Ramgarh Magnetic Anomaly in the Chambal Valley Sector of Vindhyan Basin: A Possible Meteorite Impact Structure and its Implications in Hydrocarbon Exploration*

Jitendra Kumar[1], M.S. Negi[2], Rajesh Sharma[2], D. Saha[2], Sanjive Mayor[2], and Manoj Asthana[2]

Search and Discovery Article #80145 (2011)
Posted April 29, 2011

*Adapted from extended abstract presented at GEO-India, Greater Noida, New Delhi, India, January 12-14, 2011

[1]KDMIPE, Oil & Natural Gas Corporation Ltd., Dehradun, Uttarakhand, India (jitendra_202002@yahoo.com)
[2]KDMIPE, Oil & Natural Gas Corporation Ltd., Dehradun, Uttarakhand, India

Abstract

The Vindhyan Basin, a classic example of Proterozoic intra-continental basin in the central part of the Indian shield is widely regarded as a frontier basin. It is broadly divided into two sub-basins: Son Valley (eastern sector) and Chambal Valley (western sector). The present paper deals with the Chambal Valley sector of the Vindhyan Basin. It has often been observed that new plays are often successful when old paradigms are challenged and replaced by different out of box ideas. A new play related to a buried meteorite impact structure has been identified from magnetic signatures by special processing of aeromagnetic data in the Ramgarh Dome area. It is also supported by other geophysical and geological evidences. The oval-shaped magnetic anomaly near Ramgarh lends credence to the interpretation that it is an impact structure. Various interpretations have been put forward by earlier workers for this feature. Some have opined it to be a dome while others have interpreted it as a meteorite crater. Comparison of Ramgarh impact structure with other craters of the world reveals that the Meteor Crater, Arizona has a similar shape and the magnetic anomaly and is analogous to Jackpine Creek magnetic anomaly of British Columbia. The importance of impact structure from hydrocarbon point of view lies in the fact that when meteorite impact occurs in a sedimentary basin, it can create a trap generating structure (rim and central uplift) and reservoir rocks (ejecta piles and breccia infill), both at the same time. The meteorite impact structures/craters can be very good hydrocarbon prospects. Steen River in Alberta, Viewfield in Saskatchewan, Ames Hole in Oklahoma, and Red Wing Creek in North Dakota are examples of oil and gas fields producing from buried impact structures. Identification of meteorite impact structure enhances the hydrocarbon prospect of Chambal Valley sector of Vindhyan Basin.

Copyright © AAPG. Serial rights given by author. For all other rights contact author directly.

Introduction

Magnetic methods have been used in the oil and gas exploration since the 1920s but were mainly used to investigate major fault zones and map basement rocks. However, under favorable conditions (and especially in combination with other geophysical and geochemical methods), magnetic techniques can play a bigger role in locating oil and gas fields. Integrated interpretation of shapes of magnetic anomaly with other G&G data can reveal patterns which can lead to identification of features of hydrocarbon interest. It is well known that neither seismic nor gravity methods can fully map the basement, although both can map part of it. Subsurface data cannot help in mapping the basement in greater detail due to the limited number of basement intercepts in most basins. Only magnetics can map the covered basement pattern. Therefore magnetic data is in a unique position to divulge the basement pattern in detail. This paper deals with the strikingly different uses of aeromagnetics that are emerging. The present paper makes an attempt to present the analysis of magnetic, seismic, and geological data of the Chambal Valley sector especially the Ramgarh Dome area.

Geological and Tectonic Setting

The Vindhyan Basin in the central part of the Indian shield is a large intracratonic super order negative structure with its maximum thickness of about 7000 m and comprises a succession of sandstone, shale, and limestone/dolomite with a prominent horizon of volcaniclastic sediments (Porcellanite) particularly in the lower part. The basin is divided into eastern sector (Son Valley) and western sector (Chambal Valley) and is sickle-shaped, girdling the basement of the Bundelkhand Granite-Gneiss Complex in the middle (Figure 1).

The Survey of India topographical sheet 54C, Sawai Madhopur, scale 4 miles to 1 inch (first published in 1908), shows an isolated hill of annular shape, forming an almost complete circle approximately 3 km in external diameter at the location defined by the latitude 25°20'N, longitude 76°37'30"E (Figure 2), (Crawford, 1972). This feature lies in eastern Rajasthan almost on the boundary with Madhya Pradesh. It has a domal nature due to its oblong feature. Its occurrence in a comparatively flat country of Sirbu Shale has made it conspicuous. It displays conspicuous depression and prominent topography in an otherwise alluvial flat country. The country there is almost flat, although the region lies within the general outcrop of the upper Precambrian Vindhyan system. The bedrock is almost entirely obscured by a wide belt of alluvium. Where Vindhyan rocks are exposed in the vicinity, they are flat lying and undisturbed. This has drawn the attention of geoscientists and various ideas have been thrown about to explain the structure. It is a prominent oblong landform characterized by a peripheral almost circular ridge and central depression. The highest part is 150 m above ground level. The Ramgarh domal structure exposes the Govindgarh Sandstone in its axial portion followed by Ganurgarh Shale in the centre; Lakheri Limestone, Samria Shale, and Bundi Hill Sandstone occurring as girdle or ring.

The central depression is due to faulting, collapse, and erosion. The Bundi Hill Sandstone has quaquaversal dips away from the centre.

