Delineation of basement configuration of Chambal and Son valleys in Vindhyan Basin

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Abstract

Deccan trap covered Chambal valley and Son valley areas of Vindhyan basin remains as least explored area. Availability of geophysical data is limited in the area except few sparse gravity data and aeromagnetic data. Though reports of gas seepage are there in the trap covered area no aggressive exploration work has been carried out in this part.

Gravity modeling carried out integrating with other avialble G&G data shows the basement in Chambal valley is dipping on either side of Singoli-Rajgarh ridge and may have sediment thickness of ~3km. Upto 3 km sediments may be expected at the gravity low near Ujjain. The Son valley is found to be dipping towards south and more than 5 km sediment are expected in this valley in the area adjacent to north Narmada-Son fault.

The study has brought out a basement high ridge connecting the western part of Bundelkhand with granite expose area of western Hosangabad.

Introduction

Vindhyan Basin, in the central part of India occupies an area of about 1,62,000 sq.km. of which about 80,000 sq.km. km is under thick Deccan trap. It contains more than 5000 m thick sequence of sandstones, shales and limestones and extends into the Ganga valley in the north and northeast beneath the tertiary sediments of the Himalayan foredeep,

The Basin is bounded in the northwest by the Delhi-Aravalli orogenic belt (the Great Boundary Fault) and in the southeast by the Narmada-Son lineament. To the south it is bounded by the Narmada-Son Geofracture in the south, the Monghyr-Saharsa Ridge in the east and the Bundelkhand Massif and Indo-Gangetic Plains in the north.

It is believed that the Bundelkhand Massif divides this basin into two parts – the Son Valley in the eastern and south-eastern side and the Chambal Valley where exposures occur from Agra (Uttar Pradesh) to Chittorgarh (Rajasthan) in western and north western side.

