

Qualitative Assessment of Tectonic Lineaments Over the Coastal and Innershelf of Kakinada and Kalingapatnam, Central East Coast of India

A.S.SUBRAHMANYAM, G. P. S. MURTY, K.V.L.N.S. SARMA, K. MOHANA RAO, N.P.C. REDDY,
M.M. MALLESWARA RAO, V. SUBRAHMANYAM, P. SUNEETHA RANI,

A. ANURADHA and K.S.R.MURTHY

National Institute of Oceanography, 176, Lawson's Bay Colony, Visakhapatnam - 530 017

Email: subbu_a@yahoo.com

Abstract: Earth tremors of low to moderate intensity (3.0 to 5.5) recurring over last century in and around coastal and shelf regions of Visakhapatnam has prompted us to acquire and study the geophysical data between coastal regions of Kakinada and Kalingapatnam in western part of Central Bay of Bengal (17°N - 18°30'N) for understanding the recent seismicity of the region. Preliminary analysis of magnetic and shallow seismic data reveals the presence of some prominent land-Ocean tectonic lineaments, reactivation of which is considered to be responsible for tremors in the region. Total field magnetic anomaly map of the study area shows two major anomaly lineations such as: (a) N-S trending medium amplitude (~250 nT) lineation off Visakhapatnam which is considered to be offshore fragment of converging point of two onshore lineaments. Also the lineament is associated with five earth tremors of magnitude 3.7 to 4.3 at 40 m water depth. Impact of tremors is also observed in the overlying sedimentary strata in the form of vertical faults, (b) A NE-SW high amplitude anomaly zone (~820 nT) off Kalingapatnam trending NE-SW, which is in close proximity with the epicentral location of earth tremors of 5.5 magnitude. This lineament can be spatially correlated to onshore NW-SE trending structural lineament indicating the probable reactivation of offshore segment resulting in the earth tremors. Off Vizianagaram, reactivation of preexisting structural lineaments associated with the NW-SE trending Kandivalasa river fault may be the source of tremors at 20 m water depth. Magnetic basement contour pattern changes from NE-SW to NW-SE off Visakhapatnam. It may be inferred that the basement is bounded by two fault controlled lineaments passing through epicenters of earth tremors off Visakhapatnam and Vizianagaram. Basement structure shows down faulted basement (2 to 3 km) underlying the epicentral location along the lineaments trending NW-SE in the innershelf of visakhapatnam. Shallow seismic data also indicate steeply dipping sub bottom fault in the study area of Visakhapatnam. South of Visakhapatnam, shallow seismic records indicate vertical faults and shearing reflectors in the lower sedimentary layers. From the deformed lower sedimentary layers. It may be considered that the region might have undergone seismic activity in the recent past, but presently there are no reported tremors in this region. Even undeformed top sedimentary layers suggest lack of recent tectonic activity between Visakhapatnam and Kakinada in coastal and shelf regions. It may be summarized from the preliminary analysis of the geophysical data that the earth tremors observed north of Visakhapatnam are caused mainly due to reactivation of tectonic lineaments whereas south of Visakhapatnam it is relatively free from any seismicity. Based on the felt reports, tremors are attributed to shallow focus origin. Detailed investigations from multidisciplinary approach like geological, geomorphological, geophysical and remote sensing observations coupled with seismic information in the study area will throw more light on the micro seismic activity and related recent tectonics of this coastal region of east coast of India.

Keywords: Tectonic Lineaments, Magnetic anomalies, Microseismic activity, East coast, Andhra Pradesh.

