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Presence of illites in Bay of Bengal – An analysis of the sample obtained from GEODROME

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GEODROME stands for Geophysical Deep-water Research Observatory for Multidisciplinary Experiment. The instrument can withstand up to a depth of 6000 m with its full operational conditions. GEODROME is a benthic station measurement consisting of several modular structures for research of geophysical and geochemical processes at the sea bottom. The multiparameter geophysical and geochemical measurements from the instrument would provide knowledge about earthquake processes taking place in the marine environment. It may also provide insight about the ongoing physical and chemical processes in the subsurface. The stand-alone recording has facilities to record data for long periods. In this study we have analysed the sample collected during our GEODROME experiment and some results are presented.

Keywords: Bay of Bengal, GEODROME, illite.

THE Indian continental margin is an important element in the evolutionary history of the break-up of the Indian Plate from Gondwanaland. The break-up between the east coast of India and Antarctica led to the development of the eastern continental margin of India followed by its subsidence and sediment deposition in the basins. The Bay of Bengal region is covered with pre- and post-collision sediments[1]. The nature of the crust beneath the Bay of Bengal is still controversial and it has been argued that either it is continental or oceanic type[2]. Controlled source seismic investigations delineated the sediment thickness at 13°N lat., which is of the order of 6–7 km and decreases to 2–3 km at distant fans[3]. Two prominent linear, geological features, viz. 85°E and 90°East Ridge have been identified in the Bay of Bengal. The 85°E Ridge is buried under sediments and geophysical investigations have traced its continuity 17°N, but the extension in the northern region is being debated.

A unique experiment to understand the nature of the crust and mantle in the Bay of Bengal area and to understand the genesis of the 85°E Ridge was taken up under Indo-Russian collaboration. The experiment envisaged the deployment of the Geophysical Deepwater Research Observatory for Multidisciplinary Experiment (GEODROME) in the Bay of Bengal during October 2003. The deployment was done using the Department of Ocean Development (DOD) Vessel *ORV Sagar Kanya*. Apart from understanding the genesis of the ridge, the equipment was itself being tested for sustenance in deep waters and in this aspect it was first type of experiment. Due to logistic constraints the instrument was deployed for short periods for the test run and retrieved. It was expected that receiver function analysis of the collected seismological data would provide one-dimensional configuration of the crust and mantle. Three broadband seismometers simultaneously operated on the eastern coast to calibrate the GEODROME. With the data from these equipment it was expected to resolve the nature and probably the physical characteristics of the underlying crust and upper mantle and thereby lay constraints on the geodynamics of this region.

The GEODROME consists of multicomponent geophysical as well as geochemical measurement units such as block for registration of seismic sensor, hydro-acoustic signals, magnetometer, salinity and temperature measurement units, broadband seismometer and hydrophone. These units are properly connected with connection cables and these cables are connected with a continuous DC power supply. The power supply with data recording units is placed within a spherical pressure chamber. The power supply is provided by a number of 1.5 V cells connected in series. These units are situated on a frame so as to sit on the ocean bottom as a single unit.

An Indian delegation visited Moscow during November 2000 to formulate the collaborative programme in certain specified branches of earth sciences. During the deliberation, a programme was signed for the development of GEODROME in the deep waters of Indian continental margins. The experiment was aimed at testing the operation of the GEODROME at water depths of around 3000 m. The project proposal included running of three observatories on the coast along with the deployment of the GEODROME in the Bay of Bengal.

A subsurface basement rise-like feature approximately parallel to 85°E longitude has been identified on the long-

