Some major tectonic elements of western Ganga basin based on analysis of Bouguer anomaly map

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The Bouguer anomaly map of Ganga basin is largely characterized by NE-SW trending regional gradient with a few superimposed short-wavelength anomalies. The spectral analysis of Bouguer anomaly provides five linear segments approximately at depths of 37.0, 23.5, 14.5, 6.6 and 3.6 km. The first segment corresponds to the average depth of the Moho and the second and the third segments are crustal layers, which are confirmed from seismic studies just south of this region across Aravalli. The shallow segments represent the basement providing its depth in the deeper and the shallow sections. The Moho and the crustal layers under Ganga basin are deeper by 6–7 km compared to those under Vindhyan basin just south of this area, which may be due to the lithospheric flexure caused by Himalayas.

The residual Bouguer anomaly obtained from subtracting second order surface from the observed field appears to be more effective in defining the shallow basement tectonics compared to High Pass filtered maps. The residual field indicates a large uplift of basement east of Delhi which might be a part of Aravalli changing trend from NE-SW under Ganga basin. This uplift is the centre of the several basement ridges of this region from where they emanate as Delhi–Moradabad ridge, Delhi–Hardwar ridge and a NW-SE ridge which may be synonymous to Delhi–Lahore ridge and its extension southwards. The Great Boundary fault (NE-SW) which separates the Vindhyan rocks from the Aravalli basement rocks appears to be extending as Agra–Shahjahanpur basement ridge which changes its trend from NE-SW to E-W under Ganga basin, suggesting the extension of Vindhyan rocks towards north up to this ridge. The changes in structural trends from NE-SW to E-W under Ganga basin may be attributed to the collision of Indian and Eurasian plates. The intersection of these structural trends around Delhi makes it vulnerable to seismic activities.

THE Ganga basin is one of the largest basins formed due to the collision of the two plates, namely the Indian and the Eurasian plates. Towards north, it extends up to the Main Boundary Thrust (MBT) along which the Indian plate has subducted below the Eurasian plate. It thus forms the foredeep before the subducting plate analogous to the trenches formed along the present-day island arc settings. This explains the thick pile of sediments along the foothills of Himalayas and signifies a very important aspect of plate tectonics in this region. The sediments are largely derived from rising Himalayas resulting from the continent–continent collision and are, therefore, characterized by continental sedimentation of fluvial environment. Due to its hydrocarbon potentiality, several geophysical surveys were carried out and deep borewells were drilled which have provided a wealth of information about the subsurface structures up to the basement[1–3]. It is an east-west oriented basin along the Himalayan foothills which is divided into several sub-basins by ridges and faults. Due to vastness of this basin, we have confined to the western part which includes the exposed Aravalli basement up to south of Delhi and rest is covered by alluvium[4].

Bouguer anomaly map

The Bouguer anomaly map of western Ganga basin[4] shows a NW-SE trending regional anomaly trend varying in amplitudes from –50 to –300 mgal along with short wavelength anomaly closure around Delhi and south of Delhi. This gradient is attributed to the thickening of the crust under Himalayas[5,6]. A part of this map available with us on a 1 : 250,000 scale at 5 mgal contour interval is digitized for computer-based processing and reproduced in Figure 1. Superimposed over the large gradients (Figure 1), there are a few kinks in the contours emanating around Delhi and spreading towards the Himalayas. Another important anomaly is the 'high' around Agra of approximately 30 mgal, located over alluvium and patches of Vindhyan sediment indicating a shallow basement. This 'high' extends towards Nepal Himalayas passing through Shahjahanpur in the form of 'kinks' in the Bouguer anomaly contour. It is likely that the actual nature of this anomaly over Ganga basin might be obscured due to a large gradient referred to above and is reflected only as the kinks in the contours.

There are several other linear 'kinks' in the Bouguer anomaly contours embedded in the large gradient referred to above which may represent some tectonic features. It is, therefore, essential to filter out the regional gradient observed in Bouguer anomaly originating from the deep-seated sources. As the observed Bouguer anomaly is the cumulative effect of sources at different levels, the first task is to find the depths to the various levels from which the signals are originating and secondly the signals from deep-seated sources should be separated or suppressed in order to enhance the effect of the shallow sources[7]. Both these objectives are achieved by the spectral analysis[8] of the digital data set obtained from this map. The field from deep-seated sources is characterized by the low-frequency band or large wavelengths, while the shallow sources are represented by high-frequency bands or smaller wavelengths referred to as the residual field[9,10]. The other approach for the separation of potential field signals from deep-seated sources and shallow sources, namely the regional and residual fields is the Trend Surface Analysis[11] using polynomial approximation. Both these methods are applied on the present data set as described below.