Dips of the sandstone at crestal part of the ridge ranges from 45° to 78°and gradually flattens down to outer slope and 5° to 15° in the foothill region. Thus, it flattens out and opens up in either oblong ends. A fault trending N10°E- S10°W which appears to be along the axial plane of the oblong anticline is probably responsible for the opening (Prasad,1984), (Figure 3).

Few highly magnetic pieces with characteristic pitting and polish from inside the crater and magnetic spherules from the clay outside the impact area were collected (Ahmad, 1974). Preliminary study revealed that these pieces could have been part of nickel-iron meteorite. Dips of the sandstone in the crestal part of the ridge range from 45° to 78° and gradually flatten down to the outer slope to about 5° to 15° in the foothill region and opens up in either oblong ends. A fault trending N10°E - S10°W which appears to be along the axial plane of the oblong anticline is probably responsible for this opening. The crater walls are made up of Bhander Sandstone, dipping radially outwards, at angles between 32° and 54°. The rocks along the crest of the crater wall are highly fractured but the intensity of fracturing also decreases downhill. Almost in the middle of the crater, green shales are exposed dipping vertically, probably due to the impact of the meteorite. A specimen found in colluvium near the centre of the feature seems shatter-coned (Crawford, 1972). An examination of the crater revealed that it was not of volcanic origin. It also did not show any evidence of igneous intrusion. For had there been an igneous intrusion, which cooled and allowed the bubble to collapse, the fracture pattern would have been more or less symmetrical and significantly different from what is seen in the area. Similarly, it was not a subsurface salt dome from which salt was subsequently dissolved by percolating water and the whole edifice collapsed thereafter (Ahmad, 1974). Therefore in the absence of any other evidence and on the basis of two magnetic pieces of nickel-iron found in the crater and magnetic spherules collected from outside the crater area, it seems that the crater was formed due to the impact of a meteorite. Besides, no magnetite exists in the country rocks for several kilometers in this area.

Based on the special processing of Jackpine Creek aeromagnetic data, a magnetic anomaly has been classified as resulting from meteorite impact structure (Goussev, 2003). Extending this analogy to Vindhyan Basin in India, a similar oval-shaped magnetic anomaly has been identified in the Ramgarh Dome area. The objective of the paper is to interpret the magnetic signatures of the anomaly after special processing of the aeromagnetic data and integrate it with existing geological and geophysical data viz. surface geological and seismic data to arrive at a possible cause of the anomalous feature. 60000 line kilometers of aeromagnetic data were acquired during 1993-94 and 1994-95 to unravel the tectonics of the basin. This data has been used to decipher the magnetic anomaly in the Ramgarh Dome area.

Methodology

A key component of this study is to enhance the image of existing aeromagnetic data. Image-enhancement processing of aeromagnetic data proved to be critical for resolving basement structural fabric within areas that appear as ‘magnetically flat’ on unprocessed total field maps.

The magnetic anomaly map delineates the lateral variations of magnetization variations in the crust. It is used to locate rocks or minerals having unusual magnetic properties, which reveal themselves as anomalies in the intensity of the earth's magnetic field. Magnetic anomalies are often used in a qualitative way to assist regional geologic interpretations. However, unlike gravity anomalies that correlate directly with the causative source bodies, magnetic anomalies generally show no simple correlation with their source bodies. It is desirable to derive magnetic anomalies that are positioned directly over the magnetic source bodies, similar to gravity anomalies. The repositioning is usually accomplished by applying the standard reduction-to-the-pole (RTP) filtering of the data which is carried out to remove the directional dependency of the earth's field and transformed anomalies into one that would be observed with vertical magnetization. This facilitated the integration with seismic and gravity data with magnetic data set.

The aeromagnetic anomaly map (Figure 4) shows the Ramgarh Dome located off the crest of a magnetic high. However, the aeromagnetic data was processed by applying the standard reduction-to-the-pole (RTP) filtering of the data. Interestingly, the RTP processed map shows oval-to-circular shaped positive anomaly (Figure 5). This shape of anomaly has striking similarity with the magnetic anomaly of Jackpine Creek which is attributed to a meteorite impact structure (Figure 5A and Figure 5B). The fault pattern of the Jackpine magnetic anomaly (Figure 6) is a complex one and matches with the fault pattern of the Ramgarh Dome anomaly as mapped by the GSI (Figure 3). The analogous shape and fault pattern of the anomalies makes one infer to the same cause of the anomaly. Meteor Crater, Arizona has a similar shape. Crawford (1972) has expressed his opinion that the feature seems likely to be some kind of impact structure.

Recently, good quality regional seismic data has been acquired in the area close to Ramgarh. The footprints of the impact crater seem to be present in the seismic data. The Vindhyan rocks being of high velocity depict feeble low amplitude signatures of rims and crater and central uplift is discernible with effort owing to the reasons stated earlier. This confirms the possible meteorite impact structure in the Ramgarh area. The seismic feature resembles the Jackpine Creek meteorite impact structure (Figure 7 and Figure 8).

