

CONTRIBUTIONS IN MARINE SCIENCES

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REGIONAL MARINE GEOPHYSICAL STUDIES OF THE SOUTH WESTERN CONTINENTAL MARGIN OF INDIA

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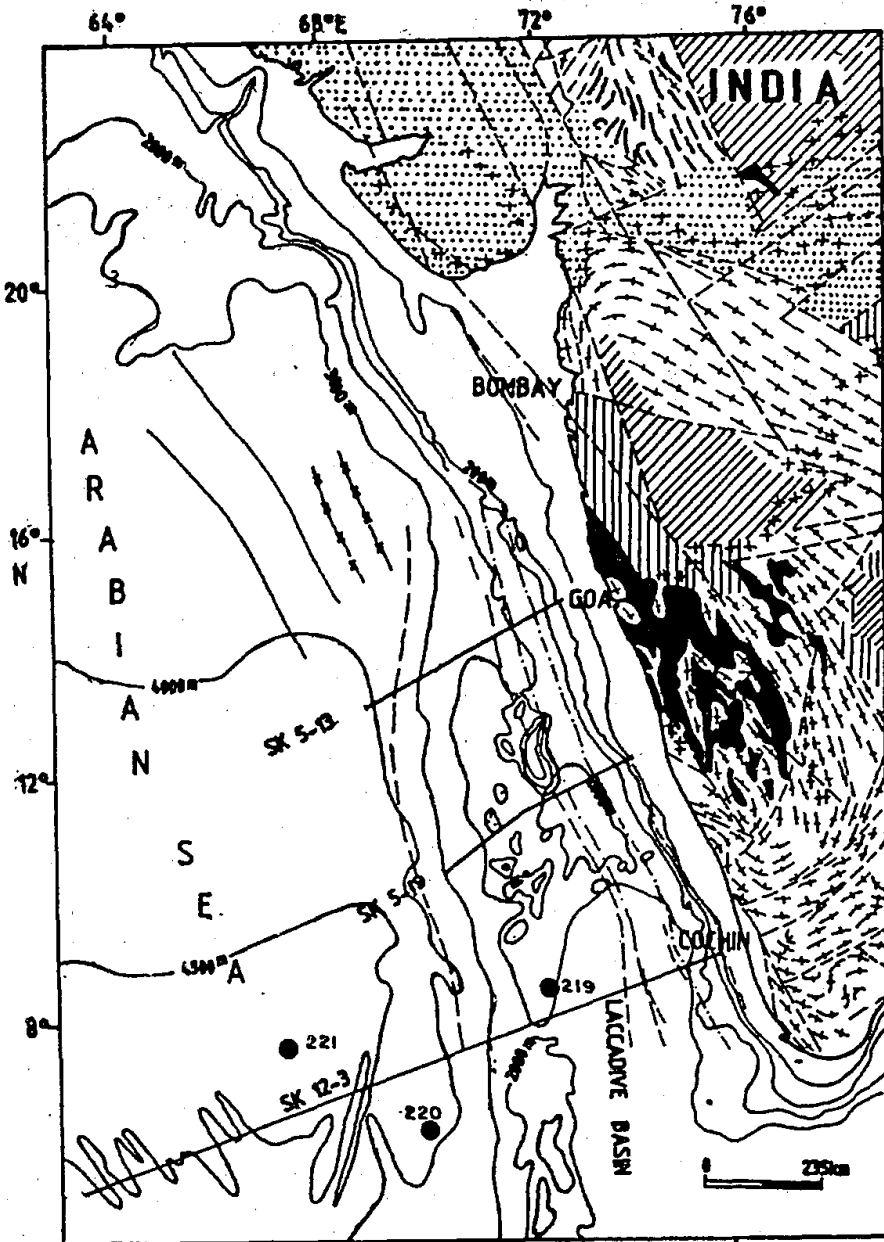
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ABSTRACT

