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Studies on the Increase in Seismicity in the Antarctic Plate: Observations from BB Seismological Observatory (MAIT) at Maitri, Antarctica during 25th IAE

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ABSTRACT

The permanent Seismological Observatory was established in 1997 at Maitri in Central Dronning Maud Land, East Antarctica (70°45' south 11°43' east) primarily to monitor the seismicity in and around Antarctica, the space and time distribution of earthquake occurrences and obtain hypo central parameters, magnitudes of earthquakes, velocity inversion for underground structure and earthquake source mechanism. The observatory has been upgraded during 25th Indian Silver Jubilee Scientific Expedition to Antarctica (December 2005 to February 2007). Uninterrupted good quality digital Broad Band Seismic data is continuously being acquired. The SEISAN 8.1 software was used for final processing and analysis of about 306 earthquakes recorded. The tele-seismic events, and quite a number of regional earthquakes of the order of 4 to 6.0 magnitude within Antarctic Plate, 23 in South Sandwich Islands, 7 in Scotia Sea, 2 in Macqurie Islands and 23 in Mid Oceanic Ridges in the Indian Ocean were recorded. 48 earthquakes of the magnitude above 4.5 from the nearby South Indian Ocean, South of South Africa, Chile, Argentina, Bolivia and about 40 earthquakes of the magnitude above 5.0 from the Indonesian Region were analyzed. An earthquake of magnitude Ms=7.3 from the seismically active region of South Sandwich Islands Δ=16.5°, Mb=7.8 earthquake from Tonga Islands and Mb=7.2 earthquake from Java were the large earthquakes that were recorded. All the analyzed monthly data was reported to the I.S.C., U.K., Global Data Centre for the final processing and inclusion in the yearly ISC Seismic Bulletin. The increasing seismic activity in and around Antarctic plate and along the oceanic ridges in the Indian Ocean confirms the emerging deforming zone in the Indian Ocean between India and Antarctica and gives an insight into the spreading rates of the ridges and reorganization of Plate Boundaries.

Keywords: SEISAN, Local Seismicity, Mid-Oceanic Ridges

INTRODUCTION

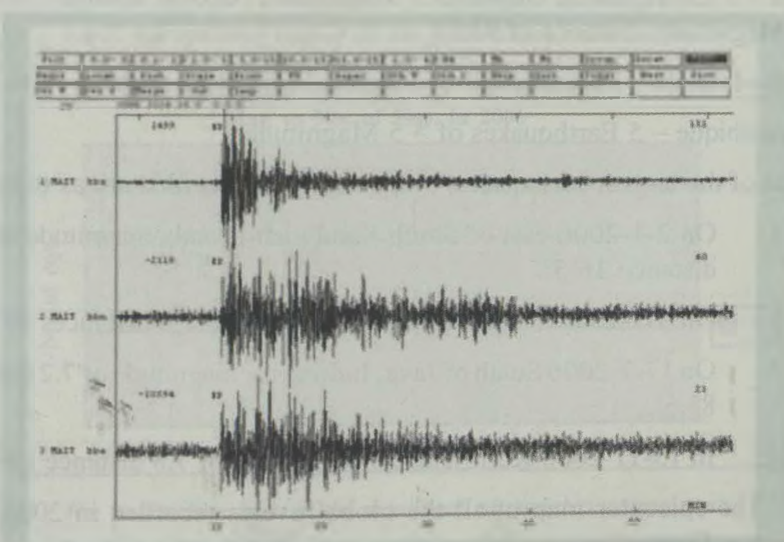
The classic Triple junction in the Indian Ocean named as Rodrigues Triple junction (RTJ) where the three plates Somalia-Antarctica-Indo-Australia diffuse plate boundary meet makes an interesting study of sources of seismicity in the Indian Ocean and hence the Indian Plate Kinematics. The three mid-ocean ridge (MOR) systems that form the Triple junction are (i) South West Indian Ridge (SWIR), (ii) South East Indian Ridge (SEIR), and (iii) Central Indian Ridge (CIR) and its northwestern continuation Carlsberg Ridge (CR) and they strikingly illustrate the complexities of applying ideal rigid plate tectonics to ocean plates. Many earthquakes of magnitude 6 or 7 have occurred in this century near the Ninety East Ridge (90ER) and give a rate of seismic moment release comparable to that along the San Andreas Fault in California[1]. The history of earthquakes and their seismic fault plane solution analysis reveal that most of the faults in the Indian Ocean are strike–slip faults and a few are thrust faults near the Indo-Australia diffuse plate boundary. Surprisingly no normal fault solution has been reported. Earlier plate motion models treated the area as containing oceanic lithosphere from African, Indo-Australian, and Antarctic plates interacting with neighboring Eurasian and Arabian plates. However, it was recognized that the true picture was more complex. Although much has been learned using marine geophysical and seismological data and described by geologic plate motion models based on magnetic anomalies, transform azimuths, and earthquake slip vectors, the kinematics are poorly characterized compared to simpler regions, which inhibits understanding of the regional dynamics.

