

## Studies on Seismotectonics and Geodynamical Processes between Antarctica and India

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### Abstract

The on-going research activities at Antarctica were successfully carried out during 21st IAE by participating and contributing data to the Global data centers. Both GPS and Seismic Observatory at Maitri, Antarctica have gone global and working in tandem aid mutually, the studies on tectonic processes, analyzing the seismic activities in and around Antarctica, yield a comprehensive picture on Indian Plate Kinematics. Acquisition of uninterrupted good quality Broad Band digital seismic data as well as GPS data continued. The seismic data was processed and analysed at NGRI using SEISAN software, up to September 2002 and reported to International Seismological Centre, United Kingdom. This data is quite useful in global epicentral determination, particularly about the earthquakes of South of Africa, Indian Ocean and South Sandwich Islands. About 314 events have been reported to ISC out of which 3 earthquakes of above 7 magnitude, 30 earthquakes of above 6 magnitude and the rest are of magnitudes 5 and 4. The nearest region of South Sandwich Islands region also experienced with 27 major earthquakes and this data will be useful for further research activities.

Keywords : ISC, SEISAN, Broad Band, Earthquakes and Epicenter, GPS, Geodesy, Very Long Baselines.

### Introduction

The need to focus the study on the Indian Ocean Margin becomes mandatory in the present scenario of intraplate and interplate earthquakes that do occur frequently in India forcing to re-evaluate the rigidity of the Indian plate as well as Indian Ocean Margin. GPS-Geodesy and Seismic Studies are extended to envelop the large Indian Ocean lithosphere. To broad "base these studies and to understand the tectonic activity, crustal deformation in the south of Indian peninsula, the driving mechanisms and the response of the Indian Ocean Lithosphere, the GPS data from the IGS stations in the islands surrounding Indian plate is included in the global network solution The worldwide seismic network'In stable Antarctica

located only ten earthquakes with magnitudes above four during last three decades. In order to monitor the seismic activity in and around Antarctica and Indian Ocean, a reconnaissance survey for site selection and the feasibility of operation of seismological observatory in Antarctica was initiated during 16th Antarctic Expedition. A permanent Digital Seismological Station has been installed during 17th expedition. The station was fully commissioned on 26 January 1998 with analog and short period digital systems. This observatory was further upgraded with the installation of Broad Band seismic system in 20th IAE. During the 21<sup>st</sup> IAE only analog and Broad Band systems were used for daily recording and it is continuously operational and the seismic station is also a part of AnSWeR. (Antarctic Seismic Web Resource.) Figure 1.

### Antarctic Broad Band Seismic Observatories

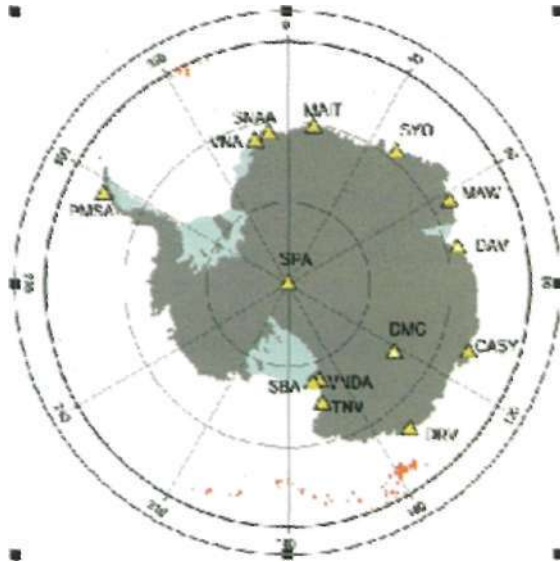


Fig. 1

### Scientific Aims and Objectives

#### A. "Continuous GPS monitoring between India and Antarctica"

- Since the Indian Ocean Basin is bound by the plates Arabia, Somalia, Antarctica, and a diffuse India-Australia boundary, it becomes significant to kinematically describe the plates and their boundaries to address the following questions:

1. *How rigid is the Indian Plate?*
  2. *Does its relatively high level of intraplate seismicity indicate internal deformation in excess of other plates?*
  3. *Is this related to Indo-Eurasian collision and the generation of Himalayas?*
- With the inclusion of the data from Antarctica in the global data analysis, the studies on interplate motion and crustal deformation between India and Antarctica are highly focused.
  - Besides, crustal uplift after deglaciation and elevation changes in Antarctica could also be studied.
  - With the estimation of Very Long Baseline vectors and their changes between India and Antarctica, signatures of crustal deformation and strain accumulation in the south of Indian Peninsula would be obtained.
  - Dynamics and the kinematics of the newly emerging platelet named as Capricorn and their influences on the Indian Plate would be studied by including various sites in the Indian Ocean and other plates in the Global Network solution.
  - Since the final objective is to establish the time evolution of baseline length between Hyderabad and Maitri to precisely estimate the crustal deformation between India and Antarctica and to understand the serious tectonic and geodynamical processes that do take place in the Indian Ocean Basin, a new strategy was adopted wherein many stations in between India and Maitri, which have longer time series of site coordinates in the IGS network were included so that the short base lines between the stations estimated would ultimately be tied.

#### **B. "Continuous operation of permanent Seismological Observatory at Maitri"**

- The establishment of the seismic station with high-resolution digital short-period and Broad Band seismograph system as well as analog seismic recorder was intended to monitor the seismic activity within Antarctica.
- The station also aims at monitoring of tele seismic activity as well as the activity in mid oceanic ridge in the Indian Ocean.
- Data exchange with other stations besides participating in the global earthquake epicentral determination while contributing data

to International Seismological Centre, U.K. is being continued in this expedition.

- The main work of a seismic observatory is to quickly process the seismic signal and extract the phase data information.

### **Methodology**

#### **"Continuous GPS monitoring between India and Antarctica"**

Already GPS receiver is commissioned and operational continuously at Maitri since 1997.

- GPS data acquisition in RINEX format and preprocessing at Maitri
- GPS data processing and analysis using Bernese Software version 4.2 •
- Estimation of very long base lines between the stations using global network solution.
- Estimation of site coordinates of all the chosen stations and velocity vectors.
- Estimation of Euler vectors for the plate-pairs.
- Finally estimation of the strain accumulation in the southern Indian Peninsula and the continental Dynamics between India and Antarctica.

#### **Continuous operation of permanent Seismological Observatory at Maitri**

An underground pit has been dug and a special thermally insulated vault was buried in it some 20 meters away behind Tirumala hut. An electronically controlled  $t$  temperature device has been installed in the seismic vault, which maintains the inside temperature at 17 to 24 deg. Celsius. Recording of the data is being done in the Tirumala hut, which is 200 meters away from the Maitri main building. Inside this hut is wooden partitioned to separate seismic observatory from the 10-12 summer component scientific personnel who uses this hut for their stay and for scientific experiments. Proper care is always taken to maintain above +15 deg temp even in winter period inside this observatory. A vertical component analog RV-320B recorder is also being operated simultaneously. During 20th IAE, this seismic observatory was upgraded *m-.C*

with the installation of additional 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. This seismic observatory is running satisfactorily without any interruption till date. During this expedition i.e., from January 2002 - February 2003 continuous recording of seismic data has been done and the same has been archived and stored in CDs and dat tapes for further processing and analysis.

Using SEISAN software the final analysis work of this data has been completed and reported to International Seismological Centre, United Kingdom as per their time schedule and the balance data analysis will be completed soon and then the MAIT Seismological Bulletin for the 2002 will be published.

### **Instruments and Software Used**

#### **Broad Band Recorders**

Recorder: REFTEK 72A/07/G/ND      Sl.No.8029

Sensor: CMG-3ESP 50Hz to 100 sec flat response (velocity) Sl.No. 3815

Analog: Teledyne Geotek RV-320B ink recording

#### **REFTEK and SEISAN Software**

Both these softwares are standard and installed on our computers at NGRI, Hyderabad and Maitri, Antarctica. Data is acquired using the REFTEK software on the Data Acquisition System manufactured by M/s. REFTEK, USA.

SEISAN software is a standard software used globally for processing digital seismic data. Both Reftek and Seisan Software were tested and used before sending the systems to Antarctica.