Results

Ramgarh magnetic anomaly stands out in the area. Its shape (oval-to-circular on RTP processed map) and its resemblance with the Jackpine Creek magnetic anomaly leads us to infer that it is a meteorite impact structure. Nearby seismic data also exhibits characteristic signatures of rim and crater which too reasonably match with the seismic of Jackpine Creek magnetic anomaly. In addition, its morphology matches with the Meteor Crater, Arizona. Presence of two magnetic pieces of nickel-iron in the crater and magnetic spherules collected from outside the crater area also point to the cause of crater as meteorite impact. The faulting pattern and almost vertical dip in the middle also lend credence to the interpretation that it is related to the meteorite impact. The fault pattern of Ramgarh and Jackpine Creek meteorite impact structure has striking similarity leading one to believe that it is caused by impact of a meteorite. The presence of all these evidences is ample proof that Ramgarh Dome is a meteorite impact structure.

The importance of this impact structure lies in the fact that impact process can cause trap generating structure (rim and central uplift) and reservoir rocks (ejecta piles and breccia infill), both at the same time. The buried impact structures/craters have been found to be very good petroleum prospects. Steen River in Alberta, Viewfield in Saskatchewan, Ames Hole in Oklahoma, and Red Wing Creek in North Dakota are examples of oil and gas fields producing from buried impact structures. The Vindhyan Basin has poor characteristics of the reservoir facies but the impact structure can itself provide both reservoir facies and trap which augurs well for this basin where no commercial discovery has been made so far. The impact structure enhances the hydrocarbon prospect of the basin. Gas shows are also recorded in the nearby area. Up dip shallow oil accumulations can be targeted in this area.

Conclusions

The study demonstrates a one-to-one relationship between Ramgarh magnetic anomaly and Jackpine Creek magnetic anomaly. Integrated analysis of G&G data has led to the conclusion that Ramgarh magnetic anomaly is a meteorite impact structure. The correlation of aeromagnetic data over the proven oil fields has indicated other potentially prospective anomalous zones which need to be investigated in detail. Thus, aeromagnetic data when used with other data is a powerful and relatively inexpensive tool in areas which are inaccessible and have data acquisition problems.

Acknowledgements

The authors are grateful to the Director (Exploration), Oil and Natural Gas Corporation Ltd. for his kind permission to publish this paper. They also want to convey sincere thanks to Shri P.K. Bhowmick, ED-HOIKDMIPE for giving opportunity and constant encouragement for publication of this paper. The views expressed in this paper are of the authors only and not necessarily of the organization they represent.

References

Ahmad, N., et al., 1974, Ramgarh Meteorite crater: Current Science, p. 598.

Crawford, A.R., 1972, Possible impact structure in India: Nature, v. 237/5350, p. 96.

Goussev, S.A., R.A. Charters, J.W. Peirce, and W.E. Glenn, 2003, Jackpine Creek magnetic anomaly: Identification of a buried meteorite impact structure: The Leading Edge, v. 22/8. p. 740-41.

Prasad, B., M.V.A. Sastry, and A.K. Moitra, 1984, Geology, sedimentation and paleogeography of the Vindhyan supergroup, southeastern Rajasthan, Part I: Geological Survey of India Memoir, v.116, 148 p.

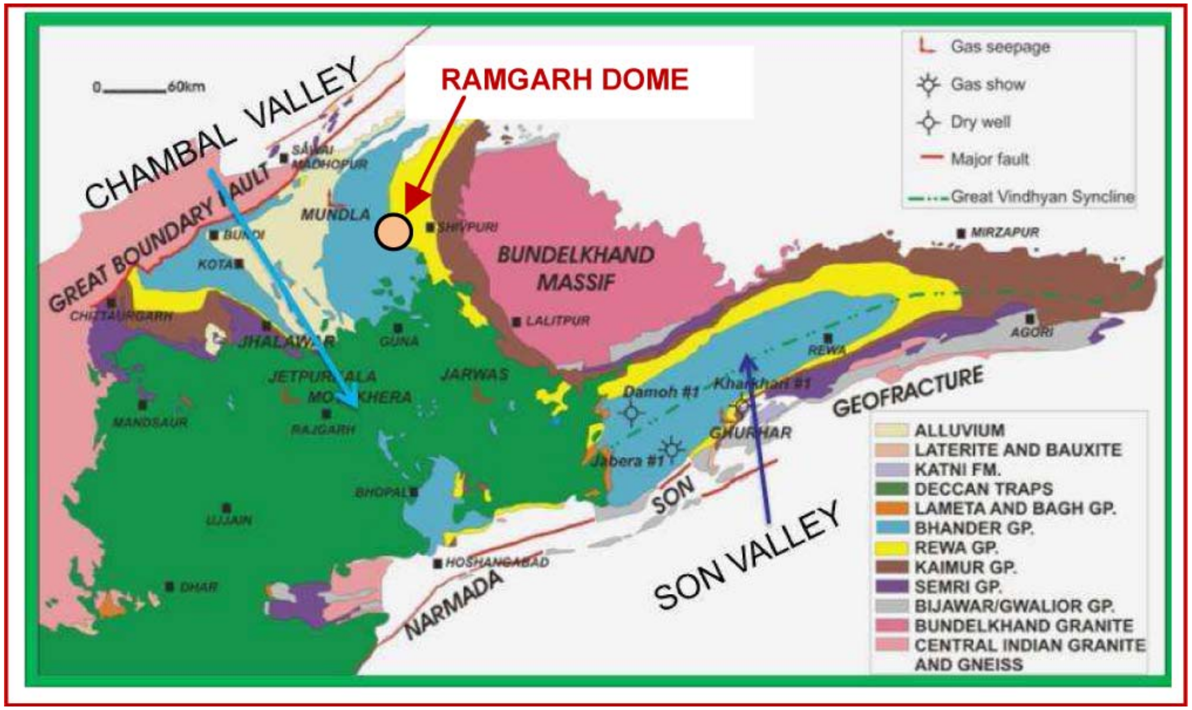

Figure 1. Geological Map of Vindhyan Basin showing the Chambal Valley and Son Valley sectors.