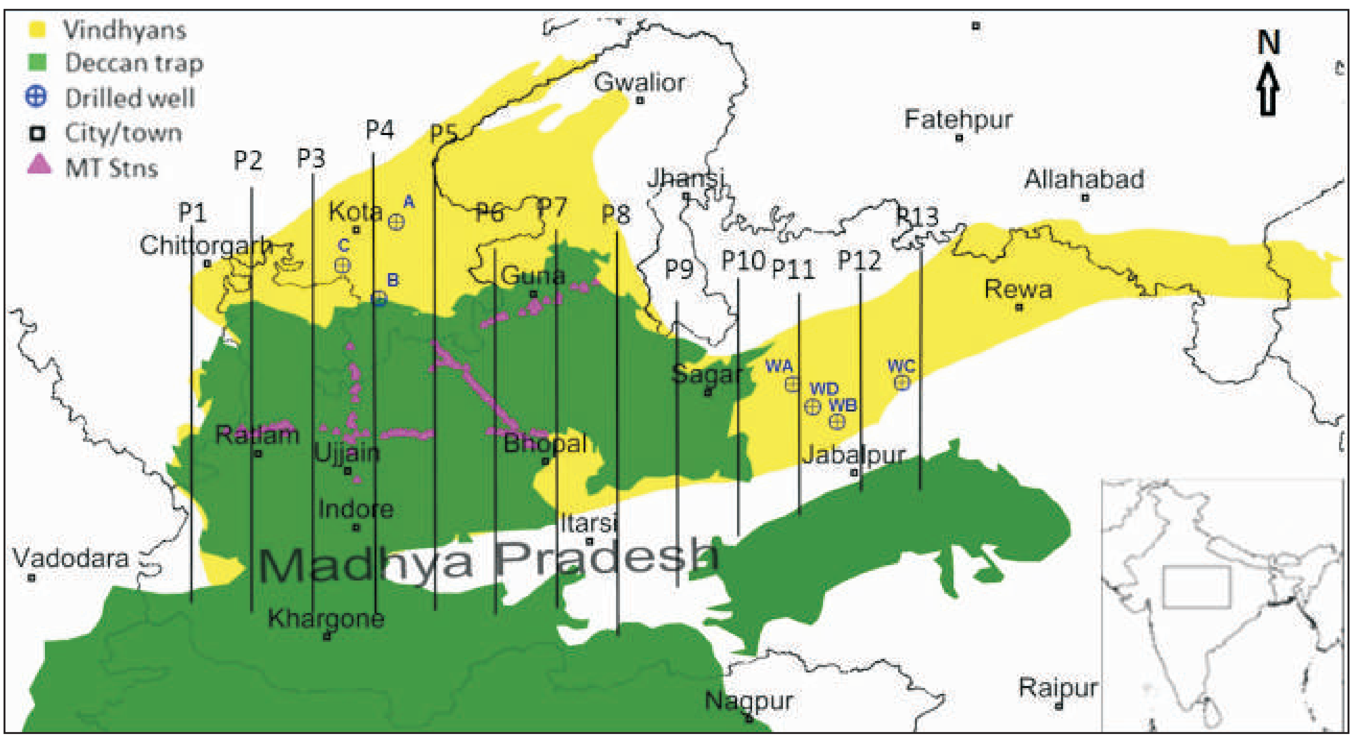

Fig. 1: Location map of study area.

The study area, the Deccan traps covered part of Vindhyan basin remains as most neglected area from hydrocarbon exploration point of view. Even the potential field data coverage in this area is very sparse. Bouguer gravity anomaly contour map of interval 5 milligals prepared and published by NGRI after merging GSI data has been widely used and referred by many earlier workers. Aeromagnetic data acquired in two campaigns at a flight height of 5000ft and 6800ft are also available to supplement the integrated study.

Abundant studies were carried out by academic and government institutions such as NGRI, IIG etc. in the southern part of the study area across Narmada–Son lineament. In the boundary of the trap covered area published report of five Deep Seismic Sounding (DSS) profiles – 1. Hirapur-Mandala, 2. Khajuriakalan-Pulgaon, 3. Ujjain-Mahan, 4. Thuadara-Sindad, and 5. Nagaur-Kunjer are available for augumenting the integrated studies. Also few Magneto Telluric (MT) profiles over Bundelkhand and across the CITZ are available for reference and constraining the gravity modeling.

In Son valley, the eastern part of the study area, where Vindhyans are exposed has been explored by ONGC, few wells have been drilled on the basis of outcome of seismic campaigns in which presence of hydrocarbon is indicated in Rohtas limestone formations. Of late similar efforts were put in Vindhyan exposed areas of Chambal valley also. Three wells A, B and C have been drilled based on seismic data acquired under NELP regime. The well C shows gas bearing column from a depth of 514 m to 1405 m. But the trap covered areas of Chambal valley remains unexplored even though gas seepage is reported.

For few years ONGC has carried out MT survey along four profiles in trap covered areas of Chambal valley. More than 150 MT stations were acquired in this area. Along with MT data, gravity and magnetic data was also acquired in Banswara-Sanchi, Kota-Indore, Bhopal-Jhalawar and Biora-Guna profiles. Being sparse the gravity data is suitable for carrying out regional studies only.

Gravity data

Vintage ONGC gravity data and data acquired in NELP and PML block in western, eastern and southern part of the basin is merged with published NGRI gravity data and World Gravity Data 2012. A gravity anomaly map is prepared by using these data, shown in fig.2 is used for integrated study.

A prominent gravity low, up to -180 milligals, in the north eastern corner is seen. It may be due to lower density Ganga basin sediment together with root effect of the Himalayas. Delhi-Aravali trend, in the north-west and western part, shows a NNE-SSW elongated gravity high of up to 8 milligals which has a steep gravity low on either side of this feature. The Great Boundary Fault (GBF) has no significant gravity signature. This may be due to the density of Vindhyan sediment is comparable with the basement/sediments in the up-thrown side in the north western part of the fault.

The Bundelkhand massif has a gravity signature characterized by an east-west elongated low of up to –70 milligals. It is surrounded by three gravity high trends in the north, south and as well as in the west. The gravity high in the