SEISAN has a simple time ordered database and a set of programs. The most important programs are EEV, MULPLT, HYP, EPIMAP, and BUL. In addition to these programs, several other programs are available for database creation, input and output of large data sets and conversion and manipulation of waveform data.

#### **Station (MAIT) Coordinates**

Latitude: 70° 45' 56.898909" South Longitude: 11° 44' 8.530495" East  
Height: 134.0612 Meters

## Results and Discussion

### "Continuous GPS monitoring between India and Antarctica"

Since Maitri is one of the SCAR GPS stations contributing to the SCAR database, Maitri data till 2003 is included in the International Data Base of the SCAR Epoch GPS campaigns (Fig. 2). With the continuing Indo-German mutual scientific collaboration with Institute of Planetary Geodesy, Technical University of Dresden, Germany, and with the participation of two of the German Scientists even in the 20<sup>th</sup> expedition with our NGRI scientists, SCAR 2000 to 2003 Epoch GPS campaigns and the other details including the online station description of Maitri are made available in the data archive for the global access for any user for geodynamics. The data and all the other details of the expedition can be accessed at the following websites:

<http://www.tu-dresden.de/ipg/SCARGPS/MAIT.html>

[http://www.tu-dresden.de/ipg/SCARGPS/db\\_2000.html](http://www.tu-dresden.de/ipg/SCARGPS/db_2000.html)

[http://www.tu-dresden.de/ipg/SCARGPS/db\\_2001.html](http://www.tu-dresden.de/ipg/SCARGPS/db_2001.html)

[http://www.tu-dresden.de/ipg/SCARGPS/db\\_2002.html](http://www.tu-dresden.de/ipg/SCARGPS/db_2002.html)

[http://www.tu-dresden.de/ipg/SCARGPS/db\\_2003.html](http://www.tu-dresden.de/ipg/SCARGPS/db_2003.html)

### Maitri as one of the SCAR Stations in 2003 GPS Campaign

#### SCAR GPS Campaigns: Participation (II)

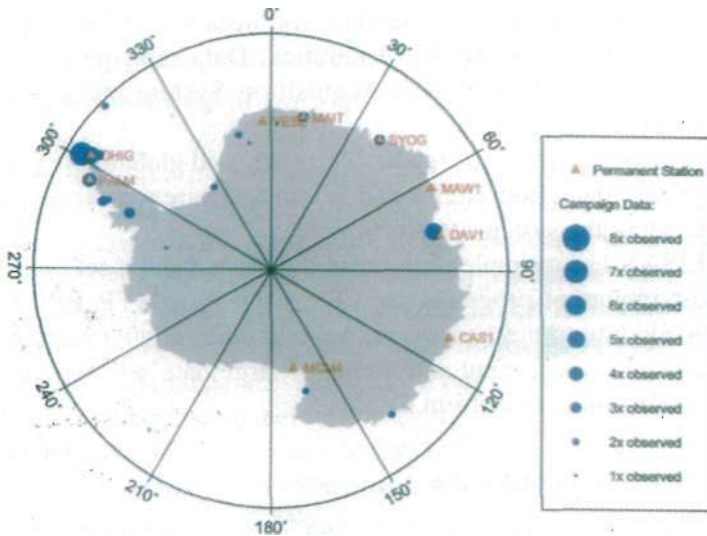


Fig. 2

By contributing data to SCAR, Maitri has become one of the SCAR stations and hence would continue to be one of the SCAR stations and remain in the global scenario of GPS Geodesy. Maitri Permanent GPS Station plays a major role to realise ITRF Global Reference Frames by contributing data to IERS, France.

