structures preserved on the shelf edge seaward of the modern barrier reef was cored from a dynamically positioned vessel. A total of 34 boreholes across 17 sites were cored in depths ranging from 42.27 to 167.14 meters below sea level (lowest astronomical tide [LAT] taken from corrected EM300 multibeam bathymetry data). Borehole logging operations in four boreholes provided continuous geophysical information about the drilled strata. The cores were described during the Onshore Science Party (OSP) at the IODP Bremen Core Repository (Germany) in July 2010, where minimum and some standard measurements were made. Scientific objectives of Expedition 325 were:

1. To establish the course of postglacial sea level rise at the Great Barrier Reef.

2. To define sea-surface temperature variations for the region over the period 20 to 10 ka.

3. To analyze the impact of sea level changes on reef growth and geometry

Source of above information:

http://www.eso.ecord.org/expeditions/325/325.php
http://publications.iodp.org/preliminary_report/325/325pr_4.htm

Indian Participation(On-shore)

Dr. Manish Tiwari
Inorganic Geochemist
Scientist, Marine Stable Isotope Lab (MASTIL)
National Centre for Antarctic & Ocean Research
Headland Sada, Vasco-da-Gama, Goa, India

Dr. Manish Tiwari, India

Contribution:

Publication(s):

1. Webster, J.M., Yokoyama, Y., Cotterill, C., and the Expedition 325 Scientists, 2011. *Proc. IODP*, 325: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.325.2011
2. Felis T. et al (including Tiwari M.), 2014, Intensification of the Meridional Temperature Gradient in the Great Barrier Reef Following the Last Glacial Maximum. Nature Communications, 5, 4102, doi: 10.1038/ncomms5102.
3. Harper B.B et al (including Tiwari M.), 2015. Mixed Carbonate–Siliciclastic Sedimentation Along the Great Barrier Reef Upper Slope: A Challenge To the Reciprocal Sedimentation Model. Journal of Sedimentary Research, 85, 1019-1036, doi: 10.2110/jsr.2015.58.1

IODP cores laid out in the reefer

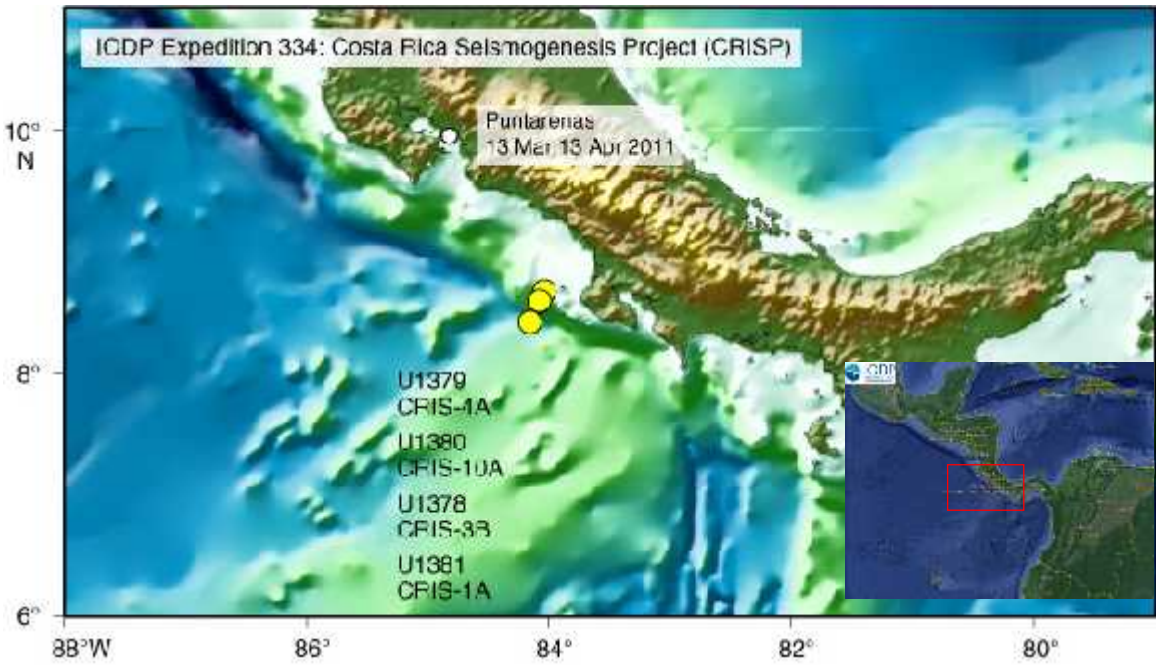
Integrated Ocean Drilling Program Expedition 334

Costa Rica Seismogenesis Project (CRISP)

Sampling and quantifying input to the seismogenic zone and fluid output

General Information

Sites: U1378-U1381
Dates: 13 March to 13 April 2011
Ports: Puntarenas to Puntarenas, Costa Rica
Co-chief Scientists: Paola Vannucchi & Kohtaro Ujiie
Staff Scientist: Nicole Stroncik
Logging Staff Scientist: Alberto Malinverno



Source: http://iodp.tamu.edu/scienceops/maps/exp/334/334_map.jpgl

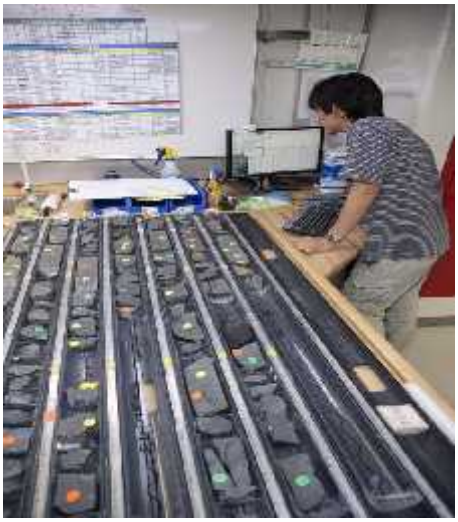
Summary and Objectives:

Integrated Ocean Drilling Program Expedition 334, also known as the Costa Rica Seismogenesis Project (CRISP), was designed to understand the processes that control nucleation and seismic rupture of large earthquakes at erosional subduction zones. CRISP involved the only known erosional end-member of convergent margins within reach of scientific drilling. With a relatively thin sediment cover, fast convergence rate, abundant seismicity, subduction erosion, and change in subducting plate relief along strike, CRISP offered excellent opportunities to learn the causes of earthquake nucleation and rupture propagation. This project complements other deep-fault drilling (San Andreas Fault Observatory at Depth and Nankai Trough Seismogenic Zone Experiment) and investigates the first-order seismogenic processes common to most faults and those unique to erosional margins. The primary objectives of Expedition 334 were

1. Characterization of lithological, physical, and frictional properties of upper plate material;
2. Estimation of subduction channel thickness and the rate of subsidence caused by subduction erosion;
3. Characterization of the fluid flow system and thermal structure of the erosive margin; and
4. Determination of the change in the stress field across the updip limit of the seismogenic zone.

Source of information:

http://publications.iodp.org/preliminary_report/334/334pr_4.htm
http://iodp.tamu.edu/scienceops/expeditions/costa_rica_seismogenesis_334.html



Polka dotted core on the sampling table. (Credit John Beck, IODP/TAMU)

Indian Participation

Dr. Yatheesh V
Geophysicist
Scientist, Marine Geophysics
Geological Oceanography Division
National Institute of Oceanography, Goa, India.

Contribution:

Publication(s):

1. Vannucchi, P., Ujiie, K., Stroncik, N., and the Expedition 334 Scientists, 2012.*Proc. IODP*, 334: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.334.2012
2. Vannucchi P., Sak P. B., Morgan J.P., Ohkushi K., Ujiie K., and IODP Expedition 334 Scientists (including V. Yatheesh), 2013. Rapid pulses of uplift, subsidence, and subduction erosion offshore Central America: Implications for building the rock record of convergent margins. Geology 41(9), 995-998.
3. Vannucchi P., Ujiie K., Stroncik N., Malinverno A., and IODP Expedition 334 Scientists (including V. Yatheesh), 2013. IODP Expedition 334: An investigation of the sedimentary record, fluid flow and state of stress on top of the seismogenic zone of an erosive subduction margin. Scientific Drilling, vol.15; 2013; 23-30

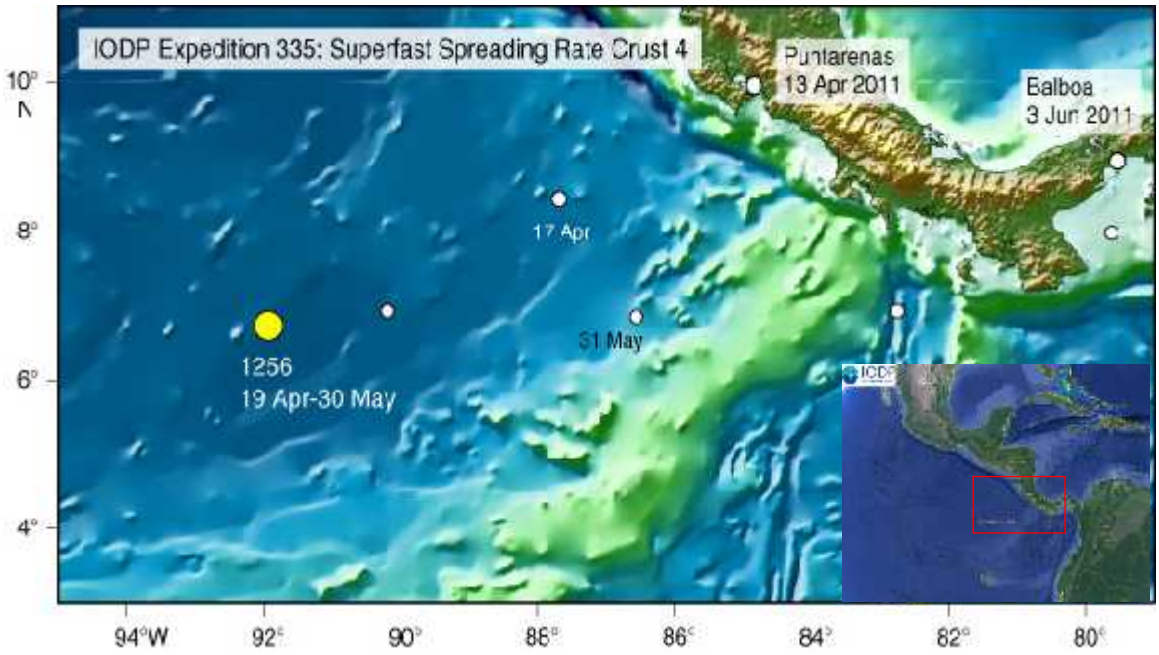
Integrated Ocean Drilling Program Expedition 335

Superfast Spreading Rate Crust 4

Drilling gabbro in intact ocean crust formed at a superfast spreading rate

General Information

Site: 1256
Dates: 13 April to 3 June 2011
Ports: Puntarenas, Costa Rica to Balboa, Panama
Co-chief Scientists: Damon Teagle & Benoît Ildefonse
Staff Scientist: Peter Blum
Logging Staff Scientist: Gilles Guèrin & Natalia Zakharova



Source: http://iodp.tamu.edu/scienceops/maps/exp/335/335_map.jpg

Summary and Objectives:

Integrated Ocean Drilling Program (IODP) Expedition 335, "Superfast Spreading Rate Crust 4" was the fourth scientific drilling cruise of the Superfast Spreading Crust campaign to Ocean Drilling Program (ODP) Hole 1256D. The expedition aimed to deepen this basement reference site several hundred meters into the gabbroic rocks of intact lower oceanic crust to address the following fundamental scientific questions:

1. Does the lower crust form by subsidence of a crystal mush from a high-level magma chamber (gabbro glacier), by intrusion of sills throughout the lower crust, or by some other mechanism? How does melt percolate through the lower crust, and what are the reactions and chemical evolution of magmas during migration?

2. Is the plutonic crust cooled by conduction or hydrothermal circulation? What are the role and extent of deeply penetrating seawater-derived hydrothermal fluids in cooling the lower crust and the chemical exchanges between the ocean crust and the oceans?

3. What are the relationships among the geological, geochemical, and geophysical structure of the crust and, in particular, the nature of the seismic Layer 2–3 transition?

4. What is the magnetic contribution of the lower crust to marine magnetic anomalies?

Sources of information:

http://publications.iodp.org/preliminary_report/335/335pr_4.htm
http://iodp.tamu.edu/scienceops/expeditions/superfast_rate_crust.html

Dr. Parijat Roy explaining the results obtained from portable XRF onboard JOIDES

Indian Participation

Dr. Parijat Roy
Geochemistry
National Centre for Antarctic and Oceanic Research,
Vasco-da-Gama, Goa, India

Contribution:

Publication(s):

1. Teagle, D.A.H., Ildefonse, B., Blum, P., and the Expedition 335 Scientists, 2012.*Proc. IODP*, 335: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/ iodp.proc.335.2012
2. Teagle Damon et al (including Roy Parijat), 2011. Battling through the thermal boundary layer: Deep sampling in ODP Hole 1256D during IODP Expedition 335. Inter Ridge Newsletter, Vol.20, 12-17.
3. Teagle Damon et al (including Roy Parijat), 2012. Deep Sampling in ODP Hole 1256D. Scientific Drilling, 13, 28-34.

Abstracts:

1. Ildefonse Benoit et al (including Roy Parijat). Battling through the thermal boundary layer: Deep sampling in ODP Hole 1256D during IODP Expedition 335. American Geophysical Union Fall Meeting, December 5-9, 2011 (San Fransisco, USA).
2. Kurz Mark D. et al (including Roy Parijat), Noble gases in the oceanic crust: preliminary results from ODP hole 1256 D. American Geophysical Union Fall Meeting, December 5-9, 2011 (San Fransisco, USA).
3. Abe Natsue et al (including Roy Parijat). The progress of the oceanic basement drilling the status of MoHole Project. Annual Meeting of Japan Association of Mineralogical Sciences, September 9-11, 2011 (Mito, Ibaraki, Japan).

Core samples recovered during Expedition-335(Credits IODP)

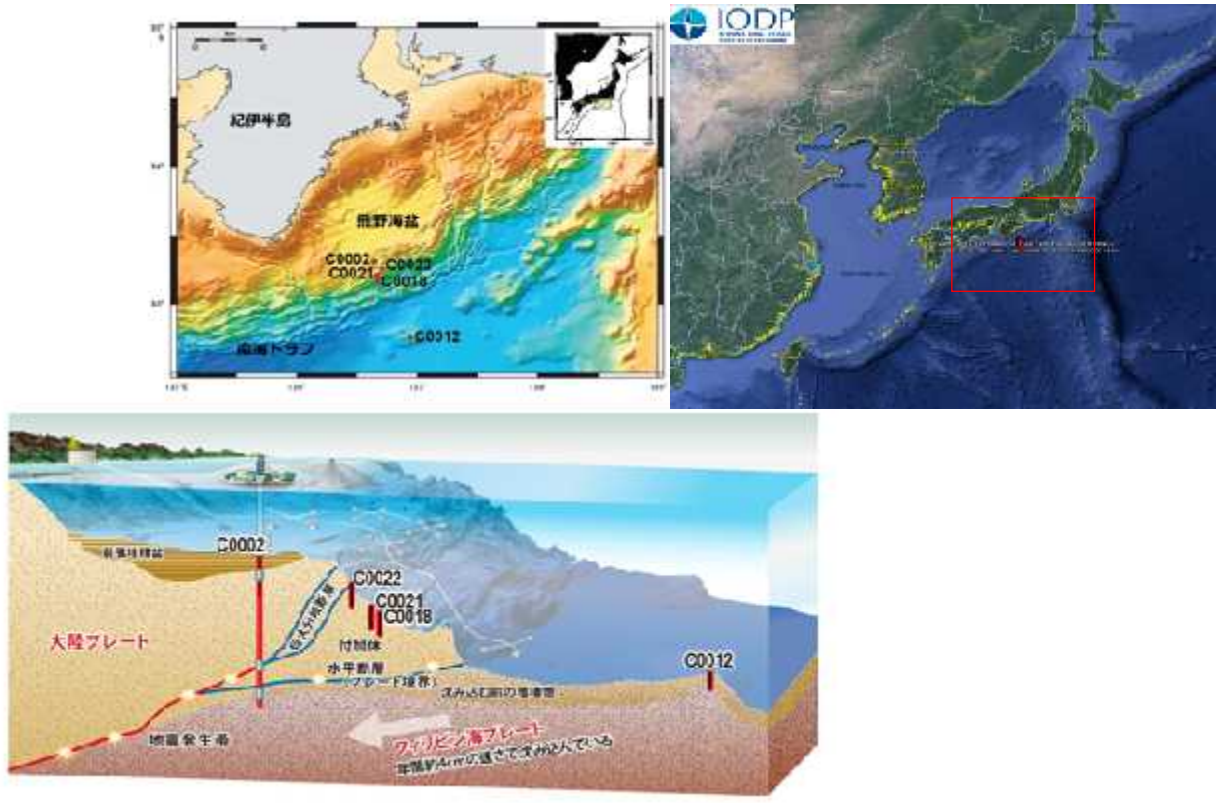
Integrated Ocean Drilling Program Expedition 338

Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE)

Ultra-deep drilling towards the megasplay fault (continued)

General Information

Sites: C0002
Dates: 1 Oct 2012 to 13 Jan 2013
Location: 80 km off the Kii Peninsula at Nankai Trough.
Co-chief Scientists: Brendon Dugan, Kyuichi Kanagawa, Gregory Moore, Michael Strasser.