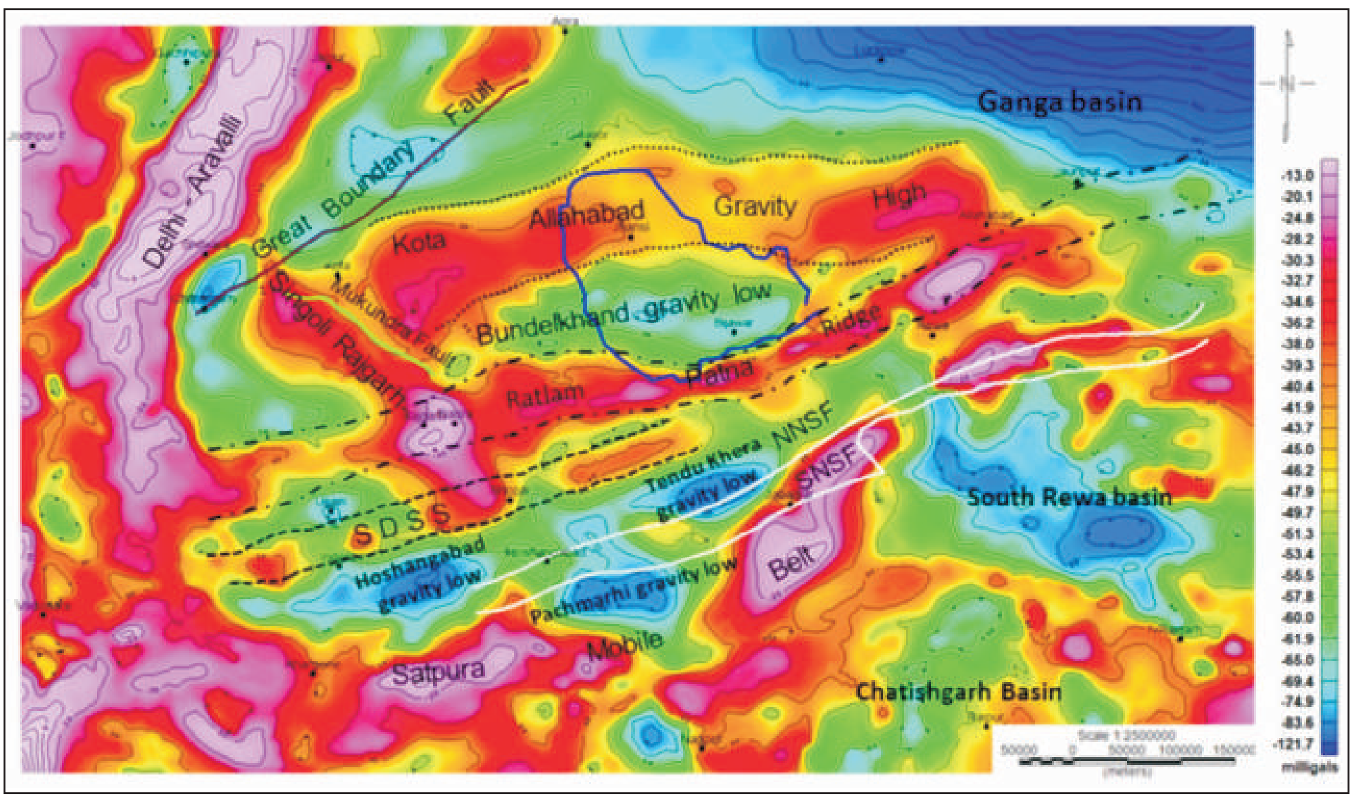

Fig. 2: Bouguer gravity anomaly map. Blue continuous line marks Bundelkhand outcrop. Dark brown line shows the location of GBF and white lines show the NNSF and SNSF

north extends from west of Kota to Allahabad where it meets with southern boundary gravity high feature Ratlam-Patna (RP). To little south of RP another gravity high feature is east-west direction which is almost parallel to RP, Sardpur-Dewas-Sehore-Sagar (SDSS) ridge which seems to terminate at the edge of Son valley. These ridge like gravity features are intercepted by another gravity high feature Singoli-Rajgarh (SR) ridge as western boundary of Bundelkhand massif. The Mukandra fault can be traceable upto north of Rajgarh beyond which it is not clear.

To the south of South Narmada-Son fault (SNSF), where gravity highs are prominent between the rivers Narmada and Tapti is associated with Satpura Mountains. It is characterized by chain of gravity high trending east west till south middle part from where it turns towards northeast. Jabalpur gravity high, which has a maximum of -8 milligals, remain as the western boundary of gravity low of South Rewa basin, is also part of this chain. These gravity highs are due to a thick mafic body at the base of crust and presence of high density Mahakausals.

A gravity low of -86 milligals is seen over the Satpura basin known as Pachmarhi gravity low, it may be due to low density Gondwana sediments. A prominent gravity low of upto -98 milligals signifies the south Rewa basin.