### **Continuous operation of permanent Seismological observatory at Maitri**

The Broad Band Seismological Observatory has recorded high quality seismic data during 21<sup>st</sup> Indian Antarctic Expedition and the same was transferred to CDs and brought back to Antarctica Studies Group of National Geophysical Research Institute, Hyderabad. The processing and final analysis work from January- September 2002 completed and being reported to International Seismological Centre, United Kingdom as per their monthly schedule. After completion of 314 earthquakes final analysis, it is confirmed that only telesismic activity prevailed during this expedition period and no regional seismicity observed except few icequakes, iceberg collusions that are common in Antarctica. The nearest area of South Sandwich Islands, which are in 18 - 23 degrees distance from Maitri Seismic Observatory (MAIT), produced 28 earthquakes of Magnitudes ranging from 4.3 to 5.8 (Table 1). The farthest event recorded is from Kuril Islands 151.5 deg. Many earthquakes from south of Indian

**Table 1: South Sandwich Islands Region Earthquakes**

Date	Distance <sup>0</sup>	Latitude	Longitud	Magnitude
14/1/02	22.1	-55.547	-25.913	4.7
22/1/02	16.8	-58.449	-15.976	4.6
26/1/02	18.8	-59.83	-26.427	4.8
10/02/02	22.7	-55.928	-29.086	5.6
12/02/02	18.7	-59.754	-25.995	5.2
19/2/02	21	-56.721	-25.484	5.4
10/04/02	22.1	-56.07	-27.447	4.7
15/4/02	18.6	-60.069	-26.497	4.9
18/4/02	18	-60.732	-26.084	5.6
20/4/2002	20.1	-57.642	-25.084	4.6
06/05/02	22.9	-55.323	-28.06	4.7
08/05/02	21.7	-56.253	-26.567	4.7
28/5/02	22.2	-56.014	-27.685	4.9
16/7/02	22.5	-55.73	-27.872	4.9

(Contd.)

**Table 1: South Sandwich Islands Region Earthquakes (Contd.)**

Date	Distance <sup>0</sup>	Latitude	Longitude	Magni
18/7/02	19.4	-58.644	-25.417	4.9
29/7/02	22.2	-55.737	-26.847	5.5
30/7/02	19.3	-57.939	-23.291	5.8
30/7/02	22.2	-55.772	-26.861	4.9
03/08/02	19.4	-57.822	-23.402	4.4
04/08/02	20	-58.103	-25.993	4.7
12/08/02	18.7	-59.579	-25.683	4.8
23/8/02	22.2	-55.525	-26.133	4.3
27/8/02	22.2	-55.685	-25.968	4.9
30/8/02	21.8	-56.108	-26.581	4.6
07/09/02	19.8	-57.951 ..	-25.088	5.1
09/09/02	22 ,	.-56.142	-27.391	4.3
19/9/02	21.5	-56.561	-26.681	4.6

**Table 2: Earthquakes from the regions of Latitude:30 deg. South and below  
Longitude: 30 deg. West to 120 deg. East-South  
Sandwich Islands Region which falls in same region (see separate Table)**

Date	Latitude	Longitude	Region	Magnitude
7/1/02	-52.673	27.463	South of Africa	5
20/2/02	-52.129	15.705	South West of Africa	5
20/2/02	-52.117	15.653	South West of Africa	4.9
17/3/02	-45.143	34.76	Prince Edward Islands Region	5.7
2/3/02	-34.809	-16.534	Southern Mid-Atlantic Ridge	5.5
8/4/02	-50.999	139.263	West Indian Ridge	6
12/4/02	-30.773	59.503	South West Indian Ridge	4.9
17/4/02	-39.215	78.503	Mid-Indian Ridge	4.8
2/5/02	-51.843	139.811	West Indian Antarctic Ridge	4.8
14/5/02	-36.497	78.744	Mid-Indian Ridge	4.9
14/5/02	-36.612	78.84	Mid-Indian Ridge	6.1
20/5/02	-32.748	57.143	South West Indian Ridge	4.9
13/6/02	-47.776	99.561	South East Indian Ridge	6.6
14/6/02	-47.239	101.985	South East Indian Ridge	5.4
15/6/02	-53.267	23.643	South of Africa	4.6
15/6/02	-53.279	23.478	South of Africa	4.9

(Contd.)