Source: http://www.jamstec.go.jp/e/about/press_release/20130117/img/image001.jpg

Summary and Objectives:

The NanTroSEIZE expedition plans for FY2012 included drilling from 860 to 3600 m below the seafloor at IODP Site C0002, located 80 km off the Kii Peninsula. After drilling reached 2000 m below the seafloor, sudden changes in sea and weather conditions resulted in damage to vital drilling equipment (Previously reported on 22 November 2012). This necessitated in switching to contingency drilling plans and drilling scheduled for FY2014 at other NanTroSEIZE locations was conducted, including collection of core samples and logging-while-drilling (LWD).The objectives of the contingency drilling plans were:

5. To obtain information on the history of mega-splay fault activity.

6. To obtain the physical properties of the geological strata of the oceanic plate prior to subduction.

7. To obtain the internal structure of the accretionary prism after forming from material accreted from the subducting oceanic plate.

The data collected was expected to be analyzed and integrated with previously collected data from earlier NanTroSEIZE IODP expeditions. The goals of NanTroSEIZE remain clarifying the structure and formation processes for oceanic plate subduction zones and changes in plate boundary faults with the objective of elucidating the mechanisms for occurrences of mega-earthquakes and tsunamis.

Source of above information: http://www.jamstec.go.jp/e/about/press_release/20130117/

Indian Participation

Dr. Ravi Mishra
Inorganic Geochemist, Sedimentologist
Scientist, National Centre for Antarctic and Oceanic Research,
Vasco-da-Gama, Goa, India

Contribution:

Publications:

1. Strasser, M., Dugan, B., Kanagawa, K., Moore, G.F., Toczko, S., Maeda, L., and the Expedition 338 Scientists, 2014. *Proc. IODP*, 338: Yokohama (Integrated Ocean Drilling Program). doi:10.2204/iodp.proc.338.2014

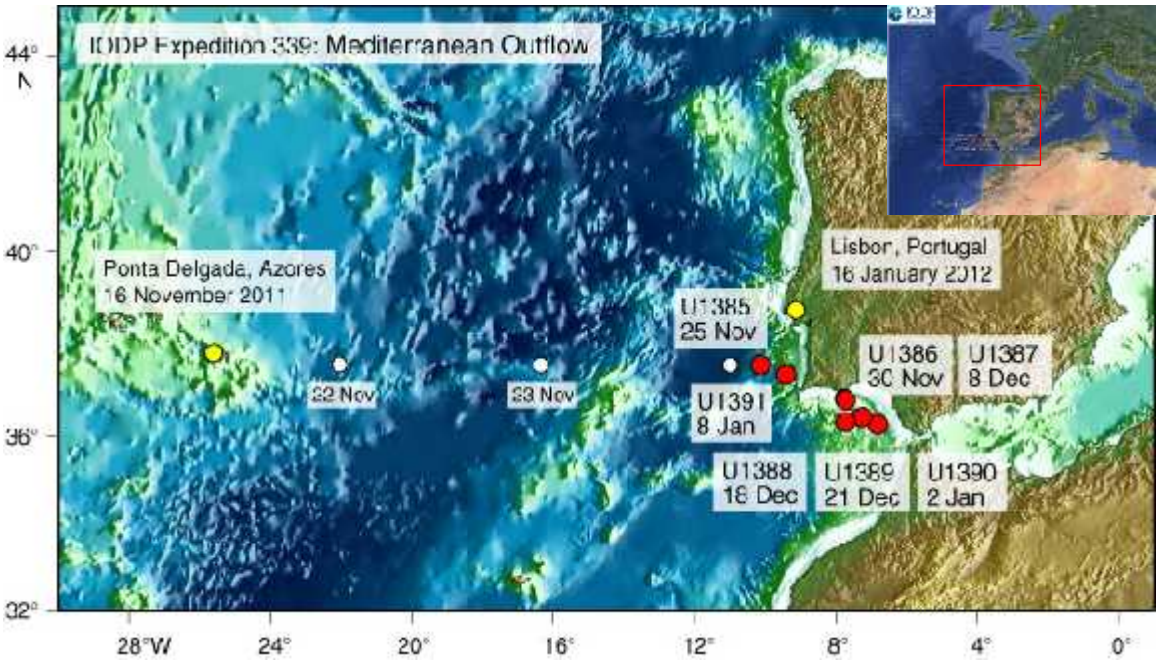
Integrated Ocean Drilling Program Expedition 339

Mediterranean Outflow

Environmental significance of the Mediterranean Outflow Water and its global implications

General Information

Sites: U1385-U1391
Dates: 16 November 2011 to 17 January 2012
Ports: Ponta Delgada, Azores to Lisbon, Portugal
Co-chief Scientists: Francisco J. Hernández-Molina & Dorrik Stow
Staff Scientist: Carlos Alvarez-Zarikian
Logging Staff Scientist: Trevor Williams & Johanna Lofi



Source: http://iodp.tamu.edu/scienceops/maps/exp/339/339_map.jpg

Summary and Objectives:

During Integrated Ocean Drilling Program Expedition 339, five sites were drilled in the Gulf of Cádiz and two sites were drilled off the West Iberian margin from November 2011 to January 2012. Total length of recovered core was 5447 m, with an average recovery of 86.4%. The Gulf of Cádiz was targeted for drilling as a key location for the investigation of Mediterranean Outflow Water (MOW) through the Strait of Gibraltar gateway and its influence on global circulation and climate. The gulf is also a prime area for understanding the effects of tectonic activity on evolution of the Strait of Gibraltar gateway and margin sedimentation.

The key scientific objectives were:

1. Understand the opening of the Strait of Gibraltar gateway and onset of MOW.

2. Determine MOW paleocirculation and global climate significance.
3. Establish a marine reference section of Pleistocene climate (rapid climate change).
4. Identify external controls on sediment architecture of the Gulf of Cádiz CDS and West Iberian margin.
5. Ascertain synsedimentary neotectonic control on architecture and evolution of the CDS

Source of above information:

http://publications.iodp.org/preliminary_report/339/339pr_4.htm

http://iodp.tamu.edu/scienceops/expeditions/mediterranean_outflow.html

Indian Participation

Prof. A. D. Singh
Micropaleontology and Paleoceanography
Banaras Hindu University, Varanasi, India

Prof. Arun Singh discuss the biostratigraphic zonations with a fellow scientist (Credit Johanna Lofi & IODP). (Left); Prof. Arun Singh steps onto the Catwalk to survey the recovery a core. (Right)

Contribution:

Project sponsored by the IODP-India

NCAOR (IODP-India, MoES) sponsored project "Mediterranean Outflow Water (MOW) - 'Paleoceanography and its impact on global climate during the last 3 M.y" 2013-2016'.

Publications:

1. Hernandez-Molina F.J. et al (including A.D. Singh), 2013. Expedition 339 (Mediterranean outflow: environmental significance of the Mediterranean Outflow Water and its global implications); Proceedings of the Integrated Ocean Drilling Programme, v.339, Tokyo (IODP Management International, Inc.) doi:10.2204/iodp/proc.339.101-109.2013.
2. Singh A.D., Verma K., Jaisawal S., Alonso-Garcia M., Li B. and Abrantes F., 2015. Planktic foraminiferal responses to orbital scale oceanographic changes off the western Iberian margin since the MPR: Results from the IODP site U1391. Global and Planetary Change, Elsevier, 135, 47-56.

3. Singh A.D., Rai A.K., Tiwari M., Naidu P.D., Verma K., Chaturvedi M., Niyogi A. and Pandey D., 2015. Fluctuations of the Mediterranean Outflow Water circulation in the Gulf of Cadiz during the MIS 5 to 7: Evidences from benthic foraminiferal assemblage and stable isotope records. Global and Planetary Change, Elsevier, 133, 125-140. doi: 10.1016/j.gloplacha.2015.08.005.
4. Hodell D., Lourens L., Crowhrust S., Konijnendijk T., Tjallingii R., Jimenez-Espejo,F. L. Skinner, P.C. Tzedakis and the Shackleton Site Project members (including Singh A.D.), 2015. A reference time scale for Site U1385 (Shackleton Site) on the SW Iberian margin. Global and Planetary Change, Elsevier, 133, 49-64.
5. Hernandez-Molina F.J. et al (including Singh A.D.), 2014. Onset of Mediterranean Outflow into the North Atlantic. Science, USA, 344, 1244-1250.
6. Dorador J., Rodrigue-Tovar F. J., and IODP Expedition 339 Scientists (including Singh A. D.), 2014. Quantitative estimation of bioturbation based on digital image analysis. Marine Geology, doi: 10.1026/j.margeo.2014.01.003.
7. Hernandez-Molina F.J., Stow D.A.V., Alvarez-Zarikian C. and Expedition 339 Scientists (including A. D. Singh), 2013. IODP Expedition 339 in the Gulf of Cadiz and off West Iberia: Decoding the environmental significance of the Mediterranean outflow water and its global implication. Scientific Drilling**,** 16, 1-11, doi:10.5194/sd-16-1-2013.
8. Hodell D., Lourens L., Stow D.A.V., Hernandez-Molina F.J., Alvarez-Zarikian C. and the Shackleton Site Project Members (including Singh A.D.), 2013. The "Shackleton Site" (IODP Site U1385) on the Iberian margin. Scientific Drilling, 16, 13-19, doi:10.5194/sd-16-13-2013.
9. Dorador J., Rodrigue-Tovar F.J., and IODP Expedition 339 Scientists (including Singh A. D.), 2013. Digital image treatment applied to ichnological analysis of marine core sediments. Facies, Springer-Verlag Berlin Heidelberg, DOI 10.1007/s10347-013-0383-z.

Seminar / Symposium (Abstracts):-

1. Singh, A. D., 2016. (Key note speaker) Neogene-Quaternary low-mid latitudes climate variability and its linkages to the evolution of ocean gateways. International Conference on 3rd Neogene Climate Evolution in Eurasia (NECLIME) Asian Meeting at BSIP Lucknow.
2. Routledge, C.M., Kulhanek, D.K., Tauxe, L., Scardia, G., Singh, A. D., Steinke, S. and expedition 355 scientists, 2015. Miocene-Pliocene calcareous Nanofossil biostratigraphy of IODP site U1457, Arabian Sea. GSA-2015, Baltimore, Maryland, USA, 1-4 November, 2015.
3. Singh, A. D., Tiwari, M., Naidu P.D., Niyogi A., Verma K., Rai, A.K., Chaturvedi M., Pandey D. and IODP Expedition 339 scientists, 2014. Variability pattern of the Mediterranean Outflow during the last two glacial cycles: Evidences from benthic foraminiferal assemblages and stable isotope records at the Site U1387, Gulf of Cadiz. 2nd IODP 339 Post-Cruise Meeting. Tarifa (Cadiz), Spain, 1-6 June, 2014.
4. Singh A. D., Verma K., Jaisawal S. and IODP Expedition 339 scientists, 2014. Planktic foraminiferal response to orbital scale oceanographic changes off the western Iberian margin since the MPR: Results from the IODP Site U1391. 2nd IODP 339 Post-Cruise Meeting. Tarifa (Cadiz), Spain, 1-6 June, 2014.
5. Singh A. D. et al., 2013. Evolution of the Mediterranean Outflow Water and its oceanographic-climatic implications: Preliminary Results of IODP Expedition 339 in the Gulf of Cadiz and west off Portugal. PAGES 4th Intl. Open Science Meeting 2013, Goa.
6. Singh, A. D., 2014. On linkages between Mediterranean Outflow Water (MOW), Thermohaline Circulation (THC), global climate shifts and plate tectonic events: New findings. In: Natl. Conference on Climate Change and Environmental Sustainability, Lucknow, p.7.

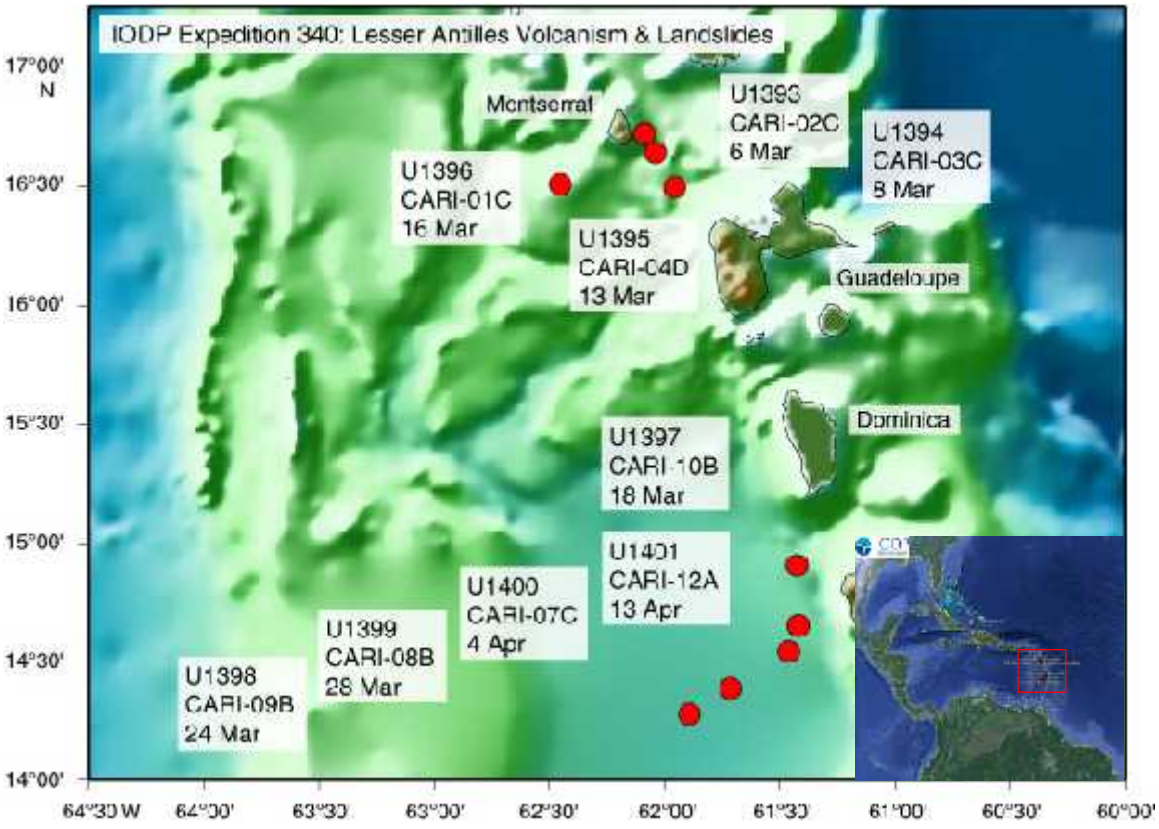
Integrated Ocean Drilling Program Expedition 340

Lesser Antilles Volcanism and Landslides

Implications for hazard assessment and long-term magmatic evolution of the arc

General Information

Sites: U1393-U1401
Dates: 2 March to 17 April 2012
Ports: San Juan, Puerto Rico to Curacao, Dutch Antilles
Co-chief Scientists: Anne Le Friant & Osamu Ishizuka
Staff Scientist: Adam Klaus
Logging Staff Scientists: Angela Slagle & Sally Morgan



Source: http://iodp.tamu.edu/scienceops/maps/exp/340/340_map.jpg

Summary and Objectives:

Data acquired during this IODP expedition 340 was expected to be utilized to further investigate magmatic evolution and eruptive activity along the Lesser Antilles arc. In addition, IODP hopes to reach a better understanding of the mechanisms involved in both the transport and deposition of volcanic debris avalanche deposits and to assess the potential for volcanic hazards associated with these avalanches.

