

ORV Sagar Kanya Cruise No.217



Multi-Disciplinary Oceanographic Surveys to study the Post-Tsunami Impact in the Bay of Bengal and Andaman & Nicobar Region

16-01-2005 to 21-02-2005

**NATIONAL CENTRE FOR ANTARCTIC & OCEAN RESEARCH,
GOA.
NATIONAL INSTITUTE OF OCEANOGRAPHY,
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TO STUDY THE POST-TSUNAMI IMPACT
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CRUISE SUMMARY

This cruise was planned to collect environmental, geological and geophysical data in the Bengal Fan and Andaman & Nicobar regions, mainly to study the impact of the twin mega- events; the 9.0 magnitude earthquake and Tsunami that originated in Aceh Province on the NW of Sumatra, Indonesia on 26th Dec.2004. Both these catastrophic events have drastically affected the coastal areas of India and Srilanka, in the form of damage caused by the earthquake and the following surge due to tsunami.

A team of 31 scientists from NIO, Regional Centre, Visakhapatnam, NCAOR, Goa, NIO, Goa, NPOL, Kochi and engineers from NORINCO, Chennai have participated in this cruise. The vessel sailed out from Chennai on 16th Jan.2005 and after a 36-day expedition returned back to Chennai on 21st Feb. There was a five-day halt at Port Blair from 27th Jan. to 1st Feb.

In this cruise, geophysical data like, bathymetry, gravity, sub-bottom profiling and swath-bathymetry were collected along traverses crossing the Bengal Fan, Andaman and Nicobar Trench and Andaman Basin. Surface and subsurface sediment samples were also collected in the study area.

In addition, environmental parameters like water quality, biological species, temperature-salinity (CTD), etc., were also collected at selected locations in the above regions, covering the Bengal Fan, Andaman & Nicobar Trench and Andaman Basin.

A total of 8406 line kms. each of bathymetry, gravity, shallow seismic and swath data were collected. The total number of sediment (grab/spade core/gravity core) samples is of the order of 23. Temperature – salinity (CTD) data was collected at nearly 25 stations. XBT was operated at half-degree interval along the return path from Andaman to Chennai following 13°N. ADCP and Thermo-salinograph were continuously operated through out the cruise.

Water samples were collected at 20 stations using the CTD rosette for analysis of various parameters like Dissolved Oxygen, pH, and Nutrients (Nitrate, Nitrite, Phosphate and Silicate). Around 133 numbers of water samples were collected at 11 stations for phytoplankton and chlorophyll analysis, while 14 numbers of particulate water samples were collected for analysis of biochemical parameters. Benthic samples were collected at 11 stations to study the benthic biology. Multiple Plankton Net of mesh size 200µm was operated to collect zooplankton samples in the water column. Sea surface water samples were collected from 19 stations to study biochemical parameters

It is expected that this multi-disciplinary oceanographic data collected within few weeks of the twin-disaster might help to estimate the impact caused by the earthquake and tsunami on our coastal areas, including the east coast and A & N regions. It is significant to note that the data were collected in the A & N regions in the presence of frequent aftershocks during the cruise period, even after more than 6 weeks of the major event.

INTRODUCTION

Between the Christmas of 2004 and New Year Day of 2005, the South Asian countries like India, Indonesia, Thailand, Sri Lanka, etc received a twin-shock, which they had never expected in their lifetime. A major earthquake of magnitude 9.0 on Richter scale that occurred at about 0640hrs on 26th December 2004 near Aceh, northwest of Sumatra, Indonesia triggered a Tsunami surge that has engulfed the coastal areas of Indonesia, Thailand, Sri Lanka and the eastern margin and Andaman Nicobar islands of India. Though there were rare instances of tsunami in the Indian Ocean, it was never envisaged that this major earthquake that occurred at the interface of Indian and Burmese plates along the Sumatra subduction zone, would cause such a vast devastation. It has claimed nearly 1,50,000 lives and resulted in loss of property worth few billion rupees. Preliminary locations of larger aftershocks following this earthquake show that approximately 1000 kms length of the plate boundary slipped as a result of this earthquake. Subsequent scientific reports also indicated that this earthquake has even resulted in a micro level tilt in the earth's orbital axis and even an increase in the speed of its rotation. Though some of these findings need to be further substantiated, the fact remains that the Sumatra earthquake has caused significant changes to the earth's tectonic processes. Some earlier studies also suggest the break-up of Indo-Australian Plate as the probable cause for the Sumatra earthquake.

As far as India is concerned, the southern part of the eastern continental margin is the worst affected due to the surge caused by the Tsunami waves, which has started inundating the coastal stretches within 2-3 hours of the earthquake. Andaman and Nicobar area including Car Nicobar, Katchel, Campbell Islands were not only affected by the earthquake but also by the tsunami surge. It is now believed that a subsidence of 1-2 meters has been affected in the Andaman and Nicobar Islands with the maximum down throw at Indira point near Great Nicobar. This resulted in a permanent sea level rise of the same order, thereby inundating the coastal settlements and narrowing down the beautiful beach stretches of the island. Andaman Nicobar Islands have experienced as many as 200 after shocks between 26th Jan 2004 to till date with magnitude of the order of 3-6.5. The Sumatra earthquake and resultant Tsunami surge might have definitely caused significant changes in the marine environment, not only in the physiography and tectonics of the region but also in the environmental parameters of the upper column of the ocean waters.

It is in this context that the National Centre for Antarctic and Ocean Research (NCAOR), Goa and the National Institute of Oceanography (NIO), Goa under the coordination of Department of Ocean Development (DOD), New Delhi initiated a multi-parameter oceanographic study in the Bay of Bengal and Andaman Sea, mainly to study post-Tsunami Impact in the Coastal and deeper-sea waters.

