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CRUSTAL FEATURES OF THE OCEAN BOTTOM OFF KATHIAWAR COAST

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INTRODUCTION

Seismic refraction experiments were conducted by METEOR and INS KISTNA over the continental margins off the Gulfs of Cambay and Kutch in February - March 1965 as a part of the International Indian Ocean Expedition programme. Preliminary results obtained from these experiments were presented by Rao (1967) and Closs and Hinz (1967) in the Symposium on "Upper Mantle Project" at Hyderabad. Final analysis and interpretation of the above seismic records have been carried out at the BUNDES-AUSTALT FUR BODENFURSCHUNG, Hannover, West Germany jointly by Dr. H. Closs, Dr. K. Hinz and the present author. Recently magnetic surveys over the continental shelf off the Kathiawar Coast were carried out by the author during March-April 1970 on board INS SUTLEJ.

Geophysical surveys conducted over the oceanic areas adjacent to the Kathiawar coast and Cambay basin are meagre. Other than the work reported here, as far as the author is aware, seismic surveys in the Gulf of Cambay by the Oil and Natural Gas Commission (Sengupta, 1967), gravity and magnetic surveys off Bombay by H.M.S. OWEN (Takin, 1965) and magnetic survey off Bombay by National Geophysical Research Institute (NGRI Annual Report, 1968-69) have been conducted.

Crustal features as established by the joint interpretation of the seismic records (Rao, 1968) and those delineated by the author from the recent magnetic surveys are discussed in relation to the already known tectonic features over the neighbouring continental areas and the ocean bottom.

TECTONIC FEATURES OF THE AREA

Detailed discussions on the tectonic features of the Indian Sub-continent have been presented by Krishnan (1963, 1964) and the same related to the area under the present study have been summarised in the succeeding paragraphs. These features include, particularly, the folding and faulting in the Kathiawar, the faults in the Gulf of Cambay, the Narmada trough valley and the Deccan Traps.

Kathiawar and Cambay areas are known to have undergone severe faulting and folding owing to the tectonic forces associated with the Himalayan Orogeny and Deccan Traps. A major fault, about 38 miles in length has been traced just north of the Rann with its course partly E-W and partly WNW-ESE. There is also an E-W strike-fault in Kutch proper. These faults, particularly the one in the Rann, are still active and are responsible for the fairly severe earthquakes which Kutch experiences at frequent intervals. These faults must have been formed late in the Tertiary or Quaternary as a result of slight opening of the Kutch basin during the last phase of the Himalayan Orogeny connected with the drift of the peninsular India in the Pleistocene. It is further believed that the same Orogeny might have accentuated the fault north of the Rann and the Makran coastal fault which continue into the Persian Gulf. The folding in the area could be observed in the Jurassic strata which has been folded along WNW-ESE axis. One of the explanations offered by Krishnan (1964) for this folding was that the Kutch basin was compressed by the southern block (including Kathiawar) moving faster than the northern part during the early part of the continental drift.

Gulf of Cambay appears to have been step faulted in which the Deccan Traps have been let down to a depth of about 8000 m. below the sea level. The eastern fault runs

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along the Bombay coast and western one along the Kathiawar coast. As a result of these faults, the coastal region off Bombay has developed a monoclinal flexure, called "Panvel Fluxure", marked by several hot springs. Another notable tectonic feature in this area is the Narmada trough valley which has opened out to the west into the Arabian sea occupying the northern Gujarat and Kutch. This might have continued into the Rann of Kutch which was a sedimentary basin during the Mesozoic. The Rann shows the post Deccan Trap folding of the marine Jurassic rocks and is subject to fairly frequent earthquakes at present.

RESULTS OF GEOPHYSICAL SURVEYS OFF KATHIAWAR COAST

Seismic refraction experiments were carried out by two-ship method on board R.V. METEOR and INS KISTNA. A helicopter had also been employed as another recording station. The records were analysed adopting the standard techniques as detailed in the earlier reports (Rao, 1967; Closs and Hinz, 1967). Velocities and thicknesses of the crustal layers obtained from these experiments are presented in Figure 1.