INTRODUCTION

Southern Peninsular India has long been considered to be an aseismic zone being shield area. However during the last 50 years, eight moderate size earthquakes (Anjar, 1956, 6.0; Ongole, 1967 5.4; Koyna, 1967, 6.3; Bhadrachalam,

1969, 5.7; Mt Abu, 1969, 5.3; Broach, 1970, 5.4; Killari, 1993, 6.1; Jabalpur, 1997, 5.8;) have occurred in the Indian Stable Continental Region (SCR). Figure 1 shows the epicenters of earthquakes of East Coast of India, Recent earthquake off Pondicherry (25 Nov. 2001) and tremors off

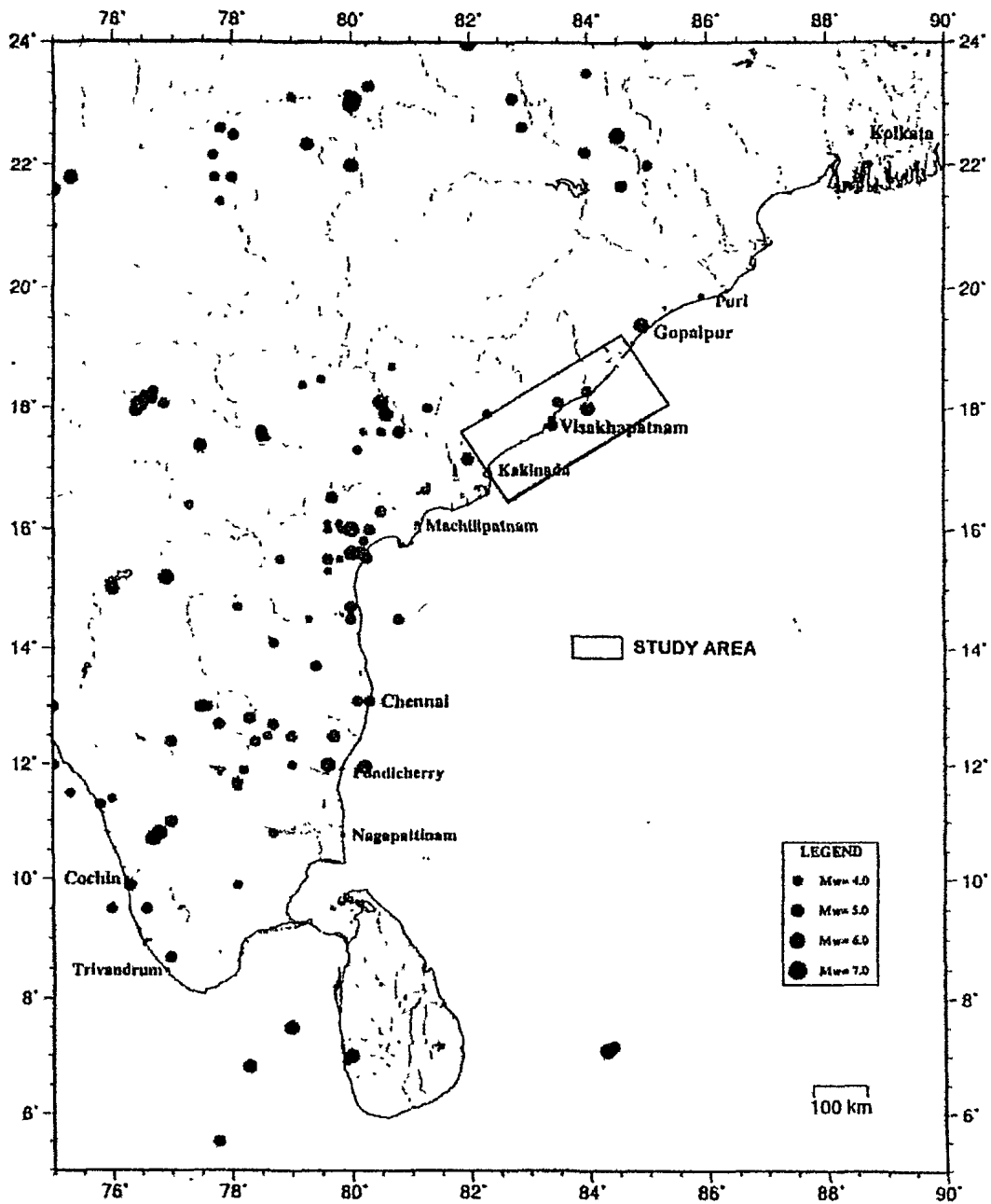


Fig.1. Earthquake distribution map of East Coast of India.