Integrated bathymetric, gravimetric, magnetic and multichannel seismic reflection studies were carried out on the south western continental margin of India along three regional profiles. The study area lies between 60m and 4900m isobath and cover from east to west, the shelf edge, Kerala-Laccadive graben, the Laccadive ridge and the abyssal plains. A preliminary study of the data revealed. i) the acoustic basement in the shelf margin basin is in the form of ridge complex which widens and deepens towards south and is overlain by sedimentary sequence of maximum thickness of about 2.5 sec. of two way travel time. The Laccadive ridge system is characterised by a generally raised acoustic basement mantled by transparent sediments. Further the morphology of the acoustic basement over the Laccadive ridge system is governed at places by steep scarps and at places by volcanic intrusives reflected by large amplitude magnetic anomalies. The crest of the ridge is associated with a graben like feature.

INTRODUCTION

The important geological provinces on the continental margin off the south west coast of India include the narrow shelf, the wide shelf margin basin and the linear Laccadive ridge system. The shelf margin basin (termed also as Kerala - Laccadive graben/basin) parallels the shelf edge. The Laccadive ridge system (in water depths of 4000 m) extends for about 2200 kms from 10°S to 12°N latitudes as positive bathymetric feature. It rises above the adjacent seafloor by about 3000 meters and its width varies from 220 to 290 km. Based on several regional marine geophysical studies a first order evolutionary history of the area has been proposed by several earlier workers, but the origin and location of this area in time and space still remains a matter of debate. The National Institute of Oceanography (NIO) initiated surveys for detailed mapping of this area. In this paper we present the preliminary findings from studies along three regional profiles across this area (Fig.1).



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|-------------------------------------|---|--|
| SK 5-D CRUISE TRACK | ----- MAJOR STRUCTURAL LINEAMENTS INFERRED FROM LAND SAT IMAGES | ++++ MESOZOIC - CENOZOIC PLATEAU BASALTS (LIMITS) |
| ----- BOUNDARIES | ● OSDP SITE | ▨ AREAS OF DHARWAR-IRON ORE ARAVALI FOLDING AREA |
| ----- PRATHAP RIDGE | — 2000 m ISOBATH (IN METERS) | ▨ AREAS OF SEMI CUDDAPAH FOLDING |
| ----- CHAGOS-LACCADIVE RIDGE SYSTEM | ▨ TERTIARY-QUATERNARY GRABENS/FAULT BASINS | ▨ AREAS OF VINHYAN PLAT- FORM DEVELOPMENT |
| ===== LAXSMI RIDGE | | |
| ----- BASEMENT HIGH | | |

Fig.1. The physiography, regional geology and tectonic setting along the Western Indian peninsula and continental margin.

GEOLOGIC AND TECTONIC FRAMEWORK

Onshore

The geological formations of the adjacent onshore areas are mainly the Dharwars (2,500 my.) consisting granites, peninsular gneisses and charnokities^{1,2}. These rock formations are at places covered with thin Miocene and Pliocene sediments. Further these rock formations are also fragmented into blocks by several deep NW-SE and WNW-ESE trending crustal faults^{3,4}. They further suggested that, these blocks subsided into the Arabian Sea and extend upto the west of the Laccadive ridge system.

Offshore

The nature of the basement in the shelf area is not clearly known however, the shelf is covered with about 500m to 800m thick Palaeogene - Neogene sediments. Seismic and borehole studies indicated that this thin sediment cover is inter-vened by several basaltic sills. Basalts were met at about 0.8 km depth in a bore well (K-1-1) off Cochin⁵. Occurrence of magnetic basement at deeper depths (>2.5 kms) possibly indicating block faulting was reported⁶.

The shelf margin basin is bound on the east by the shelf edge and on the west by the Laccadive ridge system, contains a relatively thick sedimentary accumulations. Naini⁷ proposed that the shelf margin basin all along the western continental shelf of India have been formed by the process of taphrogeny.

The Laccadive ridge system is a positive bathymetric feature. The origin, nature and history of the sediments and rocks associated with this ridge system has been studied by several workers. The opinions regarding the origin of this ridge vary from continental^{3, 4, 8, 9} partly volcanic/oceanic^{10, 11} and lava outpouring of a moving hotspot¹²⁻¹⁶. Avraham and Bunce¹⁷ suggested multiple origin of the ridge. According to Narain et al⁸ the continent ocean boundary lies west of the ridge.