Magnetic surveys were carried out on board INS SUTLEJ using the Proton Precession Magnetometer fabricated at the Naval Physical and Oceanographic Laboratory (Raju and Rao, 1967). Intensity of the earth's total magnetic field was measured along one profile each across the continental shelf off Dwaraka, Porbandar and Bombay (fig. 2). The measured total field intensities were averaged over each Kilometre. Total field anomalies were obtained as the difference between the measured field and the regional total field read from the charts for the Epoch 1965 supplied by the US Naval Oceanographic Office. No corrections for the diurnal variation and the ocean bottom depths were applied. The total field anomalies were found to be negative over the three profiles except at two places along the profile off Bombay (around 20°N, 70°40'E and 19°30'N, 72°E) (fig. 2).

Following assumptions have been made while analysing the observed anomalies.

(a) The dykes extending infinitely downwards.

(b) The strike of the dykes is in the SE–NW direction.

(c) The magnetizing field of the dykes is mainly the earth's magnetic field.

(d) The direction of magnetization of the dykes is in the direction of the earth's magnetic field.

Curve fitting technique using the contour diagrams of the anomaly field for dykes (Bosum and Hahn, 1966) has been adopted in fitting the model bodies to the observed anomalies. The orientation of the body has been rotated clockwise by 90° for fitting to the positive anomaly of 160 gammas observed around 19°30'N and 72°E. The total field anomalies plotted along the profiles and the fitted model bodies are shown in figure 2.

SEISMIC SURVEYS

The crustal layers observed off the Gulfs of Cambay and Kutch, in seriatum from the surface of the ocean bottom to the basement rock are :—

(a) Unconsolidated sediments with the velocity increasing vertically downwards from 1430 to 3000 m/s.

(b) Miocene sediments with the velocity ranging between 3000 and 4000 m/s.

(c) A layer with velocity between 4000 to 5000 m/s. and

(d) Basement rock with the velocity between 6200 and 6800 m/s.

It can be seen from the cross-section of the crustal layers (fig. 1) that the sediment thickness increases from the shelf towards the slope and then decreases over the abyssal plains. Maximum thicknesses of the sediments of about 5000 and 8000 m. are observed over the continental slope and rise off the Gulfs of Cambay and Kutch. The layer with