Vizianagaram (18 Dec.1995) in the innershelf regions of South India indicate that nearshore regions are also not free from seismicity. In the present study we have attempted to analyse the geophysical data to understand the possible causative sources of Earth tremors around Visakhapatnam Studies subsequent to the earthquakes (Rajendran et al. 1996a; Rajendran et al. 1996b; Murty et al. 2002; Subrahmanyam et al. 1999); have led to the identification of pre-existing faults that have been considered to be

reactivated in recent times causing the earthquakes. Studies carried out over southern part of Indian Peninsula have also brought out evidence of Quaternary earth movements (Ramasamy, 1989; Narasimhan 1990). Table 1 shows the earth tremors in the study area occurred over last 150 years ranging from 3.0 to 5.5. Earlier geophysical studies along with some reported locations of epicenters of recent tremors suggest reactivation of some tectonic lineaments extending from coast to the continental shelf (Murthy et al. 2001).

Table 1. Earth tremors reported over the study area: historic to recent times

S.No.	Year	Location		Area	Magnitude	Epicenter
		N	E			
1.	06-01-1827	17° 42'	83° 25'	Innershelf off Visakhapatnam Bay of Bengal (40 m water depth)	4.3	A
2.	1853	17° 42'	83° 25'	Innershelf of Visakhapatnam Bay of Bengal (40 m water depth)	3.7	A
3.	24-08-1858	17° 42'	83° 25'	Innershelf of Visakhapatnam Bay of Bengal (40 m water depth)	3.0	A
4.	19-12-1870	17° 42'	83° 25*	Innershelf of Visakhapatnam Bay of Bengal (40 m water depth)	3.7	A
5.	31-12-1927	17° 42'	83° 25'	Innershelf of Visakhapatnam Bay of Bengal (40 m water depth)	4.3	A
6.	17-04-1917	18° 00'	84° 00'	off Kalingapatnam (55 m water depth)	5.5	B
7.	18-12-1995	18° 00'	83° 42'	of Vizianagram (20 m water depth)	4.5	C
8.	1858	18° 18'	84° 00'	North of Kalingapatnam	4.3	D
9.	24-08-1859	18° 06'	83° 30'	Vizianagram	3.7	E
10.	23-12-1959	18° 06'	83° 30'	Vizianagram	4.3	E
11.	09-08-1959	18° 06'	83° 30'	Vizianagram	4.3	E
12.	16-04-2003	18° 18'	83° 42'	NE of Vizianagaram	3-3	F
13.	25-08-2004	18° 36'	83° 18'	NW of Vizianagaram	3.3	G

Most of the earthquakes south of 20° N occur along the coastal regions suggesting the possibility of an edge effect near the continental margin which could be of some significance in causing the earthquakes (Umesh Chandra, 1977). Bott and Dean (1972) suggested that the differences in thickness and density distribution in the continental and oceanic crust at the continental margin boundary might generate a stress system favorable to the development of normal faults in the continental crust and thrust faults in the oceanic crust. The seismicity is largely (80%) confined to linear belts (Valdiya, 2001) in the southern Peninsular India. East coast of India is characterized mostly by infrequent earthquakes of magnitude >4.5 or intensity higher than V. This region corresponds to the Kakinada-Midnapore and Ongole seismic zone (Umesh Chandra, 1977). However, there is a concentration of low and moderate magnitude earthquakes 3.5 and 5.9 along coast and inner shelf of east coast of India. The southern peninsular region, including coastal and shelf regions of east coast of India thus warrants a detailed insight into the seismotectonic scenario in the southern part of India responsible for these shaky events. A number of wave erosional features like rock cut terraces, benches, cliffs etc, are present (Vaz et al. 1998). Visakhapatnam coast is erosional type, fault controlled and hence vulnerable to tremors of low to moderate intensity (Banerjee et al. 2001). A network of shear zones traverses the Eastern Ghat Mobile belt. Most of the major river courses in the Eastern Ghat Mobile Belt (EGMB)

