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Regional geological studies over parts of Deccan Syneclise using remote sensing and geophysical data for understanding hydrocarbon prospects

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An integrated study using remote sensing and multi-geophysical data was carried out over parts of Deccan Syneclise, for eliminating the inherent ambiguities associated with each of the individual methods, and to understand the hydrocarbon prospects. The subsurface sections constructed using geophysical data such as gravity, electrical resistivity, deep resistivity sounding, magnetotellurics and seismics along various profiles were interpreted for identification of subsurface faults along with their stratigraphic association. The locations of these faults were projected vertically upwards onto the ground surface and marked as point locations on the map in order to facilitate conjunctive study with satellite data interpretation by superimposing one over the other. Additionally, some more regional faults were interpreted from gravity data and superimposed over the above. A prominent geomorphic anomaly was also interpreted from satellite data and correlated with geophysical signatures. Based on

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the integrated study, some of the faults were identified as structural traps for possible hydrocarbon occurrences.

Keywords: Deccan Syneclise, geophysical data, hydrocarbon prospects, remote sensing.

WITH the increase in demand for petroleum products and diminishing indigenous production, it has become necessary to look for probable potential zones even in locales that were hitherto known as bleak prospects. Mesozoic sediments throughout the world are known for hydrocarbons and are potential source rocks for more than 50% of the world's hydrocarbon reserves. The discovery of hydrocarbons in the Mesozoic sediments in Jaisalmer basin (Goru and Pariwar formations) and East Godawari sub-basin (Narsapur and Mandapeta structures) indicated the importance to look for structures entrapping hydrocarbons in Mesozoic sediments in Cambay basin and adjoining trap-covered areas[1]. The satellite and geophysical investigations in the trap-covered areas of Kutch and Saurashtra by the National Remote Sensing Centre (NRSC), Hyderabad[2] and the National Geophysical Research Institute (NGRI), Hyderabad[3,4] respectively, were successful in the delineation of the structures. The hydrocarbon prospects of the Deccan Syneclise are still poorly understood, as they are based on studies in sparse sedimentary exposures. Magnetotelluric (MT) method is considered to be one of the effective techniques in the delineation of sediments buried below the trap-covered layers, since it has a marked resistivity contrast with the underlying basement and also with the overlying volcanic cover[4]. The gravity, electrical resistivity, deep resistivity sounding (DRS), MT and seismic data were acquired and processed by NGRI and a technical report was prepared[3]. This report and the contour maps and subsurface sections were the basis for the present geophysical interpretation for delineation of the point locations of various faults and lineaments along with stratigraphic association. As the objective of this study was to find out the possible locations of hydrocarbon occurrence, which are in general associated with regional features, coarse-resolution IRS-P6 Advanced Wide Field Sensor (AWiFS) geo-coded digital data, having a spatial resolution of 60 m, were used for the interpretation of the geological structures such as faults, lineaments and geomorphology. The study area lies within long. 73°00′–75°05′E and lat. 20°50′–22°00′N, covering six topographic maps of SOI on 1 : 250,000 scale (Figure 1). The study area is bounded by the northwestern parts of the Deccan Syneclise, which is a super-order negative platform structure with appreciable thickness of sediments below the trap[1], covering an area of approximately 28,000 sq. km. The Deccan Traps consist of a series of basaltic lava flows presumed to have erupted onto the surface during the Cretaceous–Tertiary period, blanketing all pre-existing rocks ranging in age from pre-Cambrian to Cretaceous. The flows are generally horizontal with a gentle westerly dip, attaining a maximum thickness near the Mumbai coast. Some of the recent deposits of Quaternary are seen along the Narmada valley and between Narmada and Tapti rivers. Few patches of Lameta and Bagh beds are also exposed. The area is dominantly covered by the Deccan Traps, which form plateau topography and are generally prone to intense weathering and form a thick weathered horizon.

The generalized stratigraphy of the area[1] is described in Table 1.

