

# Baseline geophysical data for hazard management in coastal areas in relation to earthquakes and tsunamis

The International Journal of  
Ocean and Climate Systems  
January–April 2016: 27–31  
© The Author(s) 2016  
Reprints and permissions:  
sagepub.co.uk/journalsPermissions.nav  
DOI: 10.1177/1759313115623161  
ocs.sagepub.com



**KSR Murthy**

## Abstract

A systematic study of geophysical data of the Eastern Continental Margin of India was taken up to identify the land–ocean tectonic lineaments over the east coast of India and the possible neotectonic activity associated with them. These studies helped in delineating the offshore extension of some of the coastal lineaments. Analysis of magnetic, gravity and shallow seismic data, combined with reported seismicity data, indicates moderate seismicity associated with some of these land–ocean tectonics of the Eastern Continental Margin of India. The coastal/offshore regions of Vizianagaram (north of Visakhapatnam) and Ongole of the Andhra Pradesh margin and the Puducherry shelf of the Tamil Nadu margin have been identified as zones of weakness where neotectonic activity has been established. Bathymetry data over the Eastern Continental Margin of India revealed the morphology of the shelf and slope of this margin, which in turn can be used as the baseline data for tsunami surge models. Detailed bathymetry map and sections of the Nagapattinam–Cuddalore shelf (from 10.5° to about 12°N) indicate that one of the main reasons for the higher run-up heights and inundation in the Nagapattinam–Cuddalore coast during the Indian Ocean Tsunami of 26 December 2004 could be the concave shape of the shelf with a gentle slope, which might have accelerated the tsunami surge to flush through at a rapid force. Structural control also appears to be a contributing factor for the tsunami surge.

## Keywords

Hazard management, marine geophysical data, geomorphology and tsunami surge, coastal seismicity

Date received: 7 August 2015; accepted: 15 October 2015

## Introduction

The Indian Ocean Tsunami of 26 December 2004 caught us off guard on several aspects. Not only with the absence of a Tsunami Warning System, but we also did not have substantial data on the morphology, structure and coastal seismicity of our coastal areas. These data are very essential for identifying the areas vulnerable to higher tsunami surge, the expected surge heights at these locations and also to demarcate seismic hazard zones in the coastal areas, which might get reactivated due to the impact of major earthquakes such as the Sumatra event.

The Sumatra earthquake of magnitude more than 9.3 on the Richter scale and some of the stronger after-shocks shook the coastal areas of the east coast of India. Even the recent earthquake of 21 May 2014 in the deep sea Bay of Bengal created tremors over much of the coastal cities of east coast of India. Even though the Eastern Continental Margin of India (ECMI) is a

passive margin with no record of significant seismic activity, the major earthquakes in the vicinity of this margin, particularly at the convergent boundary along the Andaman–Sumatra–Java Trench, are likely to have an impact on the weak structural lineaments extending from the coast to offshore. The compressional stress regime acting over the Indian Plate due to its continuous northward movement is another factor for some of the intraplate earthquakes in the South Indian Shield, which includes the Eastern and Western Continental Margins of India.