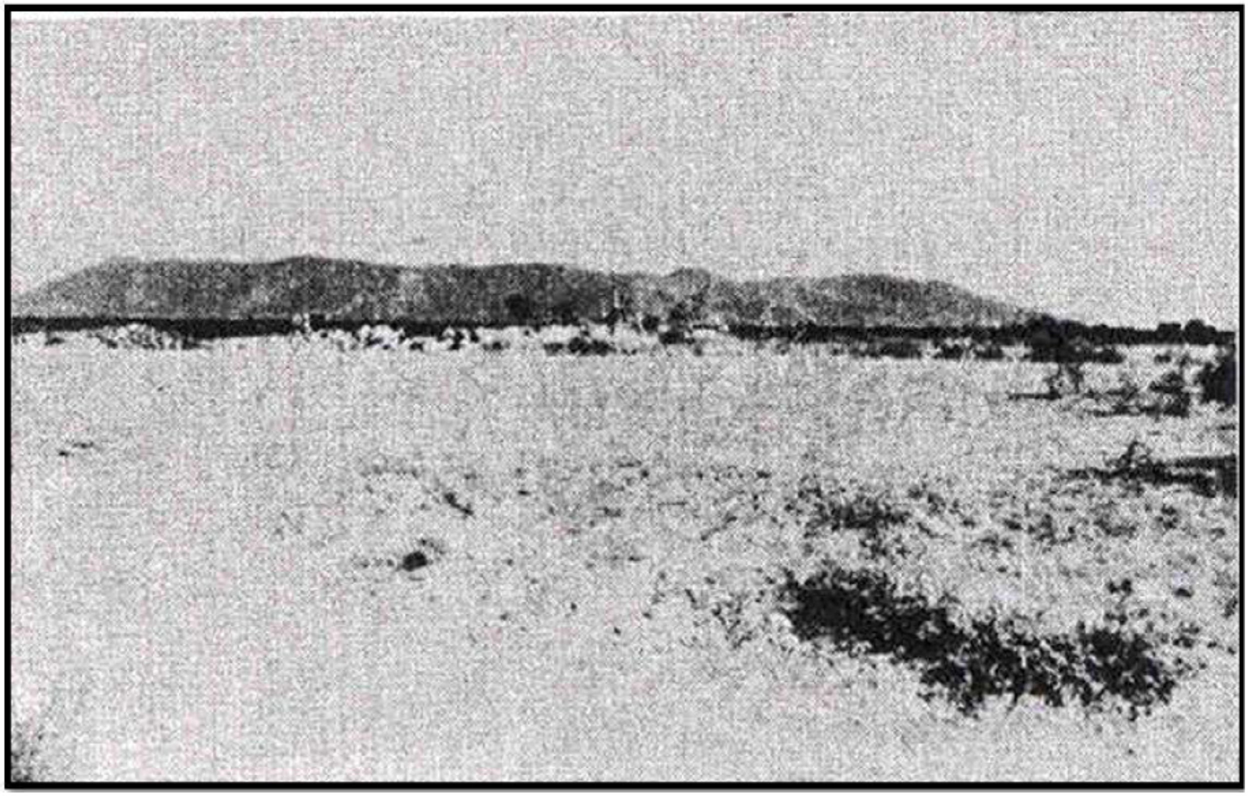

Figure 2. Field photograph showing the Ramgarh Dome (from Crawford, 1972).