MT data

Unlike trap covered area of India, such as trap covered Saurashtra where resistive basalt layer at the top followed by low resistive Mesozoic sediments sitting on highly resistive basement, in Vindhyan basin the vertical resistivity profile is in increasing order only. Topmost layer basalt which is 80-100 ohm-m is followed by the Vindhyans 120-400 ohm-m and basement of 1000 ohm-m makes it most difficult for imaging electrically.

Moreover, the MT data acquired in this area is contaminated by electric 50Hz and its harmonics. Figure 3 shows the amplitude spectrum of all the five channels recorded in the study area of LF1 band.

Pseudo-section of MT data along Bhopal-Jhalawar profile (fig.4) shows a high resistivity layer at the top followed by low resistivity layer overlying a highly resistive basement. Both TE and TM show a low resistivity intrusion in the crust at lower frequencies in the middle part of the profile. The same is also seen in the phase section with a higher phase in this corresponding part. A fault is suggested within the crust in this area.

Figure 5 shows the 2D inversion resistivity section of this profile. Though 1D inversion suggest basalt thickness in this profile vary between almost nil to 350m, because of large MT station spacing (~5km) 2D-inversion could not reconstruct the shallow features. Depth to basement is varying between 600 m to more than 5000 m along this profile shallowest near Rajgarh and deepest near Narsingarh, where Vindhyans are exposed. It shows a low resistivity intrusion in the crust near Biora.