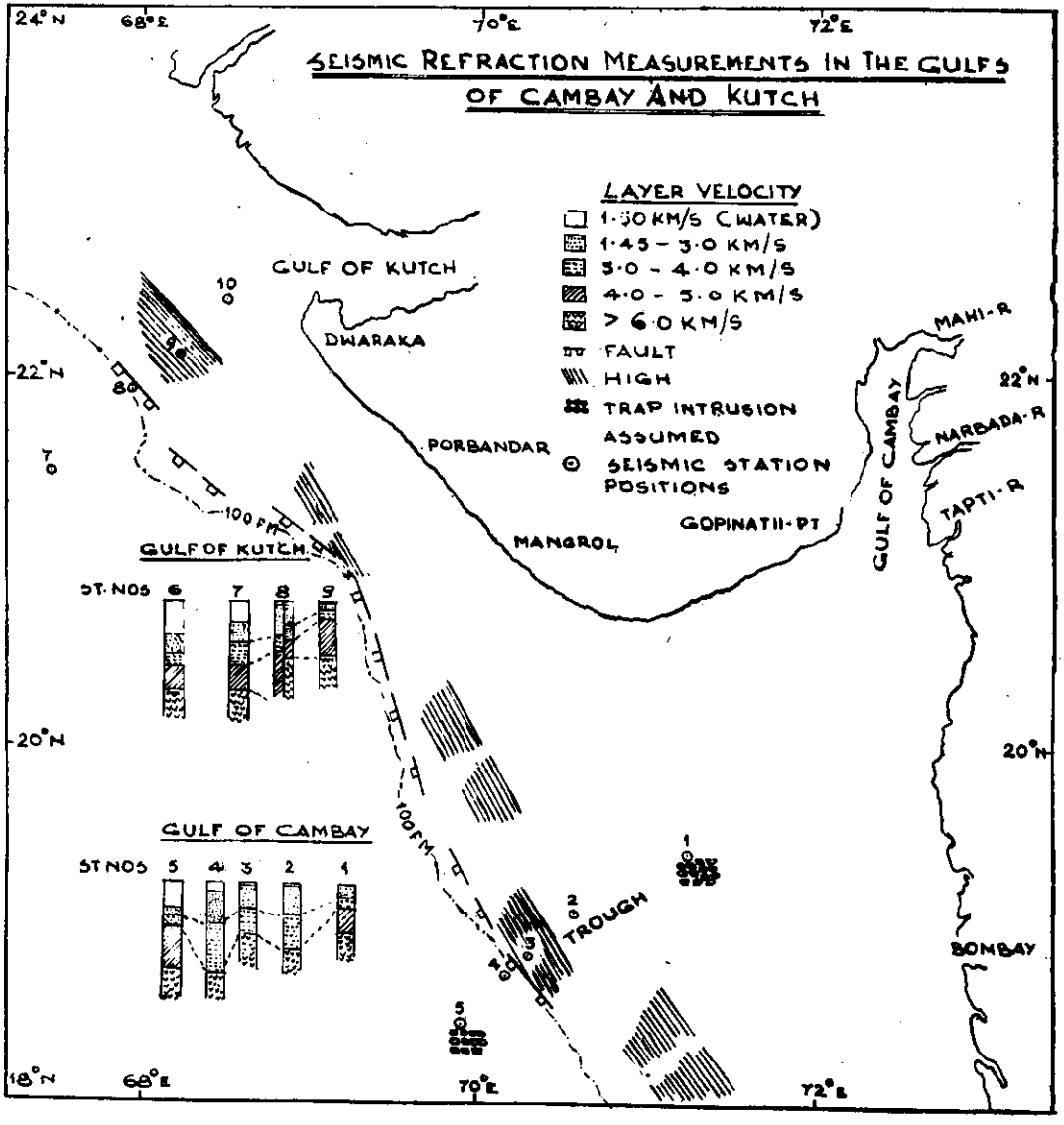

Fig. 1.

velocity between 4000 and 5000 m/s is observed at only two places off the Gulf of Cambay while the same is found in all the seismic profiles off the Gulf of Kutch. The basement layer has been uplifted over the outershelf off Cambay forming a sub-surface high. Off the Gulf of Kutch, a fault, downfaulted to the west, has been located over the edge of the continental shelf.

MAGNETIC SURVEYS

Fourteen bodies in all, arranged in three groups, have been fitted to get the best fit for the measured anomaly along the profile off Bombay. Along the profiles off Dwaraka and Porbandar six bodies each, arranged in two groups, have been fitted. The width of

the bodies fitted ranged between 20 and 40 Km. and are located at depths between 5000 and 7500 m. (fig. 2).