DATA

Underway measurements of bathymetry, gravity, total magnetic intensity and seismic reflection along the three regional geophysical profiles discussed in the present study were made on board ORV *Sagar Kanya* during 1984-85. The ship's position along the tracks were determined by an Integrated Navigation System which used a Satellite Navigator for primary position control. The bathymetry was recorded by an ELAC narrow beam echosounder (12 and 35 kHz). The gravity data was collected

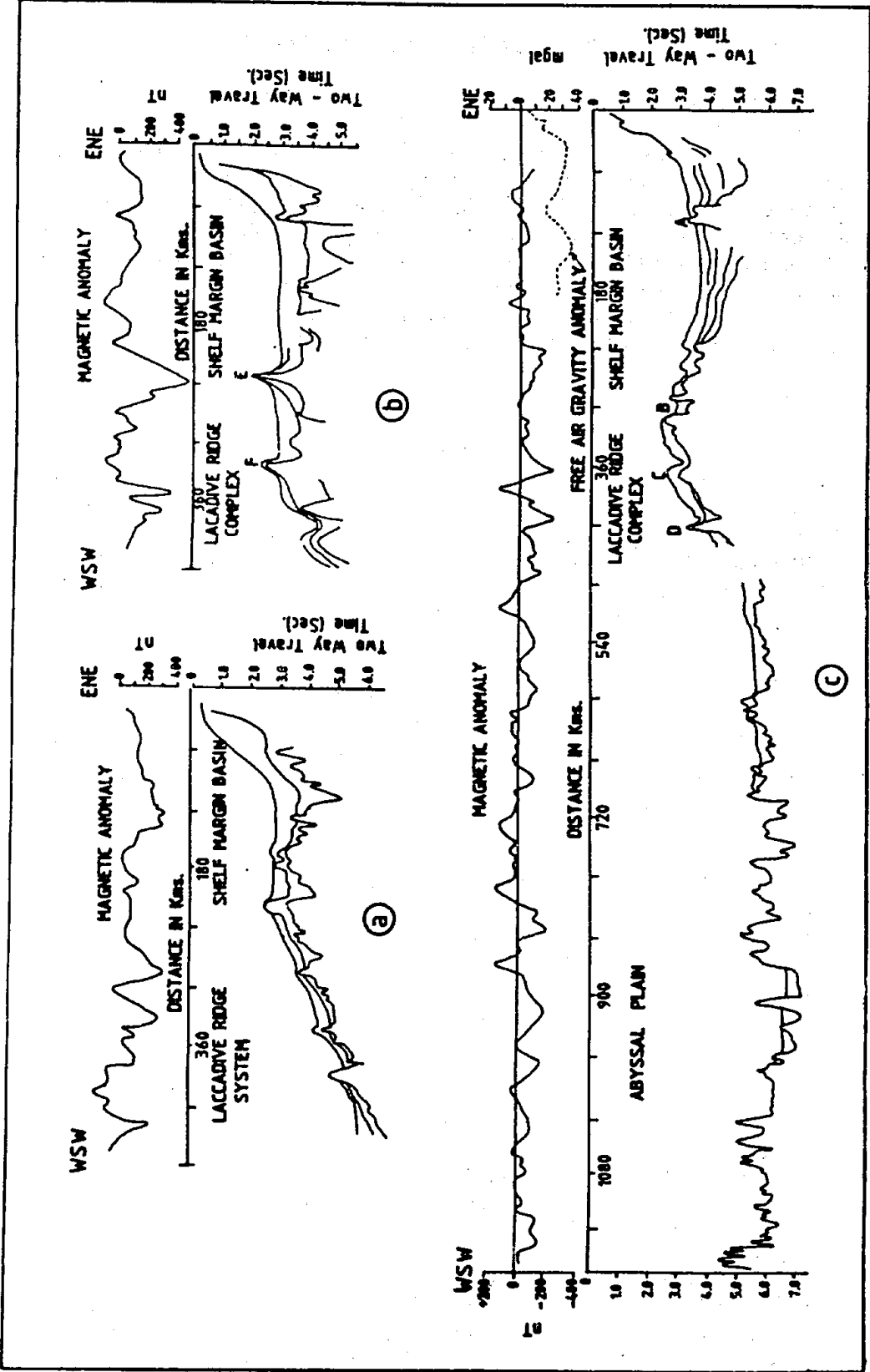


Fig-2. Composite profiles showing total intensity magnetic anomaly (IGRF removed), Free air anomaly and seismic reflection data. For location of the profiles, see Figure. 1.

using shipborne non astatized spring mass type (Bodenseewerk KSS 30) gravity meter. The magnetic data were collected by a proton precession magnetometer. The magnetic anomalies were computed by removing the International Geomagnetic Reference Field¹⁹ as the regional field. The reflection profiles were recorded by a multichannel seismic equipment, with an airgun array (total volume about 7.9 litres) as the seismic energy source. The seismic data were recorded digitally, however in the present study we have used only the analog records from a single channel (nearest channel). The bathymetric, gravity, magnetic anomalies and line drawings of the interpreted seismic sections along each profile is presented as composite geophysical sections (Fig. 2).

RESULTS

The three regional geophysical profiles (Fig.3) discussed in the present paper orient approximately ENE-WSW and traverse parts of the outer continental shelf, the shelf margin basin, the Laccadive ridge system and the abyssal plains off the south western continental margin of India (Fig.1). Brief description of the data alongwith their preliminary interpretation are presented in the following paragraphs. In the text we have used the term basement to mean the acoustic basement, which is the lowermost reflector identified within the limit of penetration of the seismic energy source used in the present investigation.

Profile SK 5-13

A prominent palaeoshelf edge characterised by steep gradient is present at about 12 kms east of the present shelf edge (Fig.2). Rapid increase in the sediment thickness was noticed at the shelf edge area. The basement in the shelf margin basin is conspicuous with its high relief and is overlain by sediments having a maximum thickness of about 2.5 to 3.0 seconds of two way travel time (TWT). The shelf margin basin is associated with a broad magnetic low. A general rise of the basement on the Laccadive ridge system is noticed which gradually slopes towards west into the abyssal plains. The magnetic anomalies are less prominent over the eastern half of the ridge as compared to the western half where high amplitude anomalies are present.