Crustal structure

The Bouguer anomaly data used for the preparation of Figure 1 is transformed in frequency domain. Its normalized radially averaged log power spectrum versus frequency plot (Figure 2) show five linear segments corresponding to the slopes given in the inset of the diagram. The slopes of the linear segments represent depths to the respective layers[10]. The deepest layer at 37 km is the average depth of the Moho in this section[12]. The second and third segments at a depth of 23.5 km and 14.5 km represent interfaces in the lower and upper crust. The spectral analysis of the Bouguer anomaly map of Aravalli region has provided an average depth of 32 km for Moho and 15.5 and 9 km for crustal layers which are in conformity with the seismic results in the Vindhyan basin adjoining Aravallies[13,14]. It is significant to note that these layers are consistently 6–7 km deeper under Ganga basin which might be due to the lithospheric

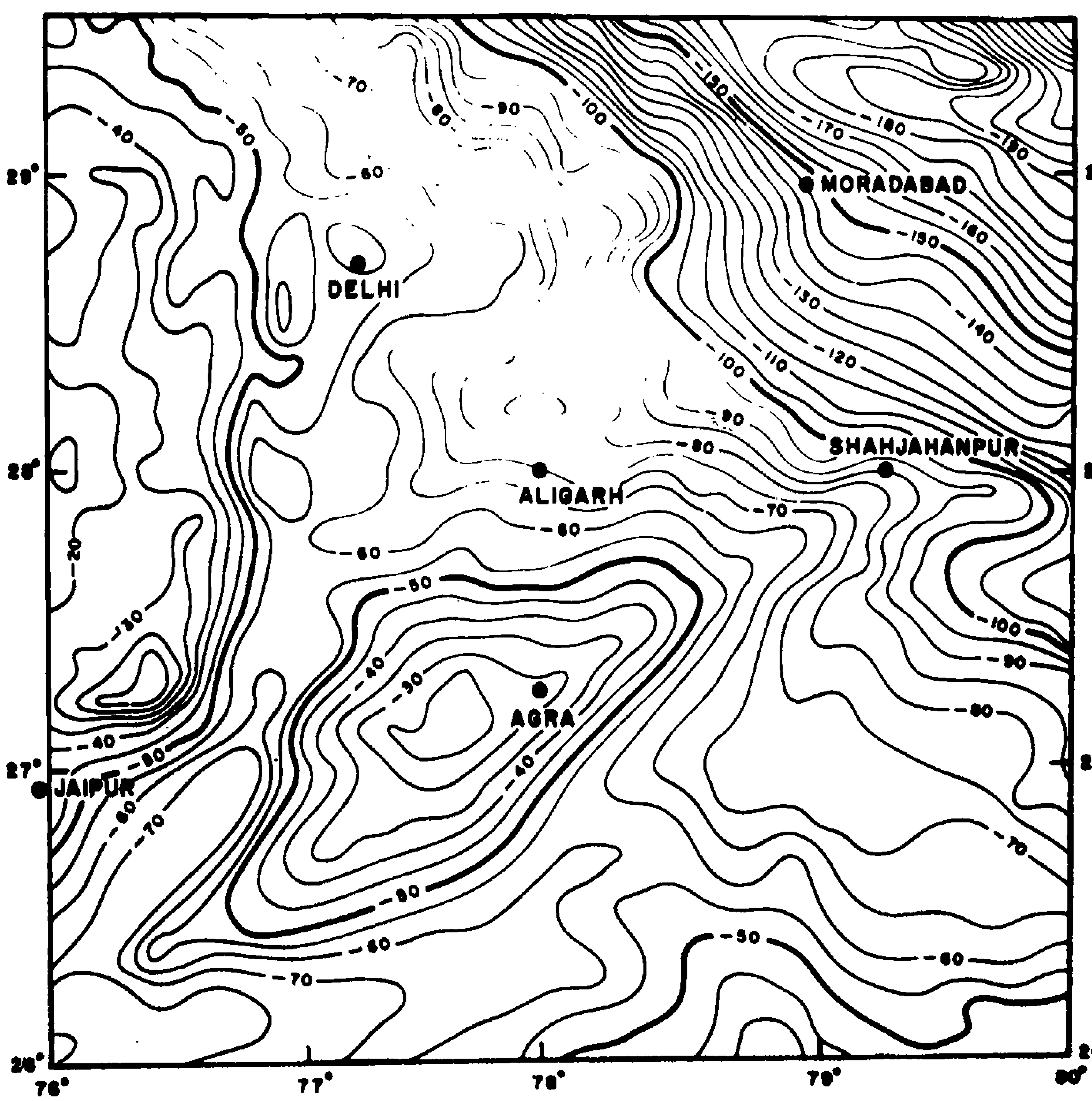

Figure 1. Bouguer anomaly map of western part of Ganga basin.

flexure caused by the regional isostacy under Himalayas. This indicates the existence of a similar kind of crust below the sediments under Ganga basin as in the peninsular shield which is also found from the seismic wave velocities[15,16]. The other two segments at 6.6 and 3.6 km may represent depth to the basement in different sections.

Basement tectonics

Residual field using waveband filters

