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## Structural Elements of the Deccan Volcanic Province in Central India Derived from the Analysis of Potential Field Data

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### Summary

*Understanding the relationships governing geometry, kinematics and spatial properties of different types of crust (brittle, brittle-ductile, and ductile) and the controlling factors in their evolution in the spatio-temporal domain enables optimum utilization of earth resources. Large and small scale structural trends in the north-western part of the Deccan Volcanic Province in Central India are deciphered on the basis of horizontal gradient computations of gravity and magnetic data over the region, which may in turn be used to characterize the subsurface geometry amenable to hydrocarbon exploration. Two major roughly E-W trends are interpreted from gravity gradient maxima along the Tapi and Burhanpur lineaments. In the southern part strong NW-SE trends re-orienting to N-S trends may perhaps indicate basement trends which are continuations of those of the Dharwar craton to the south of the study area. North of the Tapi Lineament the structural grain is largely NE-SW and from their nature may be attributed to more recent tectonic activity possibly related to the Deccan Volcanism episode.*

**Key words:** *Structural elements, basalt, gravity modeling, Horizontal Gradients*

### Introduction

In India, presence of hydrocarbon bearing Mesozoic sediments has not been established largely because the major part of these sequences lies under the Deccan traps. Mapping of the geometry of these sediments below the basaltic cover is crucial in order to delineate possible locales for hydrocarbon accumulation. Study of the structural elements of the crust offers the opportunity for interpreting the rock record for understanding the modes of growth in different geological and tectonic contexts, leading to the emergence of different theories of evolution, which is important from both a scientific point of view and for the exploration and management of geo-resources. To this aim, this study will include the analysis of gravity and magnetic data to map the faults and other lineaments for the assessment of fabric development in the north-western part of the Deccan Volcanic Province in Central India dominated by the Narmada-Tapti Lineament Zone.

The surface geology of the study area is dominated by the cover of the Deccan Traps with a central belt of Quaternary sediments; sedimentary formations belonging to the Gondwanas, Aravallis and Vindhyan Groups, Peninsular gneisses and granites are exposed to the east and west of the study area (Fig. 1).

The topography is dominated by several sub-parallel E-W trends ranging from 1000 m to mean sea level. The western part includes the coastal plains with an average elevation of 100 m and the Ajanta Plateau to the south, which is an extension of the Sahyadris; towards the centre and the east we see the highlands of the Satpura mountains. Narmada and Tapi are major rivers flowing westward along major geo-fractures.

The Narmada-Son Lineament (NSL) is believed to be a mid-continental rift system that extends eastwards from the west coast of India for about 1300 km (Choubey, 1971).