**Table 2: Earthquakes from the regions of Latitude: 30 deg. South and below Longitude: 30 deg. West to 120 deg East-South Sandwich Islands Region which falls in same region (see separate table) (Contd.)**

Date	Latitude	Longitude	Region	Magnitude
16/6/02	-53.301	23.758	South of Africa	5.1
23/6/02	-60.192	-32.977	Scotia Sea	4.6
11/7/02	-49.549	125.723	West Indian Antarctic Ridge	4.6
12/7/02	-50.658	29.103	South of Africa	4.1
15/7/02	-43.923	-16.024	Southern Mid-Atlantic Ridge	5
28/7/02	-49.242	120.757	West Indian Antarctic Ridge	4.7
4/8/02	-35.447	-15.99	Tristan Dacunha Region	5.4
8/9/02	-30.142	60.894	South West Indian Ridge	5.4

Ocean, South of Africa, Scotia Sea, Fiji Islands, Chile-Argentina border region were also recorded (Table 2). 33 earthquakes of magnitude 6 to 7.8 recorded clearly with well developed phases shows the quality and purpose of MAIT seismic data in epicentral determinations and further research about seismicity of these regions (Table 3).

**Table 3: Major earthquakes recorded of Magnitude 6 and above**

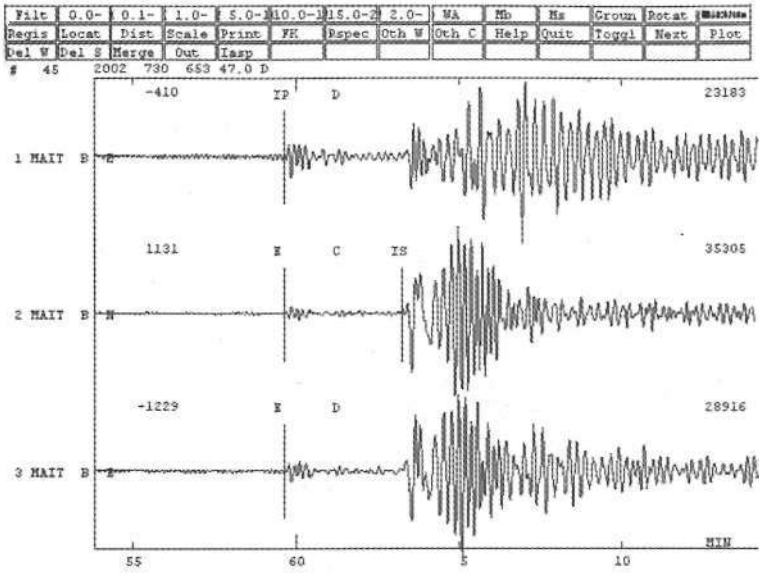
Date	Distance <sup>0</sup>	Region	Latitude	Longitude	Magnitude
02/01/02	90.1	Vanuatu Islands	17.6S	167.8E	Ms=7.5
03/01/02	90	Vanuatu Islands	17.7S	168.0E	Ms=6.4
13/01/02	99.1	New Britain Region	5.5S	150.8E	Ms/06.4
28/01/02	152.9	Kuril Islands	49.4N	155.5E	Mb=6.0
01/02/02	143.8	Primorye, Russia	45.5N	136.7E	Ms=6.1
05/02/02	99.4	New Britain Region	5.3S	151.3E	Ms=6.3
03/03/02	115	Hindu Kush Region, Afghanistan	36.5N	70.4E	Mb=6.2
25/03/02	114.3	Hindu Kush Region, Afghanistan	36.0N	69.4E	Ms=6.2
28/03/02	66.3	Chile/0 Bolivia Border Region	21.6S	68.1W	Ms=6.3
31/03/02	119.8	Tiawan Region	24.5N	122.2E	Ms=7.3
01/04/02	59.9	Near Coast of Central Chile	29.5S	71.1W	Mb=6.2
08/04/02	52,7	Westren/0 Indian Antarctic Ridge	5 LOS	139.3E	Ms=6.0

(Contd.)