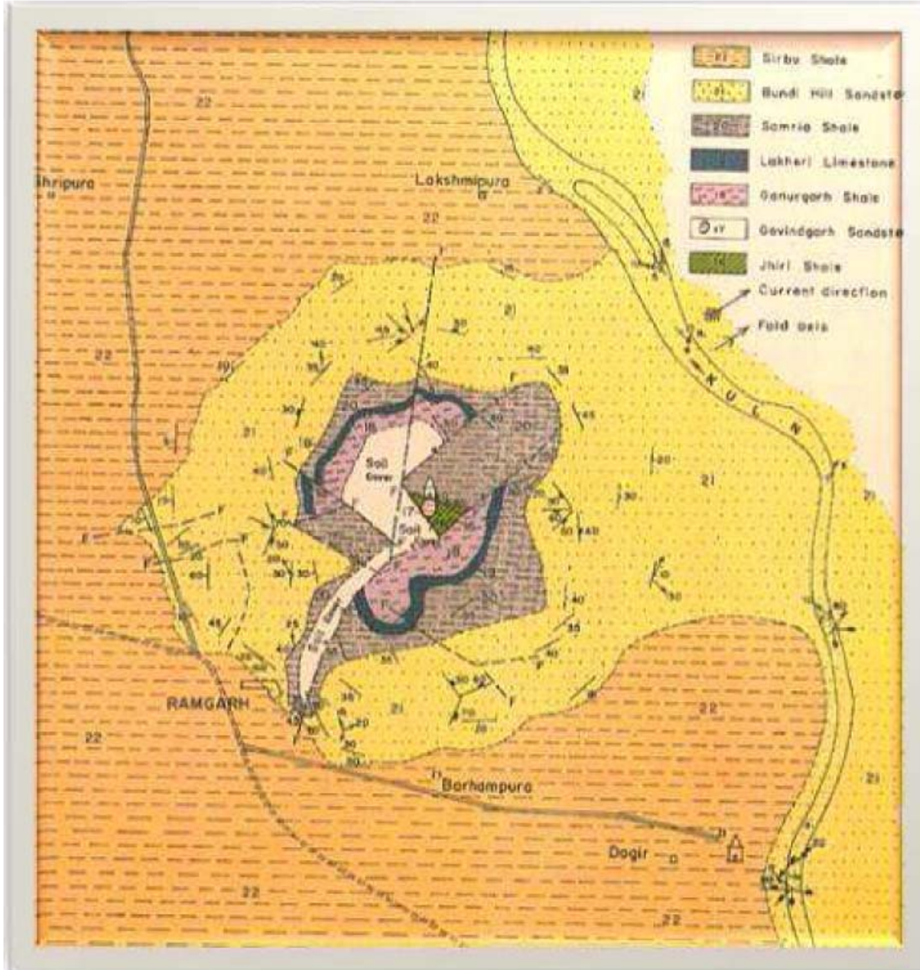

Figure 3. Geological map around Ramgarh Dome.

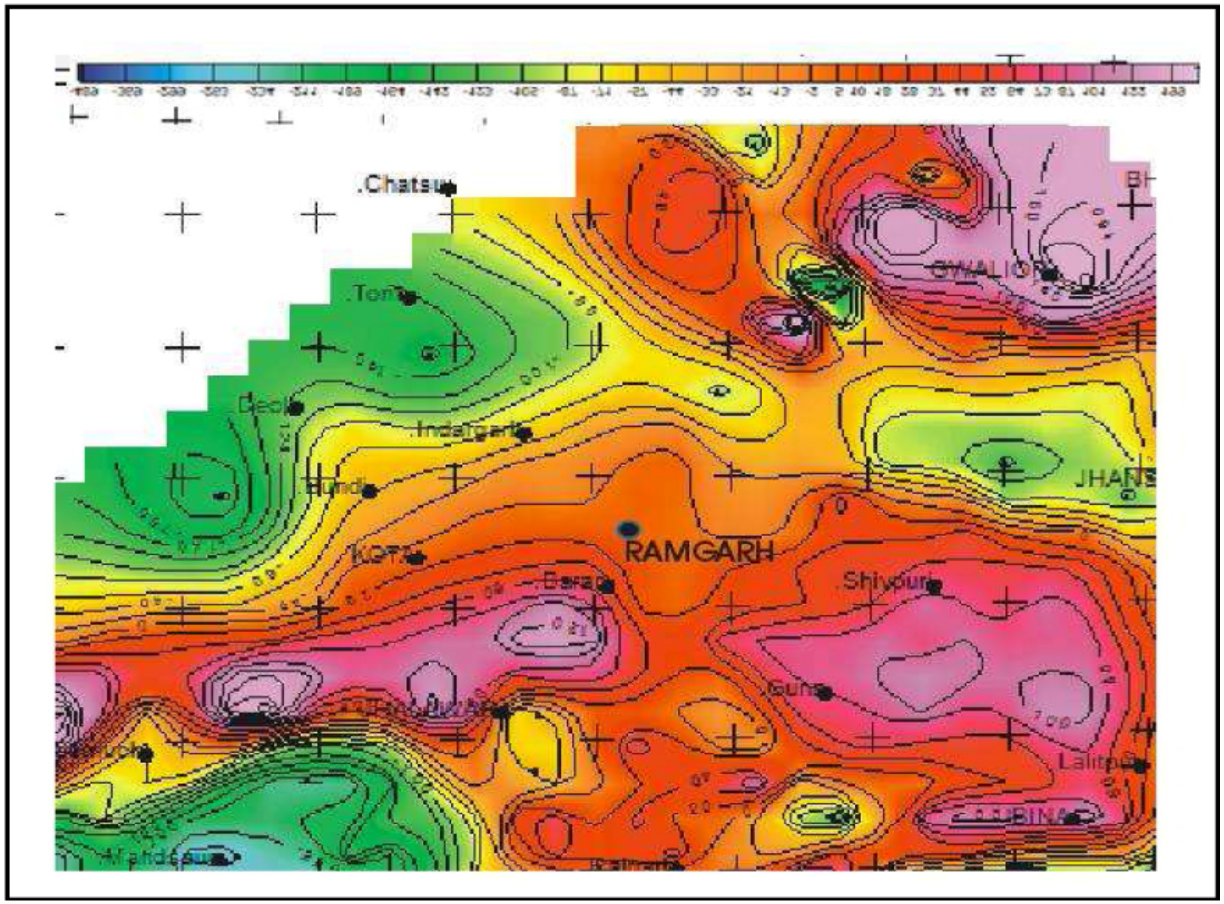

Figure 4. Aeromagnetic map of Chambal Valley, Vindhyan Basin.