Two oceanographic cruises were planned, the first one over the coastal waters adjacent to India and Srilanka and the second one in the deep-sea Bengal Fan and Andaman and Nicobar regions. This report gives details of the multidisciplinary investigations carried out in the Bay of Bengal and Andaman Sea during a 37-day cruise from 16-01-05 to 21-02-05, onboard the research vessel ORV Sagar Kanya of NCAOR, Goa.

1. OBJECTIVES OF THE CRUISE

The main objective of this cruise is to study the post- tsunami impact on the marine environment in the Bay of Bengal and Andaman and Nicobar regions. A multi-disciplinary oceanographic cruise is therefore planned by a team of scientists from NIO, Regional Center, Visakhapatnam, NIO, Goa, NCAOR, Goa, NPOL, Kochi, apart from the maintenance engineers from NORINCO, Chennai. The data collection is so planned as to reoccupy some of the areas where earlier data were available and also to collect new data in some areas, which was not attempted earlier.

2. PARTICIPANTS:

2.1 Scientific Component:

There are 31 participants in total; 7 from NIO, RC, Visakhapatnam, 9 from NCAOR, Goa, 8 from NIO, Goa, 1 from NPOL, Kochi and 6 from NORINCO, Chennai. The list of the participants is as follows:

NIO – VISAKHAPATANAM

1. Dr. K.S.R.Murthy Chief Scientist
2. Dr.V.Subrahmanyam
3. Mr. K.Mohan Rao
4. Mr. G.P.S.Murty
5. Ms. P.Suneeta Rani
6. Ms. A.Anuradha
7. Ms. B.Adi Lakshmi

NCAOR, GOA

8. Dr. S. K. Chaturvedi Dy. Chief Scientist
9. Dr. A. J. Luis
10. Dr. K.V.Swamy
11. Mr. V.Yatheesh
12. Mr. Sushant Naik
13. Dr. Ravi Mishra
14. Dr. M.V.Ramesh
15. Dr. Shailesh Pednekar
16. Mr. Nilesh Parsekar

NIO – GOA

17. Mr. S.S.Gaonkar
18. Mr. Vijay Khedekar
19. Mr. Ravidas Naik
20. Mr. Vishwas Khodse
21. Mr. Anand Dev Paul Kolli
22. Mr. Chaitanya Bhandare
23. Ms. Nisha Kurian
24. Ms. Laju Michael

NPOL, KOCHI

25. Mr. S.S.Manral

NORINCO ENGINEERS

26. Mr. K.M.Jayakrishnan
27. Mr. Rohit Hermon
28. Mr. Sharath Chandran
29. Mr. Praveen Rodrigues
30. Mr. Braulio Dias
31. Mr. Hafeezur Rahman

2.2 Ship's Component:

01.	Capt. Kshitij S. Mate	Master
02.	Mr. Satyendra Pratap	Chief Officer
03.	Mr. Kalyan Singh	2 nd Officer
04.	Mr. Bondre Alim	3 rd Officer
05.	Dr. James Jose	Medical Officer
06.	Mr. Shankar Menon	Radio Officer
07.	Mr. Pardeshi Bhagwandas Hemraj	Purser
08.	Mr. C. N. Sasidharan	Chief Engineer
09.	Mr. Mandal Sudipta	2 nd Engineer
10.	Mr. Varun Raina	4 th Engineer
11.	Mr. Kazi Abdur Rob	4 th Engineer
12.	Mr. M. P. Muthamizh Chezhiyan	4 th Engineer
13.	Mr. Radhakrishna Baliga	Electrical Officer

3. PARAMETERS MEASURED:

The parameters measured in this cruise are mainly:

- Geophysical (bathymetry, gravity, multi-beam swath, and sub-bottom profiling)
- Geological (gravity/spade cores and grab sampler)
- Physical (CTD, Continuous Sea Surface Salinity and Temperature using Thermosalinograph, Sea Surface Salinity using Auto Sal, Current velocity etc.)
- Chemical (Dissolved Oxygen, pH, nutrients, etc.)
- Biological (Phytoplankton, Chlorophyll, Zooplanktons & Benthos, Biochemical parameters etc.)

4. CRUISE ITENERARY:

Dep. Chennai: 16-01-2005; Arr. Port Blair: 27-01-2005

Stay at Port Blair 27-01-2005 to 01-02-2005

Dep. Port Blair: 01-02-2005; Arr. Chennai: 21-02-2005

5. SEQUENCE OF CRUISE PROGRAM:

The vessel sailed out from Chennai Harbour on 16th January 2005 around 1600hrs and underway-geophysical data collection has been started immediately. From Chennai, the vessel has sailed towards south and it has reached the location with coordinates 10° N and 80° 48' E by 17th January 2005 1700hrs. (Fig.1.)

i) 17th January 2005 to 22nd January 2005

Forward Profile along 10° N to Nicobar Trench.

From the above-mentioned location the vessel took a true east course following 10°N to reach the Nicobar Trench region. Geophysical data has been collected along this profile, in addition to 13 CTD stations at one-degree interval, till we reached the Nicobar trench.

ii) 22nd January 2005 to 24th January 2005

Profiles across Nicobar Trench.

After the completion of the long-range profile, two trench axis profiles P2 and P3 across the Nicobar trench were completed. Geophysical data has been collected along these two profiles (Fig.1.) Sediment/rock samples were also collected at the beginning of these two profiles P2 and P3. CTD was also deployed at one station near Profile P2.

iii) 24th Jan 2005 to 27th Jan 2005

Break in survey and sailing towards Port Blair

It was when we were proceeding from Profile P3 towards the beginning of Profile P4 in the Nicobar region that some problem started in the vessel and the vessel had to be diverted to a nearby island Nancowry. We reached Nancowry on 24th January 2005 around 1800hrs.