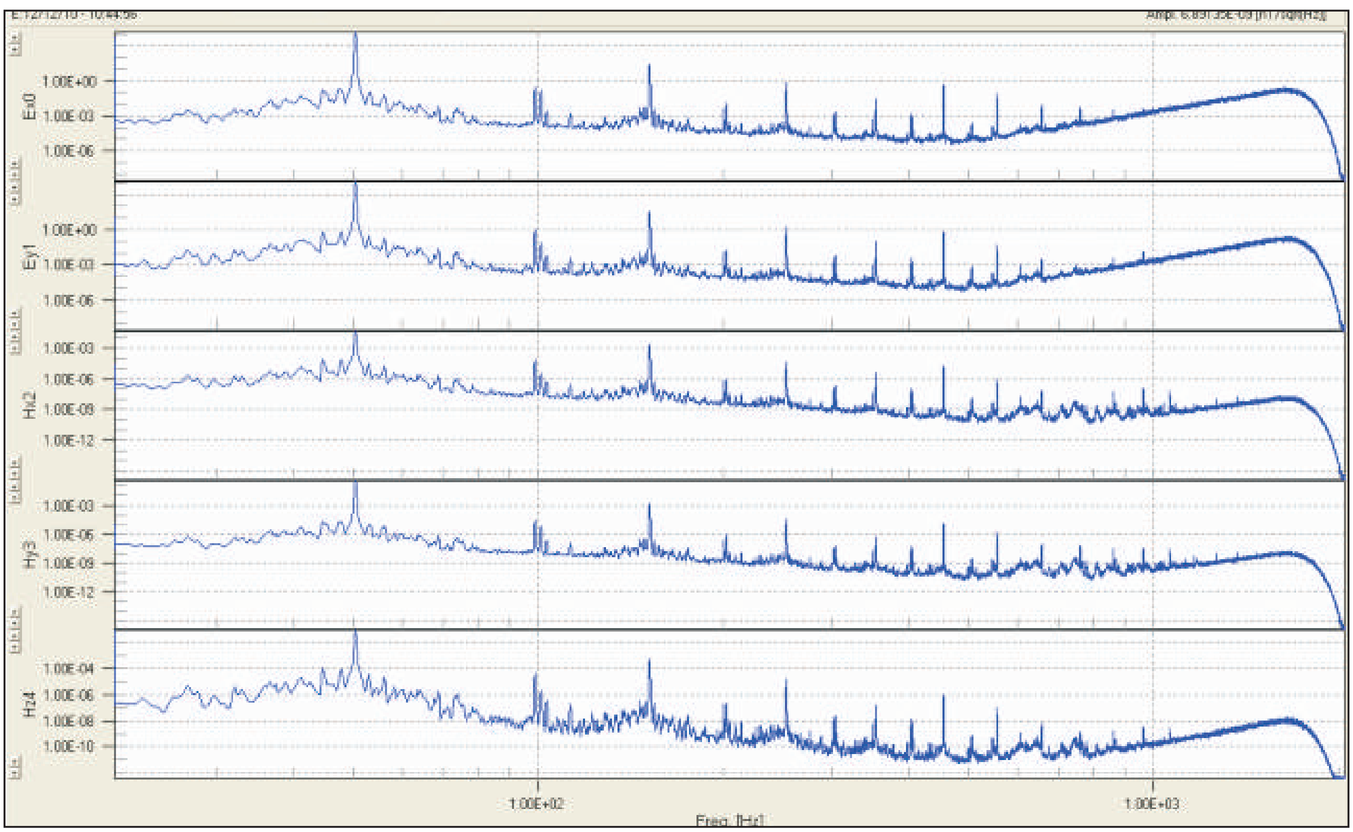

Fig. 3: Frequency vs amplitude spectrum showing 50 Hz and its harmonics.

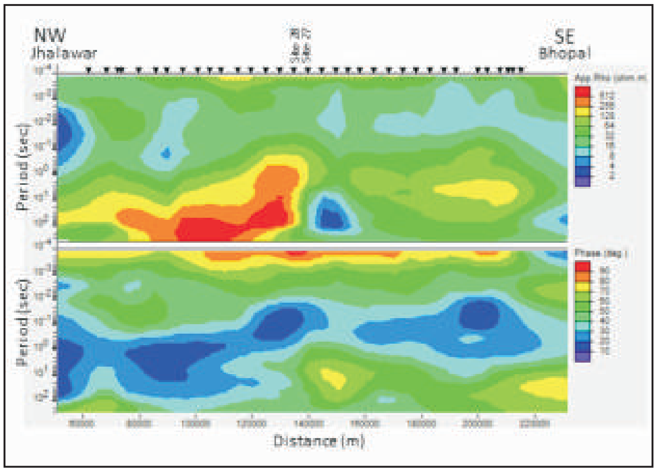

Fig. 4: Resistivity pseudo section (TE above; TM below) along Bhopal-Jhalawar profile.

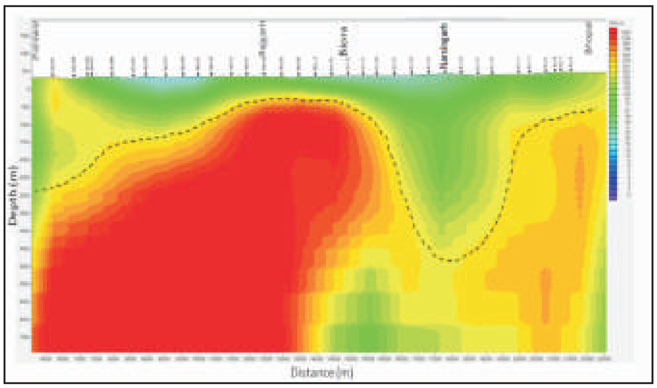

Fig. 5: 2D inversion resistivity section dash line shows the inferred basement top.

Integrated study

Initially integrated gravity modeling was carried out in regional scale by constraining shallow information from available seismic, well and MT data along Banswara-Sanchi, Kota-Indore, Bhopal-Jhalawar and along a seismic profile in Son valley (fig. 6). Deeper information such as moho depths are constraint from DSS data. A uniform density of 2.6 gm/cc for Vindhyan sediments, 2.4 gm/cc for Gondwana sediment and 2.2 gm/cc for recent sediments are taken. The basaltic trap is modeled with a density of 2.75 gm/cc while the mantle is of 3.0 gm/cc. The intrusive are only for producing the amplitude and its extent not caring its exact shape and density. Seismic data falling along the profile Hirapur-Mandala is also used for constraining the horizons.

Apart from above constraints, depth computed from gravity and aeromagnetic data by deploying Spectral and Euler methods are used in predicting the possible basement depth. Also Euler depth computed in different window suggests the causative of SR ridge is shallow while that of RP & SDSS ridge is having deeper roots.

Gravity modeling along these profiles (fig.8) shows thicker Vindhyan sediments in southern part of profile P7 to P13. The Vindhyan sediment thickness may be expected more than 5 km in profile P10 and P11 area. Less sediment may be expected in the middle part of the P5 and P6 and very less sediment at the western most profile P1.

Using these thirteen profile along with the initial four profiles a basement contour map is prepared and shown in figure 9.