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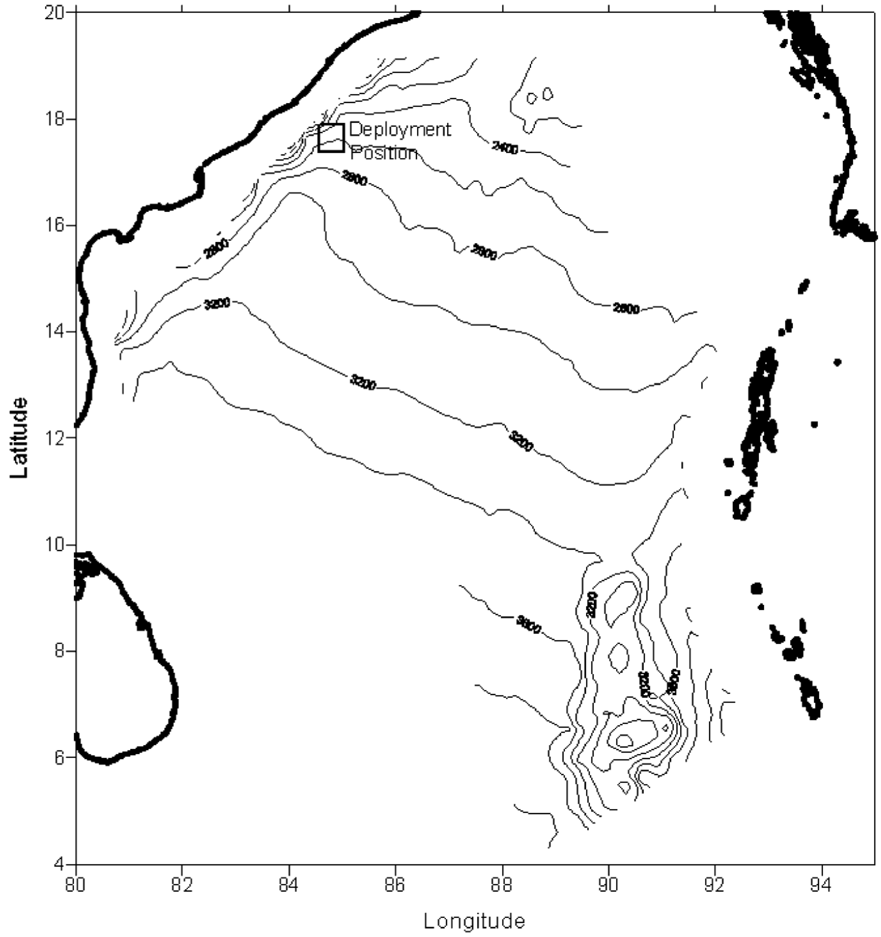

Figure 1. Map of study area.

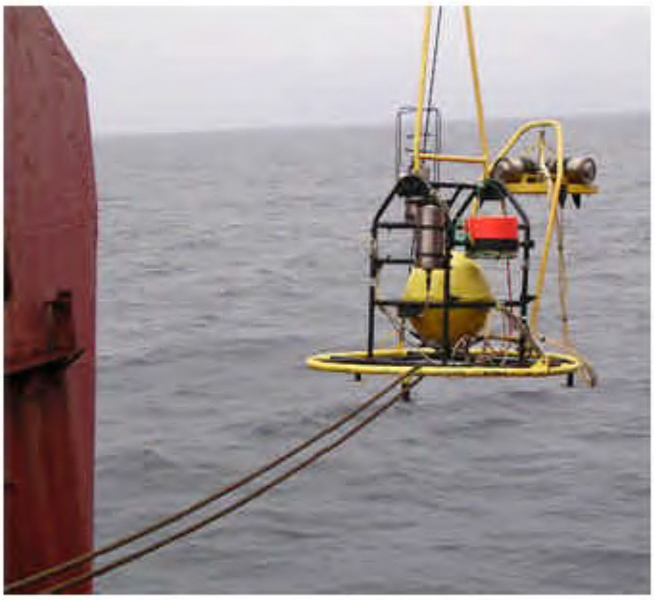

Figure 2. Deployment of GEODROME.

range E–W seismic reflection profiles in the Bay of Bengal. This feature has been named the 85°E Ridge. This ridge trends approximately N-S between 9° and 16°N lat. Off the southeast coast of Sri Lanka, it takes an arcuate shape and appears to terminate with the northward extension of the Afanasy Nikitin Seamount situated around 2°S lat. The ridge is characterized by positive magnetic (100–400 nT) and negative free-air gravity (60 mGal) anomalies with a variable width of 100–180 km. The ridge appears as a double-humped feature around 12° and 13°N lat., and as an intrusive peak and broad basement rise around 10°N. The eastern hump of the ridge, at 13°N, has been interpreted as carbonate build-up from additional seismic reflection data[4]. Results of seismic reflection data across the 85°E Ridge reveal that the ridge divides the main Bengal Fan longitudinally into two basins with more than 8 km thick sediments; the ridge is buried under > 3 km thick sediments in the north (around 13°N lat.) and relatively thin (< 2) sediments in the south (10°N lat.); the western flank of the ridge (along 13°N lat.) is steeper, while the eastern flank dips gently. A thin sediment cover blanketed the ridge since at least early Tertiary. It has been suggested that the crustal structure does not vary much between the adjacent sides of the ridge and the 85°E Ridge, and was in existence prior to the lower Eocene.