The naval divers have inspected the vessel's hull on 25th January 2005 morning and it was decided by the captain that the vessel has to proceed to Port Blair immediately to undertake repairs for the hull. The Vessel sailed from Nancowry on 25th January 2005 evening.

During our stay at Nancowry, sediment and biological samples were collected in the outer harbor of Nancowry.

The vessel has reached Port Blair outer harbour on 27th January 2005, 0700hrs and we were alongside by evening 1700hrs.

iv) 27th January 2005 1st February 2005

Stay at Port Blair

During the vessel's stay at outer harbor, sediment and biological samples were collected.

During our stay at Port Blair we have organized a study tour of the Tsunami affected areas in and around Port Blair and collected:

- i. Information on the extent of damage due to the earthquake and tsunami surge in the Port Blair area, with photographs and public enquiries
- ii. Beach sediment samples.

The vessel's repairs were completed by 1st February 2005 and we sailed out again by 1445hrs on 1st February 2005 and survey work was resumed.

v) 1st Feb. to 11th Feb., 2005

Detailed Studies in Andaman basin:

During these 10 days detailed geophysical, geological and environmental parameters were collected in the Andaman Back-Arc Basin covering in a 0.5 X 0.5° grid bounded by 10°15' to 11° 15'N and 94° to 95°E (fig.2).

Bathymetry, gravity, sub-bottom profiling and swath bathymetry data was collected in this grid. Spade and gravity core samples were collected at four stations. CTD and zooplankton data were collected at four stations up to about 3000m water depths. The details of data collected are given in Tables 1, 2 & 3.

vi) 11th Feb. to 17th Feb. 2005.

Andaman Trench:

After completion of the Andaman Basin, the surveys were continued across the Andaman Trench, west of the basin (fig.2). Here a total of 8 profiles each of about 1.5° (90.n.miles) length were covered between latitudes 10.5°N to 14.0°N and longitudes 91°E to 92.5°E. Along each profile geophysical data (bathymetry, gravity, sub-bottom profiling) were collected. At the beginning/end of alternate profiles, CTD/Zooplankton/core samples were also collected.

The details of sample collection across the Andaman Trench are given in tables 1,2 & 3. Two cores, one by Gravity corer of about 2.5m length and the other by spade corer of about 27" length are important recoveries in Andaman Trench area.

vii) 17th Feb. to 21st Feb. 2005

Return Journey to Chennai along 13° N

Along this return traverse following 13° N, underway-geophysical data was collected from 91° E to Chennai outer Harbour (around 80°E). In addition, four CTD samples at 84°, 83°, 82° and 80°50' E were also collected. One spade core sample was also collected at a depth of about 2200m over the slope off Chennai (fig.1). Before approaching Chennai, sub-bottom profiling data was also collected in a 30' X 20' grid over the Chennai shelf (12°45' to 13°15'N and 80°30' to 80°50'E), mainly to study the changes in the shelf/slope characteristics due to the tsunami surge.

The cruise was completed on 21-02-05 at 1200 hrs.

6. DATA STATISTICS (Please refer to Tables wherever necessary):

6.1. Geophysical: Underway geophysical data was collected all along the cruise tracks in the Bengal Fan, across the Andaman and Nicobar Trench and Andaman Basin (Fig.1&2.). The A & N trench was covered by nearly 10 cross profiles, where as the Andaman Back Arc Basin was covered by four profiles of bathymetry, gravity, sub-bottom profiling. In addition swath bathymetry data was also collected in the basin in a 0.5°X0.5° grid. Two long-range geophysical profiles were obtained in the Bengal Fan between Chennai and Andaman area (10° & 13° N). The total line kms. covered in this cruise are as follows:

Bathymetry:	8406 line kms
Sub-Bottom:	8406 line kms
Swath Bathymetry:	8406 line kms
Gravity:	8406 line kms

6.2. Geological Samples: In order to study the post-tsunami effects, sediment samples were collected along the Andaman and Nicobar coast and Andaman Basin. A total of 23 sediment samples including 11 Grab, 8 Spade and 4 Gravity cores were collected from different locations (fig.1&2). These samples will be utilized for micropaleontological, sedimentological and geochemical studies. The details of the sampling stations are given in Table 1. Out of several samples collected in the study area, the 2.5m core collected over the west Andaman shelf at about 200m water depth and the 27cm spade core at the northern edge of the study area (2400m depth), which represents the confluence of Bengal and Irawady Fans are considered more important samples.

6.3. Physical parameters: As a part of physical oceanographic data collection program, CTD stations were occupied at selected stations, extending from the continental slope off

Chennai in the west to the eastern Andaman Archipelago, over the Andaman and Nicobar trench, Andaman basin and also at some locations on the return path from Andaman to Chennai. The locations of CTD stations are shown in Figures 1&2. The sampling details are shown in Table 2. Nearly 25 CTD samples were collected in the Bengal Fan itself, which might give a fairly good idea of salinity – temperature structure in the post tsunami scenario. XBTs were operated at half-degree interval along the return profile from Andaman to Chennai (13°N). ADCP and Thermosalinograph were continuously operated

6.4 Chemical Parameters: Water samples were collected all along the cruise at selected stations (figs.1&2) using the CTD rosette for analysis of various parameters like Dissolved Oxygen, pH, and Nutrients (Nitrate, Nitrite, Phosphate and Silicate). Samples were collected at depths of 0,10,40,80,100,150,200,250,500,750 and 1000m. Dissolved oxygen was analyzed using the Winkler method, pH was measured using a pH meter and nutrients were analyzed using a four channel Autoanalyser. The details of sampling stations are given in Table.3. The chemical sampling stations of about 20, thus cover the entire study area including the Bay of Bengal, A & N trench and Andaman Basin.

