

# Regional Tectonic Trends on the Inner Continental Shelf Off Konkan and Central West Coast of India

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## Abstract

Satellite imagery and offshore magnetic data were analysed to correlate regional tectonic elements on the inner continental shelf off Konkan and the adjacent Deccan plateau. Three statistically important lineament trends—N-S, WNW-ESE and ENE-WSW—that prevail on land are correlatable well with the offshore trends. This positive correlation suggests simultaneous deformation. The major magnetic lineament observed off Jaigad Bay, west coast of India, may be the extension of onshore lineaments. The correlation of both the offshore and onshore trends indicates that the fracture pattern of the crystalline basement has also controlled the offshore structural pattern.

## Introduction

The importance of large linear zones of structural deformation is widely recognized for interpreting the regional and global tectonics and identification of mineralized zones. On the basis of a study of the spatial distribution of lineaments, O'Leary and others [1] redefined the term "lineament." They proposed that a lineament is a mappable, simple, or composite linear feature of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship, differs distinctly from the patterns of adjacent features, and presumably reflect a subsurface phenomenon. Therefore, the word linear is restricted to its original sense and the word lineation was restored to its fundamental petrographic meaning: one dimensional structural alignment of internal components of rocks. Hoppin and Pan [2] reviewed that the lineaments are characterized by any two or more features of tectonic significance including faults, fold belts, fracture zones, structural deformations, geothermal zones, mineral concentrations, and line of igneous intrusions and/or

volcanic centers. The use of lineaments for locating buried structure is based on the fundamental premise that lineaments are caused by fractures in bedrock propagated to the surface.

The lineaments as either faults or fractures serve as conduits through which magmatic fluids ascend from depth and deposit metal in response to declining temperature and pressure and react with the enveloping rock. The ore deposits of the south west United States are distributed along four major dominant lineaments [3]. In mineral exploration, lineaments were defined as the topographic expressions of major features or apparent alignment of plutons, mining districts, and individual ore deposits. The patterns formed by lineaments are used as a framework for ore search.

Frost [4] made extensive studies on the geopotential data, introduced the concept of geophysical lineaments, and established that lineaments on the contour maps (magnetic, gravity, and bathymetric) were linear or sublinear features or alignments of features in the contour pattern; these include:

- i) Straight-line contour patterns with a steep gradient relative to surrounding gradients.
- ii) Alignment of maxima/or minima.
- iii) Alignment of flattened terminations of maxima and or minima.
- iv) Any combination of the first three.

## Data

The total magnetic field of the earth was measured with a proton precession type Geometrics magnetometer. The data was corrected to the international geo-