The spectrum of the observed Bouguer anomaly of this part of the Ganga basin (Figure 2) suggests that the causative sources are distributed at four levels namely Moho, lower and upper crust and the basement. It is, therefore, possible to ascribe the frequency bands corresponding to these sources and separate out the observed field into different components. High pass filters with different wavelengths were tried and the residual field presented in Figure 3 represents the field for a frequency two and above corresponding to a wavelength of approximately 250 km and less. This may show the basement tectonics more clearly than the observed Bouguer anomaly (Figure 1). The various ridges and faults are better reflected in this map as compared to those in Figure 1 where they are obscured by large regional gradient. The different tectonic elements are ascribed in the filtered map (Figure 3) which appears to be emanating from the junction of the Aravalli with the Indo-Gangetic plains.

Residual fields based on trend surface analysis

Trend surfaces of different orders ranging from one to five were computed from the digital data set of Bouguer anomaly of this region. The residual field (Figure 4) obtained by subtracting 2nd order surface from the observed field presents the shallow features namely, the basement tectonics, which are almost similar to those described in Figure 3 obtained from wave band filters. However, the definition of anomalies in terms of positive and negative components is much better defined in Figure 4. The most important feature of this map is the extension of Aravalli basement towards Himalayas in the form of Delhi–Hardwar ridge and a block uplift east of Delhi. This uplift continues further eastwards in the form of Delhi–Moradabad ridge. Large magnetic