CSIR – National Institute of Oceanography, Visakhapatnam, India

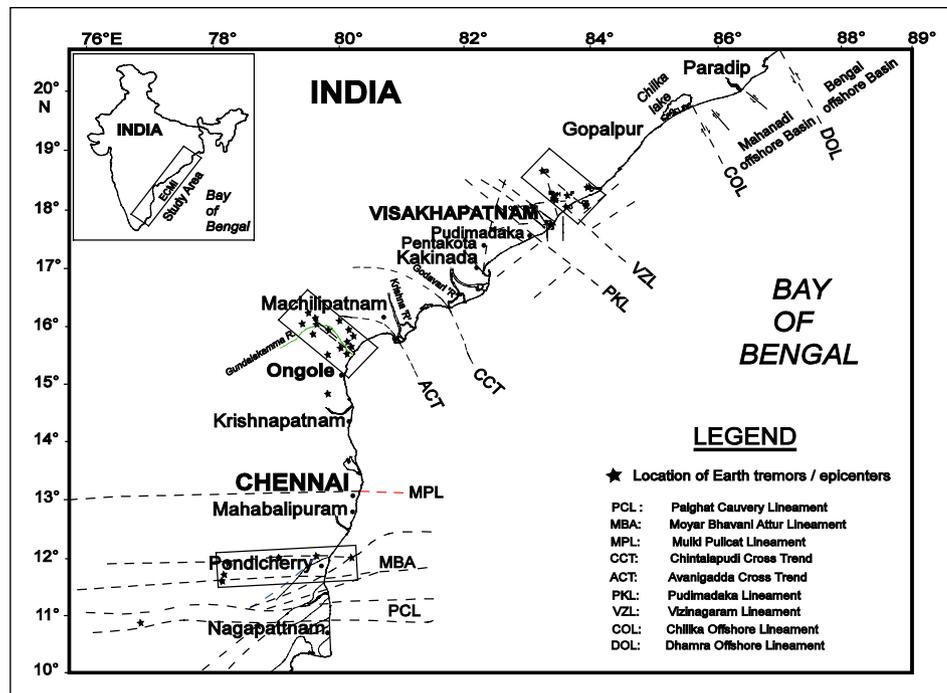
### Corresponding author:

KSR Murthy, CSIR – National Institute of Oceanography, Regional Centre, 176, Lawsons Bay, Visakhapatnam 530017, India.  
Email: murthy.ksr48@gmail.com



Creative Commons Non Commercial CC-BY-NC: This article is distributed under the terms of the Creative Commons

Attribution-NonCommercial 3.0 License (<http://www.creativecommons.org/licenses/by-nc/3.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).



**Figure 1.** Land–ocean tectonic lineaments over the ECMI (Murthy et al., 2010, 2012). Rectangular blocks represent areas identified with seismicity.

## Material and methods

### Baseline marine geophysical data over the ECMI

Since 1985, the Marine Geophysics Group of the National Institute of Oceanography (NIO) at Visakhapatnam has carried out extensive geophysical surveys over the ECMI and the Bengal Fan. Bathymetry, magnetic, gravity and high-resolution seismic surveys were carried out over the ECMI. In addition, the offshore basins (Cauvery, Krishna–Godavari and Mahanadi) and non-basinal areas (Visakhapatnam–Kalingapatnam shelf) of ECMI were covered by detailed studies. These data sets were utilized to explain the evolution, tectonics and associated hazards of a passive margin (Murthy et al., 2012). The detailed data over the offshore river basins have been used to delineate the offshore extension of some of the Pre-Cambrian Tectonic lineaments (Subrahmanyam et al., 2006). In addition, the data over the shelf/slope have been utilized to understand the seabed morphology and to analyse the seismic hazards associated with some of the land–ocean tectonic (LOT) lineaments (Murthy et al., 2012).

## Results

### Coastal seismicity

A systematic study of geophysical data of the ECMI was taken up to identify the LOT lineaments over the east coast

of India and the possible neotectonic activity associated with them. These studies helped in delineating the offshore extension of some of the coastal lineaments (Figure 1).

Analysis of magnetic, gravity and shallow seismic data, combined with reported earthquake data, indicates moderate seismicity associated with some of these LOTs of ECMI (Murthy et al., 2010, 2012). The coastal/offshore regions of Vizianagaram (north of Visakhapatnam) and Ongole of the Andhra Pradesh margin and the Puducherry (also called as Pondicherry) shelf of the Tamil Nadu margin have been identified as zones of weakness where neotectonic activity has been established (shown as three rectangular blocks in Figure 1). While Earthquake data over the coastal and offshore areas of Visakhapatnam (including the Vizianagaram part) indicate moderate seismicity (with magnitude of tremors of the order of 3–4.5), the Puducherry offshore experienced an earthquake of magnitude 5.5, in 2001, which was a fairly larger event for the South Indian shield (Murthy et al., 2002; Subrahmanyam et al., 2007). These results are useful in estimating the coastal stability of different parts of the east coast of India.