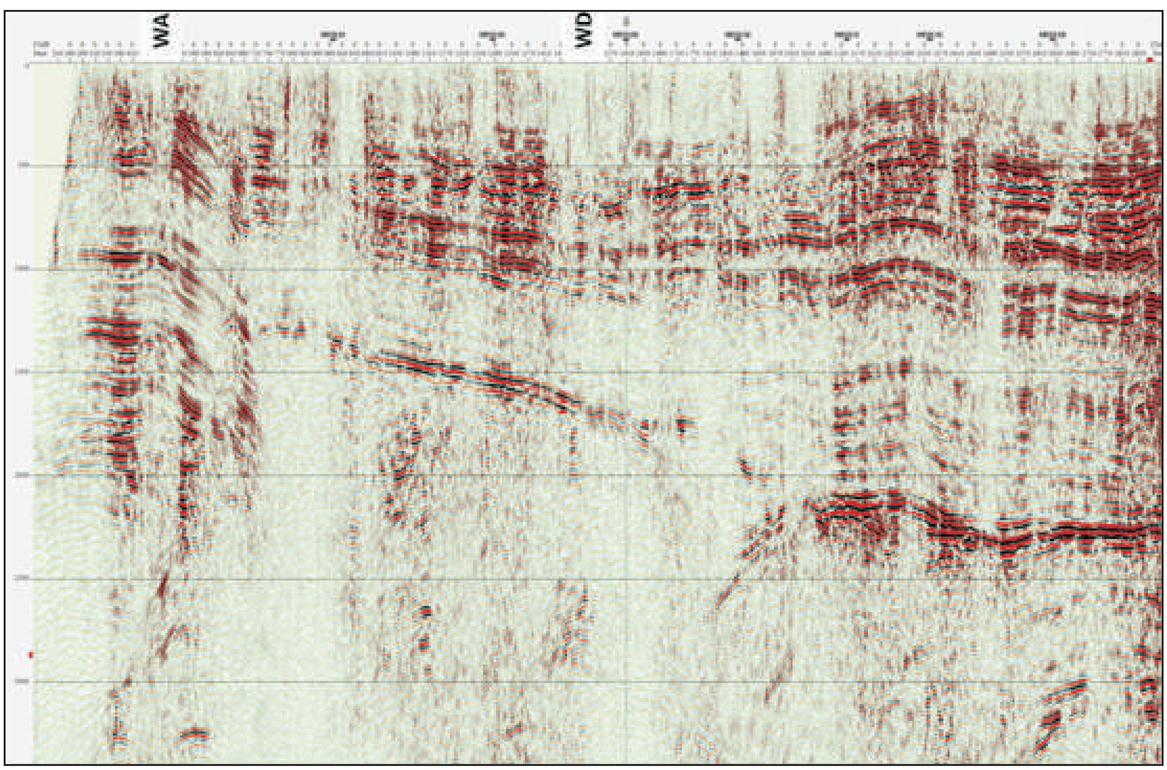

Fig. 6: Seismic section falling along a profile

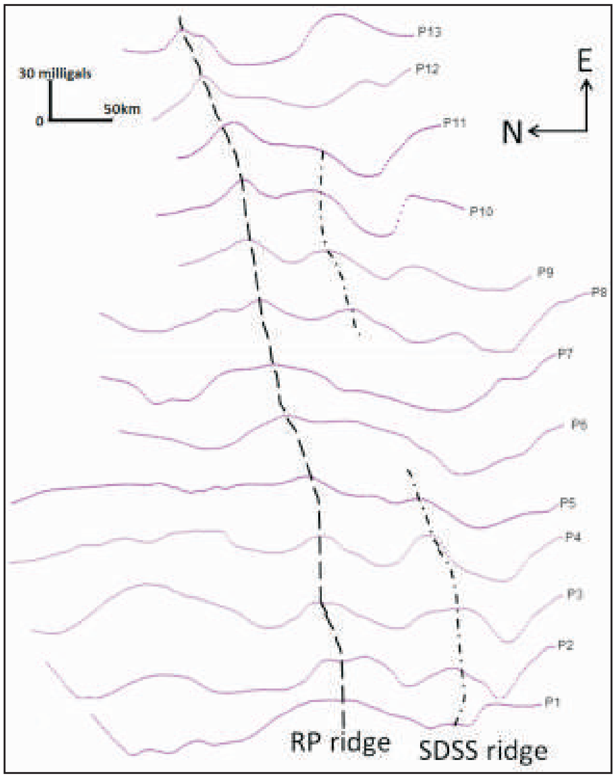

Fig: 7. Gravity data along the 13 selected profiles. The dashed lines show the axis of gravity high ridges. Further the information obtained from these four profiles are used for gravity modeling along 13 more profiles (fig. 7). These profiles are selected in north south direction from western boundary of trap covered area to the west of Rewa, spanning across the Chambal valley and Son valley, at an interval of ~50 km.