Seismic Data Acquisition and Analysis

The seismological observatory has a state-of-the-art Broad Band Seismic System with Guralp CMG-3ESP Sensor and High Resolution Digital Data Acquisition System RT 72A 121-03 from Refraction Technology Inc., USA till 2005 and the observatory was upgraded during XXV Indian Antarctic Expedition (IAE) (January 2006) with the new Broadband Seismometer, Geotech KS-2000M with Geotech- Smart 24R Digitizer as shown in Figure 1. The 3-Component short-period seismometers have also been installed by making use of the RT 121 System with the Reftech DAS unit. The observatory has recorded all the global seismic events that occurred during 2006. Totally 306 earthquakes were recorded along with some events in the nearby regions. Nearest event recorded was

Fig. 1: Geotech KS-2000M with Geotech-Smart 24R Digitizer

from South Sandwich Islands and the farthest event recorded was from Central Alaska from a dist. of 169.8 deg; Mag. =5.3 that is shown in Figure 2.



Digital Waveform of the farthest teleseismic event (about 16,000 km from Maitri) recorded at MAITRI Observatory

Fig. 2: Seismic waveform of the farthest event recorded from Central Alaska from a dist. of 169.8 deg; Mag. =5.3

Rest of the earthquakes recorded are from Sumatra, Indonesia, Kuril Islands, Japan region, Russia, Fiji islands, Kermadec islands, Korea and Vanuatu Islands. All the earthquakes that were recorded are highlighted below.

Earthquakes from nearby regions:

South Sandwich Islands region – 25 Earthquakes; magnitudes from 4.3 to 7.3, distance 16.5° to 22.4°.

Scotia Sea – 8 Earthquakes. Magnitude 4.4 to 6.8 distance of about 21.4°.

Macqurie Islands — 2 Earthquakes of 4.8 and 5.0 Magnitude..distance of 54°.

Chile – 32 Earthquakes. Magnitude 4.6 to 6.2 distance of about 60°.

Argentina–14 Earthquakes, Magnitude 4.4 to 6.0 distance of about 56°.

Peru – 12 Earthquakes, Magnitude 4.8 to 6.0 distance of about 72-79°.

Nearby Ridges—18 Earthquakes. Magnitude 4.7 to 6.0 of varying distance.

India – 3 Earthquakes, Gujarat-5.5 Magnitude, Nicobar Islands – 5.7 and 5.8 Magnitude, distance of 93.5°.

South of Africa – 3 Earthquakes of Magnitude 4.5 to 5.6 distance 18 to 25°.

Mozambique – 5 Earthquakes of > 5 Magnitude.

Some of the largest earthquakes (> 7) that were recorded are as follows:

1. On 2-1-2006 east of South Sandwich Islands magnitude of 7.3, distance 16.5°.
2. On 3-5-2006 Tonga Islands, magnitude of 7.8 distances 89°.
3. On 17-7-2006 South of Java, Indonesia, magnitude of 7.2 distance 83.5°.
4. In 15-11-2006 Kuril Islands, magnitude of 7.8 distance 149.7°.

The epicenter map of all the global events recorded in 2006 is as shown in Figure 3.