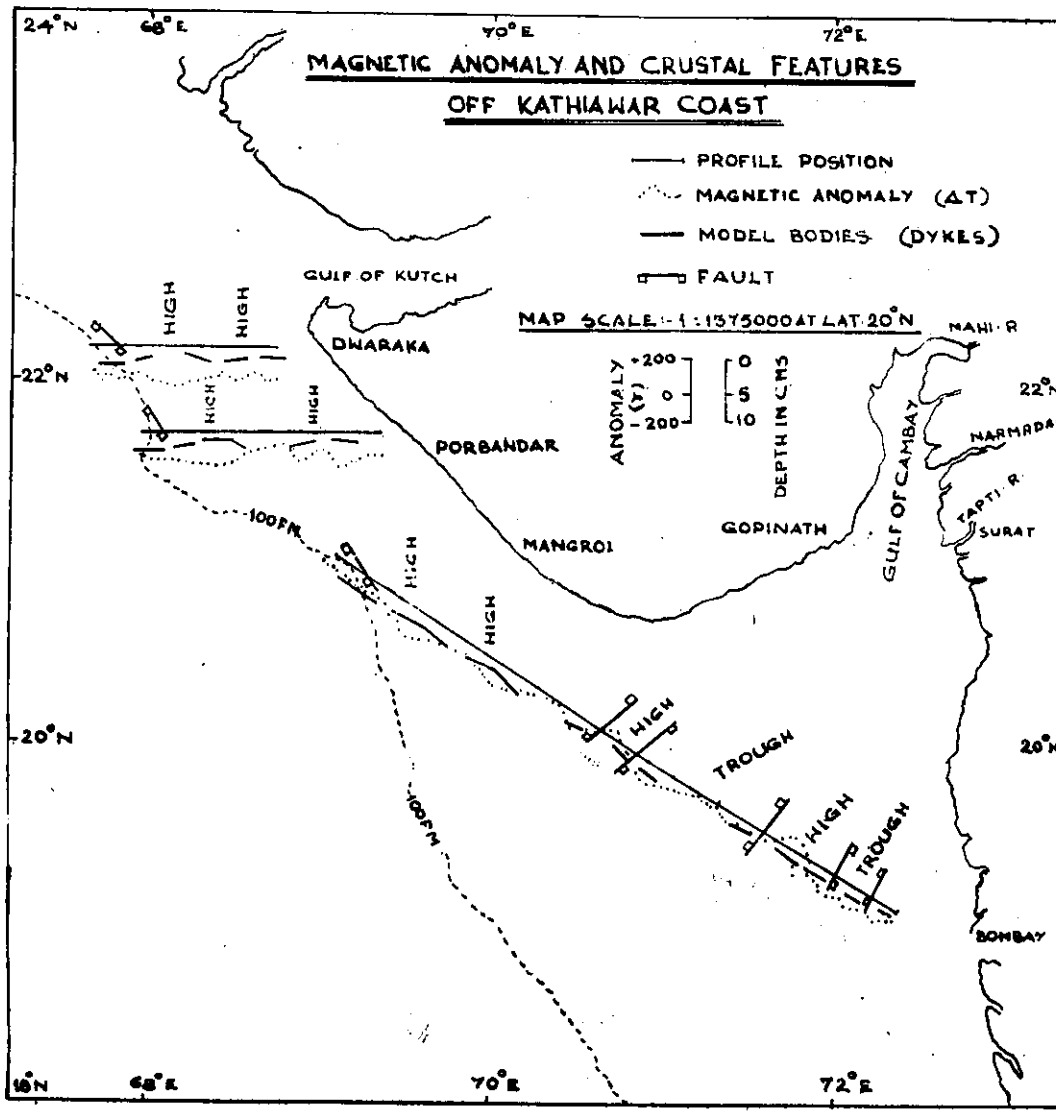

Fig. 2.

Assuming that these bodies represent the relief of the basement layer, the following inferences are drawn :—

(a) Two highs separated by a minor depression exist along the profiles off Dwaraka, Porbandar and the NW end of the profile off Bombay. They align in NW–SE direction.

(b) A high (around 19°30′N and 72°E) associated with trough faults on either side along the profile off Bombay aligning with the axis of the Gulf of Cambay in N–S direction.

(c) Two faults around 20°N and 70°40'E along the profile off Bombay.

DISCUSSION OF THE RESULTS

The sub-surface highs, faults and sedimentary basin derived from the seismic and magnetic surveys are discussed below in relation to the known crustal features of the neighbouring area.

SUB-SURFACE HIGH

A 'High' has been observed in the basement rock over the outer continental shelf off Bombay (Rao, 1967). The presence of a similar 'High off Karachi has been reported by Closs and Hinz (1967) who named it as the 'KORI HIGH' and assumed that it might continue further southwards. During the joint interpretation of the METEOR–KISTNA seismic records the presence of these two 'Highs' and also the one off Bombay as the southward extension of the Kori High have been established (fig. 1). It has been pressumed that the Kori High may continue further south and join the Laccadive–Maldive Ridge system (Rao, 1968). The 'highs' inferred from the magnetic profiles off Dwaraka, Porbandar and the NW end of the profile off Bombay further substantiate the presence of the Kori High along the coast between Karachi and Bombay as concluded from the seismic experiments.