6.5 Biological parameters: Water samples were collected from different stations to carry out the phytoplankton and chlorophyll studies (Figs.1&2). Samples were collected from 5 different depths in the water column at each station viz. 0, 10, 40, 80 and 100m. A total of 133 numbers of water samples were collected at 11 stations for phytoplankton and chlorophyll analysis. Further analysis will be carried out in NIO.

In order to study the biochemical parameters such as Carbohydrate, Uronic acid, Organic carbon, Nitrogen, Chlorophyll and Monosaccharide, sea surface water samples were collected from 19 stations in the study area. A total of 114 numbers of particulate water samples were collected for analysis of biochemical parameters. Further analysis will be carried out in NIO. Table 3 contains details of the sampling locations.

Benthic samples were collected to study the benthic biology. Multiple Plankton Net of mesh size 200µm was operated to collect zooplankton samples in water column. A vertical haul was taken and an average of 3 samples were collected from each of the total 11 stations (fig.2). Details of sampling locations are given in Table 3. Depth ranges, from where the samples were collected, are as follows:

1. 1500m – 1000m
2. 1000m - 500m
3. 500m - surface

6.6 Study Tour of Port Blair and surrounding areas: During our stay in Port Blair, we have carried out a study tour of the earthquake/ tsunami affected areas around Port Blair. We have taken photographs of the areas inundated by tsunami surge and subsidence due to the earthquake. Beach samples were also collected. Physical damages caused due to earthquakes were also observed in some areas, including the Port area.

7. SALIENT OBSERVATIONS:

- The sea surface temperature increased from 27°C off Chennai to 28°C at 92°40'. The mixed layer depth, which was inferred from temperature profiles, varied from 50 to 100m between 80° 52' to 87°E and thereafter it decreased to 70m towards Andamans. A temperature maximum was observed at 84°E at ~80m. Along the west-east section the near-surface salinity varied from 32.8 to 33.9 psu, with low salinity water (31.7 psu) identified near the Andaman Islands. A conspicuous feature identified in the vertical profiles is the occurrence of high salinity core (35.2 psu) at 100 m between 83° and 84°E; in the same region the temperature maximum (~29°C) was also encountered. In general, surface freshening occurred near Andaman region.

A comparison between the temperature profile in the Andaman basin (10.3°N, 94.2°E) and that sampled to the west of Andaman Islands (11°N, 91°E) reveal the following. The isothermal layer depth varied from ~40 m in the Andaman basin to ~80 m to the west. The thermocline is shallower by ~ 20 m for the profile from the Andaman basin. Below 300 m the profile from the Andaman basin show slightly higher temperature (0.3°C).

- From Chennai to 10° N along the shelf region, the Free-air gravity varies from 120 mGals to -34 mGals. South of Chennai very high amplitude gravity low of the order of around 90 mGals has been observed. This gravity low may be interpreted due to the extension of onshore lineaments of Cauvery basin towards offshore.

Further, along 10°N latitude traverse, cutting across the Bay of Bengal and Andaman Trench region between 81°E and 93°E longitudes, the Free-air gravity anomaly varies between -23 mGals and 127 mGals. A Free-air gravity anomaly with amplitude of 30 mGals and width of 200Km has been observed between 85°E and 87°E longitudes. This anomaly may be interpreted due to the presence of 85°E ridge submerged below thick pile of sediments. Towards east of this anomaly, a broad Free-air gravity high of the order of 44 mGals has been noticed. The source for this anomaly is probably the north-south trending Ninetyeast ridge. Towards east of this anomaly a sharp gravity low of the order of 124 mGals - 57 mGals has been noticed over the Andaman Trench region. Over the eastern edge of the trench the anomaly raised from 57mGals to 130 mGals. The Andaman fore-arc region is characterized by a broad gravity high of 122

mGals with a width of 150 km. This overall broad gravity high is associated with a series of highs and lows of the order of 20-25 mGals. These anomalies may be due to the presence of volcanic intrusions.

In the Andaman back-arc basin, the free-air gravity data has been collected along six regional traverses and in the Andaman Basin area along eighteen closed traverses. Other than this the Andaman trench area covering the fore-arc basin the gravity data has been collected along seven E-W regional traverses.

In the back-arc basin, a distinguished regional feature has been observed parallel to the Andaman Island chain between the latitudes $10^{\circ} 30'N$ and $12^{\circ} 30'N$. This feature has been marked based on the characteristic gravity high with variable width and amplitude along. The free-air gravity anomaly over this feature varies in amplitude between 150 to 75 m Gals having a variable width of 70 km to 30 km.

The Andaman trench is characterized by a significant gravity low with broad gravity highs on both the sides due to Ninetyeast ridge on the west and volcanic intrusions on the east respectively. The irregular nature in the eastern side gravity high suggests a series of volcanic out pouring. The overall amplitude variation of the gravity anomaly over the trench area is from 60 to 100 m Gals. Along $13^{\circ} N$ the gravity anomaly is characterized by a high over the $90^{\circ}E$ Ridge and a low over the $85^{\circ} E$ Ridge.

A detailed analysis of bathymetry, free-air and sub-bottom profiler data and its correlation with earlier geophysical data collected in this region would help us to demarcate any physiographic and tectonic changes that could have taken place in the Bengal fan and Andaman and Nicobar regions, due to the major earthquake of 26th Dec. 2004.