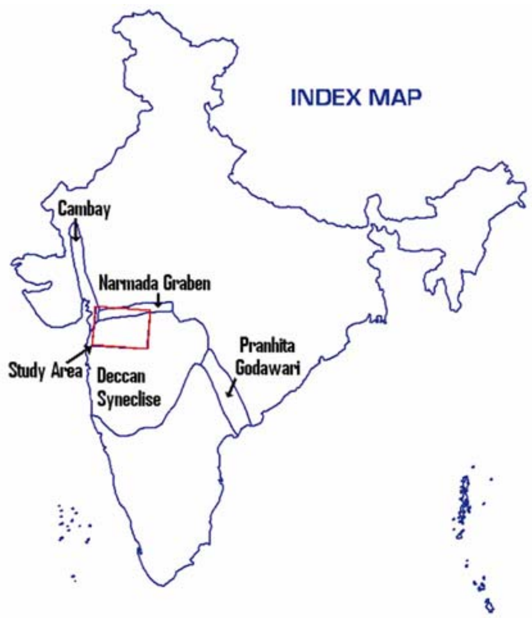

Figure 1. Map showing location of the study area (source: ref. 1).

Table 1. Generalized stratigraphy of the study area

Age	Formation
Recent	Alluvium
Pleistocene	Laterite
Palaeocene	Deccan traps
Upper Cretaceous	
------Unconformity------	
Upper Cretaceous	Lameta beds
Lower Cretaceous	Upper Gondwana
Middle Triassic	
------Unconformity------	
Lower Triassic	Lower Gondwana
Upper Carboniferous	
------Unconformity------	
Lower Palaeozoic	
	Vindhyan
Upper pre-Cambrian	
------Unconformity------	
Upper pre-Cambrian	Cuddapah
------Unconformity------	
Lower pre-Cambrian	Dharwar

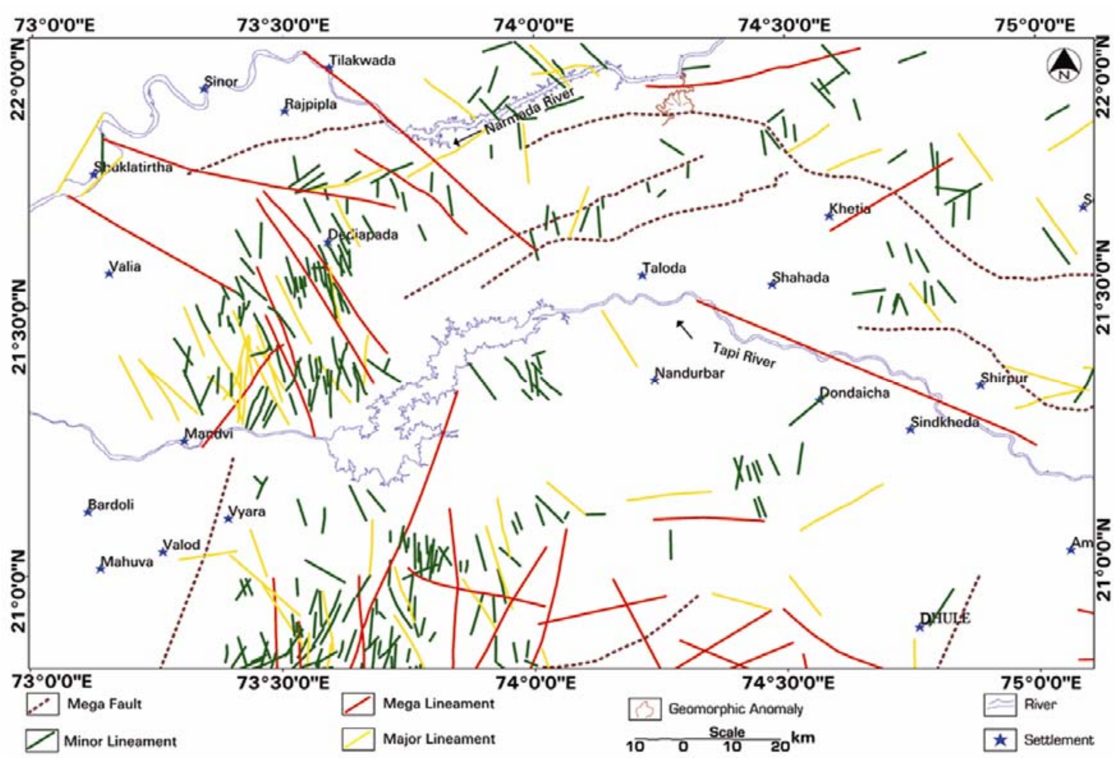

Figure 2. Map showing geological structures and geomorphic anomaly interpreted from IRS-P6 AWiFS data.