**Table 3: Major earthquakes recorded of Magnitude 6 and above (Contd.)**

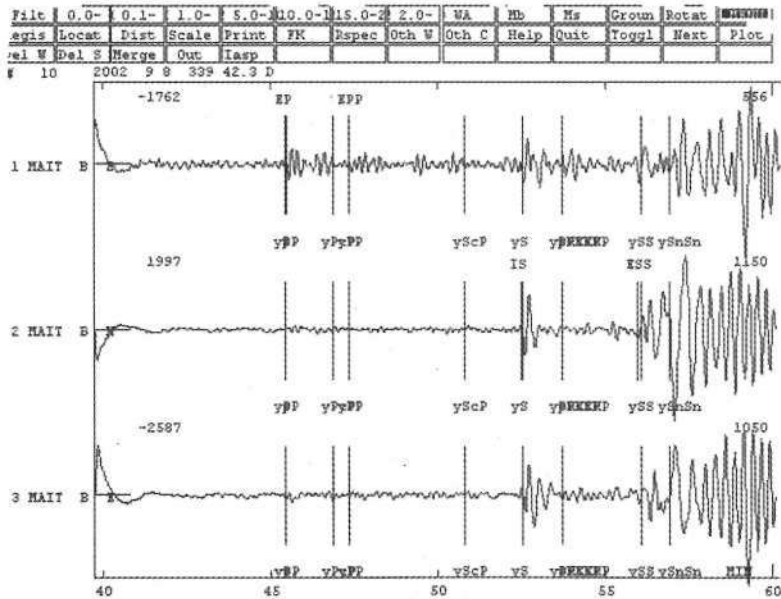
Date	Distance <sup>0</sup>	Region	Latitude	Longitude	Magnitude
11/04/02	93.3	Vanuatu Islands	14.4S	167.6E	Ms=6.2
18/04/02	113.3	Mexico	16.95S	100.8W	Ms=6.0
18/04/02	61.5	Near Coast of Northern Chile	27.5S	70.6W	Mb=6.2
20/04/02	91.9	Fiji Islands Region	16.4S	173.2E	Mb=6.0
24/04/02	48.9	Southern East Pacific Rise	56.2S	122.0W	Ms=6.0
14/05/02	48.2	Mid Indian Ridge	36.6S	78.8E	Ms=6.1
28/05/02	58.9	Catamarca Province, Argentina	28.9S	66.6W	Mb=6.1
13/06/02	45	South East Indian Ridge	47.8S	99.6E	Ms=6.6
18/06/02	58.7	Chile Argentina Border Region	30.8S	7 LOW	Mb=6.0
27/06/02	84.1	South West of Sumatra, Indonesia	7.0S	103.9E	Ms=6.5
28/06/02	140.3	Eastern Russia /0 NE China Border	43.7N	130.7E	Mb=6.8
19/08/02	87.2	Fiji Islands Region	21.7S	179.5W	Mb=6.7
19/08/02	84.9	South of Fiji Islands Region	23.9S	179.4E	Mb=6.9
19/08/02	84.9	South of Fiji Islands Region	23.9S	179.4E	Mb=6.0
08/09/02	99.4	Near North Coast of New Guinea	3.3S	142.9E	Ms=7.8
13/09/02	99.5	Andaman Islands, India	13.0N	93.2E	Ms=6.8
20/09/02	98.8	Indonesia	1.5S	134.4E	Ms=6.4
24/09/02	57.4	San Juan Province, Argentina	31.4S	69.0W	Mb=6.3
24/09/02	96.2	Solomon Islands	10.5S	161.2E	Ms=6.2
24/09/02	96.1	Solomon Islands	10.5S	161.0E	Ms=6.3
24/09/02	96.1	Solomon Islands	10.6S	161.2E	Ms=6.5

One earthquake of magnitude 6.8 from Andaman Islands, India was also recorded on 13-9-2002, distance of 99.5 deg. Lat: 13.013N Long: 93.147E. All the reported data to ISC is now available in their web site: <http://www.isc.ac.uk> as well as in our data base: ISC2002 with all identified phases, location, distance and magnitudes along with wave form files for future scientific purposes. Three well-recorded earthquakes from minimum, middle and maximum distances from MAIT can be seen in Figures 3 to 5.