The key scientific objectives were:

1. To understand the timing and emplacement processes of potentially tsunamigenic large debris avalanche emplacements.
2. To document the long-term eruptive history of the arc to assess volcano evolution (cycles of construction and destruction) and major volcanic hazards.
3. To characterize the magmatic cycles and long-term magmatic evolution of the arc.
4. To document dispersal of sediment into the deep ocean.

Core Samples (Source: Dr. K.S.V. Subramanyam)

5. To determine the processes and element fluxes associated with submarine alteration of volcanic material.

Source of above information: http://publications.iodp.org/preliminary_report/340/340pr_4.htm

Indian Participation

Subramanyam K.S.V
Geochemist
Scientist, National Geophysical Research Institute,
Hyderabad, India

Contribution:

Expedition research results

1. Hatfield. R.G., 2015. Data report: stratigraphic correlation of Site U1396 and creation of a composite depth scale and splice. In Le Friant, A., Ishizuka, O., Stroncik, N.A., and the Expedition 340 Scientists, Proceedings of the Integrated Ocean Drilling Program, 340: Tokyo (Integrated Ocean Drilling Program Management International, Inc.).http://dx.doi.org/10.2204/iodp.proc.340.202.2015
2. Jutzeler, M., Talling, P.J., White, J.D.L., and the Expedition 340 Scientists, 2016. Data report: coring disturbances in IODP Expedition 340, a detailed list of intervals with fall-in and flow-in. In Le Friant, A., Ishizuka, O., Stroncik, N.A., and the Expedition 340 Scientists, Proceedings of the Integrated Ocean Drilling Program, 340: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). http://dx.doi.org/10.2204/iodp.proc.340.206.2016

3. Coussens M.F. et al, (including Subramanyam, K.S.V.), 2016. Synthesis: stratigraphy and age control for IODP Sites U1394, U1395, and U1396 offshore Montserrat in the Lesser Antilles, doi:10.2204/iodp.proc.340.204.2016.

Abstracts

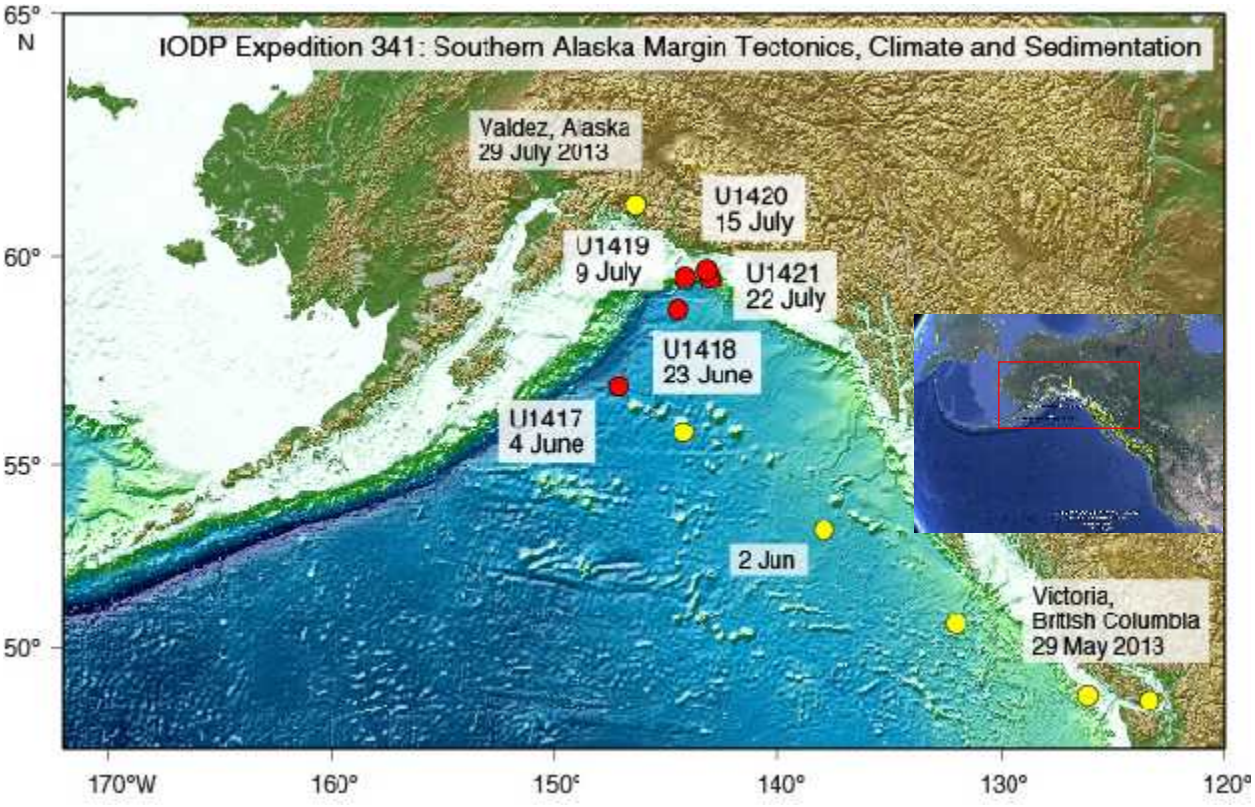
4. Jutzeler, M., Manga, M., White, J.D., and Expedition 340 Scientists, 2012. Flotation experiments with seafloor-sampled pumice lapilli, IODP 340—preliminary results [presented at the 2012 American Geophysical Union Fall Meeting, San Francisco, CA, 3–7 December 2012]. (Abstract V53E-2884) http://www.agu.org/meetings/fm12/waisfm12.html
5. Le Friant, A., Ishizuka, O., Stroncik, N., and Expedition 340 Scientists, 2012. Implications for hazard assessment and long-term magmatic evolution of the Lesser Antilles arc: Integrated Ocean Drilling Program (IODP) Expedition 340—Lesser Antilles Volcanism and Landslides [presented at the 2012 American Geophysical Union Fall Meeting, San Francisco, CA, 3–7 December 2012]. (Poster V53E-2880) http://www.agu.org/meetings/fm12/waisfm12.html
6. Slagle, A.L., Morgan, S., and the Expedition 340 Scientific Party, 2012. Characterization of Lesser Antilles volcanic landslide deposits from downhole logging, IODP Expedition 340 [presented at the 2012 American Geophysical Union Fall Meeting, San Francisco, CA, 3–7 December 2012]. (Abstract V43G-07) http://www.agu.org/meetings/fm12/waisfm12.html
7. Talling, P.K., Kataoka, K., Endo, D., Watt, S.F., Le Friant, A., Ishizuka, O., IODP Expedition 340 Scientific Party, Berndt, C., Crutchley, G., and Karstens, J., 2012. New insight into composition and source, single or multistage emplacement, and relationship to eruption cycles from first drilling of volcanic island landslides, offshore Montserrat [presented at the 2012 American Geophysical Union Fall Meeting, San Francisco, CA, 3–7 December 2012]. (Abstract V43G-08) http://www.agu.org/meetings/fm12/waisfm12.html
8. Aljahdali, M.H., Behzad, A., Missimer, T.M., Wise, S.W., and the Integrated Ocean Drilling Program Expedition Scientists, 2013. Extreme diagenesis displayed by Pliocene–Pleistocene calcareous nannofossils in IODP Hole 1396A, adjacent to Montserrat Island in the Lesser Antilles [presented at the American Geophysical Union Fall 2013 Meeting, San Francisco, CA, 9–13 December 2013]. (Abstract PP13A-1860) http://abstractsearch.agu.org/meetings/2013/FM/sections/PP/sessions/PP13A/abstracts/PP13A-1860.html
9. Talling, P. et al (including Subramanyam, K.S.V.), 2015. New insights from IODP Expedition 340 offshore Montserrat: first drilling of large volcanic island landslides. Geophysical Research Abstracts, 17:EGU2015-5420.http://meetingorganizer.copernicus.org/EGU2015/EGU2015-5420.pdf.
10. Fraass, A., Castaneda, I., Phu, V., Leckie, R.M., and the IODP Expedition 340 Science Party, 2012. Preliminary foram biostratigraphy and organic biomarker paleotemperature results from Site U1396, IODP Exp. 340. Geol. Soc. Am. Abstr. Progr., 44(7):122. https://gsa.confex.com/gsa/2012AM/finalprogram/abstract_213024.htm
11. Aljahdali, M., Alsuwailem, A., Batang, Z., Behzad, A., Missimer, T., Wise, S., and Expedition 340 Science Party, 2013. Pliocene-Pleistocene calcareous nannofossil biostratigraphy of IODP Hole 1396C, adjacent to Montserrat Island in the Lesser Antilles plus experimentally induced diagenesis [14th International Nannoplankton Association Meeting (INA14), Reston, VA, 15–21 September 2013].

Integrated Ocean Drilling Program Expedition 341

Southern Alaska Margin Tectonics, Climate and Sedimentation

General Information

Sites: U1417-U1421
Dates: 29 May to 29 July 2013
Ports: Victoria, Canada to Valdez, Alaska, USA
Co-chief Scientists: John Jaeger & Sean Gulick
Staff Scientist: Leah LeVay (previously Schneider)
Logging Staff Scientists: Angela Slagle & Laureen Drab



Source: http://iodp.tamu.edu/scienceops/expeditions/alaska_tectonics_climate.html

Summary and Objectives:

A cross-margin transect was drilled during Expedition 341 to investigate the northeast Pacific continental margin sedimentary record formed during orogenesis within a time of significant global climatic deterioration in the Pliocene–Pleistocene that led to the development of the most aggressive erosion agent on the planet, a temperate glacial system.

Major objectives for drilling in the Gulf of Alaska were as follows:

1. Document the tectonic response of an active orogenic system to late Miocene to recent climate change;
2. Establish the timing of advance and retreat phases of the northwestern Cordilleran ice sheet to test its relation to dynamics of other global ice sheets;
3. Implement an expanded source-to-sink study of the complex interactions between glacial, tectonic, and oceanographic processes responsible for creation of one of the thickest Neogene high-latitude continental margin sequences;
4. Understand the dynamics of productivity, nutrients, freshwater input to the ocean, and surface and subsurface circulation in the northeast Pacific and their role in the global carbon cycle; and
5. Document the spatial and temporal behavior during the Neogene of the geomagnetic field at extremely high temporal resolution in an undersampled region of the globe.

IODP-341 Scientific Party onboard JR

Indian Participation

Dr. Shyam M. Gupta
Micropaleontologist (radiolarians)
National Institute of Oceanography
Goa, India

Contribution

Publication(s):

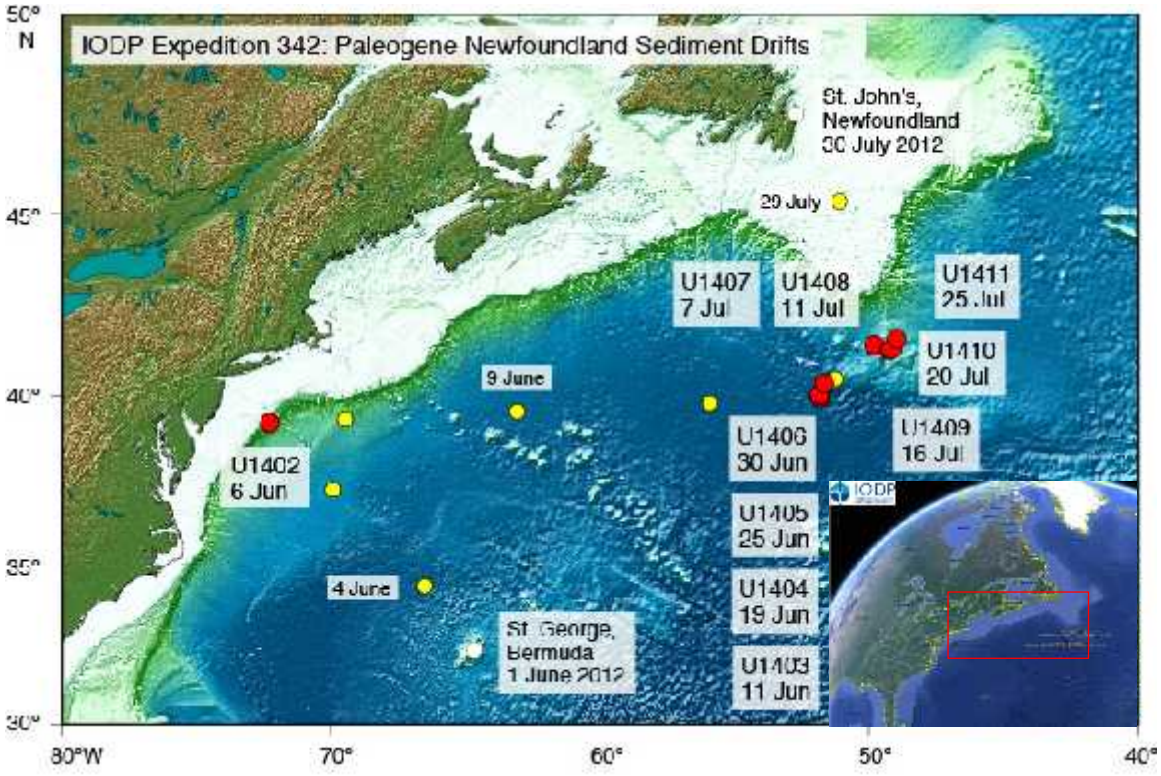
1. Daigle, H., and Piña, O.L., 2016. Data report: permeability, consolidation properties, and grain size of sediments from Sites U1420 and U1421, offshore southern Alaska. *In* Jaeger, J.M., Gulick, S.P.S., LeVay, L.J., and the Expedition 341 Scientists, *Proceedings of the Integrated Ocean Drilling Program*, 341: College Station, TX (Integrated Ocean Drilling Program).http://dx.doi.org/10.2204/iodp.proc.341.201.2016

Integrated Ocean Drilling Program Expedition 342

Paleogene Newfoundland Sediment Drifts

General Information

Sites: U1402 (MDHDS test) and U1403-U1411
Dates: 2 June to 1 August 2012
Ports: St. George, Bermuda to St. John's, Newfoundland
Co-chief Scientists: Richard Norris & Paul Wilson
Staff Scientist: Peter Blum
Logging Staff Scientist: Annick Fehr



Source: http://iodp.tamu.edu/scienceops/expeditions/newfoundland_sediment_drifts.html

Summary and Objectives:

Integrated Ocean Drilling Program Expedition 342 was designed to recover Paleogene sedimentary sequences with unusually high deposition rates across a wide range of water depths (Sites U1403–U1411). The expedition was primarily targeted at reconstructing the Paleogene carbonate compensation depth (CCD) in the North Atlantic for reference to recently obtained high-fidelity records of the CCD in the equatorial Pacific.The combination of sites yields a record of the history of CCD change over a 2 km depth range from the ocean abyss to middle range water depths. Notable findings include the discovery of intermittent calcareous sediments in the Cretaceous, Paleocene, and early to middle Eocene at 4.5 km paleodepth, suggesting a deep Atlantic CCD during these times.

The key scientific objectives were:

1. Recover data on the history of the Paleogene carbonate compensation depth and forcing factors for Paleogene hyperthermals.
2. Determine the flow history of the Atlantic Deep Western Boundary Current.
3. Obtain high-resolution records of the onset and development of Cenozoic glaciation.

Source of above information:

http://publications.iodp.org/preliminary_report/342/342pr_4.htm

http://iodp.tamu.edu/scienceops/expeditions/newfoundland_sediment_drifts.html

Samples being taken in the core lab

Indian Participation

Dr. Amit K. Ghosh,
Biologist; Stratigraphic correlator
Scientist, Birbal Sahni Institute of Palaeobotany
Lucknow, India.

Dr. Amit K Ghosh with the two Co-Chief scientists.

Contribution:

Publication(s):

1. Norris RD., Wilson PA., Blum P. & the Expedition 342 Scientists (including Ghosh AK.) 2014. Proceedings of the Integrated Ocean Drilling Program 342. U.S. Implementing Organization Science Services, Texas A&M University, USA, doi:10.2204/iodp.proc.342.2014
2. Flemings PB., Polito PJ., Pettigrew TL., Iturrino GJ., Meissner E., Aduddell R., Brooks DL., Hetmaniak C., Huey D., Germaine JT. and the IODP Expedition 342 Scientists (including Ghosh AK.). 2013. The Motion Decoupled Delivery System: A New Deployment System for Downhole Tools is Tested at the New Jersey Margin. *Scientific Drilling*, Vol. 15: 51-56.
3. Friedrich O, Batenburg SJ, Moriya K, Voigt S, Cournède C, Moebius I, Blum P, Bornemann A, Fiebig J, Hasegawa T, M. Hull PM, Norris RD, Röhl U, Westerhold T, Wilson PA and the IODP Expedition 342 Scientists (including Ghosh AK.). 2016. Maastrichtian carbon isotope stratigraphy and cyclostratigraphy of the Newfoundland Margin (Site U1403, IODP Leg 342). *Climate of the Past*, doi:10.5194/cp-2016-51 (*Discussion paper under review in Climate of the Past*).