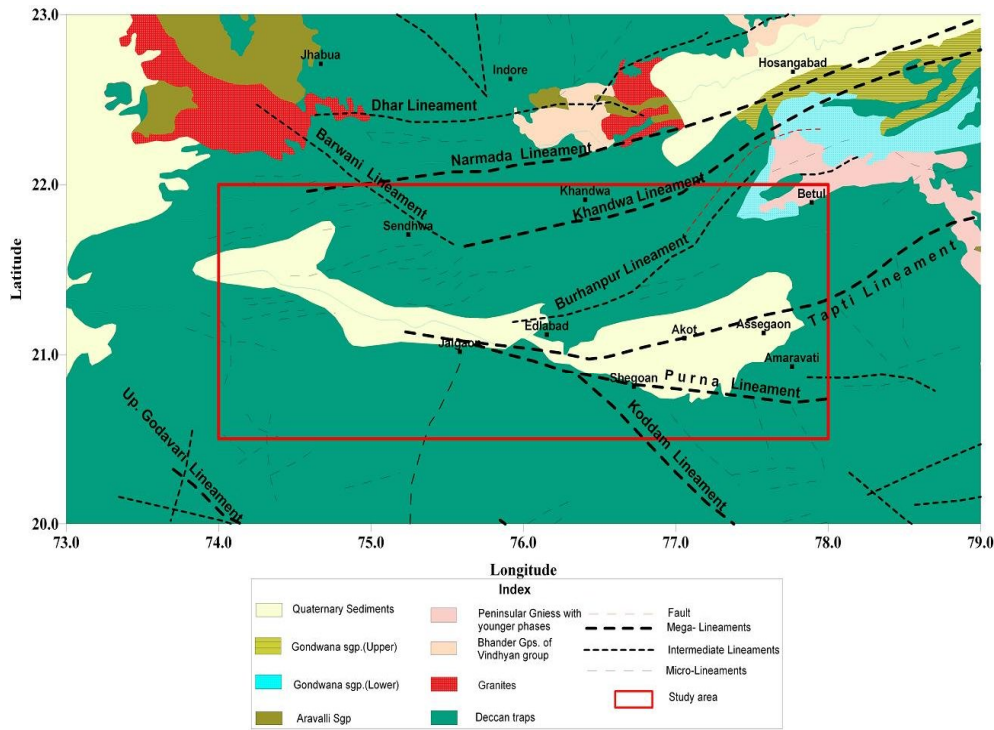


Figure 1: Geology and Tectonics of Deccan Syneclise, Central India

The NSL is believed to be a paleosuture of the Proterozoic period between the Bundelkhand Craton in the north and the Dharwar-Bhandara Craton in the south (Radhakrishna and Naqvi, 1986; Biswas, 1987; Mishra et al, 1998; Singh & Meissner, 1995). The present day Narmada valley and part of the Vindhyan

and subsequently buried beneath the flows of the Deccan Traps. The Moho configuration from DSS studies in this region reveals an ENE–WSW trending depression in the central part, which may have initiated the formation of a Mesozoic basin and the Deccan syncline. This zone is traversed by a number

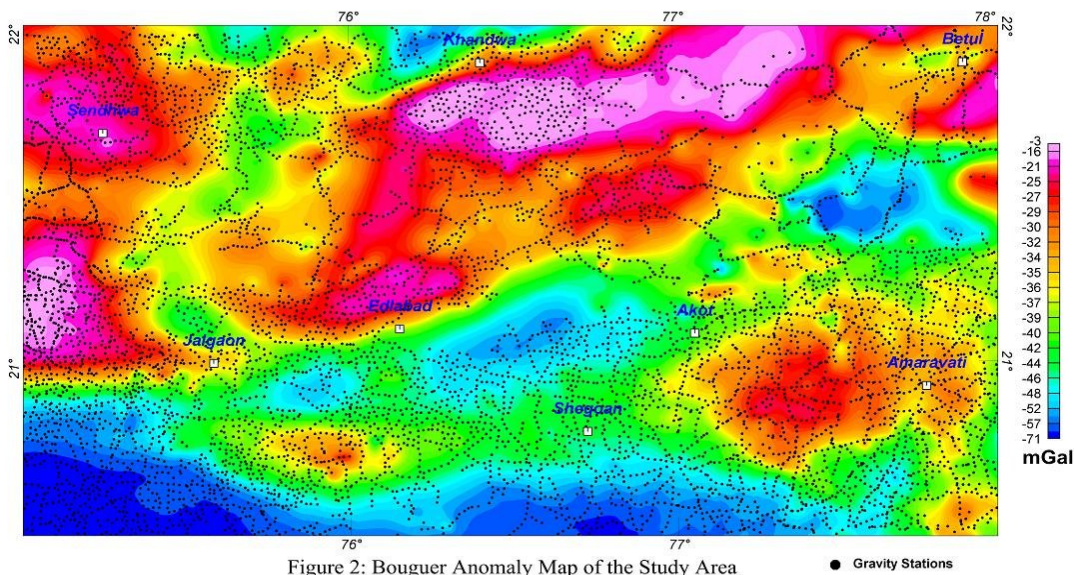


Figure 2: Bouguer Anomaly Map of the Study Area

basin were formed as the result of more recent extensional tectonics (Biswas, 1982). The region was warped uplifted and rifted along the Narmada valley

of deep faults and ductile shear zones which are instrumental in controlling the magmatism, sedimentation and earthquake mechanism. The



western part of the Indian Shield is directly affected by mantle plume activity and the dynamics of the separation of Madagascar and Seychelles from India. The impact of these episodes with mantle upwelling at the junction of Narmada-Son lineament and Cambay rift created the present day crustal structure. Interactions with mantle plumes have weakened the crust, the extent of which can be determined by imaging/mapping the subsurface. Gravity and magnetic data over this region is interpreted to throw light on the geometry of the subsurface which would help to reveal the major tectonic trends, faults and shears in this part of the country.