- **Other Observations:** During the entire survey period in the Nicobar region, earthquakes of magnitude more than 5.0 have occurred at a fairly high frequency (at the rate of 2 to 3 per day), as per the daily information we have been receiving from RC, NIO, Vizag compiled from different sources. These are mainly the aftershocks of the Sumatra Earthquake of 26th Dec. 2004 of magnitude of 9.0. Plotting of the epicenters indicated

that the area east of Katchal and Nancowry Islands is associated with more than 75 aftershocks forming a huge cluster around this part of the Nicobar Region (Fig.1., shown in red colour). Most of these events occurred after 24th Jan. An interesting part of the cruise is that we have ourselves experienced vibrations on the vessel for few seconds on 24th Jan., around 0946 hrs due to one such event of magnitude 6.3, with the epicenter located around 140 kms. SW of Katchal Islands. This epicenter position was confirmed by three independent sources and the vessel was hardly 120 kms east of this epicenter at the time of the event.

8. SIGNIFICANT ACHIEVEMENTS

- Collection of time series environmental data within few weeks after the earthquake and tsunami, which would help to study the impact of these mega events on coastal and deep-sea marine environment.
- Collection of geophysical data which might help in demarcating the tectonic changes in the Bengal Fan, across the Andaman-Nicobar trench and in the Andaman Basin, encompassing both Indian and Burmese plates.
- Collection of gravity and spade cores over west Andaman shelf.
- Creation of new database in these regions, as well as re-occupation of some of the areas, where earlier oceanographic data is available, the Andaman Basin being one such case.
- Collection of sediment (core) samples in the Andaman Nicobar shelf to study the transgressive patterns caused due to Tsunami surge.
- Collection of biological species data in the coastal waters of Andaman Nicobar Islands and Andaman Basin to study the changes in their distribution pattern following the Tsunami surge.
- Above all carrying out all these investigations in the Andaman and Nicobar Trench, in the presence of high frequency aftershocks throughout the survey period of the order of nearly 200 in one month.

ACKNOWLEDGMENTS.

The Chief Scientist and the participants are thankful to Dr.H.K.Gupta, Secretary, Dept. of Ocean Development (DOD), New Delhi for his constant encouragement and interest in the activities of this cruise. Thanks are also to Dr.P.C.Pandey, Director, NCAOR, Goa for his coordination and encouragement in successful completion of the cruise. Participants from NIO, Goa and Regional Centre, NIO, Visakhapatnam are thankful to Dr.Satish.R.Shetye, Director, NIO, Goa for giving them an opportunity to participate in this cruise and for his constant interest in the activities throughout the course of this cruise. Dr.M.Sudhakar, Head, OSSG, NCAOR helped us in planning and implementation of the cruise activities. The participant from NPOL, Kochi is thankful to Shri V.Chander, Director, NPOL, Kochi.

We are particularly thankful to Capt. K.S.Mate and his team of officers onboard Sagar Kanya for their excellent cooperation in carrying out different operations during this cruise and also for safely navigating the vessel in crucial times. M/s NORINCO, Chennai provided a reasonably good maintenance, operation and trouble shooting of equipments onboard.

Table 1: Details of Geological Sampling in the study area

St. No.	Sediment sampler	Date/Time	Water Depth (m)	Latitude	Longitude	Core Length/Remarks
Off Car Nicobar						
SK217/01	Spade Corer	22 nd Jan 05/2215	28.1	09°05.69'N	92°44.34'E	No sediment recovery in two attempts
SK217/02	Spade Corer	22 nd Jan 05/2345	37.8	09°02.65'N	92°46.00'E	No sediment recovery.
SK217/03	Spade Corer	23 rd Jan 05/0045	225	08°58.62'N	92°44.95'E	Surface sediment, Coralgalline sand associated with carbonate rock.
Off Katchll Island						
SK217/04	Grab	24 th Jan 05/ 0555	274	07°53.95'N	93°07.27'E	Sandy silt along with pieces of volcanic rocks.
Off Nancowry Harbour						
SK217/05	Grab	25 th Jan 05/0805	18.5	08°02.05'N	93°33.94'E	Top 3 cm is fine silty sand followed by coarse coral sand.
Off Port Blair						
SK217/06	Gravity Corer	27 th Jan 05/0925	42.7	11°40.99'N	92°45.01'E	Core length 54 cm. Silty clay
SK217/07	Gravity Corer	02 nd Feb05/1610	191	11°40.01'N	92°48.25'E	Sand in core catcher.
Andaman Basin						
SK217/08	Spade Corer	02 nd Feb05/2400	3483	10°37.08'N	94°21.16'E	Clay
SK217/09	Spade Corer	03 rd Feb05/1400	3116	11°02.87'N	94°29.77'E	Clay, Core length 25cm.
SK217/10	Spade Corer	04 th Feb05/0530	3172	10°34.14'N	94°44.27'E	Clay, Core length 25cm.
SK217/11	Spade Corer	04 th Feb05/1245	3483	10°19.67'N	94°14.28'E	Clay
Off Little Andaman						
SK217/12	Grab	11 th Feb05/1340	202	10°28.38'N	92°41.36'E	Calcareous sand with relict carbonated rocks
SK217/13	Grab	11 th Feb05/1530	69	10°29.39'N	92°37.15'E	Coarse calcareous sand
SK217/14	Grab	11 th Feb05/1650	50	10°29.85'N	92°34.11'E	Fine to medium sand
SK217/15	Grab	11 th Feb05/1920	30	10°29.93'N	92°10.92'E	Coarse coral sand and rocks along with live corals and organism
SK217/16	Grab	11 th Feb05/2045	108	10°32.02'N	92°05.96'E	Coarse coral sand