follow the trends of shear zones. In general, the shear zones vary in thickness from 2 to 10 km and extend along the strike between 50 to 500 km. These shear zones trend NE-SW and are parallel to the regional strike of Eastern Ghat Mobile Belt (EGMB) while the shear zones in the central part trend NNW-SSE (Chetty and Murthy, 1998). Two shear zones (Vamsadhara and Nagavali shear zones) have been identified from landsat data in the north coastal region in the study area (Fig.3).

Seismic Events in Shelf Regions of Study Area

Three epicenters of earth tremors i.e. A (3.0 to 4.3), B (5.5) and C (4.5) of low to moderate magnitude have been recorded in the innershelf regions between 10 and 55 m water depth in Bay of Bengal and three Earthquakes/tremors i.e. D (4.3), E (3.7) and F(3.3) along the coastal regions (Fig.2). At Baruva, in the study area, a well developed 30 m thick Late Pleistocene red soil shows vertical displacement across a fault. In offshore regions south of Visakhapatnam top seismic unit comprising silt and clay is also cut by faults indicating that both land and shelf areas over this part are seismically active.

Seismic Events Along the Coastal Regions of the Study Area

Epicenter of earth tremors ('D' (4.3) in Fig.2) (18°18' N and 84°00' E) occurred at 15 km SE of Kalingapatnam felt in Srikakulam district of north coastal Andhra Pradesh