### Analysis of Gravity and Magnetic Data Gravity

The Bouguer gravity map (Fig. 2) depicts a broad ENE-WSW trending high-low pair and is decomposed into the regional and residual fields by applying a Butterworth filter, on the basis of spectral analysis (Diljith et al, this issue), which indicates distinct source depths in the subsurface. The residual anomaly map corresponds to cumulative information to the basement

depth of 4-5 km from the surface and is characterised by several elongated high-low pairs.

### Magnetics

The Total Magnetic Intensity Map (Fig. 3) is distinguished by short wavelength anomalies; an elongated E-W high dominates the central part. To ensure that the magnetic signals are confined to depths of 4-5 km, representing the basement interface and are devoid of causative effects from lower crustal intrusives, we applied the same Butterworth filter as for gravity data. The remaining magnetic field now represents sources from the basement as well as the interface between Deccan Traps and the sediments. On the basis of spectral analysis we again applied a filter to separate the two sets of signals and decomposed the field into two components representing the basalt-sediment interface and the sediment-basement interface. The short wavelength field represents the variations of the basaltic layer whereas the longer wavelength one is representative of the basement undulations.

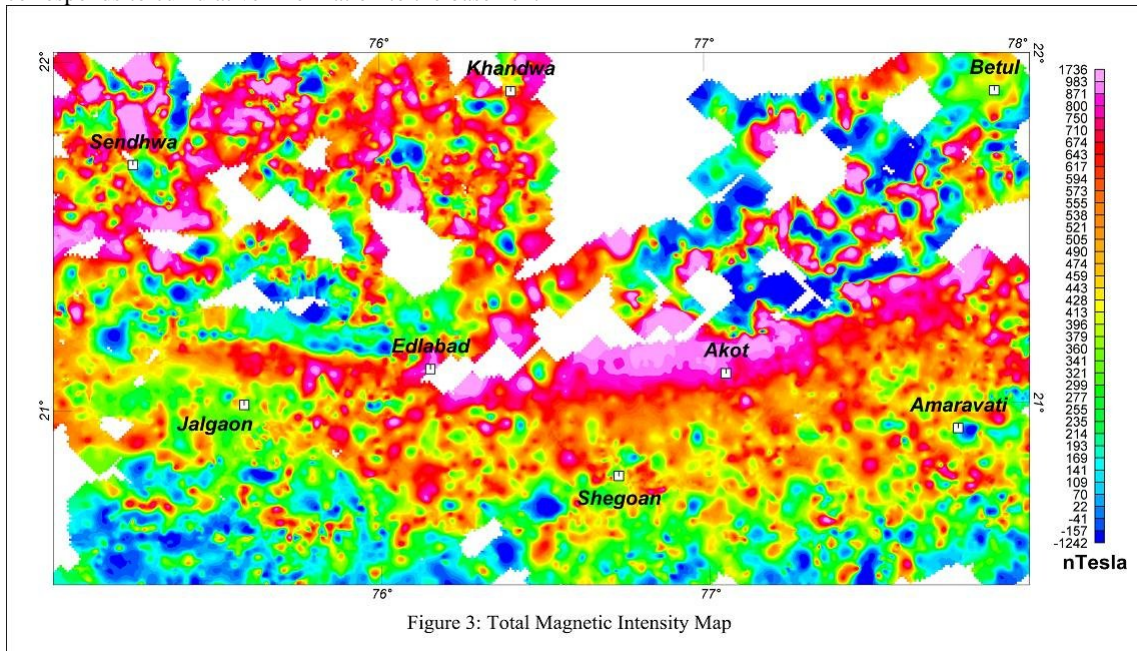


Figure 3: Total Magnetic Intensity Map

The application of 'reduction to pole' ensures that the anomalies would be the ones measured at the north magnetic pole where the induced magnetization and the ambient field both would be directed vertically down. This process shifts the anomalies laterally over their respective sources and alters their shape so that symmetrical sources cause symmetrical anomalies, thereby removing one level of complexity from the interpretive process. The pseudogravity transformation converts the total field magnetic anomaly into the gravity anomaly that would be observed if the

magnetisation direction were to be replaced by an identical density distribution (Blakely, 1996). The resultant field is easier to interpret and quantify than magnetic anomalies and this strategy is used in the present case to derive structural information from magnetic field data.