St. No.	Sediment Sampler	Date & Time	Water Depth (m)	Latitude	Longitude	Core Length/Remarks
Off North Sentinel Island						
SK217/17	Grab	13 th Feb05/0415	204	11°27.30'N	92°11.84'E	Silty sand
SK217/18	Grab	13 th Feb05/0522	113	11°28.89'N	92°12.34'E	Coarse sand
SK217/19	Grab	13 th Feb05/0623	49	11°30.24'N	92°12.62'E	Fine to medium sand
Off Middle Andaman						
SK217/20	Grab	14 ^h Feb05/1340	45	12°30.04'N	92°22.07'E	Large pieces of live corals along with little coarse coral sand
SK217/21	Gravity Corer	14 th Feb05/1530	205	12°29.70'N	92°18.82'E	Core length 245 cm. Calcareous sand-silt-clay upto 50 cm followed by clayey sediments
Off North Andaman						
SK217/22	Spade Corer	16 th Feb05/0830	2343	13°56.41'N	92°16.08'E	Core length 28 cm. Silty clay
Bay of Bengal						
SK217/23	Gravity Corer	20 th Feb05/1810	3073	13°10.91'N	80°51.96'E	Clay in core catcher: not much recovery.

Beach Sediment Sample Collection:

- (1) New Wandoor [Lat. 11°31.3'N, Long. 92°38.9'E (approx coordinates), 29.01.2005, 0915 Hrs]: Beach sediment samples were collected in two transects 100 m apart at High Tide, Mid Tide and Low Tide. In transect two, samples at 50, 100, 150 and 175m distance from High Tide were also collected.
- (2) Corbyn's Beach [Lat. 11°38.5'N, Long. 92°44.93'E (approx coordinates), 29.01.2005, 1335 Hrs] Beach sediment samples were collected at High Tide, Mid Tide and Low Tide.
- (3) Ross Island [Lat. 11°40.62'N, Long. 92°46.09'E (approx coordinates), 30.01.2005, 1100 Hrs] Beach sediment samples were collected at High Tide and Mid Tide.
- (4) Ross Island [Lat. 11°40.5'N, Long. 92°45.72'E (approx coordinates), 30.01.2005, 1200 Hrs] Beach sediment samples were collected at High Tide and Mid Tide.

Table.2 Details of Physical Oceanographic and water sample data

Sr. No.	Date	Time (IST)	Echosounder Depth (m)	Latitude (°N)	Longitude (°E)	Operated Depth (m)
CHENNAI – PORT BLAIR CTD SECTION						
1	17/01/05	1730-1830	333	10°05'	80°52'	280
2	18/01/05	0400-0500	3675	10°07'	82°02'	1000
3	18/01/05	1305-1405	3630	10°03'	83°01'	1000
4	18/01/05	2225-2325	3595	10°00'	84°00'	1000
5	19/01/05	0800-0900	3548	09°59'	84°59'	1000
6	19/01/05	1840-1923	3518	10°00'	86°00'	1000
7	20/01/05	0300-0348	3480	10°00'	87°00'	1000
8	20/01/05	1200-1300	3427	10°00'	88°00'	1000
9	20/01/05	2217-2311	3369	10°01'	89°00'	1000
10	21/01/05	0800-0854	3308	10°03'	90°00'	1000
11	21/01/05	1830-1940	3459	10°00'	91°06'	1000
12	22/01/05	0530-0620	1890	10°00'	92°00'	1000
13	22/01/05	1300-1356	975	10°00'	92°40'	1000
OFF NICOBAR						
14	23/01/05	0140-0205	252	08°58'	92°44'	200
ANDAMAN BASIN						
15	03/02/05	0720-0820	3477	10°39'	94°33'	Failed
16	03/02/05	1547-1745	3121	11°02'	94°29'	3000
17	04/02/05	0145-0419	3166	10°42'	94°58'	3000
18	04/02/05	1620-1900	3120	10°17'	94°13'	2500
MERIDIONAL SECTION (91°E)						
19	12/02/05	1033-1240	3309	11°00'	91°00'	3000
20	13/02/05	2110-2200	3300	12°00'	91°00'	1000
21	14/02/05	0612-0700	2988	13°00'	91°00'	1000
22	17/02/05	1450-1540	2925	13°30'	91°00'	1000

Sr. No.	Date	Time (IST)	Echosounder Depth (m)	Latitude (°N)	Longitude (°E)	Operated Depth (m)
PORT BLAIR – CHENNAI XBT SECTION						
1	15/02/05	1317-1327	3368	13°00'	91°30'	760
2	15/02/05	1736-1746	1906	13°00'	92°00'	760
3	17/02/05	1029-1515	2956	13°00'	90°30'	Failed
4	17/02/05	1519-1529	2976	13°00'	90°00'	760
5	17/02/05	1820-1830	3015	13°00'	89°30'	760
6	18/02/05	0046-0056	3073	13°00'	88°37'	760
7x	18/02/05	0840-0850	3113	13°00'	87°28'	760
8	18/02/05	1453-1505	3156	13°00'	86°30'	760
9	18/02/05	2215-2235	3192	13°00'	85°30'	760
10	19/02/05	0540-0550	3294	13°00'	84°30'	760
11	19/02/05	1340-1350	3337	13°00'	83°30'	760
12	19/02/05	2205-2215	3419	13°00'	82°30'	760
13	20/02/05	0730-0740	3412	13°00'	81°30'	760
14	20/02/05	1732-1800	3000	13°10'	80°50'	760
PORT BLAIR – CHENNAI CTD SECTION						
15	19/02/05	0920-1020	3310	13°00'	84°00'	Sensor Failed
16	19/02/05	1740-1828	3383	13°00'	83°00'	Sensor Failed
17	20/02/05	0215-0310	3450	13°00'	82°00'	Sensor Failed