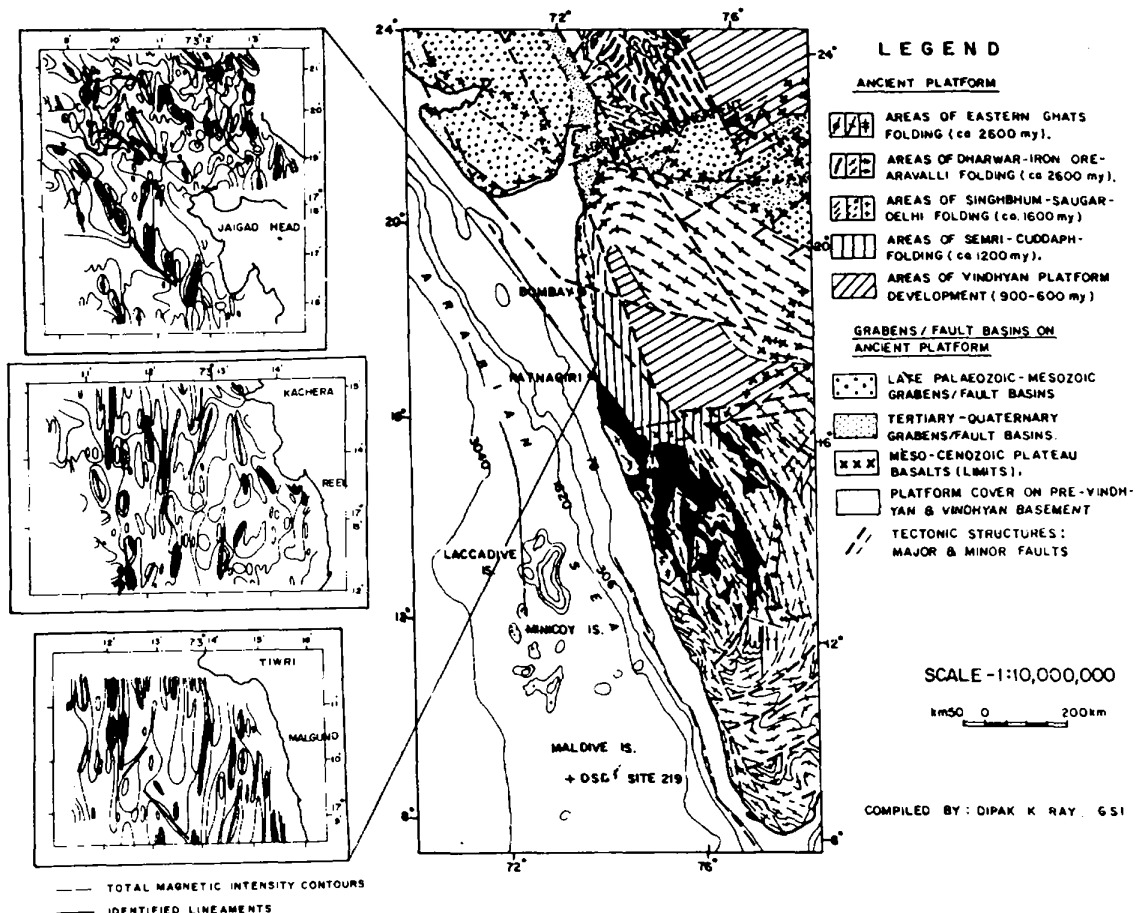


Figure 1. Lineaments shown on the total intensity magnetic maps of Jaigad, Varavada, and Ambwah Bays off Konkan, west coast of India, based on Frost's concept [4] and the tectonic map of the adjacent land mass [8].

magnetic reference field for the epoch 1980 and corrected for diurnal variations. The residual anomaly values thus deduced were used for the total intensity magnetic contour maps (Fig. 1).

Making use of Frost's criteria [4], a magnetic lineament map for the inner shelf off central Konkan has been prepared (Fig. 1) [5] and presented along with the onshore lineaments and tectonic map of India [6-8]. The significance of the lineaments and their trends is discussed in the present paper.

### Geological Framework

The area under study forms a part of the geological formation called the Deccan Traps. The Deccan Volcanic episode is one of the most important events in the geological history of the Indian shield after the fragmentation of Gondwanaland. The eruption of the Traps started out at the end of Late Cretaceous, and

continued until the Early Eocene [9]. The eruptions took place in two phases at about 65 to 60 my and 45 to 42 my [10-12]. About 518,000 km<sup>2</sup> of the Indian shield is covered by the Traps and extends offshore into the Arabian Sea [13,14]. The most conspicuous structural deformations documented over the Traps covered areas are fractures, dykes, alignment of hot springs, and earthquake epicentres (Fig. 2 and 3). Fractures extending several kilometers in length were mapped all along the mainland [6-8]. The fractures between the Narmada-Son lineament [15] and Ratnagiri along the west coast show a prominent ENE-WSW trend with NNW-SSE and WNW-ESE as secondary major trends [7] (Fig. 1).

The major dykes mapped in Western India (in Konkan) trend in NNW-SSE, N-S, NE-SW, or NNE-SSW directions. These trends are of considerable structural interest as most of these are aligned either parallel or with acute echelon disposition to the Panvel flexure [16].