Conferences/Abstract(s):

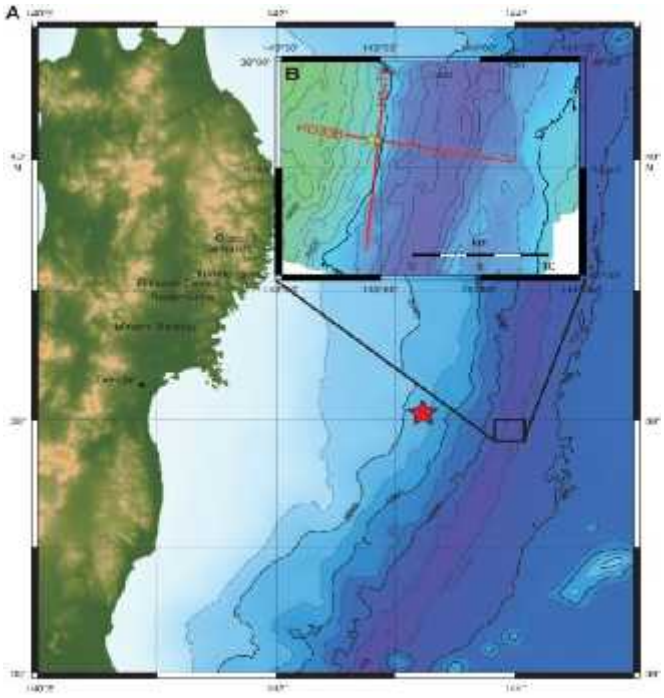
4. Ghosh AK., Chakraborty A, Chatterjee R, Singh RS. and IODP Expedition 342 Scientists. 2015. Late Oligocene to early Miocene palynomorphs (organic microfossils) and diatoms (silicified microfossils) from Site U1404 of IODP Expedition 342. *Snowbird Post-Cruise Science Meeting of IODP Expedition 342*, 22-24 September, 2015, Salt Lake City, Utah, USA.

Integrated Ocean Drilling Program Expedition 343

Japan Trench Fast Earthquake Drilling Project (JFAST)

General Information

Site: JFAST-3
Dates: 1 April to 24 May 2012
Ports: Shimizu, Japan
Co-chief Scientists: Jim Mori, Frederick M. Chester
Staff Scientist: Nobu Eguchi, Sean Toczko



A. Large-scale map showing Tohoku region and epicenter of 11 March 2011 Tohoku earthquake (red star) along with the survey lines and IODP Expedition 343 proposed drill site (in box). **B.** Close-up map, showing proposed Sites JFAST-3 and JFAST-4. Source: http://publications.iodp.org/scientific_prospectus/343/343_f1.htm

Summary and objectives:

The main science goal of the Japan Trench Fast Earthquake Drilling Project (JFAST) is to understand the physical mechanisms and dynamics of large slip earthquakes, which is a fundamental issue that is currently poorly understood. Specifically, the level of frictional stress during the earthquake rupture and the physical characteristics of the fault zone will be investigated. This topic has obvious social consequences globally for evaluating severe shaking and large tsunamis from future earthquakes at subduction zones. The scientific objectives of JFAST include characterizing the fault and wall-rock composition, fault architecture, and the nature of heat and pressure within and around the fault zone, located approximately 1000 m below seafloor.

The main scientific objectives were:

6. What was the stress state on the fault that controls rupture during the earthquake and was the stress completely released?
    3. Dynamic friction during the rupture.
    4. Rupture to the toe of the accretionary wedge.

7. What are the characteristics of large earthquakes in the fault zone, and how can we distinguish present and past events in fault zone cores?
    1. Through Core analyses.
    2. Through Laboratory experiments.

Source of above information:
http://publications.iodp.org/scientific_prospectus/343/343sp_3.htm

Indian Participation

Dr. Santanu Bose
Structural Geologist
Asst. Professor, Calcutta University,
Kolkata, India.

Contribution:

Publication(s):

1. Chester, F.M., Mori, J., Eguchi, N., Toczko, S., and the Expedition 343/343T Scientists, 2013. *Proc. IODP*, 343/343T: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.343343T.2013
2. Bose Santanu, Saha Puspendu, Mori James J., Rowe Christie, Ujiie Kohtaro, Chester Frederick M., Conin Marianne, Regalla Christine, Kameda Jun, Toy Virginia, Kirkpatrick James, Remitti Francesca, Moore J. Casey, Wolfson-Schwehr Monica, Nakamura Yasuyuki, Gupta Anchit, 2015, Deformation structures in the frontal prism near the Japan Trench: Insights from sandbox models, Journal of Geodynamics, 89: 29-38.
3. Chester Frederick M. et al (including Bose Santanu), 2013, Structure and Composition of the Plate-Boundary Slip Zone for the 2011 Tohoku-Oki Earthquake, Science 342, 1208.
4. Lin Weiren et al (including Bose Santanu), 2013, Stress State in the Largest Displacement Area of the 2011 Tohoku-Oki Earthquake, Science 339, 687.

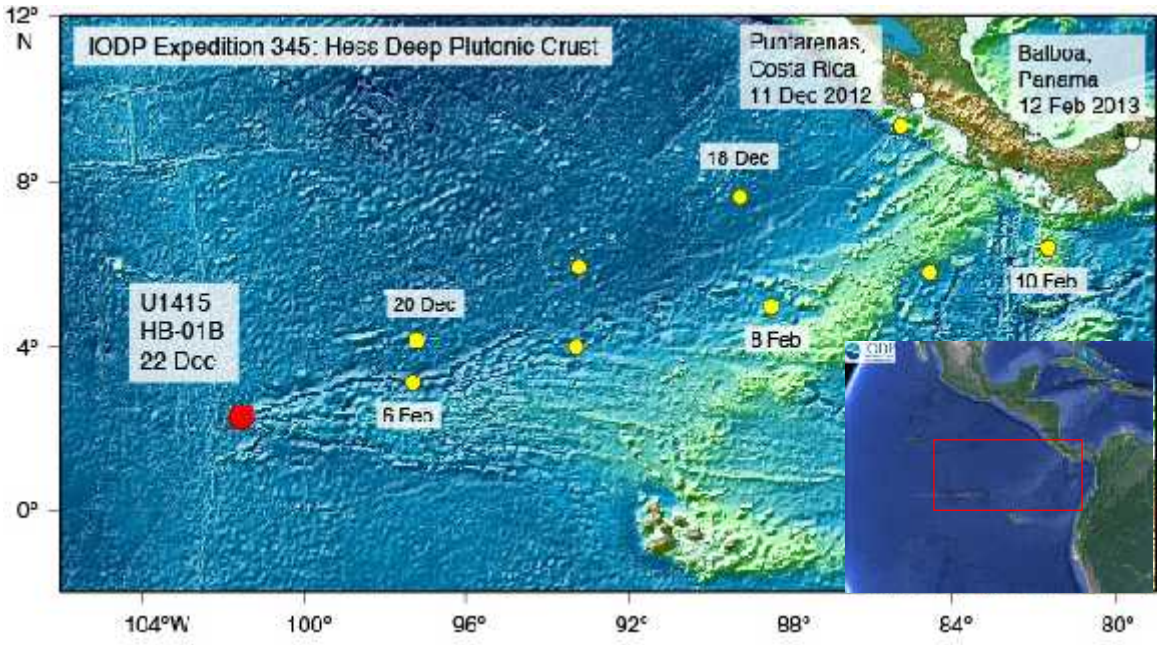
Integrated Ocean Drilling Program Expedition 345

Hess Deep Plutonic Crust

Exploring the plutonic crust at a fast-spreading ridge:new drilling at Hess Deep

General Information

Site: U1415
Dates: 11 December 2012 to 12 February 2013
Ports: Puntarenas, Costa Rica to Balboa, Panama
Co-chief Scientists: Kathryn Gillis & Jonathan Snow
Staff Scientist: Adam Klaus
Logging Staff Scientist: Gilles Guèrin



Source: http://iodp.tamu.edu/scienceops/expeditions/maps/hess.jpg

Summary and Objectives:

Integrated Ocean Drilling Program (IODP) Hess Deep Expedition 345 was designed to sample lower crustal primitive gabbroic rocks that formed at the fast-spreading East Pacific Rise (EPR) in order to test models of magmatic accretion and the intensity of hydrothermal cooling at depth. The Hess Deep Rift was selected to exploit tectonic exposures of young EPR plutonic crust, building upon results from ODP Leg 147 as well as more recent submersible, remotely operated vehicle, and near-bottom surveys. The primary goal was to acquire the observations required to test end-member crustal accretion models that were in large part based on relationships from ophiolites, in combination with mid-ocean ridge geophysical studies. This goal was achieved with the recovery of primitive layered olivine gabbros and troctolites with many unexpected mineralogical and textural relationships, such as the abundance of orthopyroxene and the preservation of delicate skeletal olivine textures.

The main scientific objectives were:

1. How is melt transported from the mantle through the lower crust?
2. What is the origin and significance of layering?
3. How, and how fast, is heat extracted from the lower plutonic crust?
4. What are the fluid and geochemical fluxes in the East Pacific Rise lower plutonic crust?

Source of above information:

http://publications.iodp.org/preliminary_report/345/345pr_4.htm

Scientists discuss about a core sample.

Indian Participation

Dr. Abhishek Saha
Petrologist, Igneous Petrologist
Calcutta University, Kolkata, India.

Dr. Abhishek Saha and the Geochemistry group

Contribution:
Publication(s):

1. Gillis, K.M., Snow, J.E., Klaus, A., and the Expedition 345 Scientists, 2014. *Proc. IODP*, 345: College Station, TX (Integrated Ocean Drilling Program).doi:10.2204/iodp.proc.345.2014
2. Gillis, K.M. et al (including Saha A.), 2013, Primitive Layered Gabbros from Fast-Spreading Lower Oceanic Crust. Nature v.505 (7482), pp.204-207.
3. Godard, M., Meyer, R., Saha, A., Gillis, K., Snow, J., Klaus, A. and Shipboard Scientific Party IE3 (2013) Geochemistry of Fast-Spreading Lower Crust: Results from IODP Expedition 345 at the Hess Deep Rift. Mineralogical Magazine, v. 77(5), p.1184.

Abstracts:

4. R. Meyer, R., Godard, M., Saha, A., Gillis, K., Snow, J., Klaus, A. and IODP Expedition 345 Scientific Party (2013) IODP Expedition 345: Geochemical Characteristics of Fast Spread Lower East Pacific Rise Crust. Abstract submitted for American Geophysical Union (AGU) 2013 meeting.
5. Koepke, J. et al (including Saha A.), 2013, Orthopyroxene omnipresent in Layered Gabbros from the Hess Deep, EPR (IODP Expedition 345). Abstract submitted for American Geophysical Union (AGU) 2013 meeting.
6. Snow J.E. (including Saha A.), 2013, Hypersolidus deformation and melt flow in the lower ocean crust: Preliminary observations from IODP Leg 345. Abstract submitted for American Geophysical Union (AGU) 2013 meeting.
7. John, B., Ceuleneer, G., Cheadle, M., Harigane, Y. and IODP Expedition 345 Science Party (2013) IODP Exp 345: Structural characteristics of fast spread lower ocean crust: implications for growth and cooling of ocean crust. Abstract submitted for American Geophysical Union (AGU) 2013 meeting.

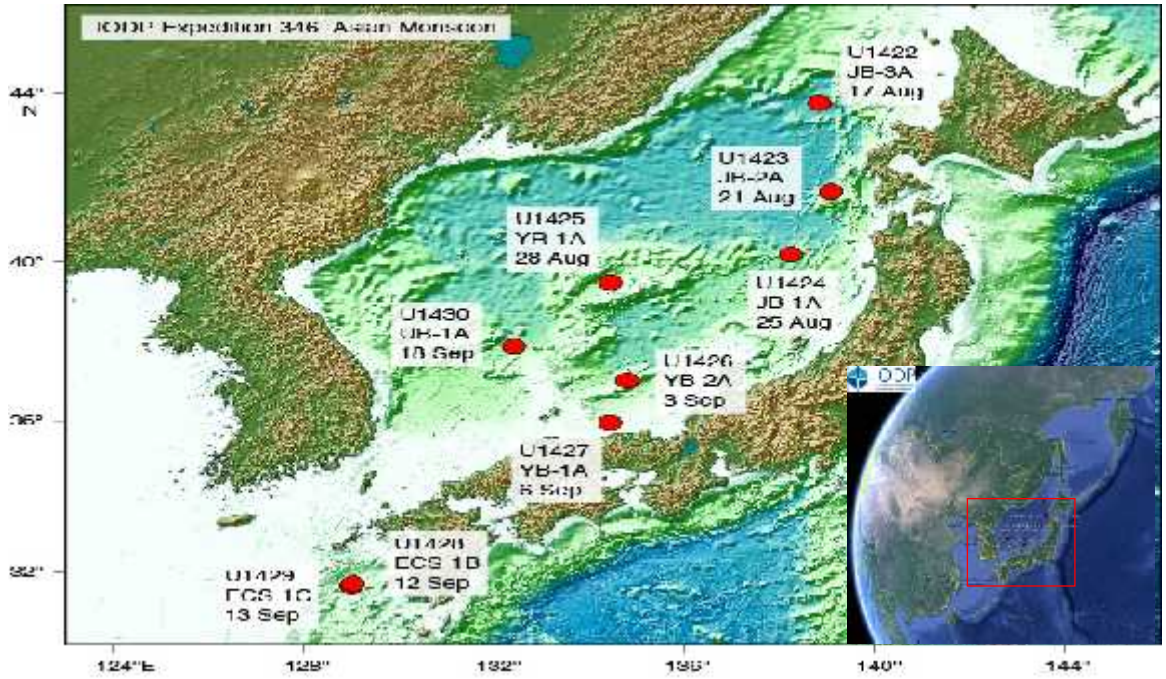
Integrated Ocean Drilling Program Expedition 346

Asian Monsoon

Onset and evolution of millennial-scale variability of Asian monsoon and its possible relation with Himalaya and Tibetan Plateau uplift

General Information

Sites: U1422-U1430
Dates: 29 July to 27 September 2013
Ports: Valdez, Alaska, USA to Busan, Korea
Co-chief Scientists: Ryuji Tada & Rick Murray
Staff Scientist: Carlos Alvarez Zarikian
Logging Staff Scientist: Johanna Lofi



Source: http://iodp.tamu.edu/scienceops/expeditions/maps/monsoon.jpg

Summary and Objectives:

Integrated Ocean Drilling Program (IODP) Expedition 346 (29 July–27 September 2013) drilled seven sites covering a wide latitudinal range in the body of water bordered by the Eurasian continent, the Korean Peninsula, and the Japanese Islands, as well as two closely spaced sites in the East China Sea. This expedition recovered 6135.3 m of core with an average recovery of 101%—a record amount of core recovered during any single IODP expedition. Expedition 346 was the first scientific drilling expedition ever to focus exclusively on the climate system in this region, which is at once so critical yet potentially vulnerable to the challenges society faces in the coming years of global climate change. With the East Asian Monsoon directly affecting the water supply of one-third of the global population, the expedition scientific

results and postexpedition research that will follow have direct bearing on society's understanding of this complex atmosphere-ocean climate system.

Key Scientific objectives were:

1. Address the timing of onset of orbital- and millennial-scale variability of the EASM and EAWM and their relation with variability of Westerly Jet circulation.
2. Reconstruct orbital- and millennial-scale changes in surface and deepwater circulation and surface productivity during at least the last 5 m.y.
3. Reconstruct the history of the Yangtze River discharge using cores from the northern end of the East China Sea, as it reflects variation and evolution in the EASM and exerts an impact on the paleoceanography of the marginal sea.
4. Examine the interrelationship among the EASM, EAWM, nature and intensity of the influx through the Tsushima Strait, intensity of winter cooling, surface productivity, ventilation, and bottom water oxygenation in the marginal sea and their changes during the last 5 m.y.