Table 1. Presence of various mineral compositions revealed by geochemical analysis

NGRI, Hyderabad
Geochemistry Division ICP-MS Lab

Sample ID: MAG-1
Sample date/time: Wednesday, 18 August 2004, 16:30:49
Sample type: Marine sediment
Concentration unit: ppm for rock and ppb for water
Instrument: Perkin Elmer Elan DRCII
Project no: Sponsored

	Concentration results		
Analyte	Mass meas.	Intens. mean	Conc. mean conc. RSD
Sc	45	35957.973	17.639
V	51	378398.648	140.162
Cr	52	164428.696	
Co	59	40741.087	19.357
Ni	60	23804.626	51.245
Cu	63	56061.327	28.598
Zn	64	93239.568	123.924
Ga	71	30861.294	20.238
Rb	85	426446.914	150.730
Sr	88	514329.143	147.162
Y	89	85719.232	28.041
Zr	90	175128.252	126.242
Nb	93	46363.928	11.984
Cs	133	36481.553	8.566
Ba	138	1566386.680	470.574
La	139	177005.080	41.984
Ce	140	333270.862	86.060
Pr	141	45771.940	9.069
Nd	142	46693.884	37.042
Sm	152	8978.589	7.347
Eu	153	3627.223	1.438
Gd	158	8041.566	5.532
Tb	159	4005.382	0.922
Dy	164	5993.744	5.245
Ho	165	3745.772	0.988
Er	166	3629.224	2.881
Tm	169	1494.623	0.409
Yb	174	3269.471	2.543
Lu	175	1398.108	0.379
Hf	180	3993.371	3.575
Ta	181	3661.237	1.065
Pb	208	166210.156	22.547
Th	232	43197.388	11.613
U	238	10423.973	2.439
Rh	103	339217.350	

	Concentration results		
Analyte	Mass meas.	Intens. mean	Conc. mean conc. RSD
Sc	45	37524.787	20.358
V	51	251403.802	102.993
Cr	52	221971.233	127.09
Co	59	48131.579	25.293
Ni	60	38694.675	92.128
Cu	63	68314.719	38.543
Zn	64	76705.493	112.754
Ga	71	26858.618	19.480
Rb	85	355698.141	139.050
Sr	88	342493.828	108.383
Y	89	65143.066	23.569
Zr	90	240321.860	191.599
Nb	93	39446.396	11.277
Cs	133	35871.633	9.316
Ba	138	1431103.578	475.502
La	139	132634.549	34.795
Ce	140	668027.254	190.787
Pr	141	32229.530	7.063
Nd	142	−18067.336	−15.852
Sm	152	6519.872	5.901
Eu	153	2824.439	1.238
Gd	158	6149.089	4.678
Tb	159	3183.557	0.811
Dy	164	4804.803	4.650
Ho	165	3326.609	0.971
Er	166	3017.501	2.649
Tm	169	1242.085	0.376
Yb	174	2696.999	2.320
Lu	175	1168.075	0.350
Hf	180	3060.975	3.030
Ta	181	3468.161	1.116
Pb	208	365911.749	54.899
Th	232	52075.727	15.484
U	238	8162.163	2.113
Rh	103	306708.010	