### Hot Springs and Earthquake Epicenters

The alignment of hot springs and earthquake epicenters depicts a NNW-SSE trend which is parallel to the fracture pattern (Fig. 2). The existence of a monoclinal flexure along the west coast with a probable

deep seated fault underneath in the basement suggest zones of crustal weakness [17].

### Results and Discussion

The analyses of trends, fracture patterns, dykes, hot springs, earthquake epicenters, and Bouguer anomaly maps is represented in the form of rose diagrams and frequency polygons (Fig. 4). The cumulative length of the lineaments are represented on the left side of the NS axis and the total number of lineaments on the right side. The circle refers to a distribution which is 20% of the total. The frequency polygon expresses the same information as the rose diagram, however, the polygon is used in quantifying the accurate orientation of the feature. Figure 4 also shows fractures, dykes, aerial photolineaments, and gravity lineaments. The results in terms of orientation are given in Table 1. Three dominant trends in N-S, WNW-ESE, and WSW-ENE directions and the less well-defined lineaments striking NW-SE and SSE-NNW are identified in the data of Das and Ray [7]. The gravity lineaments trend NNW-SSE and NNE-WSW, the WNW-ESE trend has a low amplitude indicating a smaller number of lineaments. The lineaments mapped by Das and Ray [7] show that the dykes are mainly oriented in N-S, NNE-SSW, and NNW-SSE directions, whereas less than 5% of the total number of lineaments trend in ENE-WSW and E-W directions. The total magnetic intensity map of inner shelf of central Konkan (Jaigad and adjacent areas) [18] (Fig. 1) indicate N-S, NW-SE, and WNW-ESE as dominant trends of and NE-SW, E-S, ESE-WNW, and SSE-NNW as subsidiary trends. Kaila and coworkers [17] have shown that the Deccan Volcanism has flexures

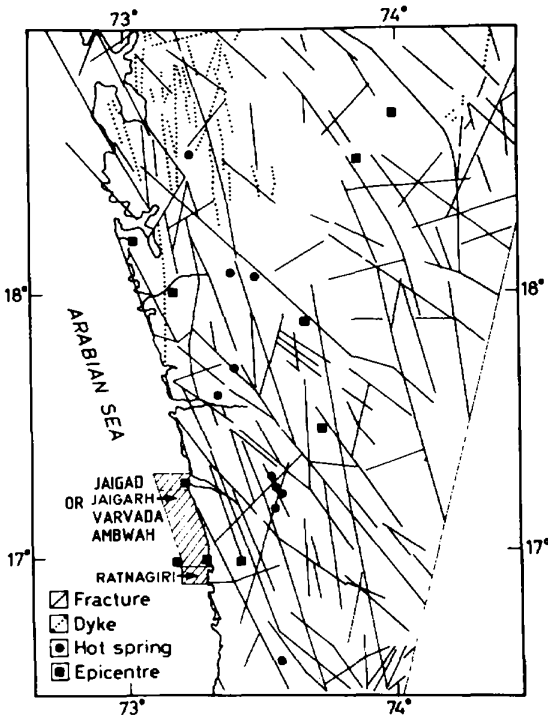


Figure 2. Major lineaments identified from the landsat imageries [6].