The synoptic coverage provided by the satellite imagery enables mapping regional structures, which is difficult in conventional ground surveys due to scanty rock exposures, soil cover, lack of continuous observations, etc[5]. The different types of geological structures, mainly faults and lineaments in the present work, can be interpreted from satellite imagery by studying the image elements such as tone, texture, colour, association, etc.[6]. Lineaments representing faults, fractures, shear zones, etc. are the most obvious structural features interpretable on the satellite imagery. They appear as linear to curvilinear lines on the satellite imagery and are often marked by the presence of moisture, alignment of vegetation, straight stream/river courses, alignment of ponds/tanks, etc. These lineaments can be further subdivided into faults, fractures and shears based on image characters and geological evidences[5]. Faults are interpreted as anomalous truncations or offsets of formations, sharp topographic break and linear alignment of streams, water bodies or vegetation[5]. The geological structures interpreted from satellite data were classified into the following categories based on their lateral extension in order to have depth manifestation essential for hydrocarbon exploration: mega fault (length > 20 km), major fault (length > 10 km and < 20 km), minor fault (length < 10 km), mega lineament (length > 20 km), major lineament (length > 10 km and < 20 km) and minor lineament (length < 10 km)[7]. The geomorphic anomaly, appearing in the form of a domal structure, was also interpreted based on the identification of a circular drainage pattern all along the above structure (Figures 2–4).

The profiles along which the geoelectrical sections have been constructed based on DRS stations were scanned, digitized, registered onto the satellite image and interpreted[3]. The gravity and resistivity profiles were also superimposed over the satellite data. Some of the regional faults were also interpreted from gravity data. The subsurface sections constructed using geophysical data such as gravity, electrical resistivity, DRS, MT and seismics along various profiles were interpreted for identification of subsurface faults based on the flexures/abrupt termination[8] of the subsurface formations along the depth section. The locations of these faults were projected vertically upwards onto the ground surface and marked as point locations on the map in order to facilitate conjunctive study with satellite data interpretation by superimposing one over the other. The age of the various faults was also inferred utilizing the subsurface electrical sections that have been modelled using MT and DRS data[2,8,9] along various profiles with the following terminology: basement fault, fault (Tertiary and Mesozoic), fault (only basement), fault extending up to the basement, fault at trap–Mesozoic boundary and fault in Mesozoic. The methodology followed is described in Figure 5.

Though interpretation of satellite data has revealed a number of lineaments, only a few of them are identified as regional faults based on displacement of the rock beds. One of the mega faults is seen north of Khetia having