From this global map as well as from the result of earlier global maps, it is evident that the seismicity is on the increase in the Indian Ocean Basin. Apart from the number of events, even the magnitude of these earthquakes are also between 5 and 6. The histogram in Figure 4 shows the

Global Seismic events of varying magnitudes recorded at Maitri during XXV IAE

Epimap-2006

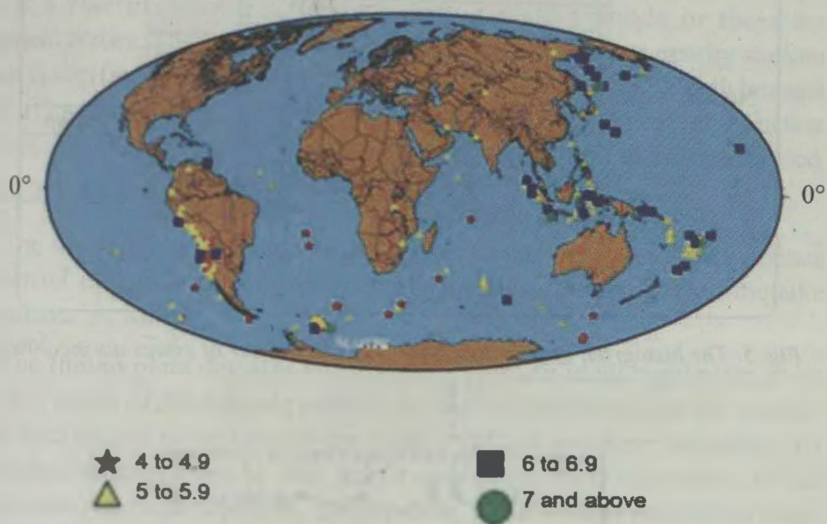


Fig.3: The epicenter map of all the global events recorded in 2006

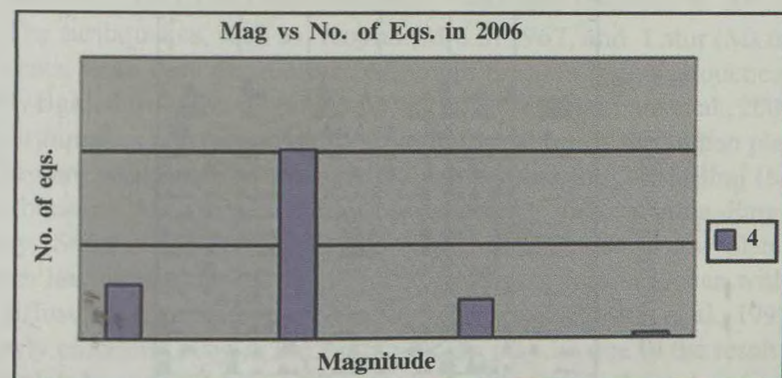


Fig. 4: The histogram of the number of earthquakes vs magnitude

number of earthquakes vs. magnitude and the Figure 5 depicts the time distribution of the number of events during 2006. From these histograms it is evident that the numbers of earthquakes of magnitude 5 to 6 are about 150, 200 and more than 200 compared to the earlier studies. This relatively high magnitude of earthquakes in the study region indicates the deforming