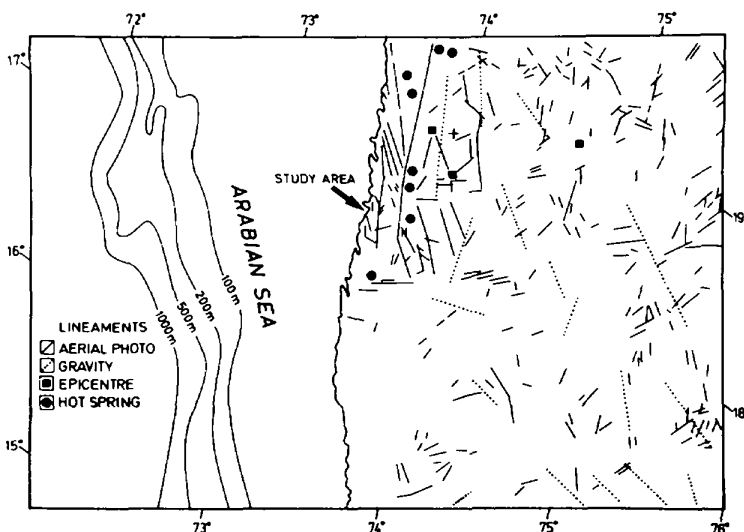
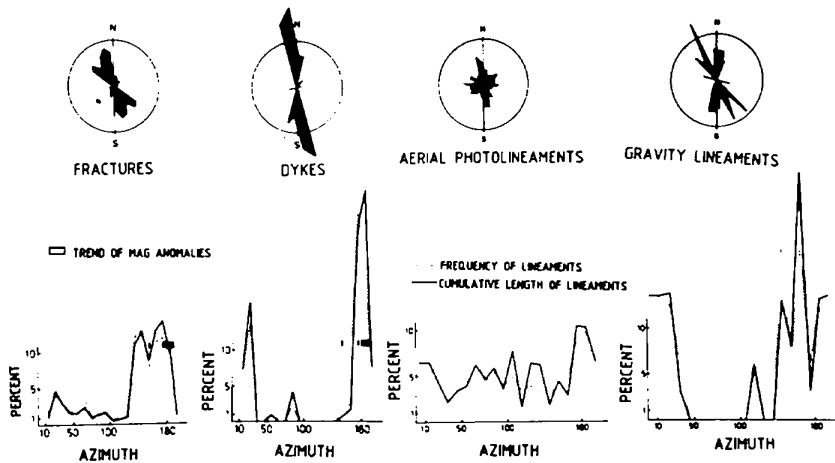


Figure 3. Lineaments, fractures, hot springs and earthquake epicenters on landsat imageries [7].



**Figure 4.** Rose diagrams along with frequency polynomials for the fractures, dykes, photo, and gravity lineaments.

in a NNW-SSE direction. The trends observed on the landsat imageries and total intensity magnetic maps are similar, suggesting a genetic link between onshore and offshore geological framework and control on the offshore structural pattern. The presence of NW-SE and WNW-ESE high amplitude magnetic closures may be due to the igneous intrusions between the faulted or fractured zones along which the magnetic fluids became enriched with ferromagnetic minerals ascending from depths.

The movement of crustal blocks associated with epeirogenic movements since Tertiary times was associated with mild seismicity in the interior parts of the Deccan peninsular shield. Some of the lineaments mapped in the inner shelf appear to be the apparent alignment of magmatic materials erupted through the fractured or fault planes. The three directions inferred from landsat (WNW-ESE to NW-SE, N-S, and NE-SW to ENE-WSW) imageries are well defined by all the geophysical data available. These lineaments also reflect structural trends similar to those in the Dharwars. However, the other less pronounced directions may also be of significance. Similar lineament pat-

terns observed in the satellite imageries and the analyses of offshore magnetic data suggest the same tectonic activity.

## Conclusions

Three statistically important lineament trends, i.e., N-W, WNW-ESE to NW-SE, and NE-SW to ENE-WSW, are documented from the landsat imageries of the Konkan area. The gravity lineaments trend NNE-WSW, NNW-SSE, and NW-SE. The aeromagnetic data also indicate a general NS trend over the Deccan Traps.

The NW-SE, WNW-ESE, and N-S trends are prominent in the offshore magnetic intensity maps, although the NE-SW, E-W, ESE-WNW, and SSE-NNW trends are less pronounced.