Source of above information:

http://publications.iodp.org/preliminary_report/346/346pr_4.htm

Micropaleontology group in the Microscopy laboratory. (Credit: Cristina Lopes & IODP)

Indian Participation

Dr. Raj K Singh
Paleontologist (foraminifer-Benthic)
Assistant Professor, School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneshwar, Bhubaneshwar, India

Contribution:

Publications:

1. Tada, R., Murray, R.W., Alvarez Zarikian, C.A., and the Expedition 346 Scientists, 2015. *Proc. IODP*, 346: College Station, TX (Integrated Ocean Drilling Program). doi:10.2204/iodp.proc.346.2015

Abstract in Seminar/Conferences

1. Singh, R.K., Das, M., Abhijeet, Barik, S.S. and Kanjilal, A., 2014. Pleistocene Planktic Foraminifera proxy – a tool to understand Asian monsoon variations. In: Climate Change and Environmental Sustainability: Geological Records from Poles to Tropics at Lucknow University Lucknow on 9-10th September 2014.

2. Abhijith, U.V. and Singh R.K., 2015. Assessment of Late Quaternary variation in Asian Monsoon using foraminifera from the sediments of the IODP site U1429A. National Climate Science Conference, during 2-3rd July 2015 at IISc, Bangalore.

3. M., Holbourn A., Kanjilal, A., Ranjan, A., Gallagher S., Kuhnt W., 2015. Paleoceanographic significance of late Quaternary deep sea benthic foraminifers of the Japan Sea - a preliminary result. 25th Indian Collaquium of Micropaleontology and Stratigraphy, during 18 – 20th December 2015 at Institute of Science Aurangabad, Maharastra.

4. Singh, R.K., Holbourn A., Kuhnt, W., Das, M., 2016. Assessing deep sea temperature variability in East China Sea. In 2ndIODP Expedition 346 post cruise meeting, 22-24 January 2016. University of Melbourne, Australia.

5. Singh, R.K., Holbourn A., Kuhnt, W., Das, M., Pandey, D.K., 2016. Assessing deep sea water mass variability in East China Sea using population abundance and Mg/Ca ratio of benthic foraminifera. In Quaternary Climate: Recent Findings and Future Challenges, 28-30 April 2016. National Institute of Oceanography Goa.

6. Das, M., Singh, R.K., Holbourn A., Farooq, S.H., Kanjilal, A., Expedition 346 Scientist, 2016. Variations in East Asian Winter Monsoon and its impact on the paleoceanography of Japan Sea over 400ka. In Quaternary Climate: Recent Findings and Future Challenges, 28-30 April 2016. National Institute of Oceanography Goa.

7. Bassetti, M.A., Alvarez-Zarikian, C., Angue-Minto'O, A.M., Courtillart M., Hull, K., Holbourn, A., Singh, R.K., Wan, S., Zhao, D., and Expedition 346 Scientist, 2016. Sediment input and bottom water trophic level in the East China Sea, in response to glacial/interglacial sea level change and monsoon rainfall intensity. Insights from the benthic microcustaceans (Ostracods) and foraminifera at IODP site U1429 (Expedition – 346). In 35th International Geological Congress, 27th August to 4th September 2016, Cape Town, South Africa.

Dr. Raj K. Singh (Paleontologist, Indian Institute of Technology, India) collects a core catcher sample for micropaleontological observations.

Sponsored Research Projects:

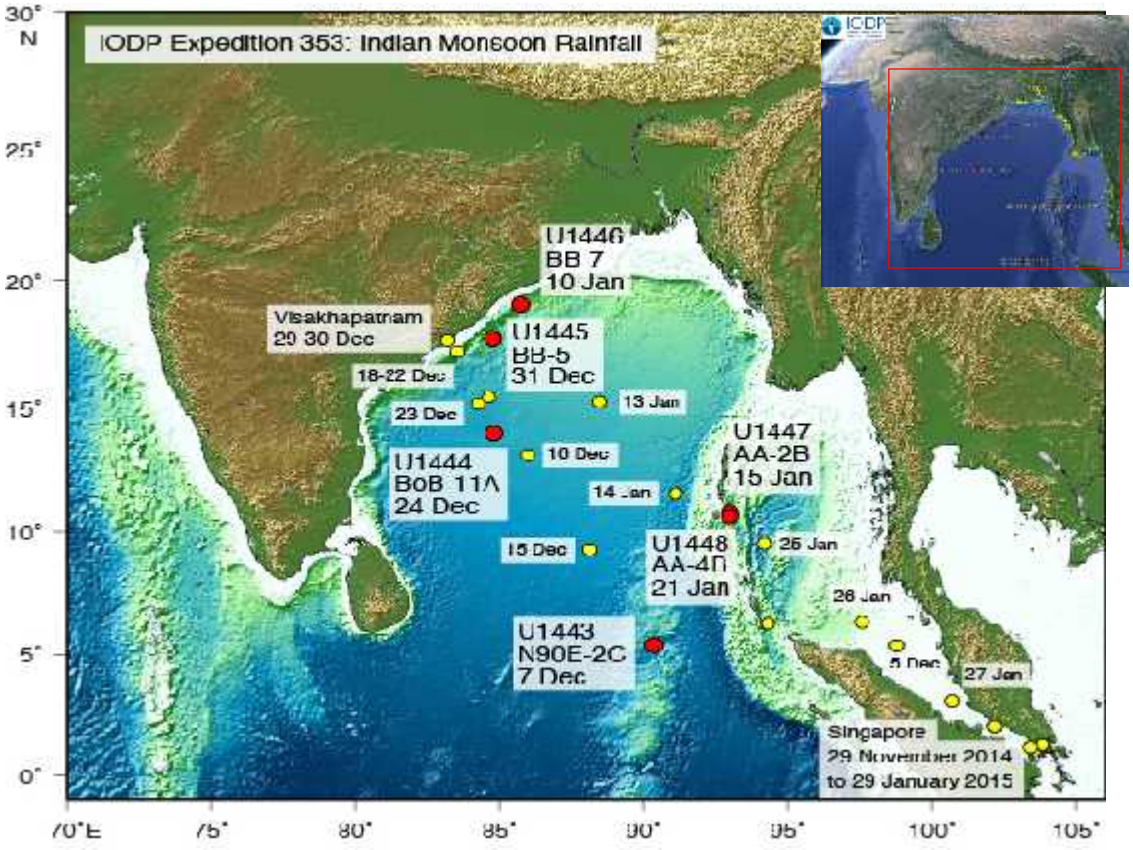
Millennial to centennial scale variability in the Asian summer monsoon: Foraminiferal perspective from the East China Sea, Sponsor: NCAOR, Goa, MoES, Govt. of India

International Ocean Discovery Program Expedition 353

Indian Monsoon Rainfall

General Information

Sites: U1443–U1448
Dates: 29 November 2014–29 January 2015
Ports: Singapore to Singapore
Co-chief Scientists: Steven Clemens & Wolfgang Kuhnt
Staff Scientist: Leah LeVay



Source: http://iodp.tamu.edu/scienceops/maps/exp/353/353transit.jpg

Summary and Objectives

International Ocean Discovery Program (IODP) Expedition 353 (29 November 2014–29 January 2015) drilled six sites in the Bay of Bengal, recovering 4280 m of sediments during 32.9 days of on-site drilling. Recovery averaged 97%, including coring with the advanced piston corer, half-length advanced piston corer, and extended core barrel systems. The primary objective of Expedition 353 is to reconstruct changes in Indian monsoon circulation since the Miocene at tectonic to centennial timescales. Analysis of the sediment sections recovered will improve our understanding of how monsoonal climates respond to changes in forcing external to the Earth's climate system (i.e., insolation) and changes in forcing internal to the Earth's climate system, including changes in continental ice volume, greenhouse gases, sea level, and the ocean-atmosphere exchange

of energy and moisture. All of these mechanisms play critical roles in current and future climate change in monsoonal regions.

The key scientific objectives were categorized as followed:

Pliocene–Pleistocene objectives

Pliocene–Pleistocene objectives include reconstructing salinity changes as well as the erosion and runoff signals in the Bay of Bengal and Andaman Sea in order to

1. Establish the sensitivity and timing of changes in monsoon circulation relative to insolation forcing, latent heat export from the Southern Hemisphere, global ice volume extent, and greenhouse gas concentrations;
2. Determine the extent to which Indian and East Asian monsoon winds and precipitation are coupled and at what temporal and geographic scales;
3. Better separate the effects of climate change and tectonics on erosion and runoff; and
4. Provide verification targets for climate models: the majority of current atmosphere–ocean general circulation models do not accurately simulate the spatial or intra-seasonal variability of monsoon precipitation.

Dr. Netramani Sagar takes a headspace gas sample for analysis.

Deep-time objectives

Deep-time objectives include the following:

Scientists gather around the description table in the Core Laboratory. (Credit: Kaustubh Thirumalai and

1. To understand the timing and conditions under which monsoonal circulation initiated and reconstruct the variability of the Indian monsoon at orbital timescales;
2. To unravel the relationship between Indian monsoon variability and major past global climatic events such as the Oligocene/Miocene cooling (Zachos et al., 1997), the onset of the mid-Miocene Climatic Optimum (Holbourn et al., 2007; Zachos et al., 2001), mid-Miocene cooling and Antarctic cryosphere expansion (Holbourn et al., 2013), and the Pliocene–Pleistocene enhancement of Northern Hemisphere glaciation (Lisiecki and Raymo, 2005, 2007);
3. To establish a complete Oligocene–present astronomically tuned timescale based on high-resolution benthic and planktonic isotope reference curves for the Indian Ocean; and
4. To incorporate high-resolution distribution studies of well-preserved Oligocene–recent calcareous and siliceous microfossils from the Indian Ocean into global compilation studies of paleoclimatic and biotic evolution.

Source of above information: http://publications.iodp.org/preliminary_report/353/

Indian Participation

1. **Dr. Netramani Sagar**
   Inorganic Geochemist
   Geochemistry Division,
   National Geophysical Research Institute,
   Hyderabad, India

2. **Dr. Aditya Paketi**
   Inorganic Geochemist
   Geological Oceanography Division,
   National Institute of Oceanography

3. **Shri. Dinesh Kumar Naik**
   Sedimentologist
   Geological Oceanography Division
   National Institute of Oceanography
   Goa, India

Dr. Aditya Paketi entering data at one of the description tables in the core laboratory. (Credit: Markus Fingerle & IODP)

Contributions:

Publication(s):

1. Clemens, S.C., Kuhnt, W., LeVay, L.J., and the Expedition 353 Scientists, 2016. *Indian Monsoon Rainfall*. Proceedings of the International Ocean Discovery Program, 353: College Station, TX (International Ocean Discovery Program). http://dx.doi.org/10.14379/iodp.proc.353.2016
2. Clemens Steven C. et al (including Sagar N., Peketi A, Naik D.), 2015, International Ocean Discovery Program Preliminary Report, 353. http://dx.doi.org/10.14379/iodp.pr.353.2015 Publisher: International Ocean Discovery Program, ISSN: World Wide Web:2372-9562.

Conferences:

3. Sagar N., L. LeVay, Naik D., Peketi A., and the Expedition 353 Scientific Party (2015) International Ocean Discovery Program (IODP) Expedition 353: Indian Monsoon Rainfall. Indian Geophysical Union: 52nd Annual Convention, 3-5 November, Goa, India.
4. Peketi A., Mazumdar A., Nahak S., and the Expedition 353 Scientific Party Pore water sulfate concentrations and sulfate sulfur isotope ratio measurements from IODP 353. Indian Geophysical Union: 52nd Annual Convention November 3-5, 2015. Goa, India.

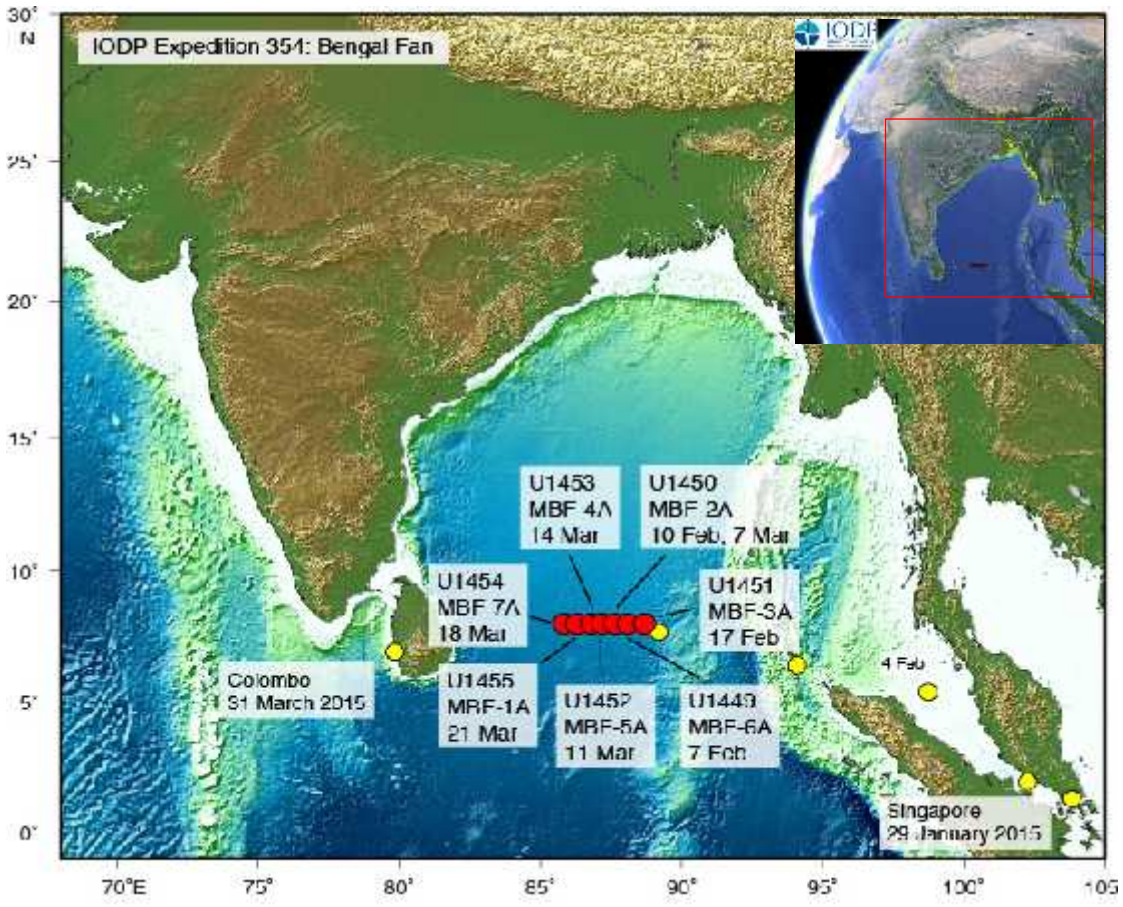
International Ocean Discovery Program Expedition 354

Bengal Fan

Neogene and late Paleogene record of Himalayan orogeny and climate: a transect across the Middle Bengal Fan

General Information

Sites: U1449–U1455
Dates: 29 January–31 March 2015
Ports: Singapore to Colombo, Sri Lanka
Co-chief Scientists**:** Christian France-Lanord &Volkhard Spiess
Staff Scientist: Adam Klaus



Source: http://iodp.tamu.edu/scienceops/maps/exp/354/354transit.jpg

Summary and Scientific Objectives:

International Ocean Discovery Expedition 354 to 8°N in the Bay of Bengal drilled a seven site, 320 km long transect across the Bengal Fan. Three deep-penetration and an additional four shallow holes give a spatial overview of the primarily turbiditic depositional system that comprises the Bengal deep-sea fan. Sediments originate from Himalayan rivers, documenting terrestrial changes of Himalayan erosion and weathering, and

are transported through a delta and shelf canyon, supplying turbidity currents loaded with a full spectrum of grain sizes. Mostly following transport channels, sediments deposit on and between levees while depocenters laterally shift over hundreds of kilometers on millennial timescales. During Expedition 354, these deposits were documented in space and time, and the recovered sediments have Himalayan mineralogical and geochemical signatures relevant for reconstructing time series of erosion, weathering, and changes in source regions, as well as impacts on the global carbon cycle. Miocene shifts in terrestrial vegetation, sediment budget, and style of sediment transport were tracked. Expedition 354 has extended the record of early fan deposition by 10 My into the late Oligocene.

Scientific Objectives:

We focused on (1) the erosional history of the Himalaya and its bearing on the development of the Himalaya and Tibet as topographic features and (2) the development of the Asian monsoon in Cenozoic time as recorded in the Bay of Bengal.