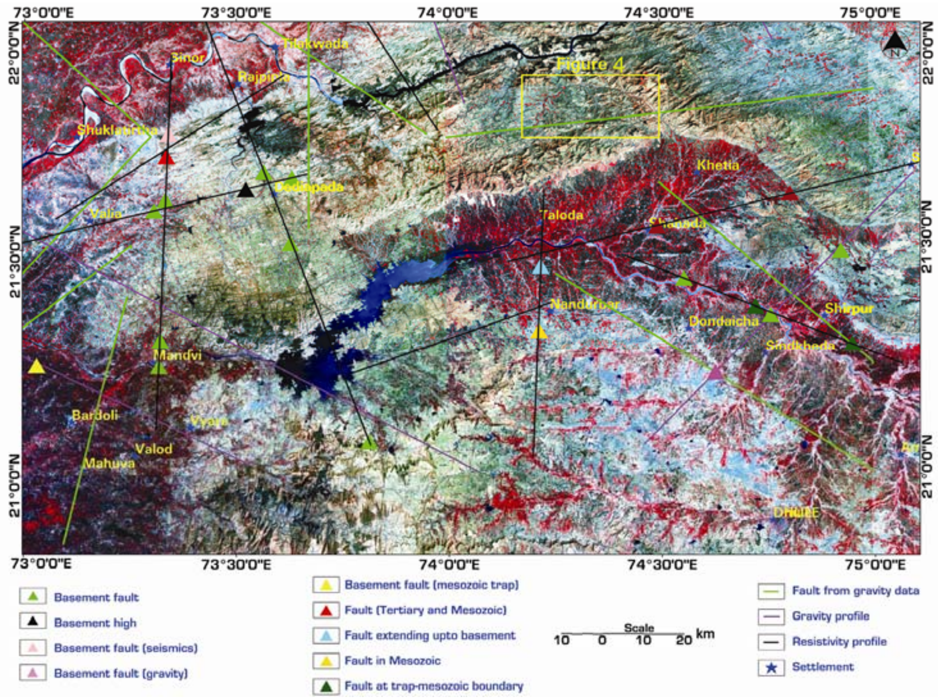

Figure 3. Map showing faults interpreted from geophysical data superimposed over the IRS-P6 AWiFS image.

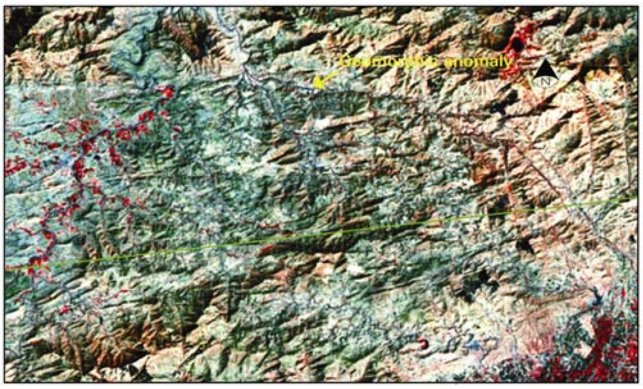

Figure 4. The interpretation of geomorphic anomaly on the satellite image based on circular drainage pattern.

curvilinear trend (ENE–WSW) (Figure 2). This is marked by a distinct geomorphic signature (NW side of Khetia) at the sharp contact between the trap outcrop and the Quaternary sediments (Figures 2–4). The general trend of the faults is in the NW–SE direction. Many sympathetic lineaments are seen trending roughly perpendicular to this trend. Another set of mega faults sympathetic to the above trend is noticed to the south of Khetia, which is marked by a sharp geomorphic contact, especially between the weathered trap and Quaternary alluvium. Many sympathetic lineaments are also observed the north of this fault in the extreme northeastern part of the study area (Figure 2). It appears that these two fault patterns were responsible for the development of a graben, in which the Tapti river is flowing. River Narmada takes an anomalous turn and makes a compressed meander around Sinor (Figure 2), possibly controlled by this fault. Around this zone mega lineaments trending NW–SE are observed. The mega lineaments in this stretch are sympathetic to each other, indicating that they are of the same generation. The density of minor and mega lineaments is high in this stretch, especially north of Mandvi (Figure 2). The high density indicates a high degree of shearing because of the closeness to the fault. Interpretation of geophysical data has revealed three major trends of lineaments and faults in the NW–SE, NE–SW and ENE–WSW directions (Figure 3). A rose diagram (Figure 6) showing the distribution of various lineaments and faults that are interpreted from satellite data, in different directions and frequency, was prepared to understand the dominant structural trend. It can be observed from the rose diagram that there is another major trend of lineaments in the N–S direction, in addition to the above-mentioned three directions; however, these are mostly smaller in length (Figure 2), and perhaps they do not have a deep-rooted origin required for obtaining geophysical signatures.