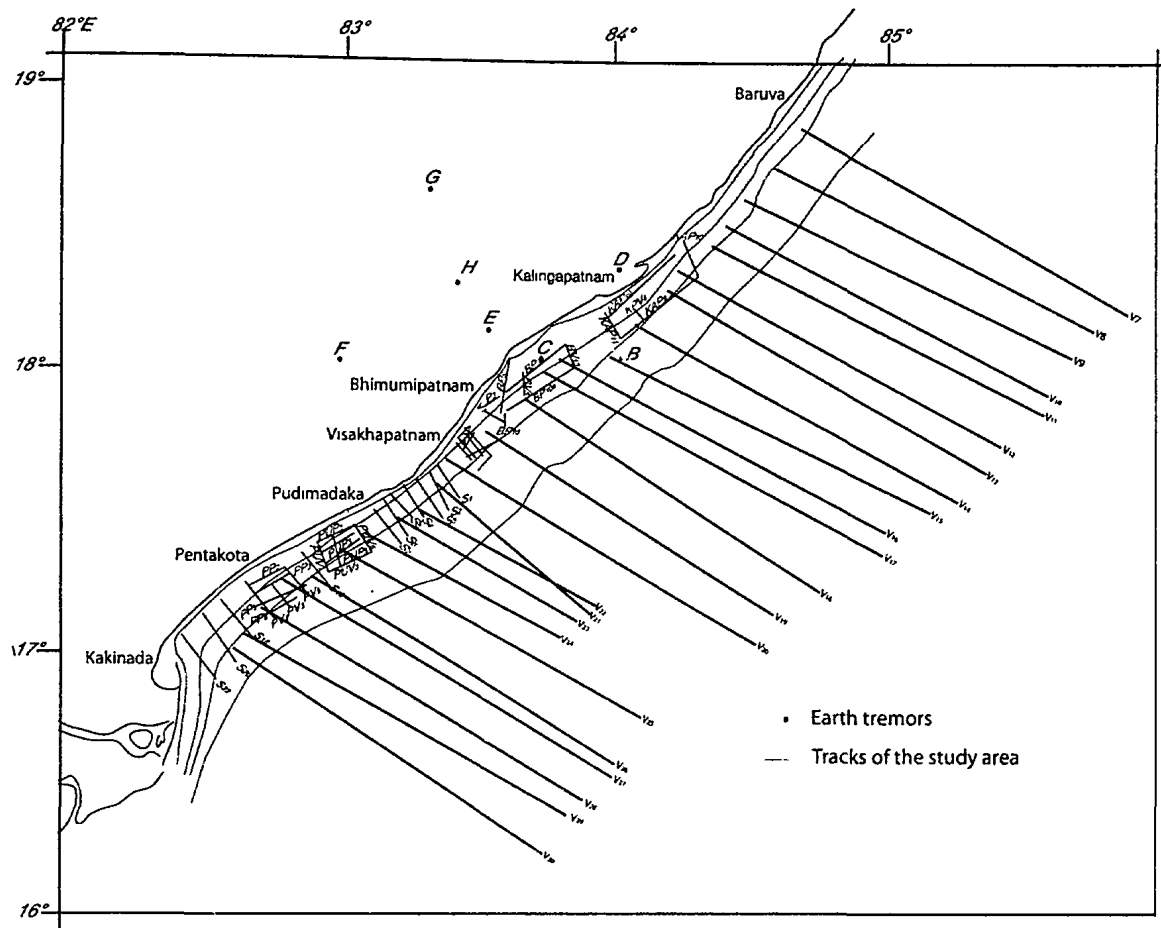


Fig.2. Track map of the study area showing cruise tracks with superposed epicentres of earth tremors.

falls over coastal point of wider shear zone near Srikakulam extending into Bay of Bengal indicating possible shear zone reactivation. Earth tremors (Table 1) along the coast at 18° 06'N and 83°30'E (E' in Fig. 1) lies over Nellimarala River course 9 km WNW of Vizianagaram. Tremors (F in Fig.2) NW of Vizianagaram (18°18' N and 83°42' E) on 16th April 2003 (*Pers. Comm.*, IMD) appear to be indicators of recent reactivation of structural features over this part of the study area. To corroborate our views, detailed geophysical study using high resolution shallow seismic and magnetic data has been taken up over near shore and shelf regions (15 to 100 m water depth) between Kakinada and Kalingapatnam (16°30' N to 18°30'N and 82°E to 84°30'E) in the north coastal Andhra Pradesh. The study aims to understand the signatures of microseismicity/recent tectonism of the area.

Data Acquisition

High resolution shallow seismic and bathymetry data

were acquired on board *Sagar Sukthi* (Coastal Research Vessel of NIO) along 19 coast perpendicular profiles of 570 line Km and 2 coast parallel profiles of 250 line Km between Visakhapatnam and Kakinada (Fig.2). Magnetic and Bathymetry data acquired during RVG 210 and 192 cruises are also supplemented to demarcate lineations.

Magnetic Studies

Total field magnetic anomaly map of the study area between Kalingapatnam and Kakinada (Fig.3) in general is characterised by (1) A major NE-SW trending negative anomaly parallel to the coast, (2) A gentle gradient anomaly zone of 250nT off Visakhapatnam trending N-S passing through epicenter of an earth tremors recurred 5 times lying at 40 m water depth. It is evident from the contour map that this NE-SW lineation is offset by a NW-SE positive anomaly zone off Visakhapatnam. Magnetic basement contour map (Fig.4) from two dimensional analysis also indicates a major offset in the basement contour pattern from NE-SW to