### Geomorphology

Bathymetry data over the ECMI revealed the morphology of the shelf and slope of this margin, which in turn can be used as the baseline data for tsunami surge models. A comprehensive bathymetry contour and section map was generated for the entire ECMI (Figure 2(a) and (b)), with

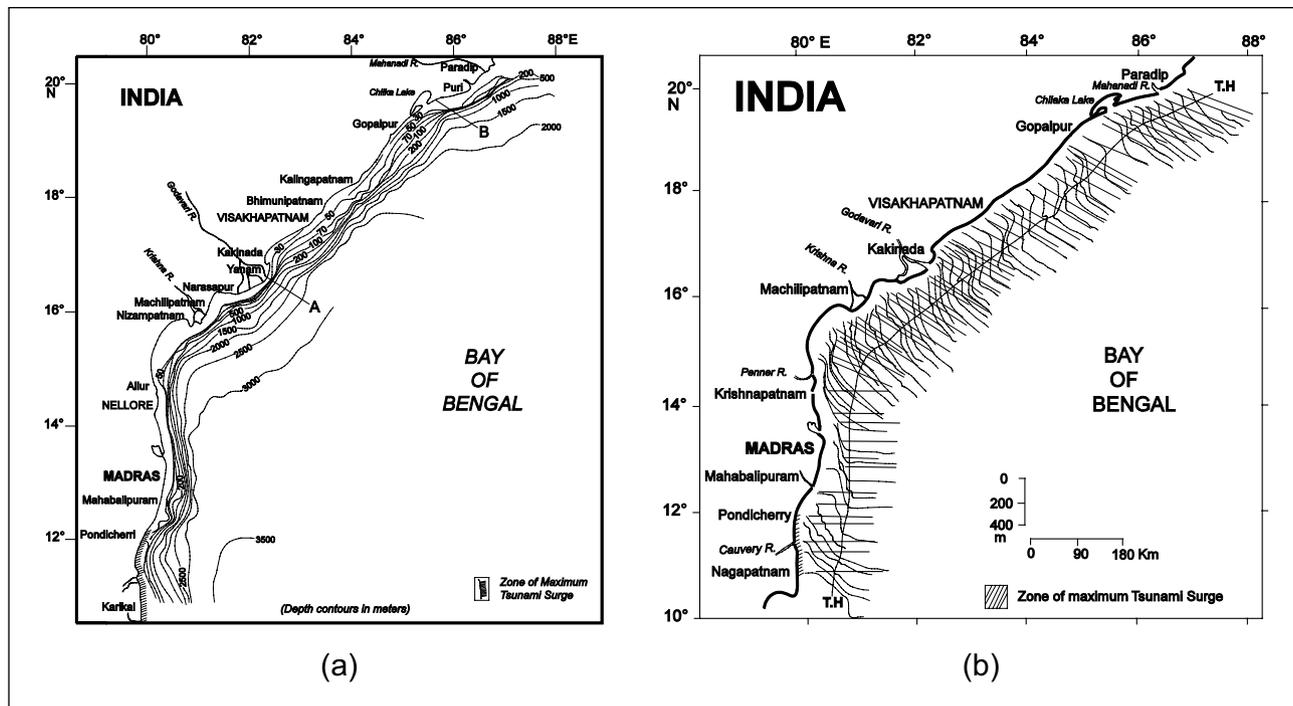


Figure 2. (a) Bathymetry contour map of ECMI (Murthy et al., 2012) and (b) bathymetry sections over the ECMI (Murthy et al., 2012).

Table 1. Shelf/slope characteristics off selected places over the ECMI (Murthy et al., 1993).