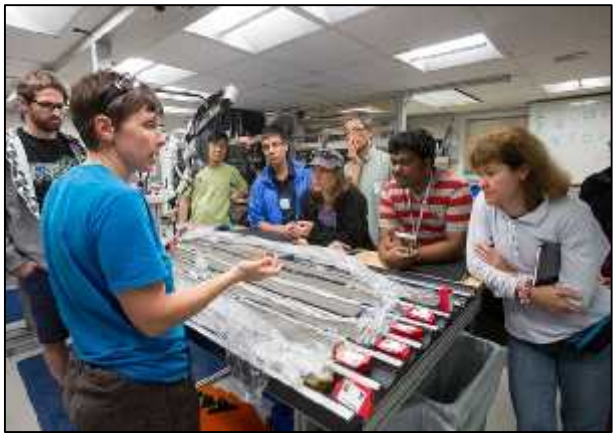
1. Calibration of Neogene to present changes
2. Forcing of the carbon cycle and climate
3. Sampling of the oldest sediment of the fan
4. Determining fan architecture and spatial depocenter variability.

Source of above information:

http://publications.iodp.org/preliminary_report/354/

http://publications.iodp.org/scientific_prospectus/354/354sp_7.htm

http://iodp.tamu.edu/scienceops/expeditions/bengal_fan.html



Lisa Crowder gives the core flow description to Scientists. (Credits: Tim Fulton, IODP JRSO)

Dr. Supriyo Das conducting analysis in the Chemistry Laboratory. (Credit: Sonja Storm, IODP JRSO)

Indian Participation

1. Dr. M.C.Manoj
Sedimentologist
Marine Micropaleontology
Birbal Sahni Institute of Palaeobotany
Lucknow, India

2. Dr. Supriyo Das
Organic Geochemist
Department of Geology
Presidency University,
Calcutta, India

Contribution:

Publications:

1. France-Lanord, C., Spiess, V., Klaus, A., Schwenk, T., and the Expedition Scientists, 2016. *Bengal Fan*. Proceedings of the International Ocean Discovery Program, 354: College Station, TX (International Ocean Discovery Program). http://dx.doi.org/10.14379/iodp.proc.354.2016

Abstracts/Conferences:

1. Dekens Petra et al (including Manoj M.C.), Paleoceanographic history of the Lower Bengal Fan during the last glacial cycle – IODP Expedition 354. AGU Fall meeting. December 2015.
2. Weber M.E. et al (including Manoj M.C.). Reconstructing the evolution of the Bengal Fan with the aid of physical and optical properties – IODP Expedition 354. German IODP meeting 2016. March 2016.
3. Yoshida Kohki, Gyawali Babu Ram, Osaki Ai, Hatano Nozomi, Manoj M.C., France-Lanord Christian, Spiess Volkard, Klaus Adam and IODP Expedition 354 Science Party. Heavy mineral assemblage in Early- Middle Miocene sands from Bengal Fan from IODP Exp. 354; preliminary report. Himalayan Karakorum Tibetan Workshop. May 2016.
4. Ponton Camilo, Galy Valier, Galy Albert and IODP Expedition 354 science party. Wood-rich turbidites in the Bengal Fan: A discovery by IODP expedition 354. Goldschmidt 2015. 2518. August 2015.
5. Huyghe Pascale, France-Lanord Christian, Spiess Volkhard, Schwenk Tilmann, Klaus Adam & IODP Expedition 354 Science party. First results on Neogene and late Paleogene record of Himalayan orogeny and climate from a transect across the Middle Bengal Fan (IODP Expedition 354). 15th French Sedimentology Society. October 2015.
6. Bahk Jang-Jun, France-Lanord Christian, Spiess Volkhard, Schwenk Tilmann, Klaus Adam, and IODP Expedition 354 Scientists. Shipboard results on record of Himalayan orogeny and climate across the Middle Bengal Fan (IODP Expedition 354). International Conference on Asian Marine Geology. October 2015.
7. Das Supriyo K., Adhikari Rishi, France-Lanord Christian, Spiess Volkhard, Schwenk Tilmann, Klaus Adam & IODP Expedition 354 Science party. Characterization of organic matter to understand methanogenesis in Bengal Fan Sediments. 52nd Annual Convention. Indian Geophysical Union 2015. November 2015.
8. France-Lanord Christian, Spiess Volkhard, Klaus Adam, Galy Albert, Galy Valier, and IODP Expedition 354 Science party. IODP Expedition 354: A Bengal fan record of Himalayan erosion, weathering and organic carbon burial during the Neogene. AGU Fall meeting. December 2015.
9. Miller Jackson, Dekens Petra, Spiess Volkhard, France-Lanord Christian and Expedition 354 Scientific Party. Reconstructing oceanographic from the Holocene to the last glacial maximum in the Bay of Bengal. AGU Fall meeting. December 2015.
10. Shiu Janice, Williams Khrista, Dekens Petra, Spiess Volkhard, France-Lanord Christian and Exp 354 Shipboard Scientific Party. ^{18}O and Mg/Ca Analysis on Mid-Pleistocene Foraminifera from the Bay of Bengal. AGU Fall meeting. December 2015.
11. Reilly Brendan, Selkin Peter, Meynadier Laure, Savian Jairo, Spiess Volkhard, Stoner Joseph, Weber Michael, France-Lanord Christian, Klaus Adam and the Expedition 354 Shipboard Scientific Party. Paleomagnetic and Environmental Magnetic Insights into the Middle to Late Pleistocene Stratigraphy of the Middle Bengal Fan, IODP Expedition 354. AGU Fall meeting. December 2015.
12. Fritz-Endres Theresa, Dekens Petra, Fox Lyndsey, Spiess Volkhard, France-Lanord Christian and Exp 354 Shipboard Scientific Party. Sedimentary Controls on Foraminifera Distribution in the Bay of Bengal. AGU Fall meeting. December 2015.

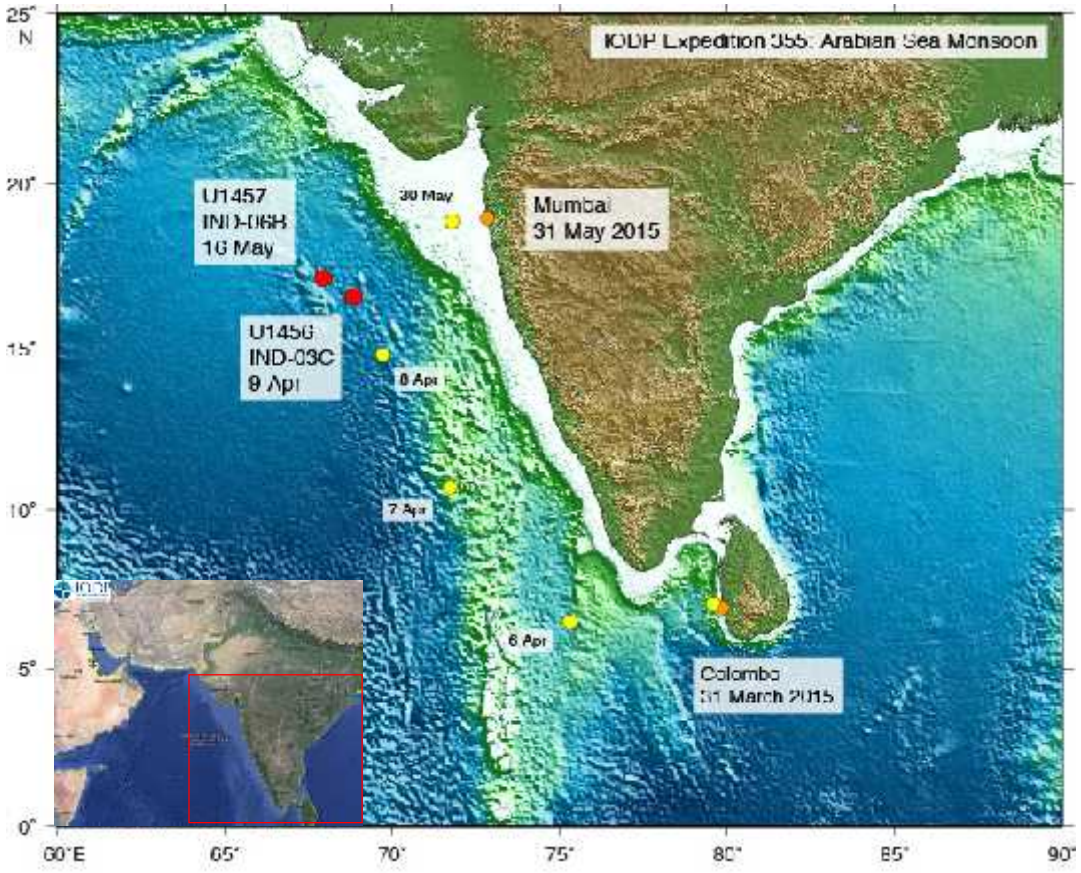
International Ocean Discovery Program Expedition 355

Arabian Sea Monsoon

Deep sea drilling in the Arabian Sea: constraining tectonic-monsoon interactions in South Asia

General Information

Sites**:** U1456–U1457
Dates**:** 31 March–31 May 2015
Ports**:** Colombo, Sri Lanka to Mumbai, India
Co-chief Scientists: Dhananjai Pandey & Peter Clift
Staff Scientist: Denise Kulhanek



Source: http://iodp.tamu.edu/scienceops/maps/exp/355/355transit.jpg

Summary and Scientific Objectives

The Indian (southwest) summer monsoon is one of the most intense climatic phenomena on Earth. Its long-term development has been linked to the growth of high topography in South and Central Asia. The Indian continental margin, adjoining the Arabian Sea, offers a unique opportunity to investigate tectonic–climatic interactions and the net impact of these processes on weathering and erosion of the western Himalaya. During International Ocean Discovery Program Expedition 355, two sites (U1456 and U1457) were drilled in Laxmi

Basin in the eastern Arabian Sea to document the coevolution of mountain building, weathering, erosion, and climate over a range of timescales. In addition, recovering basement from the eastern Arabian Sea provides constraints on the early rifting history of the western continental margin of India with special emphasis on continental breakup between India and the Seychelles and its relationship to the plume-related volcanism of the Deccan Plateau.

Key Scientific objectives include:

1. Reconstruct long-term changes in erosion and weathering rates at submillennial to millennial timescales in order to compare with existing records of high frequency climatic variability.
2. Reconstruct changes in erosion and weathering intensity over tectonic timescales and assess whether any changes occurred at ~23, 15, and 10–8 Ma to test earlier hypotheses that invoke changes in monsoon intensity at those times.
3. Decipher the nature of basement rocks in Laxmi Basin and constrain the timing of early seafloor spreading and the relationship to the emplacement of Deccan Flood Basalts. Does mantle plume initiation predate or postdate rifting and early spreading?

Co-chiefs and the scientific party reviewing seismic data for the selection of site 1457. (Credit: Bill Crawford, IODP JRSO)

Source of above information:

http://publications.iodp.org/preliminary_report/355/
http://publications.iodp.org/scientific_prospectus/355/355sp_10.htm
http://iodp.tamu.edu/scienceops/expeditions/arabian_sea.html

Indian Participation

1. Dr. Dhananjai K. Pandey
Co-chief Scientist
Department of Marine Geophysics
National Centre for Antarctic and Ocean Research
Goa, India

2. Dr. Ravi Mishra
Sedimentologist
National Centre for Antarctic and Ocean Research
Goa, India

3. Dr. Manish Tiwari
Inorganic Geochemist

Dr. Ravi Mishra examines a smear slide from one of the cores. (Credit: Bill Crawford, IODP JRSO)

National Centre for Antarctic and Ocean Research
Goa, India

4. Dr. Rajeev Saraswat
Physical Properties Specialist
Geological Oceanography Division
National Institute of Oceanography
Goa, India

5. Prof. Arun D. Singh
Paleontologist (foraminifers)
Department of Geology
Banaras Hindu University, Varanasi, India

6. **Girish K. Sharma**
Paleontologist (radiolarians)
Deparment of Geology
Kumaun University, India

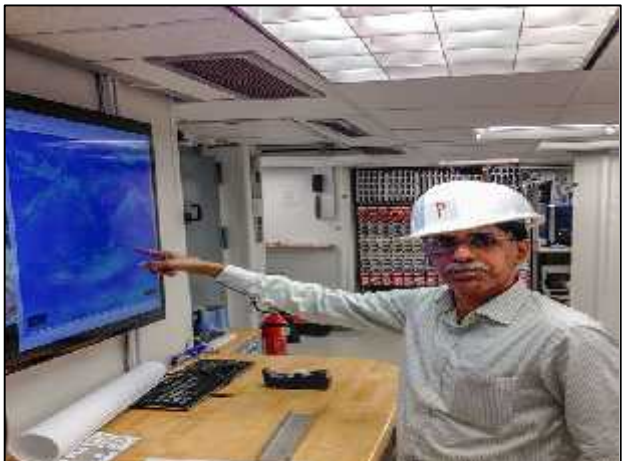
7. Tallavajhala Radhakrishna
Paleomagnetist/Petrologist
Geosciences Division
National Centre for Earth Science Studies
India

8. Mr. Anil Kumar
Sedimentologist
Department of Science and Technology
Wadia Institute of Himalayan Geology, Dehradun
India

9. Dr. Arumugam Ganesh Kumar
Microbiologist
Marine Biotechnology Department
National Institute of Ocean Technology
India

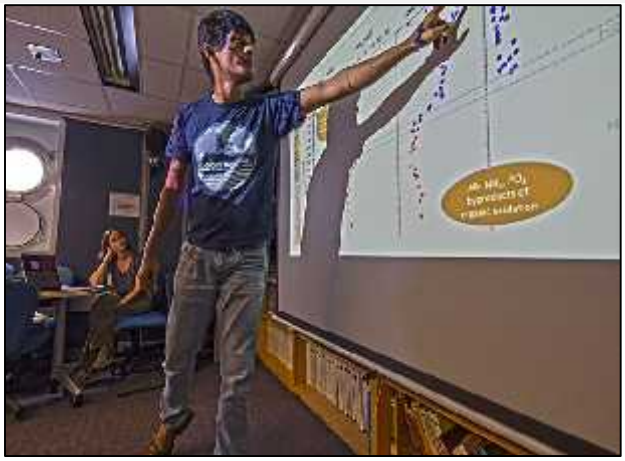
10. Mr. Gundiga P. Gurumurthy
Inorganic Geochemist
Manipal Centre for Natural Sciences
Manipal University, India

11. **Mr. Rakesh Saxena**
Physical Properties Specialist
ONGC, India



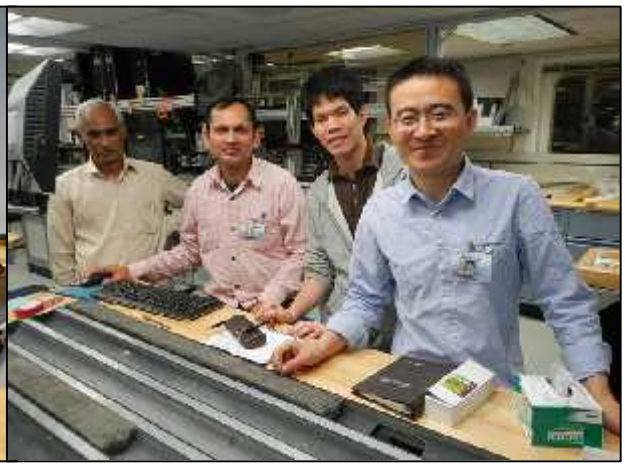
Dr. Arun Singh points to the surface wind patterns

Mr. Anil Kumar takes a small amount of sediment from a core section to examine the microscopic constituents of the sediment

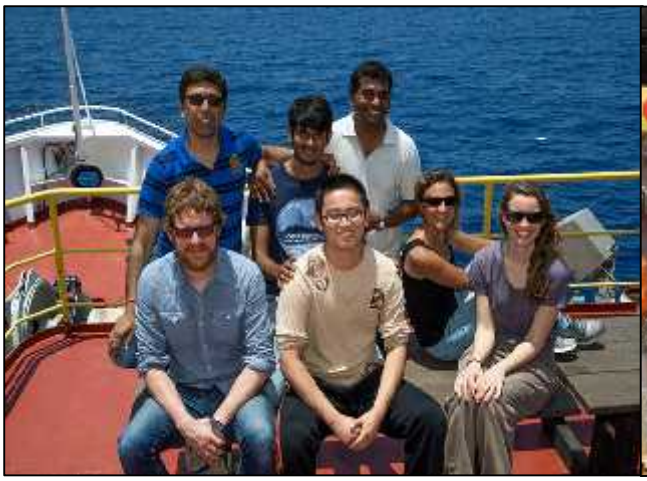


Mr. Gundiga Gurumurthy explains the interstitial water results of Site U1456 to the science party.