**Table-3A: Locations of sample stations for Phytoplankton and Chlorophyll studies
CHENNAI – PORT BLAIR SECTION**

Sr. No.	Date	Time (IST)	Latitude (°N)	Longitude (°E)
1	17/01/05	1730	10°05'	80°52'
2	18/01/05	0400	10°07'	82°02'
3	18/01/05	1305	10°03'	83°01'
4	18/01/05	2225	10°00'	84°00'
5	19/01/05	0800	09°59'	84°59'
6	19/01/05	1840	10°00'	86°00'
7	20/01/05	0300	10°00'	87°00'
8	20/01/05	1200	10°00'	88°00'
9	20/01/05	2217	10°01'	89°00'
10	21/01/05	0800	10°03'	90°00'
11	21/01/05	1830	10°00'	91°06'
12	22/01/05	0530	10°00'	92°00'
13	22/01/05	1300	10°00'	92°40'
14	23/01/05	0140	08°58'	92°44'
PORT BLAIR - CHENNAI SECTION				
15	03-02-05	1700	11°02'	94°29'
16	04-02-05	1900	10°17'	94°13'
17	12-02-05	1130	11°13'	91°50'
18	13-02-05	2215	12°10'	91°09'
19	15-02-05	0810	13°11'	91°09'
20	17-02-05	0200	13°29'	91°09'
21	19-02-05	1030	13°00'	84°00'

Table-3B: Locations of sample stations for Biochemical parameters

Station No.	Date & Time	Latitude (N)	Longitude (E)
1.	17-01-05/20:30	09 ⁰ 58'	80 ⁰ 59'
2.	18-01-05/04:00	10 ⁰ 07'	82 ⁰ 12'
3	18-01-05/ 22:45	10 ⁰ 00'	84 ⁰ 00'
4	19-01-05/ 08:30	10 ⁰ 13'	85 ⁰ 13'
5	19-01-05/ 19:00	09 ⁰ 9'	86 ⁰ 00'
6	20-01-05/ 12:30	10 ⁰ 07'	88 ⁰ 00'
7	20-01-05/ 22:10	10 ⁰ 0'	89 ⁰ 00'
8	21-01-05/08:00	10 ⁰ 4'	90 ⁰ 13'
9	21-01-05/19:30	10 ⁰ 00'	91 ⁰ 00'
10	22-01-05/06:40	10 ⁰ 00'	92 ⁰ 00'
PORT BLAIR - CHENNAI SECTION			
11	03-02-05/06.00	10 ⁰ 39'	94 ⁰ 21'
12	04-02-05/19.00	10 ⁰ 17'	94 ⁰ 14'
13	12-02-05/11.00	10 ⁰ 58'	90 ⁰ 59'
14	13-02-05/22.00	11 ⁰ 59'	90 ⁰ 59'
15	15-02-05/06.00	12 ⁰ 59'	90 ⁰ 59'
16	17-02-05/21.00	13 ⁰ 00'	89 ⁰ 00'
17	19-02-05/01.30	13 ⁰ 00'	85 ⁰ 00'
18	19-02-05/18.30	13 ⁰ 00'	83 ⁰ 00'
19	20-02-05/11.30	13 ⁰ 00'	81 ⁰ 00'