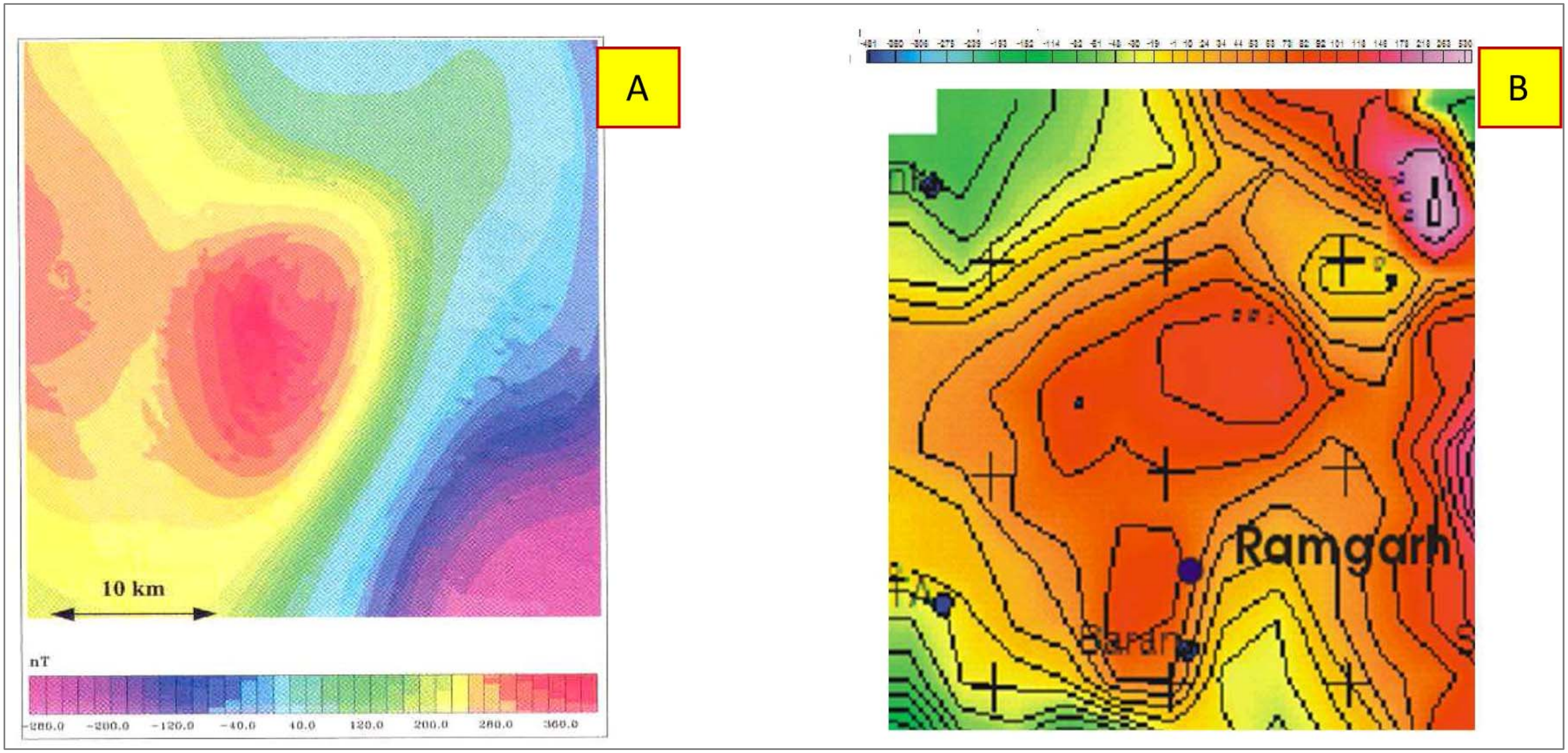

Figure 5. RTP map of Jackpine (A) and Ramgarh (B).