### Computation of Horizontal Gradients

Computation of horizontal gradients is established to be an extremely useful method in delineating the



boundaries of source rock (Cordell and Grauch, 1985; Blakely and Simpson, 1986). The steepest horizontal gradient of a gravity anomaly will be located directly over the edge of the body if the edge is vertical and far removed from all other edges or sources. The horizontal gradient is simply a measure of the lateral change in density or magnetization of upper crustal rocks. Its magnitude is dependant on the density contrast across the boundary, the vertical extent of the contrast, the dip of the boundary and its depth of burial. This analysis is performed on the residual

gravity data and the magnetic data. The sinuous sequences of dots represent boundaries of gravity and magnetic sources in Figs. 4, 5 & 6. It would, of course, be unwise to interpret all maxima in the figures as authentic source boundaries and features on the boundary map not evident on the anomaly map should be regarded with caution. Analysis of the horizontal gradient computation of the gravity and magnetic data lead us to a comprehensive understanding of the basement structures.

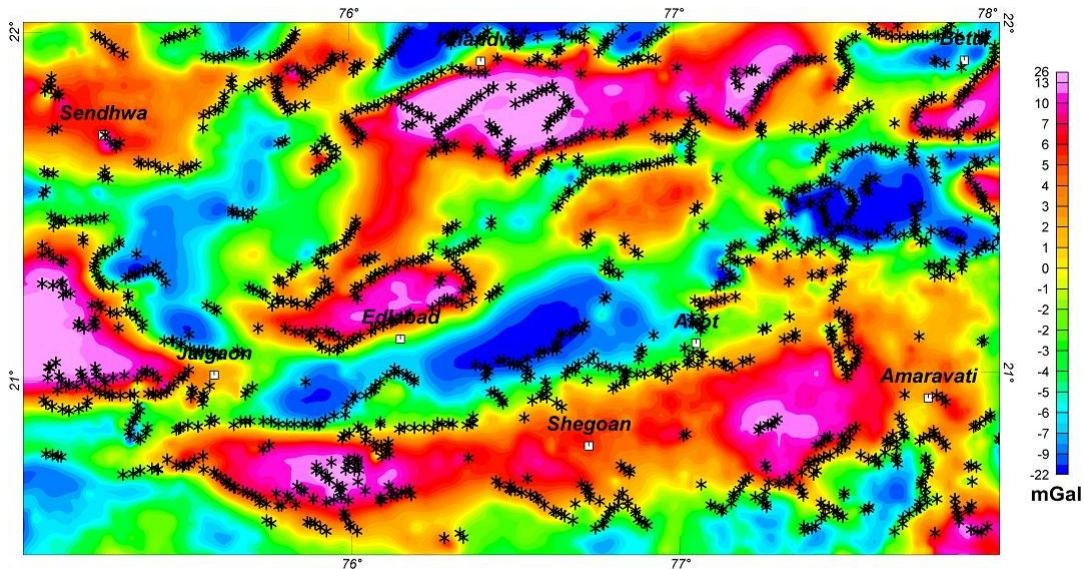


Figure 4: Residual Gravity Anomaly Map Superposed with Horizontal Gradient Maximas

Fig. 5 shows the gradient maxima derived from residual gravity data, primarily indicating basement trends. A dominant ENE-WSW grain is visible as is also true for the alignment of the anomalies themselves. The crisscross trends (Fig. 6) generated by variations in the Traps are expectedly of short distances, whereas more clearly demarcated ones are observed from the basement (Fig. 7). The nature of the basement in the west is evidently different from that in the eastern half. Again in the southern part the maxima trends are oriented NW-SE or N-S, whereas in the northern part the trends orient themselves in the NE-SW direction. Such changes in directions suggest a block faulted nature of the basement in the study region.