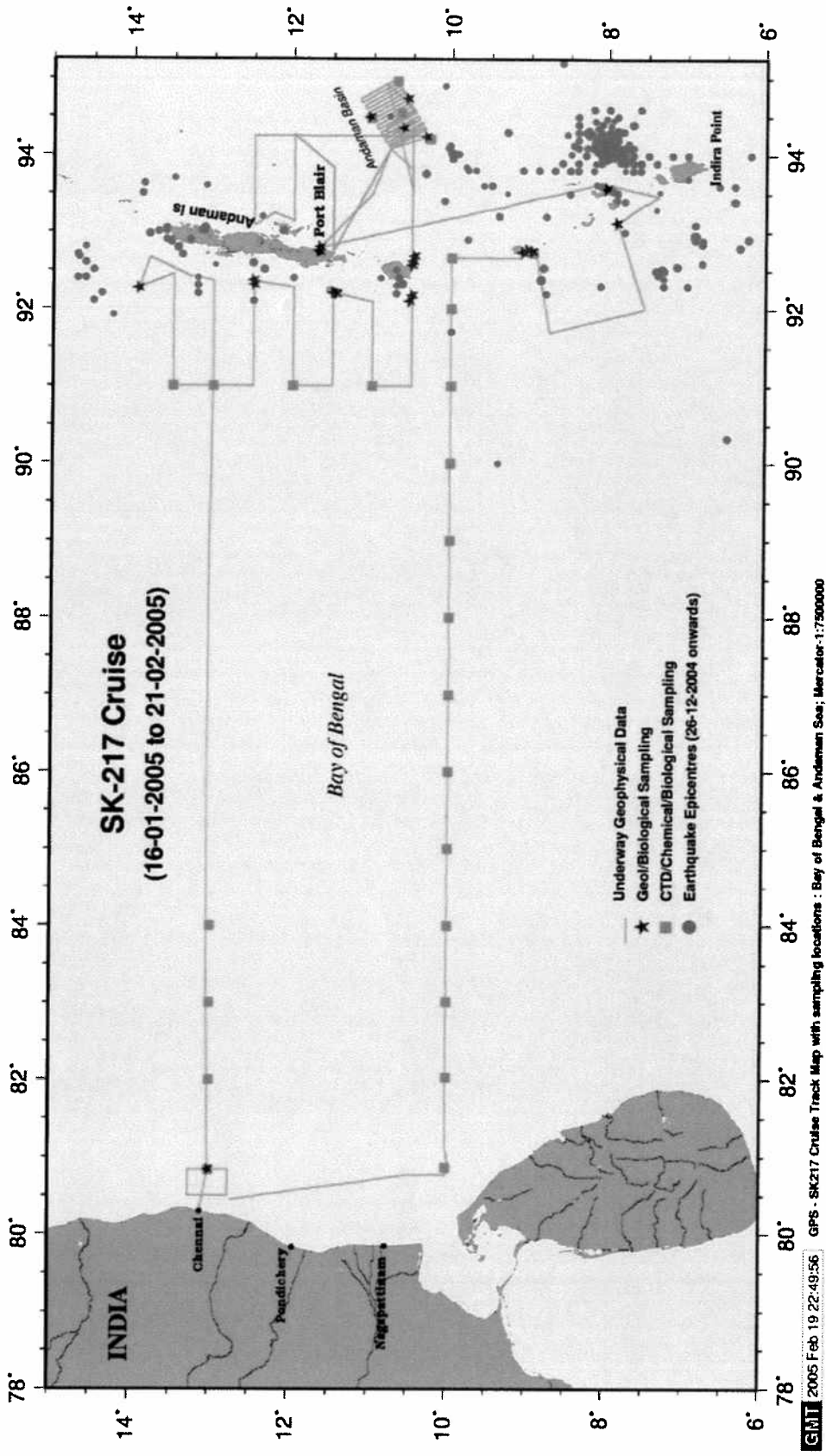


Figure-1 : Cruise track map along with different sample locations

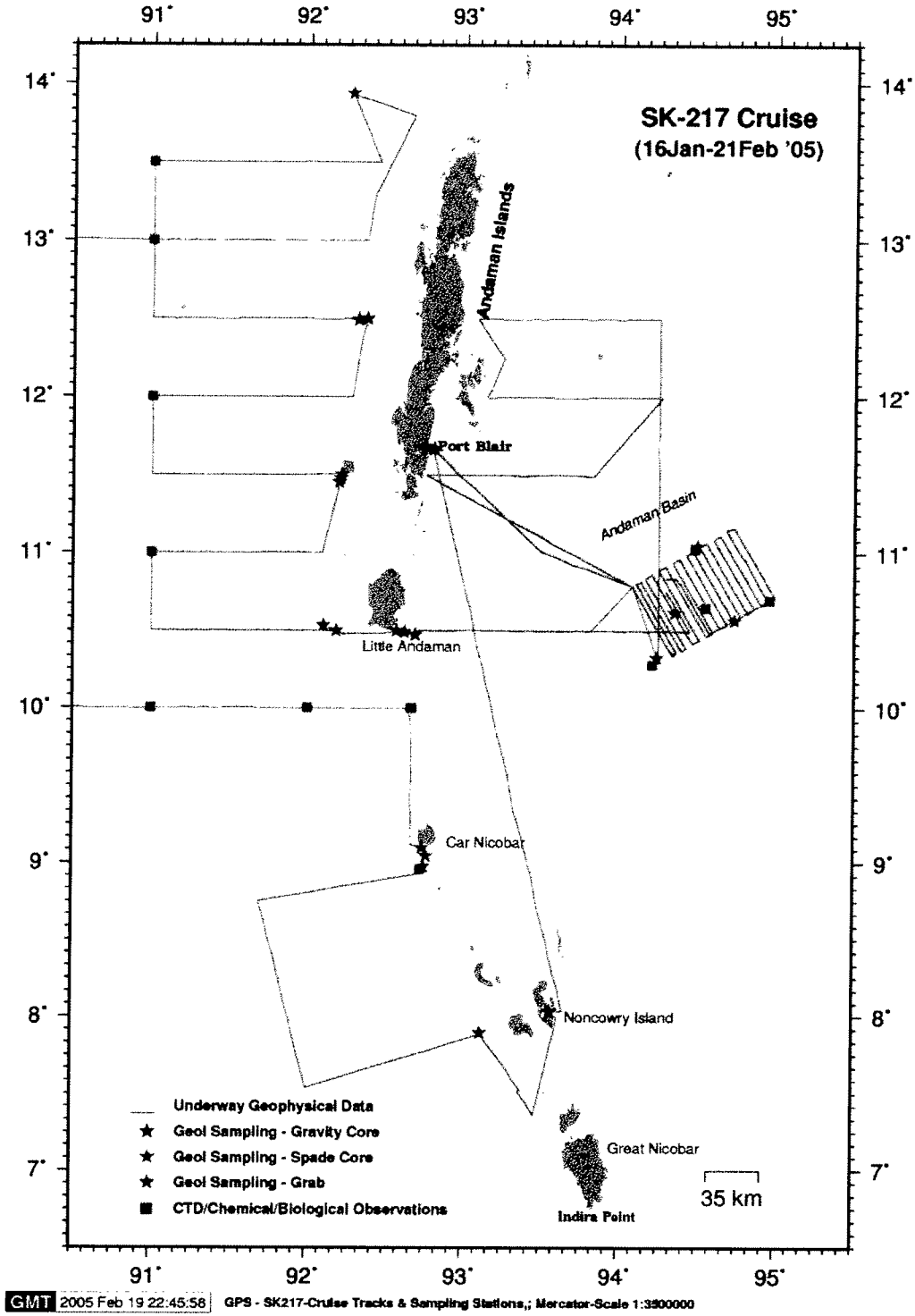


Figure-2: Details track map of Andaman and Nicobar area