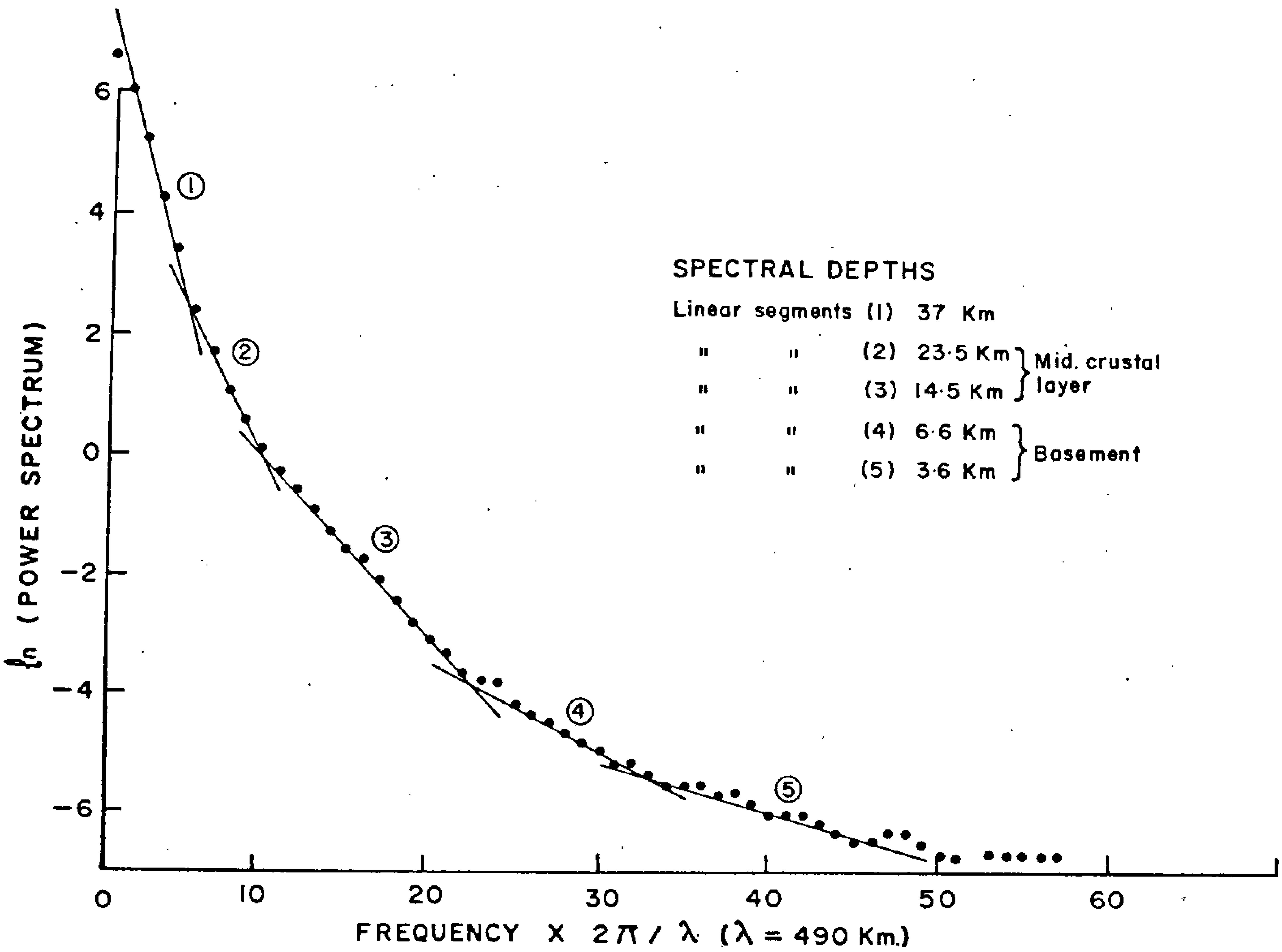

Figure 2. Normalized radially averaged power spectrum versus frequency plot of digitized Bouguer anomaly map of Ganga basin. It shows five linear segments corresponding to depths given in the figure. They can be attributed to moho, mid-crustal layer and the basement.