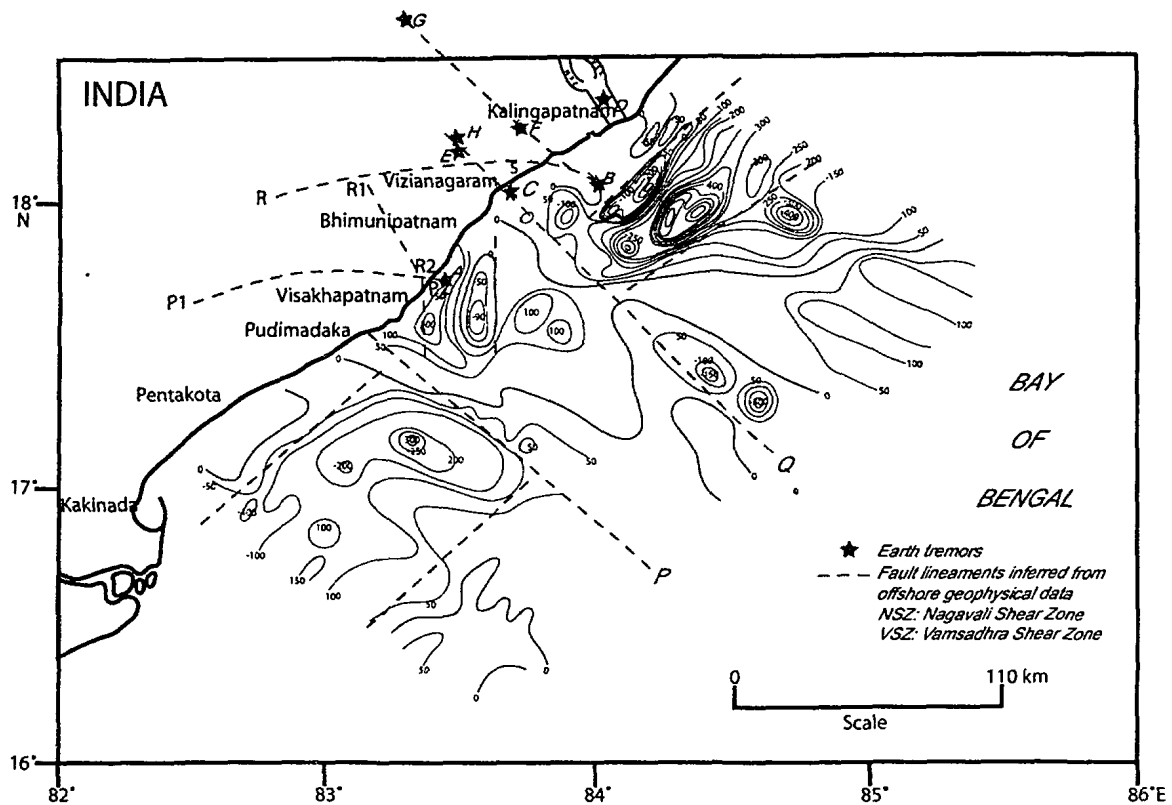


Fig.3. Total intensity magnetic anomaly contour map of the study area with shear zones on land, tectonic lineaments and earth tremors.

NW-SE off Visakhapatnam indicated by two fault controlled lineaments (X and Y in Fig.4) with downfaulted basement of 2 Km from 4 to 6 Km trending NW-SE close to epicenters "A" and "C". Converging point of two land lineaments on the coast at Visakhapatnam i.e. (a) A major structural trend (E-W) on land corresponding to high amplitude anomaly (-1300 nT) lineation P1-P2 (Radhakrishna Murthy and

Rama Rao, 2001), (b) A major NW-SE (R1-R2) lineament traversing across Visakhapatnam district and abutting the coast (Natural Hazards Map of GSI, 2001) and its offshore continuation into Bay of Bengal appears to have resulted in the cluster of five earth tremors at "A", (3) Northward limit of the this NW-SE trend also passes through epicenter "C" (north of Bhimuniapatnam). Major coast parallel trend is