The high located over the inner continental shelf off Bombay which is derived from the present magnetic surveys may perhaps resemble genetically to the model of Takin (1965) who concludes that the 'high' off Bombay derived from the positive gravity anomaly could be a chamber of secondary magma through which the Deccan Traps in the Arabian sea have fissured out. He thus supports the hypothesis of West (1959) who felt that the main sources to Deccan Traps could be to the west of Bombay and refers to the great dyke of the basic rock off Bombay (Glennie, 1934) as a particular example. The N–S orientation of the high, as stated earlier, further suggests that the Laccadive–Maldive ridge system may have continued further north into the Cambay basin through this high and the Gulf of Cambay as also postulated by Francis (1966) and Sengupta (1967). But Sewell (1935) and Krishnan (1963) opined that the Aravalle mountain range continues to south upto Laccadives through the Gulf of Cambay.

FAULT SYSTEMS

The West Coast of India has been recognised to have been let down as a result of faulting in the Pliocene at about the same time as the Makran Coastal faulting. The West Coast fault appears to run more or less straight from Cape Comerin to Karachi, coinciding with the edge of the continental shelf. The presence of this fault system has been observed in the seismic profiles off Kutch and also in all the magnetic profiles. These faults are situated over the edge of the continental shelf where the depth to the ocean bottom is between 120 and 130 m.

In addition to the West Coast fault, several faults are derived from the magnetic profile off Bombay. Two of them are located around 20°N and 70°40'E and it is presumed that they may form the westward extensions of the Narmada and Tapati faults. Alternatively they may be the continuation of the fault to the west of the Gulf of Cambay which is expected to run parallel to the Kathiawar coast. Another system of trough faults separated by a 'high' has been located around 19°30'N and 72°E. It is believed that the two troughs associated with the faults may form part of the two basin axes (saparated by an anticlinal structure as extended by Sengupta (1967).

SEDIMENTARY BASIN

The thickness of the sediments increases over the continental slope and rise from Bombay to Karachi. It is about 5000 m.. 8000 m., and 7000 m. thick off Bombay, Kutch and Karachi respectively and has thus formed a sedimentary trough over the con-

tinental slope and rise from bombay to Karachi. The formation of this thick sedimentary trough has made the northern Arabian Sea crust different from the typical oceanic crust. The absence of a layer with velocity between 5200 and 5800 m/s which is commonly present in the neighbouring continental crust has led to the presumption that the crust of the northern Arabian Sea as of transitional nature (Rao, 1968).

CONCLUSIONS

The results of the seismic experiments have stablished the Kori High off Karachi and its extension upto the outer shelf off Bombay in NW–SE direction. They also showed transitional nature of crust in the northern Arabian Sea as revealed by the thick sediments over the continental slope and rise between Karachi and Bombay and by the absence of the layer with velocity between 5200 and 5800 m/s which is commonly observed in the neighbouring continental crust. The present magnetic surveys have substantiated the seismic results in respect of the Kori High.

The high over the inner shelf off Bombay derived from the present megnetic surveys could perhaps be similar to that of the great dyke of the basement rock (Glennie, 1934) which has been assumed as one of the sources to Deccan Traps in the Arabian Sea. (West, 1959 and Takin, 1965).

Having identified the Laccadive–Maldive as of volcanic origin (Francis, 1966) it is concluded from the present seismic and magnetic results that the Laccadive–Maldive ridge system could have continued northward to join with the Kori High, the 'high' over the inner shelf off Bombay derived from the present magnetic surveys, the great dyke of the basic rock (Glennie, 1934; Takin, 1965) and the fracture system in the Gulf of Cambay (Sengupta, 1967).

The Laccadives appear to have terminated at about 15°N. It is generally believed that they extend further north through Angria and Direction Banks. Seismic and magnetic surveys over the oceanic region off the Konkan Coast may perhaps provide the necessary evidence for their extension to north.

The seismic and magnetic surveys have shown the faults over the edge of the continental shelf supporting the earlier assumption that the west coast would have been faulted along the edge of the continental shelf between Cape Comorin and Karachi. As stated earlier the trough faults around 19°30'N and 72°E are assumed to be the extension of the axes of the Gulf of Cambay into the Arabian Sea. The faults located around 20°N and 70°40'E may be the continuation of the Narmada and Tapati faults into the Arabian sea. This has to be confirmed by conducting detailed surveys.

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