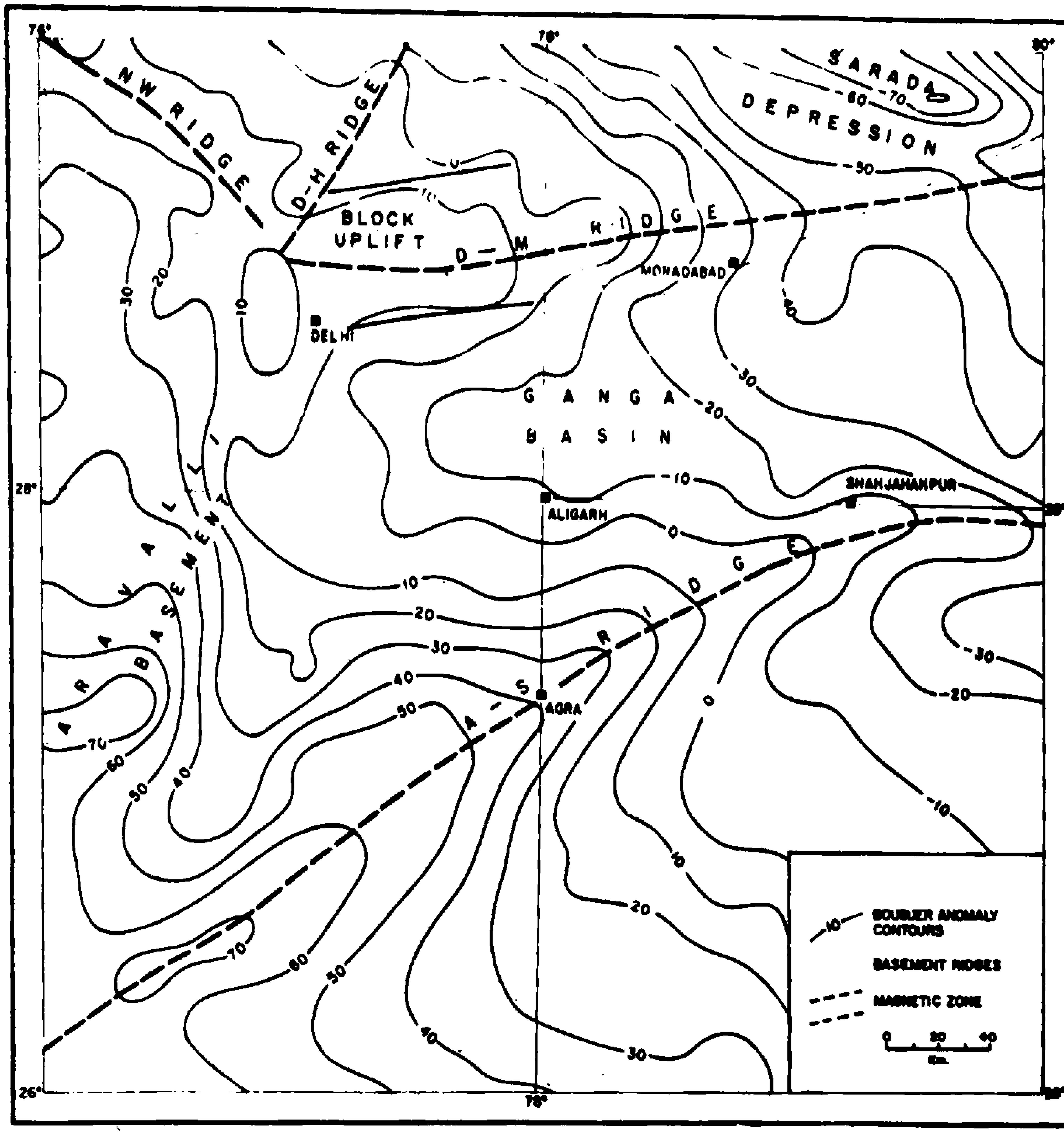

Figure 3. Filtered Bouguer anomaly map with wavelength 250 km and less. Important tectonic elements are: Agra–Shahjahanpur (A–S) ridge; Delhi–Moradabad (D–M) ridge; Delhi–Hardwar (D–H) ridge and sub-basins formed by them.

anomalies[17,18] corresponding to the uplifted block and these ridges suggest that they might be associated with basic intrusives. Two more ridges NW and SE emanating from the uplifted block are plotted in Figure 4, which might be synonymous to Delhi–Lahore ridge and its extension southwards. The Agra–Shahjahanpur ridge which is the northward extension of great boundary fault separating Vindhyan basin from Aravalli ranges changes its trend from NE-SW to E-W under the Ganga basin, suggesting the extension of Vindhyan sediments up to this ridge.

Conclusion

This study highlights the usefulness of separation of observed Bouguer anomalies in delineating basement structures embedded in large signal from deep-seated sources. The processing of Bouguer anomaly map of western Ganga basin has delineated several prominent basement ridges and suggests a deeper Moho at a depth of 37 km, indicating the crustal flexure before the subduction of the Indian plate under Himalayas. The residual Bouguer anomaly suggests an uplifted basement block east of Delhi which might be related to some basic intrusions as suggested by magnetic anomalies[17,18]. Several basement ridges such as Delhi–Hardwar, Delhi–Moradabad, NW and SE ridges emanate from this uplifted block and therefore might be related to it. The Agra–Shahjahanpur ridge which is the northward extension of the great boundary fault separating Vindhyan basin from the Aravalli ranges changes its trend from NE-SW in the peninsular shield to E-W under the Ganga basin.