Mr. Girish Sharma examines a water sample for these tiny zooplankton. (Credit: Bill Crawford, IODP JRSO)

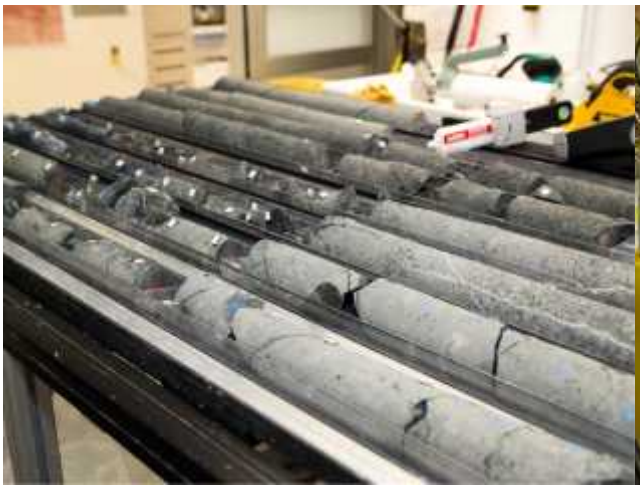


Dr. T. Radhakrishna, Dr. Ravi Mishra and other 'sunrise shift' sedimentologists.



The geochemists and microbiologist of Expedition 355

Dr. Rajeev Saraswat prepares to load a whole-round core section on the Whole-Round Multisensor Logger (WRMSL)

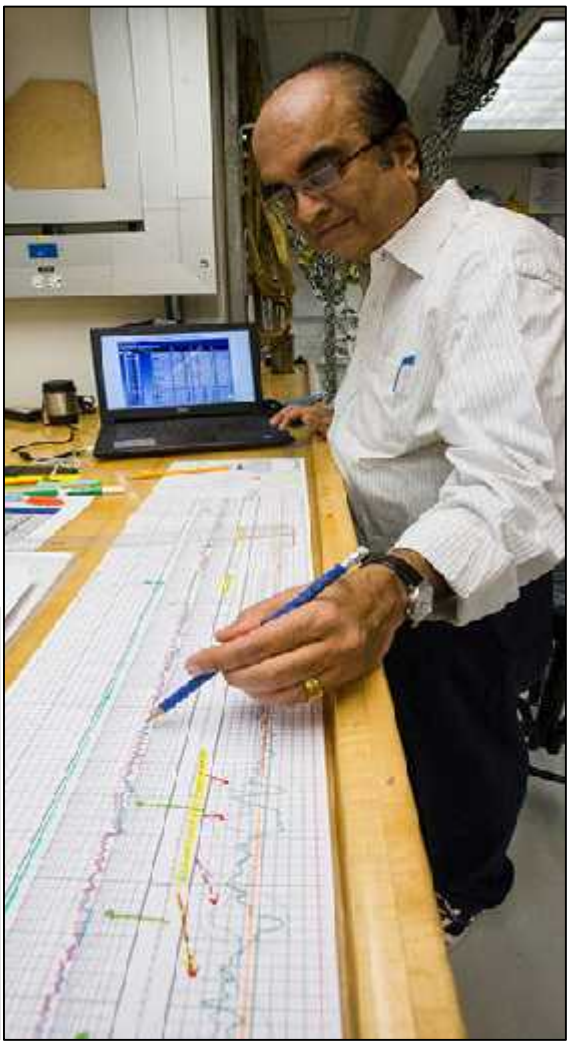


Basalt Cores from site 1457

Touching the basement

A. Ganesh Kumar prepares samples to look for microbes living in the seafloor sediment. (Credit: Bill Crawford, IODP JRSO)

The Co-Chiefs, Curator, and Staff Scientist meet with a group of scientists to discuss research plans and sample requests. (Credit: Bill Crawford, IODP JRSO)



Mr. Rakesh Saxena (ONGC, India) examines the downhole logging data from Hole U1456C.

Contributions:

Publication(s):

1. Pandey, D.K., Clift, P.D., Kulhanek, D.K., and the Expedition 355 Scientists, 2016. *Arabian Sea Monsoon.* Proceedings of the International Ocean Discovery Program, 355: College Station, TX (International Ocean Discovery Program). http://dx.doi.org/10.14379/iodp.proc.355.2016

2. Pandey, D.K., P.D. Clift, D.K. Kulhanek, and the Expedition 355 Scientists (2015). Deep sea drilling in the Arabian Sea: constraining tectonic-monsoon interactions in South Asia. Preliminary Report of International Ocean Discovery Program Expedition 355. pp. 1-46, doi:10.2204/iodp.pr.355.2015.

Paper /Poster Presented in Seminar/Conferences

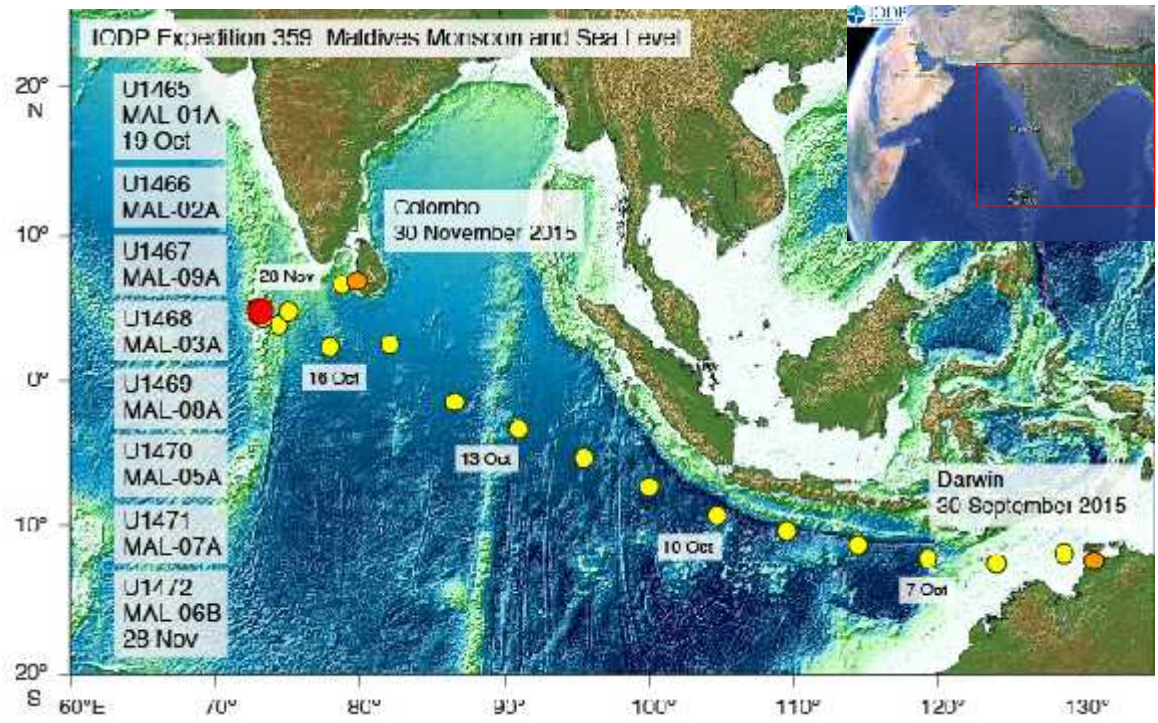
3. Mishra Ravi, Pandey D.K., Ramesh Prerna; Arab Sagar mai Sakriya Sindhu Antah samudri sarita tantra evam unaki aksansiya kriyasilata. Poster presented in National Hindi Scientific Seminar held at INCOIS, Hyderabad in 28-29 Sept 2015.
4. Mishra Ravi, Pandey D.K., Nayak G.N., Clift P.D., Kulhanek D.K. and Exp 355 Scientists Turbidites from the Indus fan at IODP sites U1456 and U1457 in the Laxmi basin. Poster presented in the 52nd Annual Convention of Indian Geophysical Union, held in NCAOR, Goa on Nov 3-5 Nov 2015.
5. Mishra Ravi, Ramesh Prerna and Pandey D. K.; Mid Indus Submarine channel morphometry and sinuosity: Result from high resolution Multibeam bathymetry data. Poster presented in International symposium on Indian Ocean "Dynamics of the Indian Ocean: Perspective and Retrospective (IO50)" Goa, India on 30th Nov to 4th Dec 2015.
6. Tripathi Shubham, Tiwari Manish, Nagoji Siddhesh and IODP Expedition 355; Productivity Variability based on Nitrogen and Carbon Isotopes in Squeeze Cake Samples recovered during IODP Expedition 355.. Poster presented in IGU, Goa 2015.
7. Tripathi S., Tiwari Manish , Lee J., Khim B.K., Nagoji S., Kumar V. and IODP Expedition 355 Scientists (2016). Denitrification in the eastern Arabian Sea since Late Miocene. In the proceedings of the conference on "Quaternary Climate: Recent Findings and Future Challenges", p.51, held at NIO, Goa from 28-30 April 2016.
8. Clift Peter D., Pandey Dhananjai K., Kulhanek Denise, Ando Sergio and the Expedition 355 Scientific Party. Cenozoic Climate-Tectonic Interactions in the Western Himalaya Recorded in the Indus Submarine Fan from IODP Expedition 355. Paper presented in AGU, 2015.
9. Liddy Hannah M., Feakins Sarah J., Tauxe Lisa, Scardia Giancarlo, Andò Sergio, Bendle James, Clift Peter D., and IODP Expedition 355 Science Party. Indus-wide C_4 expansion between 7-6 Myr: an IODP Expedition 355 discovery. Paper presented in AGU, 2015.
10. Routledge Claire M., Kulhanek Denise K., Tauxe Lisa, Scardia Giancarlo, Singh Arun, Steinke Stephan, Wise Sherwood W., and the Expedition 355 Scientific Party; Miocene–Pliocene Calcareous Nannofossil Biostratigraphy of IODP Site U1457, Arabian Sea.. Paper presented in GSA, 2015.
11. Pandey Dhananjai K., Clift Peter D., Kulhanek Denise and Expedition 355 Scientists; Deciphering Climate-tectonic interactions in the Western Himalaya through scientific drilling in the Arabian Sea: IODP Expedition 355. Paper presented in IGU, Goa
12. Lee J., Tripathi S., Tiwari M., Khim B.K., IODP Expedition 355 Scientists; δ^{13} C and δ^{15} N variations of bulk sediments at IODP Exp. 355 Site U1456: Preliminary results to provenance and productivity. Paper presented in Goldschmidt conference 2016.
13. Masao Iwai, Kenta Suzuki, Dhananjai Pandey, Peter Clift, Denise Kulhanek, and Expedition 355 Scientists Initial results of IODP Expedition 355, Cenozoic Arabian Sea Monsoon.. Paper presented in J-DESC (the Japan Program Member Office) to present at the Japan Geoscience Union Meeting, 2016.

International Ocean Drilling Program Expedition 359

Sea Level, Currents, and Monsoon Evolution in the Indian Ocean

General Information

Sites: U1465–U1472
Dates: 30 September to 30 November 2015
Ports: Darwin, Australia to Colombo, Sri Lanka
Co-chief Scientists: Christian Betzler & Gregor Eberli
Staff Scientist: Carlos Alvarez Zarikian



Source: http://iodp.tamu.edu/scienceops/expeditions/maldives_monsoon.html

Summary and Scientific Objectives:

International Ocean Discovery Program Expedition 359 was designed to address changes in sea level and currents, along with monsoon evolution in the Indian Ocean. Eight drill sites are located in the carbonate edifice of the Republic of Maldives, which bears a unique and mostly unread Indian Ocean archive of the evolving Cenozoic icehouse world. This tropical marine record is key for better understanding the effects of this global evolution in the Indo-Pacific realm. The bank geometries of the growing carbonate archipelago provide a physical record of changing sea level and ocean currents. The bank growth occurs in pulses of aggradation and progradation that are controlled by sea level fluctuations during the early and middle Miocene, including the mid-Miocene Climate Optimum. A dramatic shift in development of the carbonate edifice from a sea level–controlled to a predominantly current-controlled system appears to be directly linked to the evolving Indian monsoon. This phase led to a twofold configuration of bank development: bank growth continued in

some parts of the edifice, whereas in other places, banks drowned. Drowning steps seem to coincide with onset and intensification of the monsoon-related current system and deposition of contourite fans and giant sediment drifts. Expedition 359 cores are intended for reconstructing the changing current system through time that is directly related to the evolution of the Indian monsoon. As such, the drift deposits will provide a continuous record of Indian monsoon development in the region of the Maldives.

The specific objectives of Expedition 359 were as follows.

1. To decipher the record of Neogene environmental changes in the Maldives sediment archive.
2. To place the Maldives current system into the larger scale ocean current framework present during Neogene global cooling and monsoon evolution.
3. To obtain a continuous carbon isotopic record to calibrate a platform and platform margin record with the pelagic record.
4. To reconstruct the Cenozoic paleoclimate of the Indian Peninsula.

Dr. Nagender Bejugam at the sampling table in the core lab. (Credit: Tim Fulton, IODP/TAMU)

Source of above information:

http://publications.iodp.org/preliminary_report/359/
http://publications.iodp.org/scientific_prospectus/359/359sp_7.htm

Dr. Nagender Bejugam working at the sampling table. (Credit: Tim Fulton, IODP/TAMU)

Indian Participation

Nagender N. Bejugam
Sedimentologist
Geological Oceanography Division,
National Institute of Oceanography,
Goa, India

Contribution:

Publication(s):

Betzler Christian et al, (including Bejugam Nagender N.), 2016, The abrupt onset of the modern South Asian Monsoon winds. NATURE|SCIENTIFIC REPORTS|6:29838|DOI: 10.1038/srep29838.

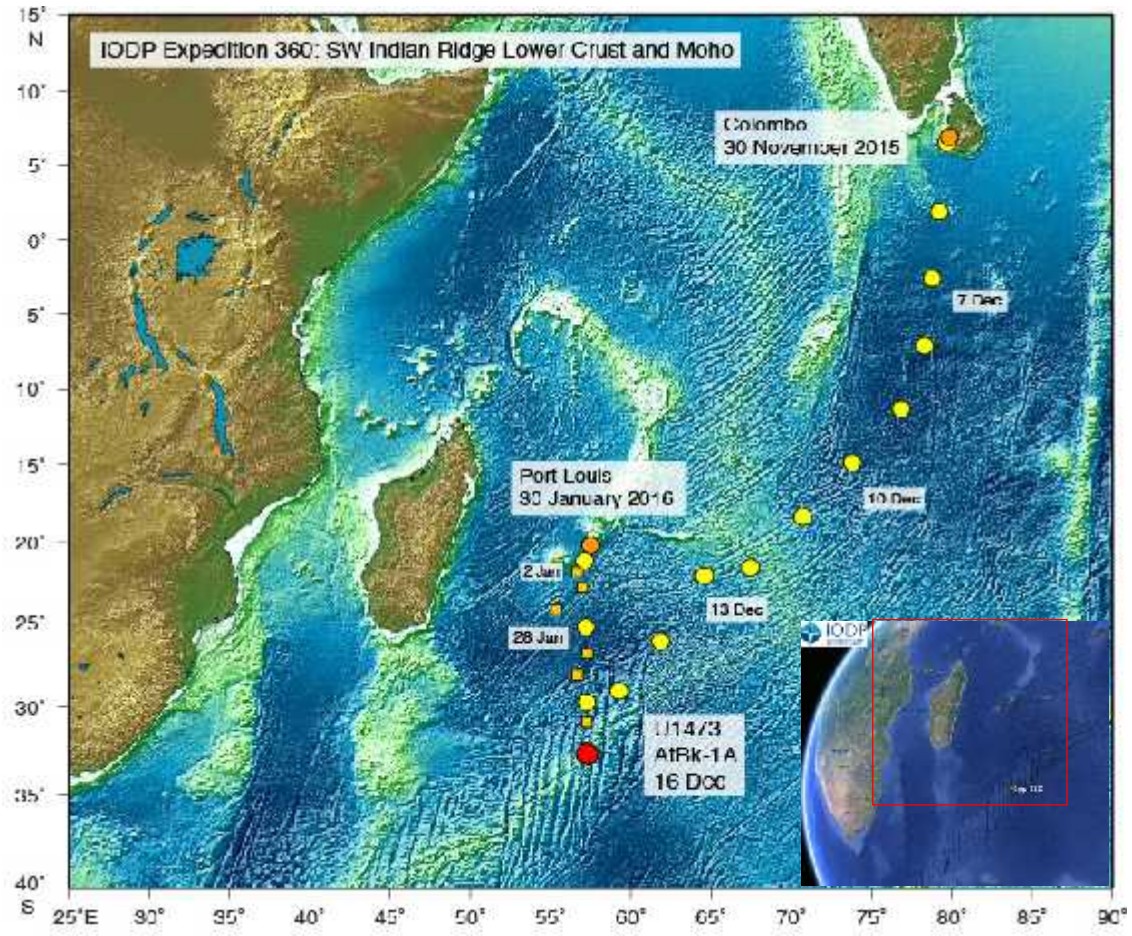
International Ocean Drilling Program Expedition 360

Southwest Indian Ridge Lower Crust and Moho

The nature of the lower crust and Moho at slower spreading ridges (SloMo-Leg 1)

General Information

Sites: U1473
Dates: 30 November 2015 to 30 January 2016
Ports: Colombo, Sri Lanka to Port Louis, Mauritius
Co-chief Scientists: Henry Dick and Chris MacLeod
Staff Scientist: Peter Blum



Source: http://iodp.tamu.edu/scienceops/expeditions/indian_ridge_moho.html

Summary and Scientific objectives:

International Ocean Discovery Program (IODP) Expedition 360 was the first leg of Phase I of the SloMo (shorthand for "The nature of the lower crust and Moho at slower spreading ridges") Project, a multiphase drilling program that proposes to drill through the outermost of the global seismic velocity discontinuities, the Mohorovičić seismic discontinuity (Moho). The Moho corresponds to a compressional wave velocity increase,

typically at ~7 km beneath the oceans, and has generally been regarded as the boundary between crust and mantle. An alternative model, that the Moho is a hydration front in the mantle, has recently gained credence upon the discovery of abundant partially serpentinized peridotite on the seafloor and on the walls of fracture zones, such as at Atlantis Bank, an 11–13 My old elevated oceanic core complex massif adjacent to the Atlantis II Transform on the Southwest Indian Ridge.