This subsurface 85°E Ridge and its origin remain a mystery. Seismic investigations in the Bay of Bengal determined the sediment thickness pattern and their sequences[5]. Magnetic studies indicate the possible presence of Cretaceous magnetic zone and Mesozoic anomalies[6]. Curray and Munasinghe postulated that the 85°E Ridge is the Crozet hotspot track. The extension of this track was linked to Rajmahal traps on the Indian subcontinent. Such hypothesis is still debatable[7]. The thick pile of sediments over the northern region hampers the detection of continuity of the 85°E Ridge in the north and delineation of deep crustal structures in the Bay of Bengal. It has been argued that the crust beneath the Bay of Bengal is of continental-type, although some studies conclude that the crust is of oceanic-type[5]. The high-frequency seismic Sn shear wave propagation studies indicate that the mantle beneath the Bay of Bengal is not warm. However, all these studies could not demarcate finer details of the mantle heterogeneities and the compensation mechanism responsible for structure like the 85°E Ridge. Seismic studies have indicated that the basement configuration across the 85°E Ridge shows a tilt towards the west, suggesting the possible plate cooling or subsi-

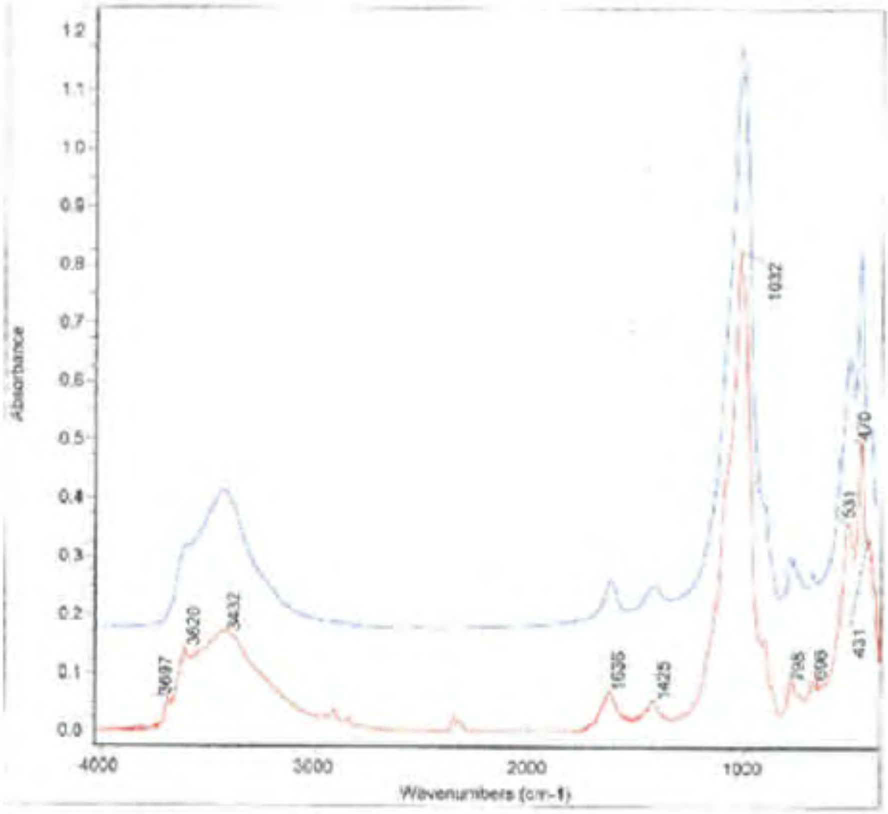

Figure 3. Background-corrected FTIR spectra of sediment sample (red) compared with standard illite (blue) from NICOLET spectral library.

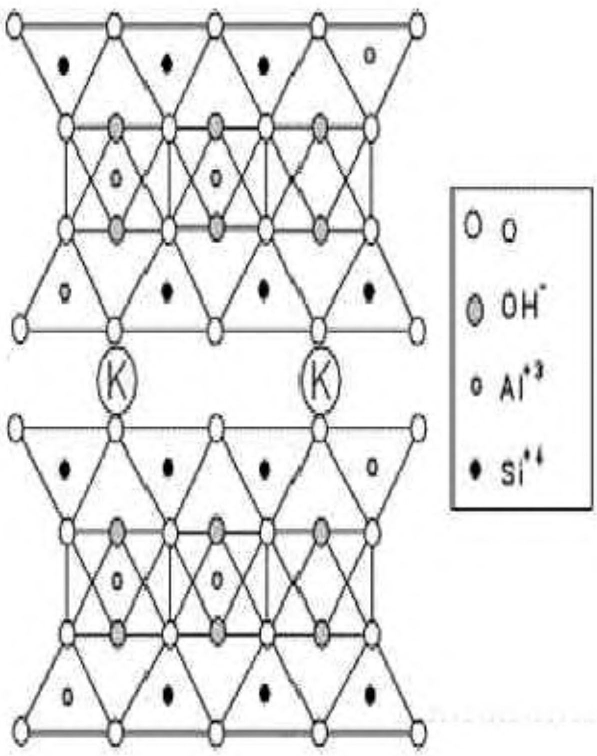

Figure 4. Structure of illite.