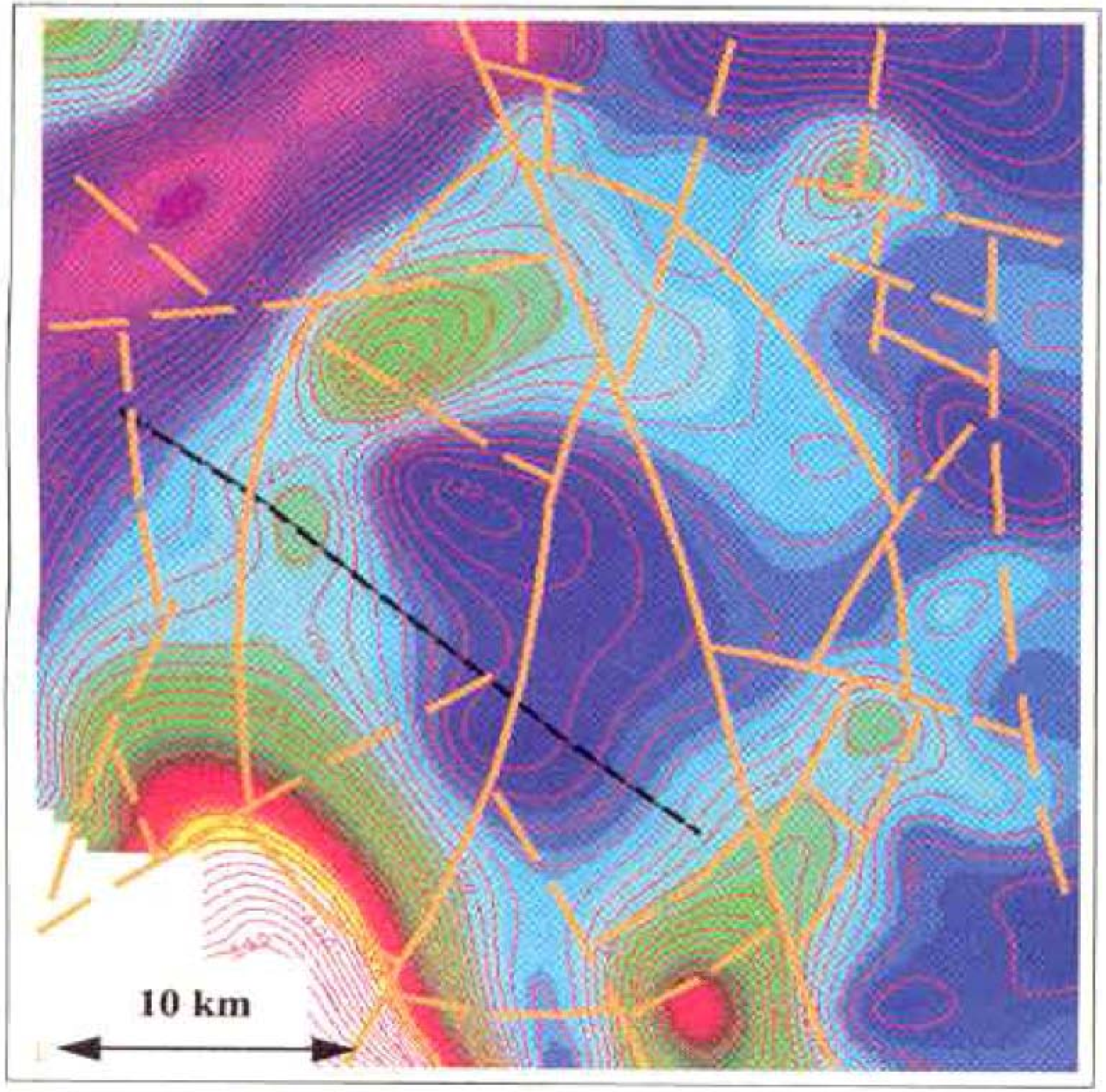

Figure 6. Jackpine fault pattern.