The key scientific objectives were:

1. What is the igneous stratigraphy of the lower ocean crust?
2. How much mantle is incorporated into the lower crust?
3. What are the modes of melt transport into and through the lower crust?
4. How does the lower crust shape the composition of mid-ocean-ridge basalt (MORB)?
5. What is the strain distribution in the lower crust during asymmetric seafloor spreading?
6. What is the nature of magnetic anomalies?
7. Is there life in the lower crust and hydrated mantle?
8. What is the role of the lower crust and shallow mantle in the global carbon cycle?

Scientists examine the core samples.

Source of above information:

http://iodp.tamu.edu/scienceops/expeditions/indian_ridge_moho.html

http://publications.iodp.org/preliminary_report/360/

http://publications.iodp.org/scientific_prospectus/360/360sp_8.htm\

Indian Participation

Dr. Biswajit Ghosh
Igneous Petrologist,
Department of Geology
University of Calcutta, India

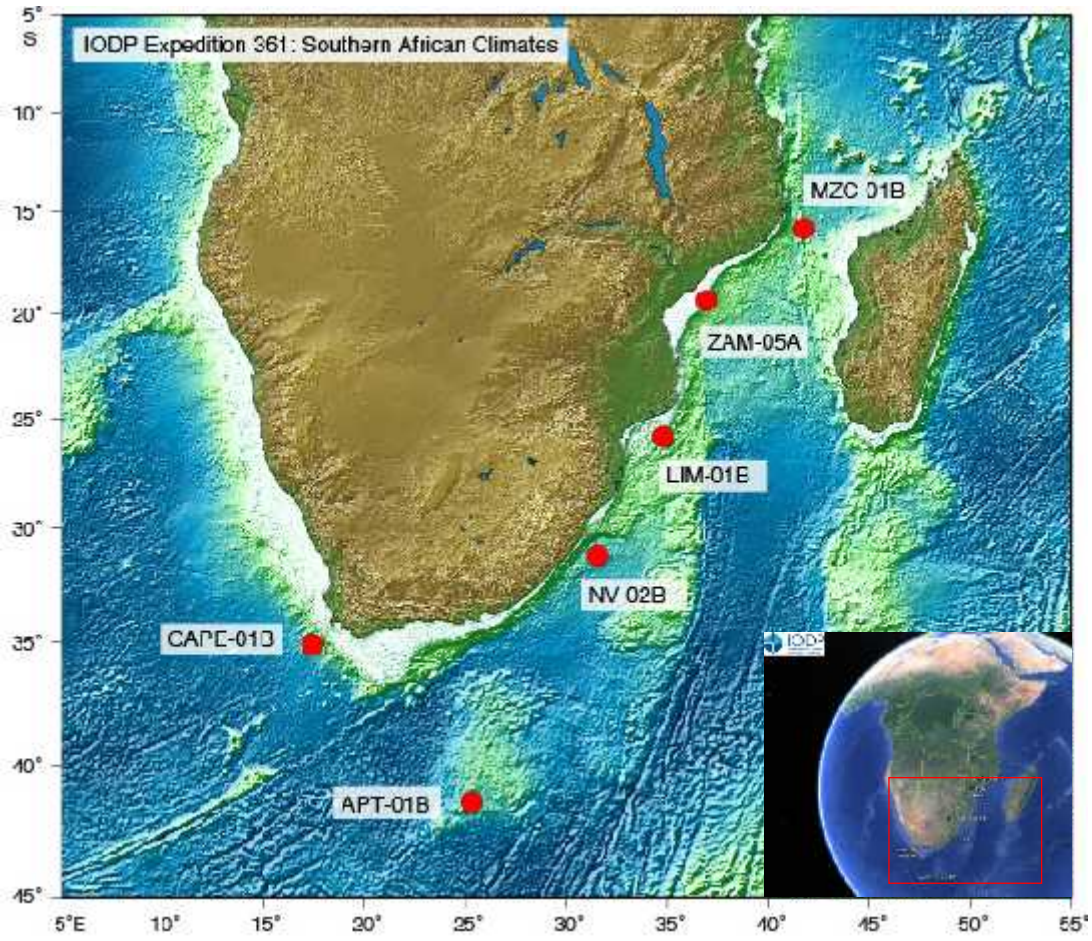
Dr. Biswajit Ghosh, India

International Ocean Drilling Program Expedition 361

South African Climates (Agulhas LGM Density Profile)

General Information

Sites: U1474–U1479
Dates: 30 January to 31 March 2016
Ports: Port Louis to Cape Town, South Africa
Co-chief Scientists: Ian Hall and Sidney Hemming
Staff Scientist: Leah LeVay

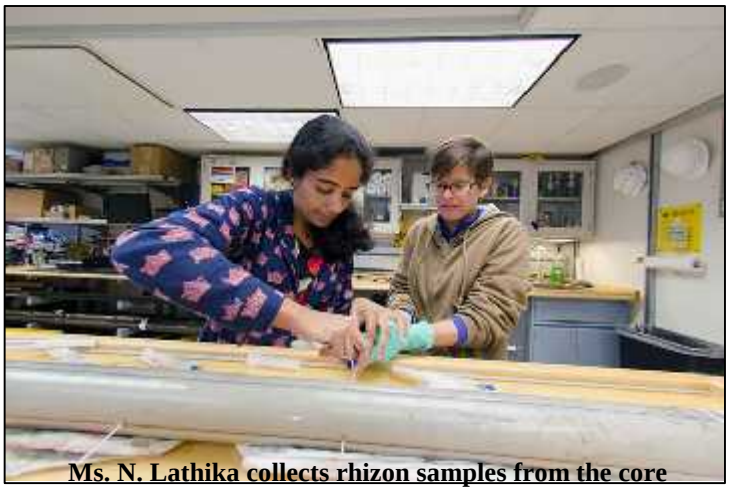


Source: http://iodp.tamu.edu/scienceops/expeditions/southern_african_climates.html

Summary and Scientific objectives:

International Ocean Discovery Program (IODP) Expedition 361 drilled six sites on the southeast African margin and in the Indian-Atlantic ocean gateway, southwest Indian Ocean, from 30 January to 31 March 2016. In total, 5175 m of core was recovered, with an average recovery of 102%, during 29.7 days of on-site operations. The sites, situated in the Mozambique Channel at locations directly influenced by discharge from the Zambezi and Limpopo River catchments, the Natal Valley, the Agulhas Plateau, and Cape Basin, were targeted to reconstruct the history of the greater Agulhas Current system over the past ~5 my. The Agulhas

Current is the strongest western boundary current in the Southern Hemisphere, transporting some 70 Sv of warm, saline surface water from the tropical Indian Ocean along the East African margin to the tip of Africa. Exchanges of heat and moisture with the atmosphere influence southern African climates, including individual weather systems such as extratropical cyclone formation in the region and rainfall patterns. Recent ocean model and paleoceanographic data further point at a potential role of the Agulhas Current in controlling the strength and mode of the Atlantic Meridional Overturning Circulation (AMOC) during the Late Pleistocene. Spillage of saline Agulhas water into the South Atlantic stimulates buoyancy anomalies that act as control mechanisms on the basin-wide AMOC, with implications for convective activity in the North Atlantic and global climate change. The main objectives of the expedition were to establish the sensitivity of the Agulhas Current to climatic changes during the Pliocene–Pleistocene, to determine the dynamics of the Indian-Atlantic gateway circulation during this time, to examine the connection of the Agulhas leakage and AMOC, and to address the influence of the Agulhas Current on African terrestrial climates and coincidences with human evolution. Additionally, the expedition set out to fulfill the needs of the Ancillary Project Letter, consisting of high-resolution interstitial water samples that will constrain the temperature and salinity profiles of the ocean during the Last Glacial Maximum.



Ms. N. Lathika collects rhizon samples from the core

The specific scientific objectives were:

- To assess the sensitivity of the Agulhas Current to changing climates of the Pliocene/Pleistocene, in association with transient to long-term changes of high-latitude climates, tropical heat budgets, and the monsoon system;
- To reconstruct the dynamics of the Indian–Atlantic gateway circulation during such climate changes, in association with changing wind fields and migrating ocean fronts;
- To examine the connection between Agulhas leakage and ensuing buoyancy transfer and shifts of the AMOC during major ocean and climate reorganizations during at least the last 5 My; and
- To address the impact of Agulhas variability on southern Africa terrestrial climates and, notably, rainfall patterns and river runoff.

Indian Participation

Ms. N. Lathika
Physical Properties Specialist
National Centre for Antarctic and Ocean Research,
Goa, India

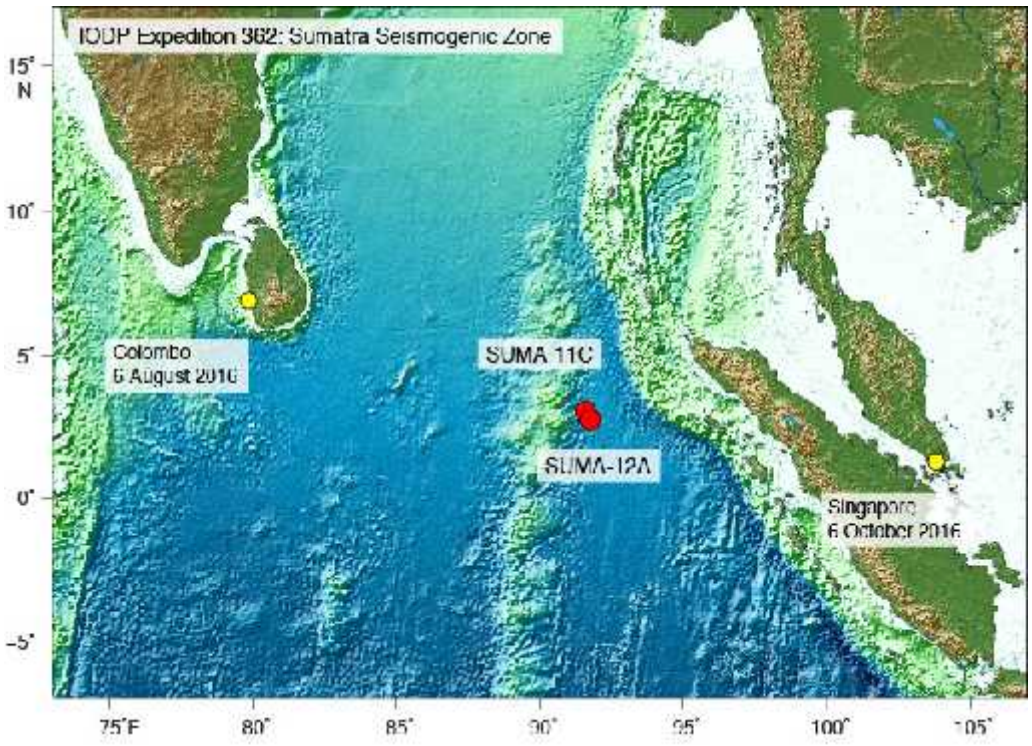
International Ocean Drilling Program Expedition 362

The Sumatra Subduction Zone:

The role of input materials in shallow seismogenic slip and forearc plateau development

General Information

Sites:
Dates: 6 August to 6 October 2016
Ports: Colombo, Sri Lanka to Singapore
Co-chief Scientists: Lisa McNeill & Brandon Dugan
Staff Scientist: Katerina Petronotis



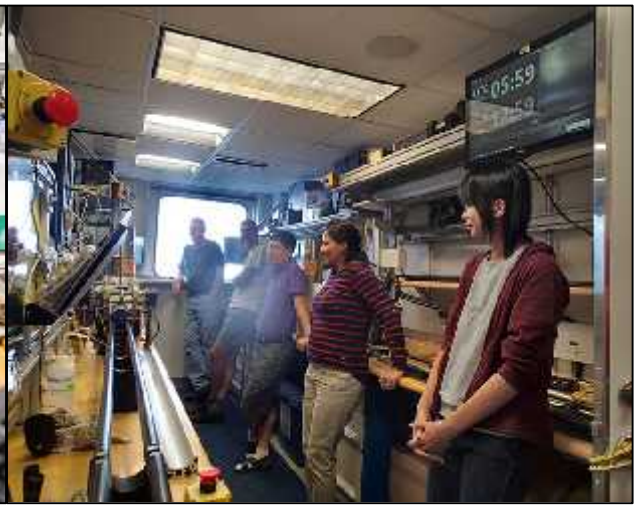
Source: http://iodp.tamu.edu/scienceops/expeditions/maps/sumatra.jpg

Summary and Objectives:

The input materials of the North Sumatran subduction zone are a distinctive, thick (up to 4–5 km) sequence of primarily Bengal-Nicobar Fan–related sediments. The correspondence between the 2004 rupture location and the overlying prism plateau, as well as evidence for a strengthened input section, suggests the input materials are key to driving the distinctive slip behavior and long-term forearc structure. The aim of Expedition 362 is to begin to understand the nature of seismogenesis in North Sumatra through sampling these input materials and assessing their evolution, en route to understanding such processes on related convergent margins. Properties of the incoming section affect the strength of the wedge interior and base, likely promoting the observed plateau development. In turn, properties of deeper input sediment control décollement position and properties, and hence hold the key to shallow coseismic slip. During Expedition 362, two primary, riserless sites (proposed Sites SUMA-11C and SUMA-12A) will be drilled on the oceanic plate to analyze the properties of

the input materials. Coring, downhole pressure and temperature measurements, and wireline logging at these sites will constrain sediment deposition rates, diagenesis, thermal and physical properties, and fluid composition. Postexpedition experimental analyses and numerical models will be employed to investigate the mechanical and frictional behavior of the input section sediments/sedimentary rocks as they thicken, accrete, and become involved in plate boundary slip system and prism development. These samples and downhole measurements will augment the internationally collected site survey bathymetric, seismic, and shallow core data that provide the regional geological framework of the margin.

Dr. Nisha Nair examines the core



Dr. Nisha Nair and others in the Physical Properties Laboratory onboard JR. (Credit: Sandra Herrmann, IODP JRSO)

Key Scientific Objectives are:

4. To determine the lithology, sedimentation rates, and physical properties of the input section and to determine marked changes in sedimentation rate and lithology with time that would influence physical properties of the section.

5. To assess whether the deep sampled input sediments that eventually will form the interior and base of the accretionary prism and develop into the décollement fault are indurated, dense, compacted, predominantly dewatered, and becoming diagenetically altered. These effects will magnify as the input section thickens and is accreted. Strengthening of the sedimentary section would contribute to a strong prism core and promote shallow seismogenic slip.

6. To determine the similarities and any distinct differences in lithology and physical properties within the stratigraphic section. In particular between (a) the gradually deposited Unit 2, comprising Nicobar Fan sediments, and (b) the more slowly accumulating pelagic sediments of Unit 3.

Indian Participation

Dr. Nisha Nair
Physical properties specialist
National Centre for Antarctic and Oceanic Research,
Goa, India

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Ministry of Earth Sciences, Government of India

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Email: iodp.india@ncaor.gov.in

ESSO NCAOR राष्ट्रीय अंटार्कटिक एवं समुद्री अनुसंधान केंद्र
पृथ्वी विज्ञान मंत्रालय, भारत सरकार
NATIONAL CENTRE FOR ANTARCTIC AND OCEAN RESEARCH
Ministry of Earth Sciences, Government of India