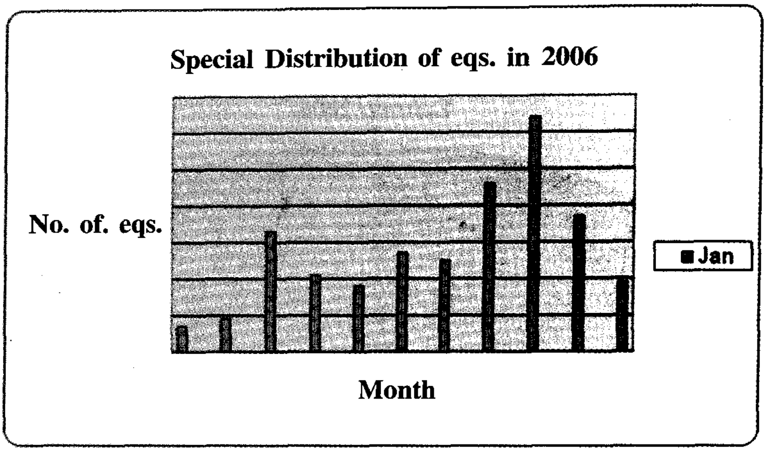


Fig. 5: The histogram of time distribution of the number of events during 2006

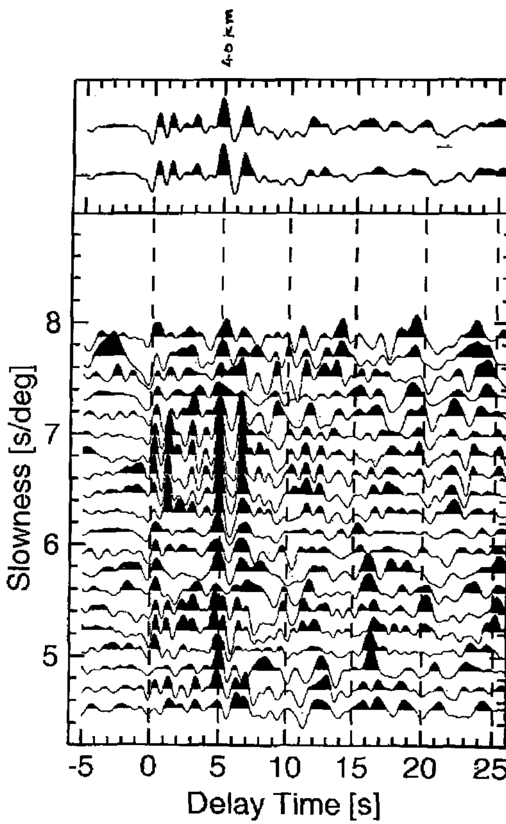


Fig. 6: Estimated MOHO depth beneath Maitri

zone in the larger part of the Indian Ocean. An interesting observation was that the number of earthquakes seems to increase during the months between June and September. This has been observed in all the four years from 2002 to 2006. This needs a rigorous investigation to determine whether there is a rise in seismic activities during these periods or these are instrument errors. This also would be confirmed if the other nearby stations records is verified. The Figure 6 shows the estimated MOHO depth beneath Maitri. This was estimated to be about 40 km using Receiver Function Analysis. For this analysis 67 receiver functions and 108 events were used.

RESULTS AND DISCUSSION

The seismicity and tectonics of Indian Ocean basin and the evidence for internal deformation of Indian plate are described using earthquake mechanisms as follows.

The Indian plate deviates significantly from an ideal rigid plate, even given that much of the oceanic seismicity and deformation near the equator is now recognized to be part of the plate's diffuse southern boundary. Its continental boundaries to the north and west also represent broad deformation zones. In addition, earthquakes occur within peninsular India south of 15° N (Bilham & Gaur, 2000) and the adjacent oceanic lithosphere north of the diffuse boundary zone, and continental crust along the west coast appears to be fixed (Subrahmanya, 1994 and Bendick & Bilham, 1999). The earthquakes, such as Koyna (M 6.3) 1967, and Latur (Ms 6.4) 1999 events, were very destructive. Although the area seems geodetically relatively rigid, the deformation may be significant (Malaimani et al., 2000). These earthquakes are viewed as internal deformation of the Indian plate, since they are well south of the seismic zone where the 2001 Bhuj (Mw 7.7) earthquakes occurred, that may be part of the diffuse India–Eurasia boundary (Stein et al., 2002, and Liu et al., 2002). Also a new platelet Capricorn has been proposed in the central-western Indian Ocean with a broad, diffuse boundary (Royer & Gordon, 1997, and Gordon et al., 1998). This newly emerging plate in the Indian Ocean may be due to the result of frequent plate boundary reorganization in the past and these boundary forces complicate the kinematic interpretations and may also contribute to the non-rigid behavior of the Indian plate and Indian Ocean Basin.

The high magnitude of the present-day regional stress field of the Indian plate results from the unique dynamic situation in which the Indian plate now finds itself. There are several factors that account for this high stress magnitude. Age variations, such as encountered along the Sunda trench, induce significant variations in net boundary forces. Coupled with the curved geometry of the plate boundary, these conditions are capable of concentrating stresses to kilobar levels. From the required torque balance Cloetingh & Worte, 1985) found that the Indian plate is undergoing a considerable net resistance at the Himalayan collision zone. There is also considerable net resistance at other large segments of the convergent boundaries of the Indian plate. This applies in particular to the Banda arc and to the northwestern part of the Sunda arc. In combination with ridge push, these features explain why compression is the dominant stress mode in the plate. A very detailed study of depths of oceanic intraplate bending earthquakes (Ward, 1983) gives strong independent evidence for the existence of intraplate stresses of a few kbar in a more general sense.