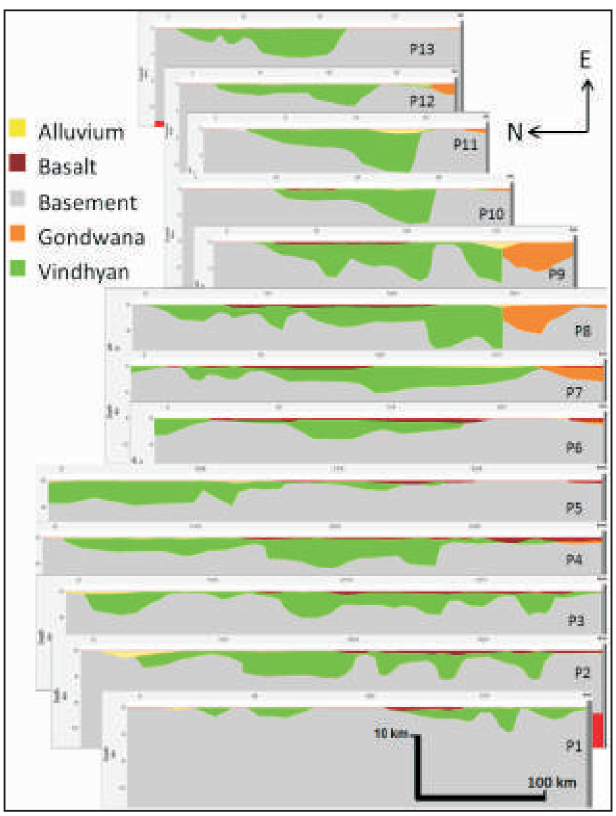

Fig. 8: Gravity modeling along the thirteen profiles.

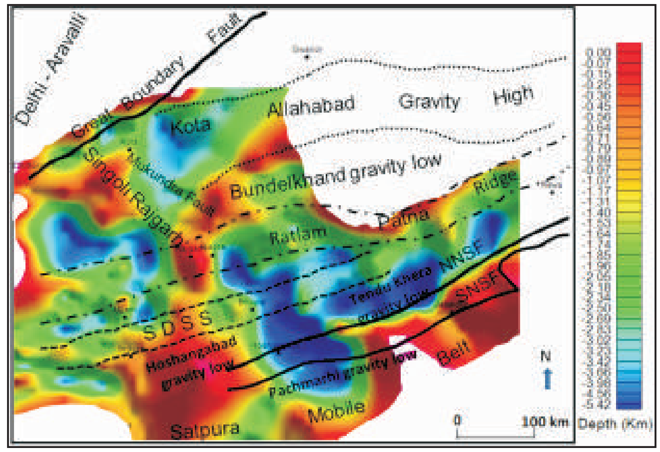

Fig. 9. Basement top contour map prepared from findings of integrated study.

The map shows that the gravity low south of SR ridge may have sediment thickness of ~3km. Upto 3km sediment may be expected at the gravity low near Ujjain. Maximum Vindhyan sediments are expected at places Tendukhera gravity low (fig.2) and South East of Bhopal where basement depressions are prominent. This basement depression is also extending towards north of Bhopal showing possibility of thick sediment ~5 km in this area.

In general Son valley is dipping towards south while the Chambal valley has basement dipping in either side of SR ridge. The eastern and north eastern part of Kota shows a basement depth upto ~3 km.

This map also shows that a ridge like basement high connecting western part of Bundelkhand (exposed) with granitic expose area of western Hosangabad passing through Rajgarh.

Conclusions

Basement map shows a number of depressions in the trap covered areas of Chambal and Son valleys of Vindhyan basin. The Western and Central part of this basin may have sediments 2-5km thick which will be good target for hydrocarbon exploration.

A ridge like basement high connecting western part of Bundelkhand with granitic expose area of western Hosangabad, passing through Rajgarh has been brought out in the basement map. This ridge (basement high) may separates Vindhyan basin into Chambal valley and Son Valley and may not by Bundelkhand craton as believed earlier.

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