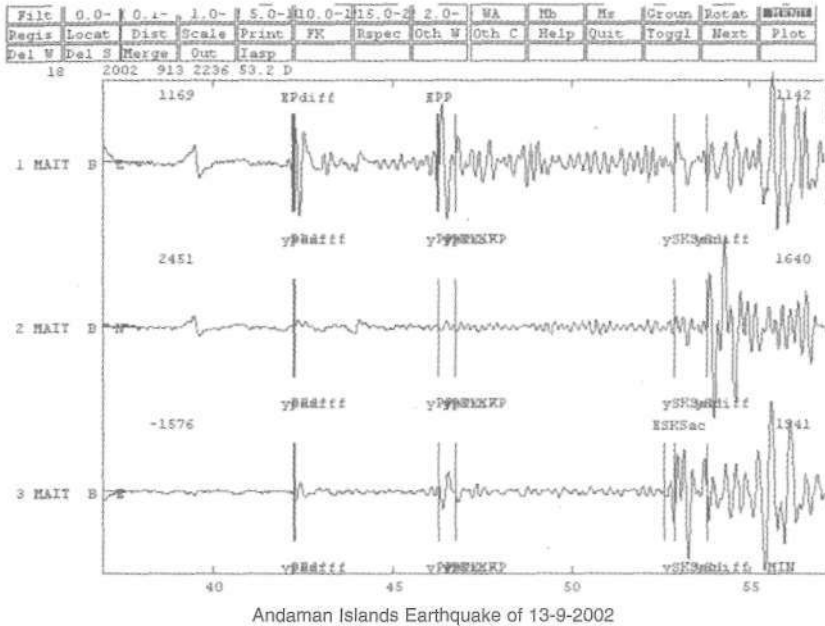
South Sandwich Islands Earthquake Mb=5.8

Fig. 3



South West Indian Ridge Earthquake Mb=5.4

Fig. 4



Andaman Islands Earthquake of 13-9-2002  
**Andaman Islands Earthquake Ms=6.8**

*Fig. 5*

Fig. 6 shows the epicentral location map of all the 314 analyzed earthquakes from January-September 2002.

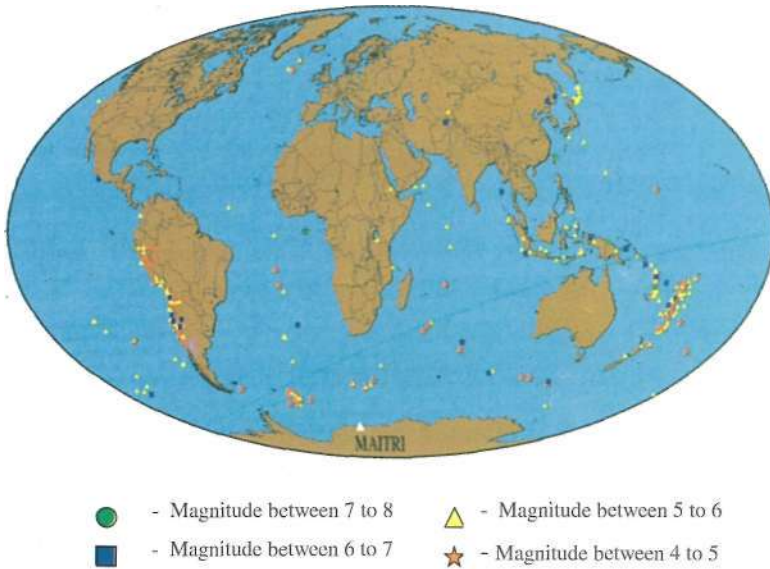
Until now, since this observatory started, five well recorded near earthquakes show local seismicity in Antarctica. These near events are 20 to 400 kms from MAIT seismic observatory of Indian Research Base Station in Antarctica. Research work is under progress about this local seismicity and soon the results will be published.

### Conclusion

The GPS and the Seismic results show the strain accumulation and deformation processes towards the Indian Plate. Therefore these studies would continue for a longer span of time to precisely estimate the seismicity and tectonic activity in and around Antarctica and in the Indian Ocean.

The collocation of a Permanent GPS Station and Seismic Observatory will also result in monitoring the space and time distribution of earthquake occurrences and obtain hypo- central parameters, magnitudes of earthquakes, release of energy, strain accumulation and stress drop, velocity inversion for underground structure and physical properties,

## Global Seismicity in 2002 from Maitri, Antarctica



*Fig. 6*

*Fig. 6*

earthquake source mechanism, receiver function analysis, attenuation of seismic waves and anisotropy studies.

### Acknowledgements

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