As representative of seismic prone regions, the South Sandwich Islands, which are in 16 to 25 degrees distance from Seismic Observatory (MAIT), recorded about 25 earthquakes of magnitude ranging from 4.1 to 7.5. Table 1 lists the number of earthquakes in this region. The Scotia Sea region, which falls between 20 to 24 degree distance from Maitri, has experienced 8 earthquakes of magnitudes ranging from 4.2 to 5.9. A total number of 306 earthquakes were recorded in 2006 alone. Minor to semi major earthquakes of magnitude varying from 3.5 to 4.5 within Antarctica have also been recorded. The increasing seismic activity in and around Antarctica and along the oceanic ridges in the Indian Ocean confirm the emerging deforming zone in the Indian Ocean between India and Antarctica.

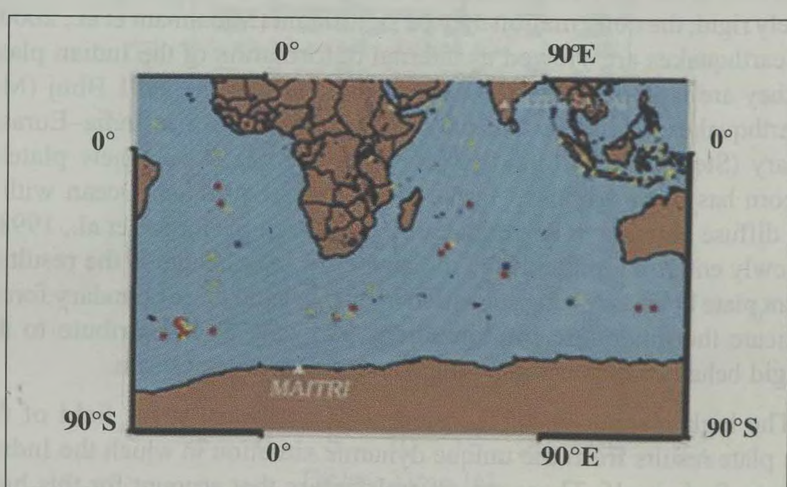
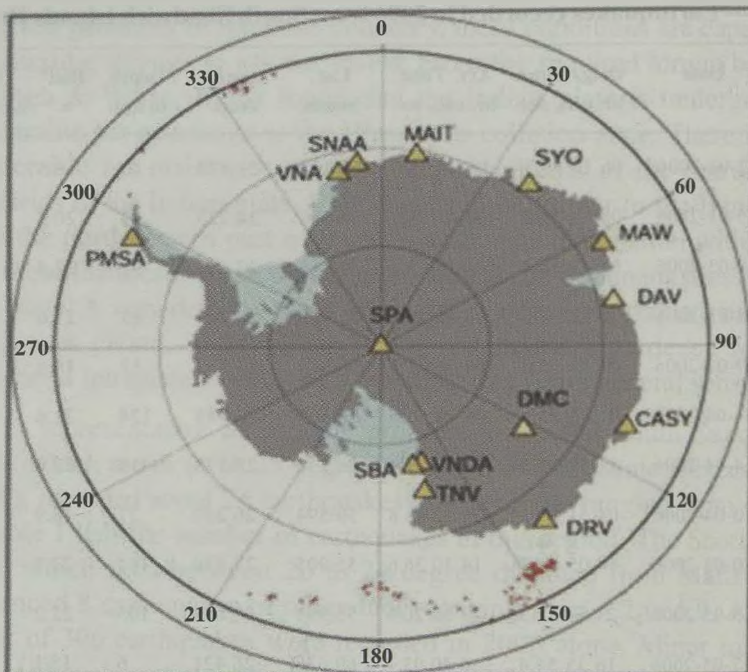