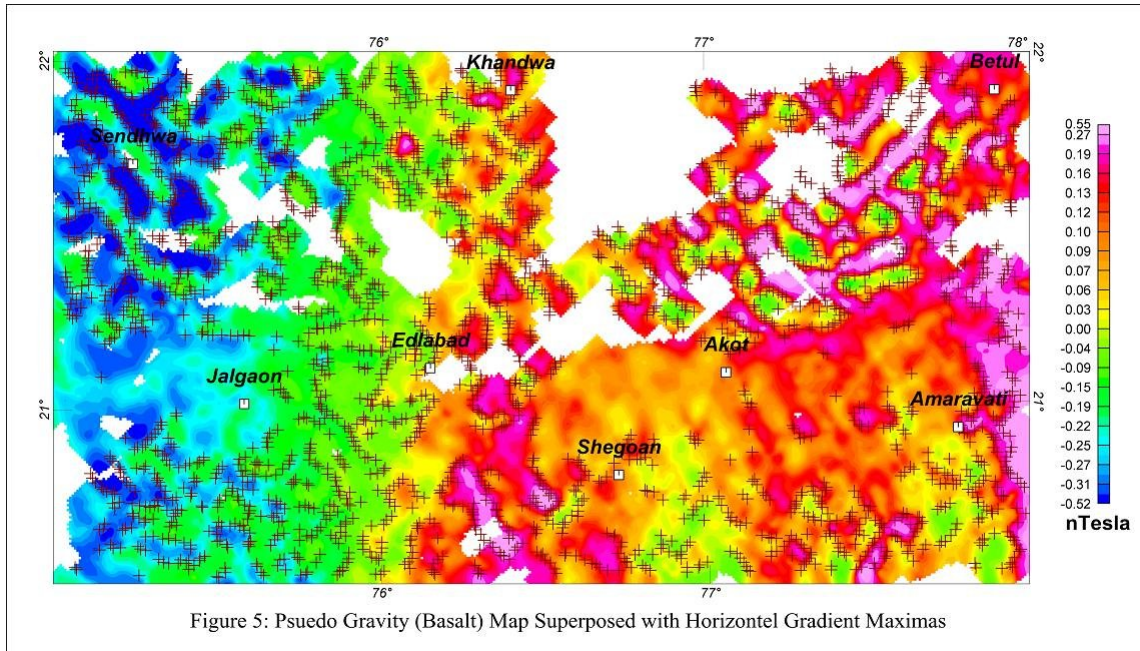


Figure 5: Pseudo Gravity (Basalt) Map Superposed with Horizontal Gradient Maximas

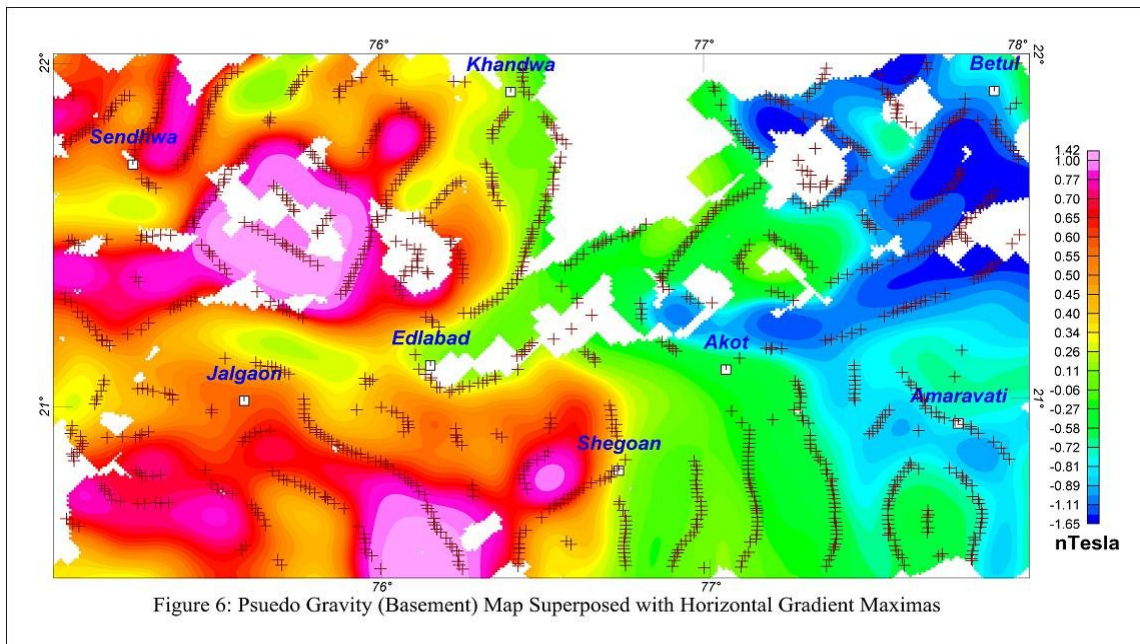


Figure 6: Pseudo Gravity (Basement) Map Superposed with Horizontal Gradient Maximas