dence due to sediment loading. The pattern of gravity and magnetic anomalies suggests that the 85°E Ridge is not wide, indicating lesser magma supply.

Analysis of the gravity profiles across the 85°E Ridge indicates that the ridge was emplaced on young lithosphere and the negative characteristics of gravity anomaly over this could be due to sediment load.

The GEODROME was deployed to study geophysical properties at ocean bottom in the Bay of Bengal at lat. 17.5°N, long. 85.0°E (Figure 1) for its test performance. It was lowered through a 450 m long mooring rope attached with a 2 ton weight and steel rope up to a depth of 2550 m with a winch on-board. Drift of the ship was adjusted with the extra steel rope and the experiment was continued for 24 h duration with special care[8] (Figure 2). Since the acoustic release did not function, the instrument was lowered using this device available in the ship. Since the deployment was done using the mooring rope and due to the high drift speed of the ship or slow speed of the winch, the GEODROME was tilted to one side. Hence, the seismic and magnetic sensors could not be released.

On retrieval of the GEODROME, the anchor winch was covered with mud indicating that the GEODROME was dragged on the sea bottom; this material was treated as a sample. Analysis of the samples was done at the laboratories of NGRI, Hyderabad. Geochemical analysis revealed the presence of various mineral compositions as listed in Table 1. This was done using ElanDRCII (Perkin Elmer). Later the same marine sediments were analysed in the Mineral Physical Laboratory and the final result indicates the presence of illite (93%) (Figure 3).

Illite is not a specific clay mineral name, but is a general term for the mica type clay minerals. It is commonly used for any nonexpanding clay mineral with a 10 Å *C*-axis spacing (Figure 4).

By definition, all illites have the mica-type structure. The basic structural unit is composed of two silica tetrahedral sheets with a central octahedral sheet. The size of naturally occurring illite particles is small, yet they are larger and thicker than montmorillonite particles and have better-defined edges. Illite is a common product of weathering if potash is present in the environment of alteration. It is a frequent constituent in many soil types, and may form in soils under certain conditions as a consequence of the addition of potash fertilizers. This is possible because illite has the ability to 'fix' potassium. Illite is common in recent sediments and is particularly abundant in deep-sea clays. It probably forms from montmorillonite and other minerals during marine diagenesis. Illite is often found in ancient sediments. It is the dominant clay mineral in shales that have been studied.

The rate of sedimentation is perhaps the highest in the Bay of Bengal region because the gradient of the many rivers run into it. The total number of samples collected was divided into 64. These 64 samples were scanned with the help of DTGS TEC detector. They were further scanned by Fourier transformation infrared spectroscope. The resolution was around 2.000, sample grain 8.0, mirror velocity 0.6329 and aperture 37.00. After all the results were correlated and calibrated, the best match was found to be illite, with 93%. Illites are indicative of mechanical rather than chemical weathering, but are more stable than mica minerals. Illites are characteristic of weathering in temperate climates or in high altitudes in the tropics, and typically reach the ocean via rivers and wind transport. These processes may have brought these sediments to the 85°E Ridge.

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Precambrian mega lineaments across the Indian sub-continent – preliminary evidence from offshore magnetic data

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Marine and airborne magnetic data over south Indian continent including the western and eastern continental margins between latitudes 12°30′N and 10°N were studied and interpreted. The total intensity magnetic anomalies over the south Indian continental block between 10°45′N and 12°30′N exhibit distinct character compared to the adjoining northern and southern blocks. The study revealed the presence of two Precambrian mega lineaments over a stretch of 750–800 km running in east-west direction. They were mapped approximately from the isobath of 1500 m in the western continental margin, across the south Indian Peninsula and through

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