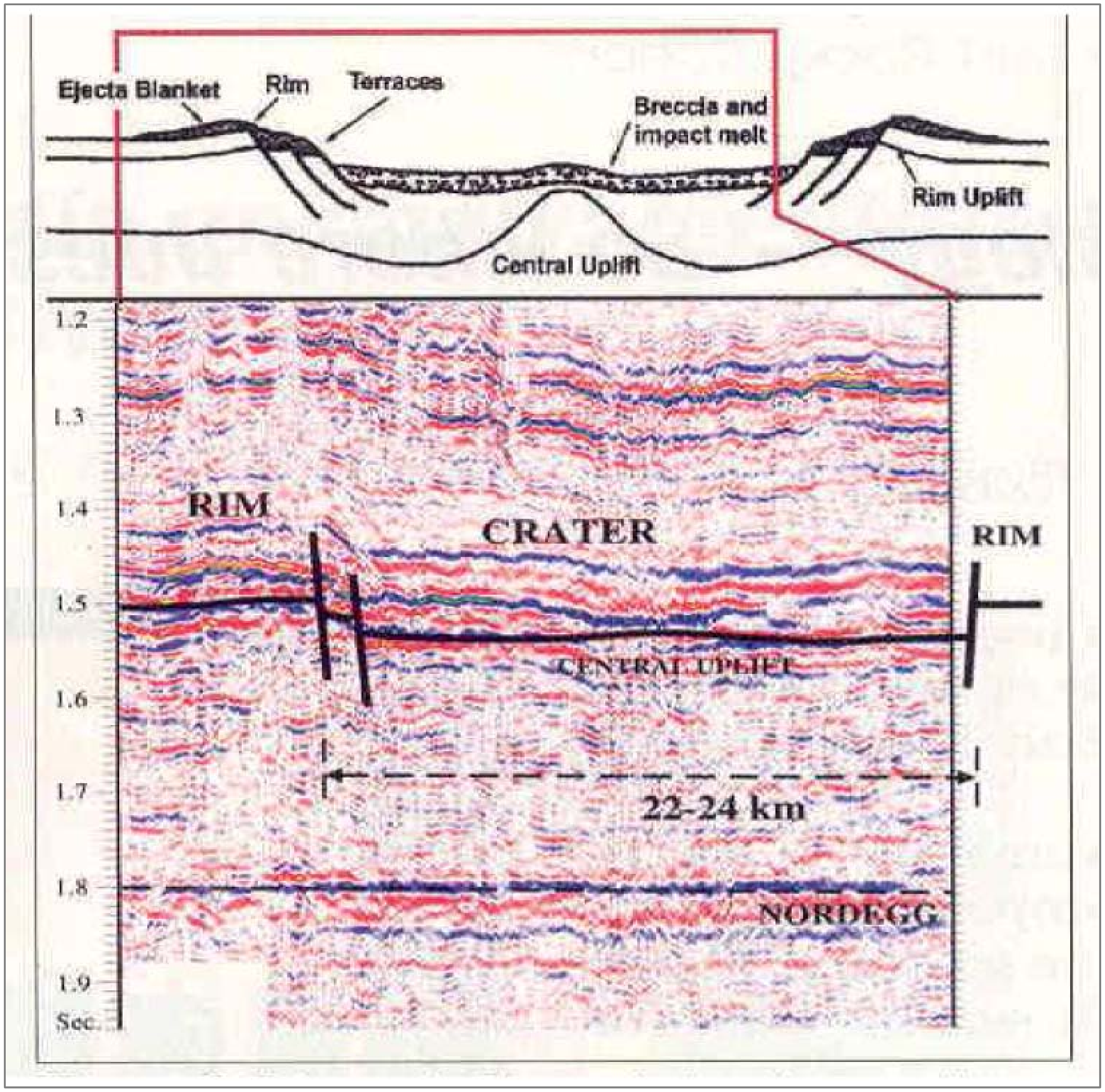

Figure 7. Interpreted impact structure on the flattened seismic section with a generalized image of the complex impact crater. The seismic lime does not extend as far as the right-hand rim of the structure.

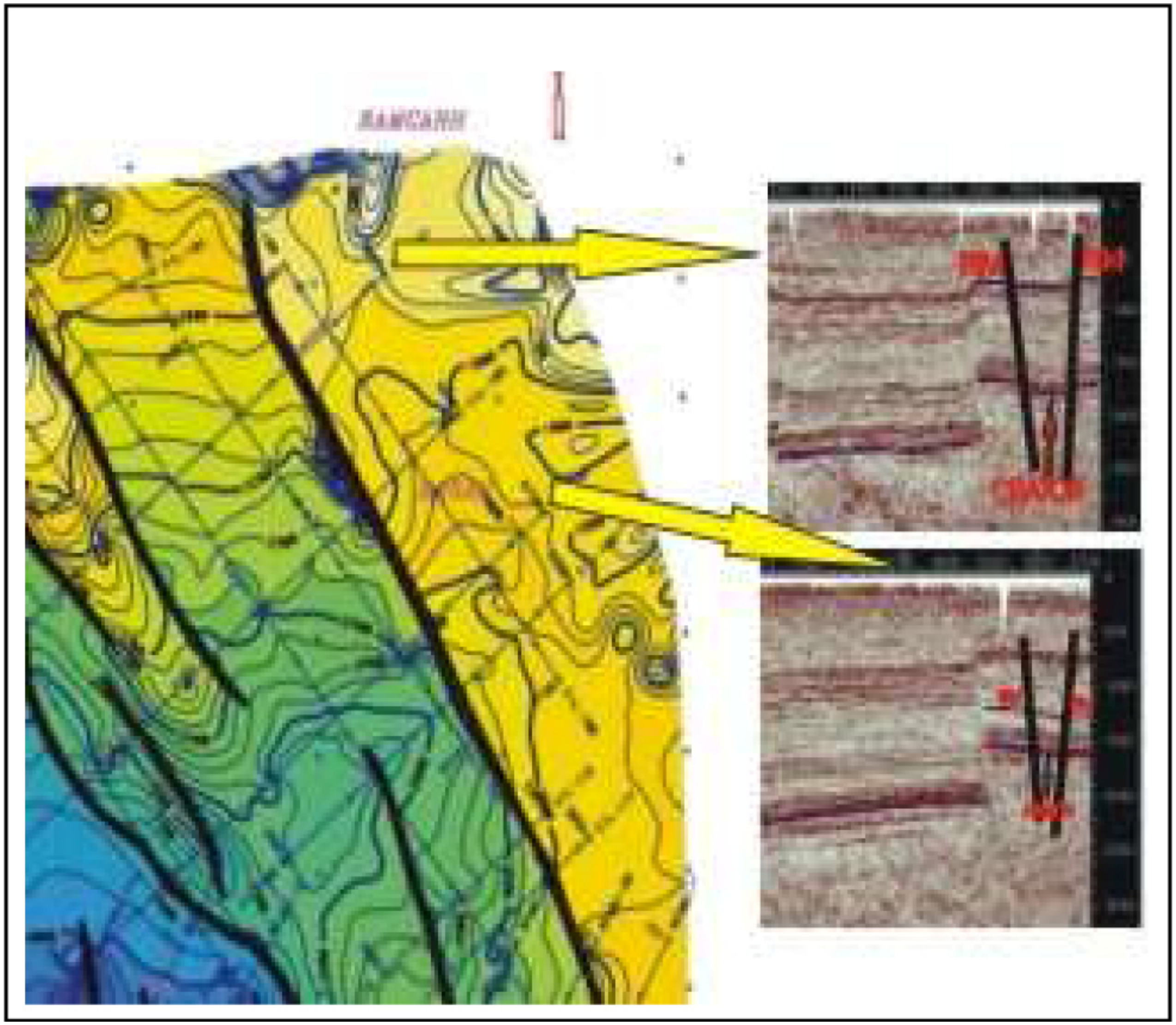

Figure 8. Isochron map near the base of Upper Vindhyans in Chambal valley showing the subsurface configuration of Ramgarh dome structure in the two proximal seismic sections.