Some of the large amplitude anomalies (greater than 1,000 to 2,000 gammas, Jaigad Bay, NW-SE and WNW-ESE) (Fig. 1), may be due to the subsurface dykes which might have intruded through the weaker zones identified as lineaments. Dykes with similar trends

**Table 1.** Results of Onshore Lineament Analyses

Lineament type	Fracture	Dyke	Aerial	Gravity	Magnetics
Dominant trends	N175E	N175E	N175E	N165E	N165-175E
	N145E		N130E	N145	
Other trends		N25E		N25E	N15E
	N25E				N35E
	N65E	N55E	N85E		N75E
		N85E	N105E	N115E	N100-130E
			N155E		N160-165E

Source of data: Das and Ray [6,7]; Magnetics: Present study.

were reported in north Konkan on land [16]. The major NW-SE trending anomaly observed in Jaigad Bay is attributed to be the offshore extension of landsat imagery observed in Figure 1.

The correlation of the onshore and offshore trends suggest that the fracture pattern of crystalline basement has also controlled the offshore structural pattern.

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### References

1. O'Leary DW, Friedman JD, Pohn HA (1976). Lineament, linear, lineation: Some proposed new standards for old terms. *Bulletin of Geological Society America* 87:1463-1469
2. Hoppin A, Pan KL (1978) Review and synthesis of tectonic lineaments of the world: A preliminary report. Proceedings of 3rd International Conference on Basement Tectonics, Durango, Colorado, May 15-19, 1978:11-28
3. Hodder RW, Hollister VF (1974) Some geological distinctions among lineaments for the mineral explorationists. Proceedings of 3rd International Conference on Basement Tectonics, Durango, Colorado, May 15-19, 1974:453-461
4. Frost RTC (1977) Tectonic patterns in the Danish Region (as deduced from a comparative analysis of magnetic landsat, bathymetric and gravity lineaments). *Geologie en Mijnbouw* 56:351-362
5. Ramana MV (1980) Absolute total magnetic intensity contour maps off innershelf of central Konkan, India. National Institute of Oceanography (maps 1-13)
6. Das SR, Ray AK (1976) Fracture pattern, hot springs and lineaments of West Coast. Geological Survey of India, 125 year Newsletter 1-6
7. Das SR, Ray AK (1977) Fracture pattern within Deccan Trap and West Coast of India. Geological Survey of India, Miscellaneous Publication 31:75-84
8. Dipak K Ray (1977) Tectonic map of India (Poster). Geological Society of India, Miscellaneous Publication 31
9. Wadia DN (1961) *Geology of India*. Macmillan, London:1-304
10. Rama (1964) Potassium/Argon dates of some samples from Deccan Traps. 22nd Inter National Geological Congress, New Delhi, 1964 Report VII:139-140
11. Wellman P, McElhinny MW (1970) K-Ar ages of Deccan Traps (India). *Nature* 227:595-596
12. Wensink H (1973) Newer paleomagnetic results of the Deccan Trap, India. *Tectonophysics* 17:41-59.
13. Raju ATR, Chaube AN, Chowdary LR (1971) Deccan Traps and geologic frame work of the Cambay Basin, *Bulletin volcanologique* 35:521-538
14. Bhagwan Sahay (1978) Geology of Bombay high and adjoining structures. Offshore South East Asia Conference, February 21-24, 1978:1-10
15. Mishra DC, Narain H (1977) Airborne geophysical surveys—A case study from central India. *Journal of Geological Society of India* 18(3):104-110
16. Auden JB (1949) Dykes in western India. A discussion of their relationships with the Deccan Traps. *National Institute of Science of India* 3 (3):123-157
17. Kaila KL, Murty PRK, Rao UK (1981) Crustal structure from deep seismic sounding studies along Koyna II (Kelsi-Loni) profile in the Deccan Trap area, India. *Tectonophysics* 73:364-384
18. Siddiquie HN, Ramana MV, Prakasa Rao TKS (1980) Identification of anomaly trends in the marine magnetic profiles of Jaigad Bay region by interprofile correlation. Proceedings of 6th Annual Convention and Seminar on Exploration Geophysics, Bangalore. A:45 (abstract)

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