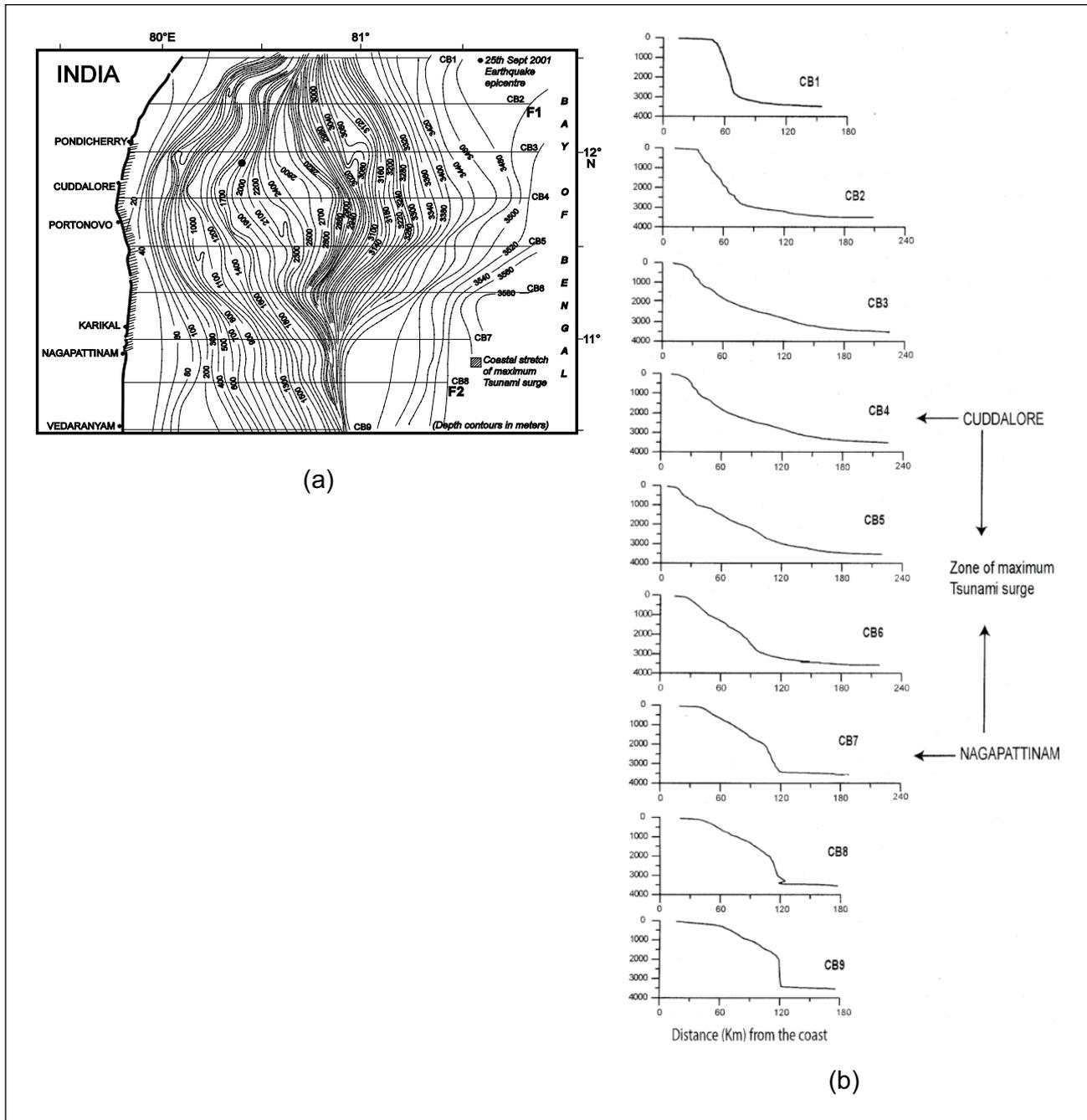
Location (see Figure 2a)	Water depth at shelf break (m)	Shelf edge distance from coast (km)	Shelf gradient (ratio)	Slope gradient (ratio)	Depth at which marginal high (T.H.) is recorded (m)	Remarks (only relative terms)
1. Paradip	100	50	1:320	1:50	Not clear	Wide shelf, gentle slope
2. Puri	130	40	1:300	1:43	Not clear	Wide shelf, gentle slope
3. Chilika Lake	220	40	1:200	1:28	800?	Wide shelf, gentle slope
4. South of Chilika Lake	220	40	1:200	1:35	Not clear	Wide shelf, steep slope
5. South of Gopalpur	220	44	1:200	1:16	1500–2000	Wide shelf, steep slope
6. Kalingapatnam	120	35	1:280	1:16	1800–2000	Narrow shelf, steep slope
7. Kalingapatnam	130	45	1:345	1:15	2000–2100	Wide shelf, steep slope
8. Visakhapatnam	200	50	1:250	1:12	1900–2100	Wide shelf, steep slope
9. North of Kakinada	200	45	1:225	1:12	2400–2600	Wide shelf, steep slope
10. Krishna River	70	21	1:300	1:25		Narrow shelf, gentle slope
11. Nizampatnam	70	22	1:300	1:25	Not clear	Narrow shelf, gentle slope
12. Chennai	200	43	1:200	1:8	2700	Wide shelf, very steep slope
13. North of Puducherry	90	35	1:400	1:6	3000	Narrow shelf, very steep slope
14. Karaikal	70	16	1:200	1:19	3000	Narrow shelf, steep slope
15. Nagapattinam	70	24	1:340	1:17	3000	Narrow shelf, average slope