Profile SK 5-19

The palaeoshelf edge is present at 15 kms east of the present shelf edge. The shelf edge again is marked by rapid increase in the thickness of the sediments. The basement on the shelf margin basin is similar to profile SK 5-13. The maximum

sediment overburden is about 2.5 seconds (TWT) thick. It is also associated with a broad magnetic low. The general rise of the basement on the Laccadive ridge is superimposed with several sharp positive bathymetric features (E and F in Fig.2b). These sharp features are also associated with high amplitude magnetic anomalies whereas no prominent magnetic anomaly due to the ridge system as a whole is observed.

Profile SK 12-03

This profile which extends from the shelf edge off Cochin to the deep abyssal plains west of the Laccadive ridge system, represents a typical geophysical section across the south western continental margin of India. Unlike the situation on the northern profiles a single prominent basement high (A in Fig.2c) is observed on the shelf margin basin in this area. This basement high is associated with a positive free air (20 mgal) gravity and magnetic (175 nT) anomalies. Basement of the Laccadive ridge system again shows a general rise similar to the northern profiles. The magnetic anomaly in the eastern part of the ridge is subdued as compared to the west. At the crest of the Laccadive ridge system a graben like feature was observed (B in Fig.2c). This feature is about 20 kms wide and its boundaries are defined by sharp offset of the acoustic basement. The offset of the basement is about 1.1 seconds (TWT). Where as the offset in the seafloor is about 0.3 seconds. The graben is filled with acoustically transparent sediments. Further westwards two subsurface highs (C and D in Fig.2c) were noticed. These features are about 15 kms. wide and are associated with prominent broad high amplitude (380 nT) magnetic anomalies. Westward of the Laccadive ridge system in the abyssal plains the basement outcrops and is associated with large amplitude magnetic anomalies. Sediments in this area are largely confined to isolated pockets of depressions.