Fig. 7: The increased seismic activity in the region of South Sandwich Islands

Table 1— Earthquakes recorded in 2006 from South Sandwich Islands Region

S.No.	Date	Orig. Time hr. mn. sec	Arr. Time hr. mn. sec	Lat. South	Long. West	Depth in km.	Dist" = °	Mag Mb / Ms
1.	02-01-2006	06 10 49.3	06 14 38.0	60.807	21.474	10	16.5	7.3
2.	05-01-2006	08 40 49.2	08 45 34.5	56.558	24.723	39	20.3	5.7
3.	18-03-2006	14 13 38.1	14 18 29.2	55.846	27.611	92	22.4	5.2
4.	18-03-2006	23 12 01.0	23 16 45.2	56.410	26.793	83	21.6	5.3
5.	19-03-2006	04 31 55.0	04 36 21.1	58.055	25.213	57	19.8	5.4
6.	04-04-2006	01 43 35.9	01 48 15.8	56.465	26.988	124	21.6	5.3
7.	14-04-2006	09 51-23.5	09 56 10.0	56.150	27.178	114	22.0	4.9
8.	30-04-2006	03 51 28.5	03 55 48.8	59.594	26.207	27	18.9	5.3
9.	30-04-2006	14 05 46.1	14 10 36.6	55.905	27.630	101	22.3	5.2
10.	13-05-2006	23 53 32.3	23 58 20.0	55.991	27.624	105	22.2	5.3
11.	17-05-2006	16 35 54.4	16 40 03.7	60.638	26.421	6	18.1	4.9
12.	03-06-2006	19 21 45.8	19 25 56.8	59.657	26.406	121	18.9	5.0
13	06-06-2006	20 41 14.9	20 45 35.4	59.456	26.151	35	19.0	4.4
14	01-07-2006	20 12 08.5	20 16 50.4	56.318	24.990	51	21.2	4.9
15.	10-07-2006	16 02 47.1	16 07 07.8	58.708	24.922	43	19.2	5.0
16.	18-07-2006	07 47 26.2	07 52 00.4	57.233	25.728	78	20.6	4.7
17.	03-08-2006	17 28 08.8	17 32 40.5	57.807	25.564	69	20.1	5.0
18.	10-09-2006	06 35 54.0	06 40 22.4	58.023	25.801	75	20.0	5.1
19.	14-09-2006	01 08 46.0	01 13 30.8	58.323	29.891	10	21.0	4.8
20.	15-09-2006	15 11 55.3	15 16 41.1	56.066	27.168	125	22.0	4.6
21.	24-09-2006	05 31 29.6	05 35 47.3	58.977	23.734	10	18.6	4.3
22.	29-09-2006	05 50 49.0	05 55 07.0	58.973	25.783	67	19.2	4.8
23.	05-10-2006	12 38 14.1	12 43 06.6	56.038	26.482	23	21.8	4.6
24.	26-10-2006	14 43 33.2	14 48 31.8	55.532	26.593	10	22.3	4.8
25.	08-11-2006	15 57 28.1	16 02 04.6	56.991	23.683	15	20.2	5.3



CODE	NAME	INSTRUMENTATION	VAULT/SITE	WHERE TO GET DATA
MAIT	Maitri Station	CMG-3ESP	Underground vault, Bedrock	ISC

Fig. 8: The Antarctic map (AnSWeR) of permanent digital broadband seismometers that are functional

This increased seismic activity in this region gives an insight into the spreading rates of the ridges and reorganization of plate boundaries. This is shown in Figure 7. The Figure 8 shows the Antarctic map (AnSWeR) of permanent digital broadband seismometers that are functional.

CONCLUSIONS

The history of the earthquakes recorded at Maitri and their fault plane solution analysis reveal that most faults in the Indian Ocean, specifically along the ridges are strike–slip faults and a few are thrust faults near the Indo-Australian diffused plate boundary. The seismic data recorded since 1997 and its analysis clearly shows an increasing trend of the seismicity in and around Antarctica. The significant result is the increasing seismicity along the ridges in the Indian Ocean and the spreading rates of them, which are of concern for the seismotectonics study and the Indian plate kinematics. Our analysis also corroborates the evidence of deforming zone in between India and Antarctica.

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