TH: Topographic High.

details of shelf break, shelf width and slope gradient at different locations (Table 1).

Morphologically, the ECMI represents a mosaic of basinal and non-basinal segments. The depth contours of the eastern continental margin nearly follow a north–south (N–S) trend in the southern part between Karaikal (10°55'N) and Nellore (14°30'N) from where they take a

northeast–southwest (NE–SW) trend up to Paradip (20°15'N) in the north, thus running sub-parallel to the coastline (Figure 2(a)). The contours indicate, in general, a narrow shelf in the south from Karaikal (10°55'N) to Nellore (14°30'N), also off the Krishna and Godavari river basins, and a relatively wider shelf to the north from Kakinada to Paradip.



**Figure 3.** (a) Detailed bathymetry map of the Cauvery Basin, Tamil Nadu coast (Murthy et al., 2006b) and (b) bathymetry sections over the offshore Cauvery Basin (Murthy et al., 2006b).

Detailed bathymetry map and sections of the Nagapattinam–Cuddalore shelf (from 10.5° to about 12°N) indicate (Murthy, 2011; Murthy et al., 2006a, 2006b) that one of the main reasons for the higher run-up heights and inundation in the Nagapattinam–Cuddalore coast (affected area marked in hatches in Figures 2 and 3) during the Indian Ocean Tsunami of 26 December 2004 could be the concave shape of the shelf with a gentle slope, which might have accelerated the tsunami surge to flush through at a rapid force (Figure 3(a) and (b)).

The sections off Vedaranyam in the south and that in the north of Puducherry indicate a wider shelf with steeper slope, representing the southern and northern boundaries of the concave shelf. The area within these boundaries is more affected by the tsunami surge.

The earliest bathymetry observations over the offshore Cauvery basin revealed the presence of submarine canyons off Cuddalore and Puducherry (Varadachari et al., 1968). Subsequent geophysical studies also suggested that major valleys off Puducherry are formed due to the existence of

mega lineaments (Rao et al., 1992). The lineament pattern played a major role in shaping the continental slope morphology, besides erosional and depositional processes. Bastia et al. (2011), from multi-channel seismic reflection data off the ECMI, concluded that the slope instability and slope canyons are the important geohazards throughout the east coast of India, particularly off the river basins. The high run-up heights and inundation in case of the Nagapattinam and Cuddalore shelf are therefore due to favourable seabed morphology, which in turn is the result of the faulted basement structure.