DISCUSSION

The basement of the shelf margin basin is in the form of a ridge system. A broad magnetic low is associated throughout with the basin. This ridge system within the shelf margin basin parallels the present shelf edge and was identified and named as the 'Prathap Ridge'⁷ (Fig.3). The Prathap ridge is reflected as a single basement high in the south (Off Cochin), whereas in the north it manifests as several basement highs. Correlation could be established between the basement high and positive magnetic anomaly in the southern profile (SK 12-03). Whereas in the northern profiles (SK 5-13, 5-19) such correlation could not be established even though several basement highs were observed. We therefore infer that the rocks forming the Prathap ridge are not homogeneous in composition or the magnetic base-

ment lies at a deeper depth towards north. The Laccadive ridge system is characterised as a positive bathymetric feature with a generally raised acoustic basement, but as a whole the ridge system does not reflect any appreciable magnetic anomalies. The magnetic anomalies over the eastern half of the ridge is relatively subdued whereas the western half of the ridge is associated with several prominent high amplitude magnetic anomalies. This possibly indicates that the western half of the ridge is intruded by volcanic materials.

The graben like feature observed on the apex of the Laccadive ridge system along the profile SK 12-03 perhaps reflects the faulting. The first opaque reflector over the Laccadive ridge system near the DSDP site 219 was identified as chert reflector¹⁹. Whitmarsh *et al.*¹⁹ also indicated the presence of sharp offsets in the chert reflector. They concluded that these features are possibly caused by draping of the chert reflector over the pre existing rough topography, the greater relief of which attributable to the vertical offsets across fracture zones. Extending the same analogy we infer that this graben like feature along profile SK 12-03 also reflects graben formation of the basement over the apex of the Laccadive ridge system. Although we have observed similar feature along profile SK 5-19, but the boundaries are not so distinct and the offset is not so much pronounced. We therefore feel that this feature represents a major tectonic feature on the Laccadive ridge system. However detail investigations are needed for exact delineation of its nature and extent. The other basement highs observed west of this graben are quite appreciable in their lateral and vertical extent. The broad high amplitude anomalies associated with them indicate their volcanic origin. Volcanic features of these dimension perhaps have to be linked with major tectonically weak zones. We therefore infer that at least the western half of the Laccadive ridge system is influenced by the fracture zones and its associated volcanic activity.

The part of the profile in abyssal plain has been identified as oceanic type of crust^{16,20}. Thus it would appear that the transition between the oceanic and continental type crust would lie either on the Laccadive ridge complex or somewhere immediately west of it.

The geographic position of the ridge governs the basin configuration which is narrow in the north (Profile SK5-13) and widened in the south (Profile SK 12-03).

CONCLUSIONS

From the studies the following conclusions are drawn.