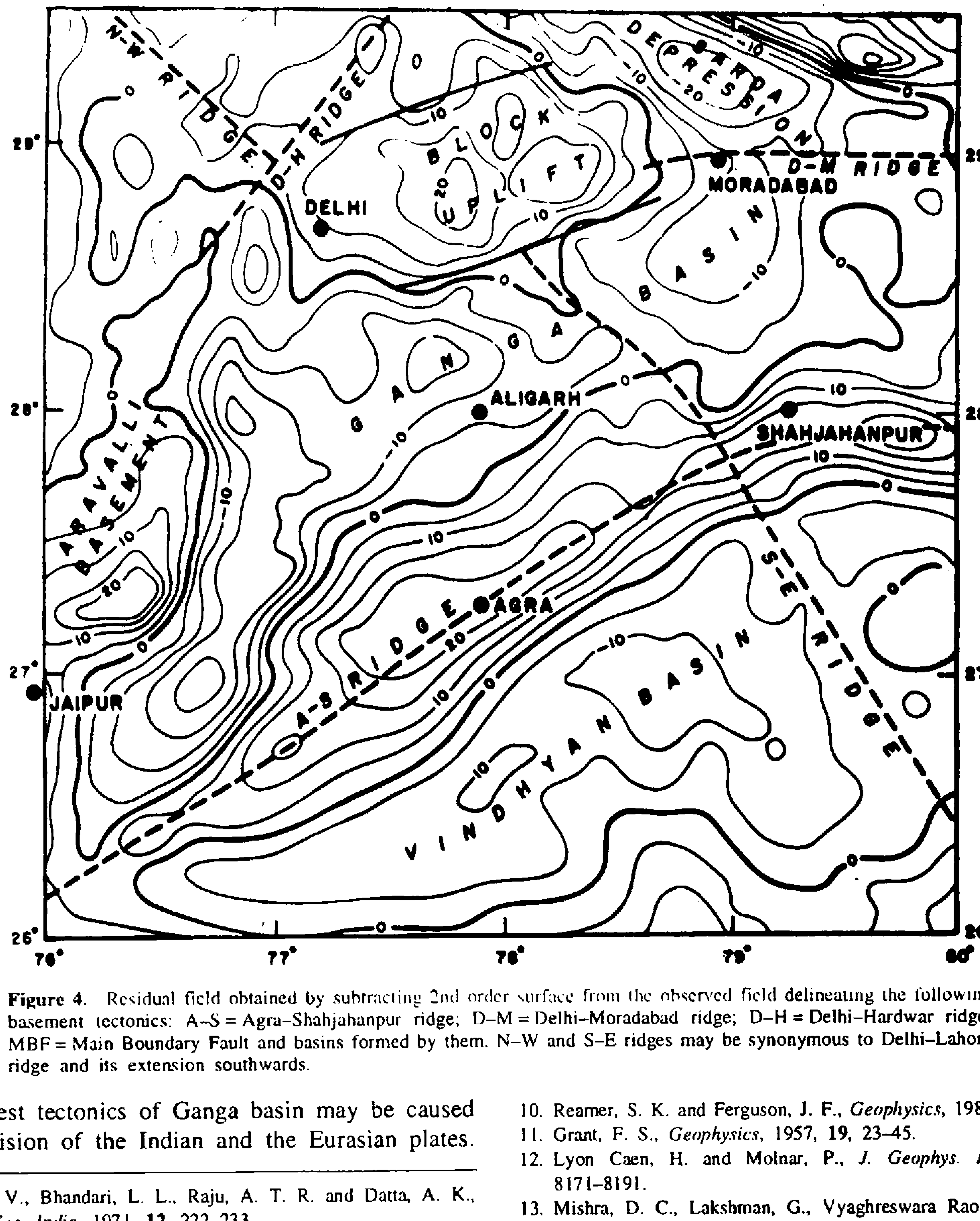

Figure 4. Residual field obtained by subtracting 2nd order surface from the observed field delineating the following basement tectonics: A–S = Agra–Shahjahanpur ridge; D–M = Delhi–Moradabad ridge; D–H = Delhi–Hardwar ridge; MBF = Main Boundary Fault and basins formed by them. N–W and S–E ridges may be synonymous to Delhi–Lahore ridge and its extension southwards.

The east-west tectonics of Ganga basin may be caused by the collision of the Indian and the Eurasian plates.

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