## Conclusion

Hazard management of coastal areas requires systematic data collection and continuous monitoring of different oceanographic processes and their impact on the coastal morphology, in particular on the stability of the coastal zone. The ECMI represents a mosaic of basinal and non-basinal morphology and is affected by both oceanographic processes and deltaic processes. The geodynamic processes of this passive margin since its evolution defined the shape of the present coastline. The Pre-Cambrian onshore tectonic lineaments have their offshore expression and most of the offshore river basins are confined within these lineaments. The morphology of the continental shelf off the river basins is dominated with the presence of submarine canyons, sediments slumps, slope failures and other such marine geohazards, which need to be studied in detail. Three zones of neotectonic activity with reported micro-seismicity were identified over the ECMI: off Puducherry, Ongole and Visakhapatnam (Vizianagaram shelf). Coastal erosion due to eustatic sea level changes as well as due to human interference is also a major hazard over the east coast.

## Acknowledgements

This work was carried out as part of the IITB-CSIR-NIO collaborative project sponsored by the Ministry of Earth Sciences (MoES/P.O. (Seismo)/1(141) 2011).

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

## Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work is supported by the Ministry of Earth Sciences.

## References

Bastia R, Radhakrishna M and Nayak S (2011) Identification and characterization of marine geohazards in the deep water

eastern offshore of India: Constraints from multi-beam bathymetry, side scan sonar and 3D high-resolution seismic data. *Natural Hazards* 57: 107–120.

Murthy KSR (2011) Some factors contributing to the changes in coastal morphology – A case study from the Eastern Continental Margin of India. In: *Proceedings of international conference on 'impact of climate change on coastal ecosystem' (ICC – ECO 2011)*, Sathyabama University, Chennai, India, 10–11 November.

Murthy KSR, Rao TCS, Subrahmanyam AS, et al. (1993) Structural lineaments from the magnetic anomaly maps of the Eastern Continental Margin of India (ECMI) and NW Bengal Fan. *Marine Geology* 114: 171–183.

Murthy KSR, Subrahmanyam AS and Subrahmanyam V (2012) *Tectonics of the Eastern Continental Margin of India*. New Delhi, India: The Energy and Resources Institute (TERI) Press, p. 180.

Murthy KSR, Subrahmanyam AS, Murty GPS, et al. (2006a) Factors guiding tsunami surge at the Nagapattinam–Cuddalore shelf, Tamil Nadu, east coast of India. *Current Science* 90: 1535–1538.

Murthy KSR, Subrahmanyam V, Murty GPS, et al. (2006b) Impact of coastal morphology, structure and seismicity on the tsunami surge. In: Murty TS, Aswathanarayana U and Nirupama N (eds) *The Indian Ocean Tsunami*. London: Taylor & Francis, pp. 19–31.

Murthy KSR, Subrahmanyam V, Subrahmanyam AS, et al. (2010) Land-ocean tectonics (LOTs) and the associated seismic hazard over the Eastern Continental Margin of India (ECMI). *Natural Hazards* 55: 167–175.

Murty GPS, Subrahmanyam AS, Murthy KSR, et al. (2002) Evidence of fault reactivation off Puducherry coast from marine geophysical data. *Current Science* 83: 1446–1449.

Rao LHJ, Rao TS, Reddy DRS, et al. (1992) Morphology and sedimentation of continental slope, rise and abyssal plain of western part of Bay of Bengal. *Geological Survey of India* 29: 209–217.

Subrahmanyam AS, Murty GPS, Sarma KVLNS, et al. (2007) Qualitative assessment of tectonic lineaments over the coastal and inner shelf of Kakinada and Kalingapatnam, central east coast of India. *Journal of Geological Society of India* 69: 1328–1334.

Subrahmanyam V, Subrahmanyam AS, Murthy KSR, et al. (2006) Precambrian mega lineaments across the Indian subcontinent-preliminary evidence from offshore magnetic data. *Current Science* 90: 578–580.

Varadachari VVR, Nair RR and Murthy PSN (1968) Submarine canyons off the Coramandel coast. *Bulletin of the National Institute of Sciences of India* 38: 457–462.

## Author biography

KSR Murthy received his Ph.D in Geophysics from Andhra University, Visakhapatnam, India in 1981. He has about 43 years of research experience in CSIR Laboratories- NIO and NGRI, India, in the field of airborne and marine geophysical studies. His areas of interest are Tectonics of Passive Margins, Land-Ocean Tectonics and Coastal Seismicity.