The integrated study of satellite and geophysical interpretation has revealed three sets of lineaments in the NW–SE, ENE–WSW and NE–SW directions (Figures 2 and 3). Faults delineated in Tertiary and Mesozoic formations, those extending up to the basement, and faults in Mesozoic Formation and in the trap–Mesozoic boundary (Figure 3) are important for hydrocarbon prospects since they cut across the Mesozoic Formation and therefore, may be understood as a structural trap. The prominent geomorphic anomaly, which was interpreted using satellite data in the northern part of the study area, can be correlated to a domal structure based on the identification of a circular drainage pattern all along the above structure (Figures 2–4). It is also observed that this geomorphic anomaly is also bounded by one mega lineament and one mega fault in the northern and southern sides respectively, indicating a structural trap situation (Figures 2–4), probably having considerable depth extension. Around Dediapada village, a basement high and a couple of basement faults were interpreted from geophysical data (Figure 3), which indicate a faulted basement, favourable for hydrocarbon occurrence. This was also supported by the interpretation of mega, major and minor lineaments from satellite data (Figure 2). In the western portion of Shirpur village, two basement faults and one fault at the trap–Mesozoic boundary were interpreted from geophysical data (Figure 3), almost along Tapti River, which was also supported by a mega lineament from satellite observations (Figure 2). All the above-mentioned areas are understood as significant for the exploration of hydrocarbons, based on (the above) integrated analysis and interpretation of remote sensing and geophysics. However, site-specific geophysical studies are recommended for further confirmation of hydrocarbon occurrence, before actually proceeding for drilling.

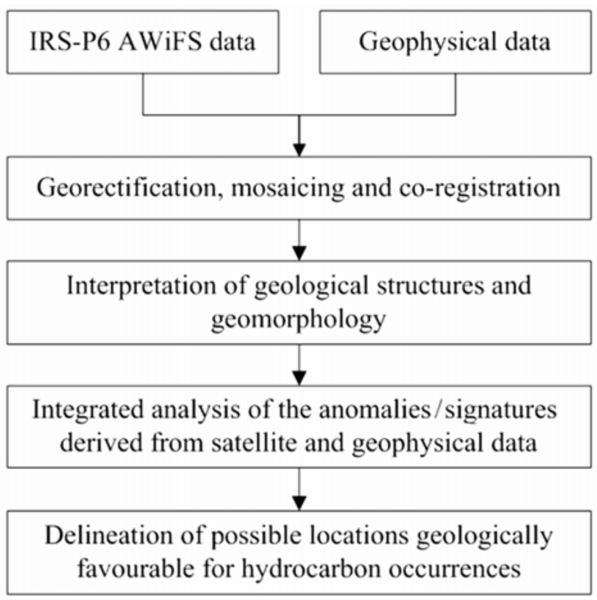

Figure 5. Methodology flow chart.

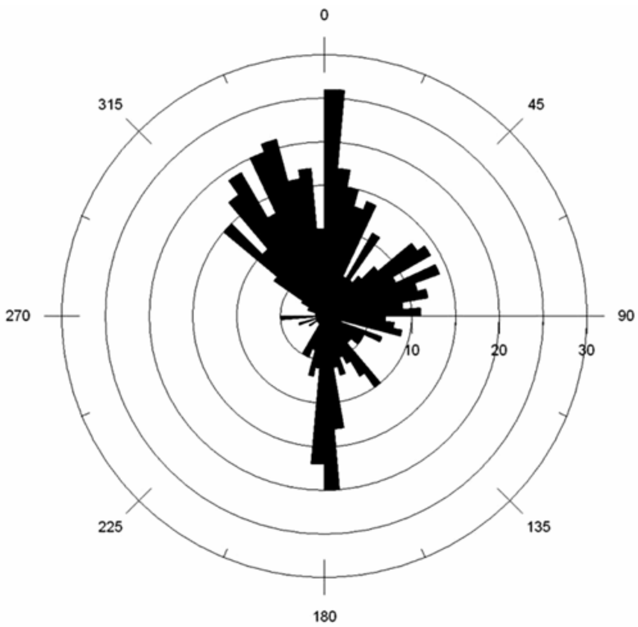

Figure 6. Rose diagram of the lineaments and faults interpreted from IRS-P6 AWiFS data. Values inside the circles indicate frequency.

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