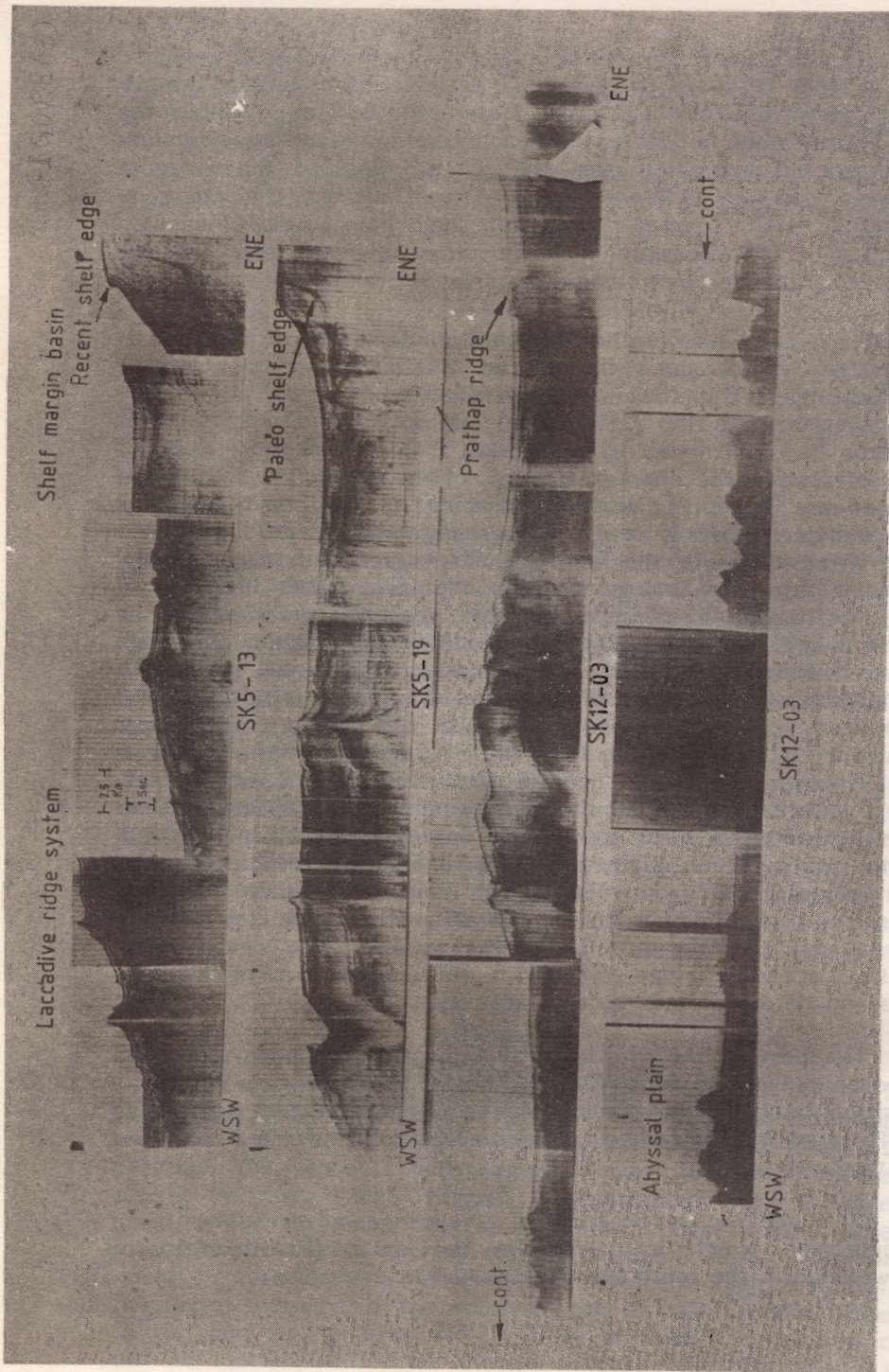


Fig.3. Continuous seismic reflection profile across the western continental margin of India and the adjoining abyssal plains, showing numerous structures described in the text. For location of profiles, see Figure 1.

1. Palaeoshelf edge in the east is observed at a distance 15 km from the present shelf edge.

2. The shelf margin basin is associated with a broad magnetic low anomaly with eastern subdued anomalies and relatively steep rising anomalies in the west. Besides basement rise associated with magnetic anomalies in the south and no appreciable magnetic anomalies in the north are noticed, which are interpreted either due to an inhomogeneous basement or relatively deeper magnetic basement.

3. The acoustic basement is in the form of crests and troughs and a maximum depth to it 2.5 to 3.0 seconds (TWT). The magnetic anomalies are less prominent over the eastern half of the Laccadive ridge system compared to the western half where many high amplitude anomalies are present. The lack of overall magnetic anomaly due to the ridge leads us to suggest continental type of the ridge crust in the study area perhaps akin adjacent onshore geology i.e., granitic gneisses etc.

4. The segment of the profile over the Laccadive ridge system is characterised by a general rise in the acoustic basement which gradually slopes towards west into the abyssal plain.

5. A graben like major tectonic feature of 20 kms. width bound by steep scarps is observed on the apex of the Laccadive ridge system.

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