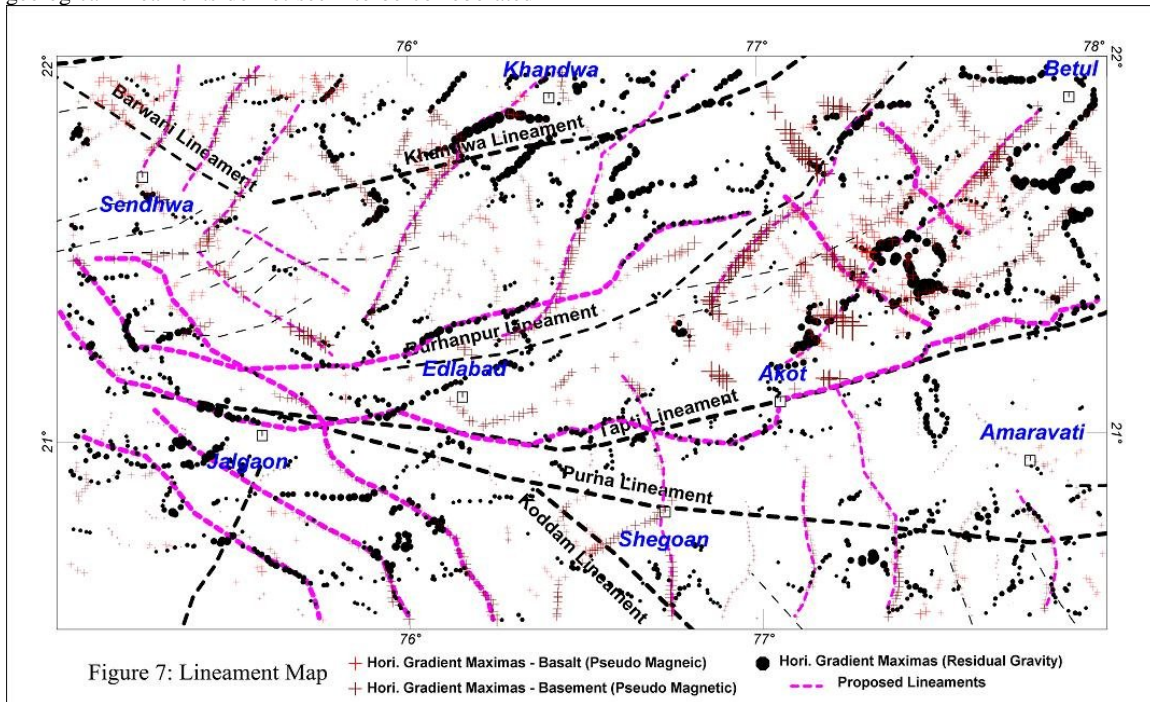
## Results and Conclusions

For the final analysis all the trends are superposed on one map (Fig. 8) along with tectonic information available from geology. Gradient Maxima from gravity data are marked by filled circles; the sizes of the circles are according to the magnitude of the maxima. For Gradient Maxima from magnetic data, the deep pink 'plus'es mark the results from the

shallower layer and the brown 'plus'es mark those from the deeper layer, meant to represent the basement. Again they are sized according to the magnitude of the maxima. We have attempted to interpret the major lineaments and these are indicated by pink dashed lines. Two major roughly E-W trends are interpreted from gravity gradient maxima along

the Tapti and Burhanpur lineaments. The other geological lineaments do not seem to be corroborated

by gravity-magnetic data. In the southern



part from west to east strong NW-SE trends re-orienting to N-S trends may perhaps indicate basement trends which are continuations of those of the Dharwar craton to the south of the area. North of the Tapti Lineament the trends are largely NE-SW and these may be attributed to more recent tectonic activity possibly related to the Deccan Volcanism episode.

Thus it can be said that the gravity and magnetic gradient maps indicate number of tectonic blocks in the area, which corroborate the known tectonic elements of the region and also bring out new ones. Such trends may be modelled as part of detailed quantitative interpretation to delineate hydrocarbon-friendly environments in the layers of sub-trappean Mesozoic sediments. It can be concluded that computation of gradients of both gravity and magnetic fields is an effective method which allows the qualitative inference of influence of structural elements in the observed field, which may in turn be related to surface and subsurface geometries. This is potentially very important for designing future strategies for detailed exploration programs.

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