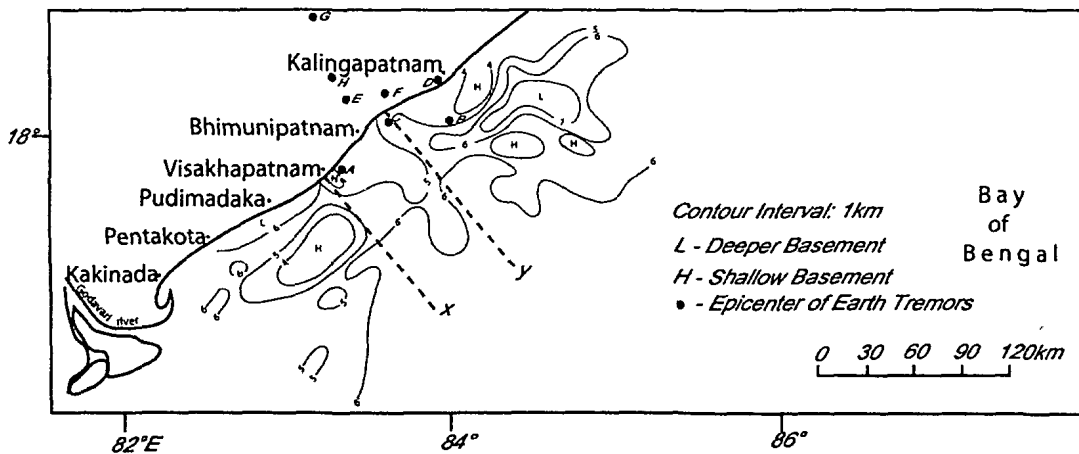


Fig.4. Magnetic basement contour map of Kakinada-Kalingapatnam shelf.

overlain by an isolated high amplitude (~820 nt) short wavelength anomaly trending NE-SW of Kalingapatnam. This anomaly is in close proximity to the epicenter of earth tremor (B) at 55 m water depth (18°00'N and 84°00'E). Interpretation of this anomaly yielded the possible causative source to be a two dimensional intrabasement intrusive feature at shallow depths. Earth tremors 'B' may have resulted from the reactivation of offshore extension of structural lineament (R-S) delineated earlier from magnetic studies. Earth tremors 'C' of magnitude 4.5 occurred at 20 m water depth in 1995 at 18°00' N and 83°42' E over Santapalle Rocks off Vizianagaram indicate the possible reactivation of offshore Jineation associated with NW-SE trending Kandivalassa River fault.

Major NE-SW trend of the negative magnetic anomaly zone between Kakinada and Kalingapatnam is offset by NW-SE lineation, seaward and landward off Pudimadaka and Vizianagaram (P and Q in Fig.3) respectively, indicating possible strike slip faulting. Occurrence of positive anomaly zone in between strike slip trend off Pudimadaka and Vizianagaram suggests possible basement uplift off Visakhapatnam which is also evidenced by shallow basement inferred from magnetic basement contour map (Fig.4). It is also indicated that this basement uplift correlates well with

the juxtaposed Kailasa hill range onland at Visakhapatnam.

Seismic Studies

High resolution shallow seismic data along parallel profile over this area also indicate steep subsurface faulting at 40 m below the sea bed (Fig.5) in the vicinity of earth tremors "C" reported off Vizianagaram at 20 m water depth.

CONCLUSIONS

It can be concluded from the preliminary study of the land, coastal, and nearshore data and spatial correlation of land-ocean tectonic lineaments, that the earthquake off Visakhapatnam at 40 m water depth result from the recent reactivation of the offshore fragment of converging point of two land lineaments i.e., NW-SE and E-W traversing across Visakhapatnam district abutting the east coast at 17° 45' N and extending into Bay of Bengal. The cause for the earth tremors off Kalingapatnam may be the reactivation of offshore extension of land lineament extending into Bay of Bengal. Kandivalasa river fault reactivation appears to be the main cause of tremors reported off Vizianagaram at 20 m water depth. Based on the spatial correlation of

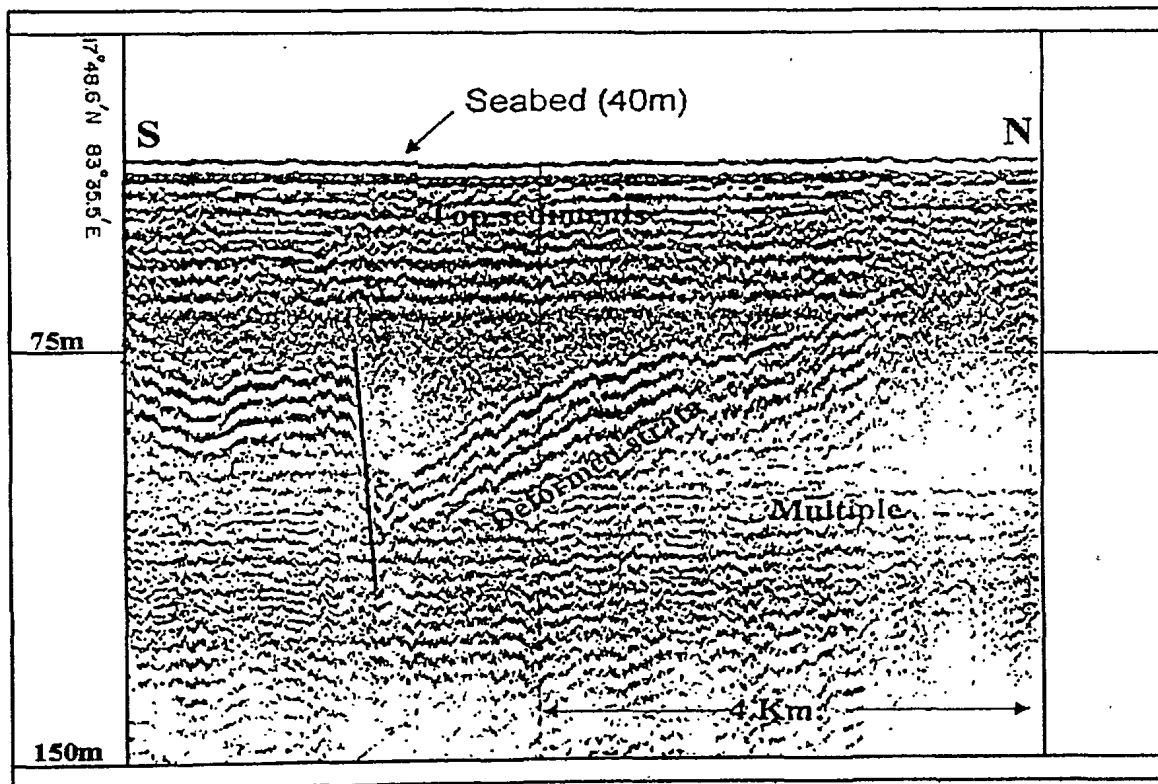


Fig.5. Shallow seismic record showing Vertical fault in sedimentary layers in the vicinity of earth tremor 'C' off Vizianagaram.

geophysical anomalies, geomorphological features and earthquake information, it appears that coastal and nearshore seismicity between Visakhapatnam and Kalingapatnam shelf is mainly due to reactivation of tectonic lineaments extending into sea from land and subsequent crustal readjustments in basement off Visakhapatnam (A) and Kalingapatnam (B) and river fault reactivation off Vizianagaram (C). However, there are no reported tremors of considerable magnitude between Visakhapatnam and Kakinada, either in coastal or shelf regions. Detailed studies on the morphology and tectonics of Eastern Continental Margin of India (ECMI)

and adjacent coastal regions help one to recognize evidence of neotectonism. Identification of active faults employing conventional geophysical methods in coastal and shelf region* would help one to understand the role of land-ocean tectonic lineaments in the recent seismic activity and changing geodynamic environment.

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