Geol. Bull. Univ. Peshawar, Vol. 25, pp. 51-58, 1992

Gravity and magnetic studies in the region of Main Boundary Thrust, west of Himalayan Syntaxis

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ABSTRACT: *The interpretation of gravity measurements in the west of Hazara Kashmir syntaxis, particularly around Main Boundary Thrust region suggests that the crustal thickness in the region is around 47km, and the Moho dips at an angle around 1.0 degree towards northeast against the calculated dip of about 4.0 degrees just south of Margala ranges. The residual gravity which corresponds reasonably to a generalised litho-structural model of the area predicts also some anomalous situation which get support from magnetic results. The density modelling along Islamabad-Haripur section gives the possibility of existence of basement or ultra-basic slices near Islamabad at a depth of 5km. Further, the MBT and Langrial faults seem to be changing dips downwards to 25° or more.*

INTRODUCTION

The Indus Suture in northern areas of Pakistan bifurcates into Main Karakoram Thrust (MKT) and Main Mantle Thrust (MMT) due to the involvement of a third tectonic element, the Kohistan Island Arc, in-between the colliding Eurasian and Indian plates. MKT and MMT represent respectively the northern and southern contact of the arc with Eurasian plate and the Indian plate (Tahirkheli, 1984). The collision has given rise to an extensive southward directed thrust system. Le Fort (1975) mentioned that the thrusting, which started at the time of initial collision, migrated successively to the Main Central Thrust (MCT) and then to the Main Boundary Thrust (MBT), probably 10 Mya ago.

MBT is the southern front of Himalayas and displays the younger but major lineament along which pre-collisional rocks are thrust over the post-collisional Murree formation of mid-Oligocene to Miocene age. This boundary received different names; in the west of Himalayan or Hazara-Kashmir syntaxis it was defined as Murree Thrust and in western-most sections as Kohat Thrust, however, Tahirkheli (1984) have shown them as the extension of MBT which dips towards north at an angle less than 15°. The significance of the boundary in Himalayan tectonics is concerned with the following aspects:

(i) It provides place for the accommodation of continued convergence of Indian-Eurasian collision (Tahirkheli, 1984).

(ii) Although it bends surficially around the Hazara- Kashmir syntaxis to join westerly extended Hazara Thrust System, the seismicity pattern related to the basement shows its extension towards northwest in the form of Indus-Kohistan Seismic Zone (IKSZ; Seeber & Armbruster, 1979; Seeber et al., 1981).

(iii) It represents Palaeozoic or Panjal suture (Ghazanfar & Chaudhry, 1985).

(iv) It shows an anomalous behaviour as the rocks involved in the east (India) are Precambrian and Palaeozoic, whereas in the west (Pakistan) are Mesozoic and Tertiary.

Those points are very critical and debatable in the understanding and formulation of a tectonic model for MBT and regions and further north. Our investigations are confined to the west of Kashmir-Hazara syntaxial bend where a series of southeast canvasing parallel thrust faults off-shoot from the northwest trending strike-slip part of MBT along Jhelum river. The area is bounded by Tanawal fault in the north and MBT in the south, and strata have undergone intense compressional stress with incompetent beds tightly folded. The faulting has given rise to overlapping of repeated sequence in the middle part, forming imbricate structures. Langrial fault (Latif 1971) and MBT are the main thrusts of our area lying between latitudes 32° 30' and 34°

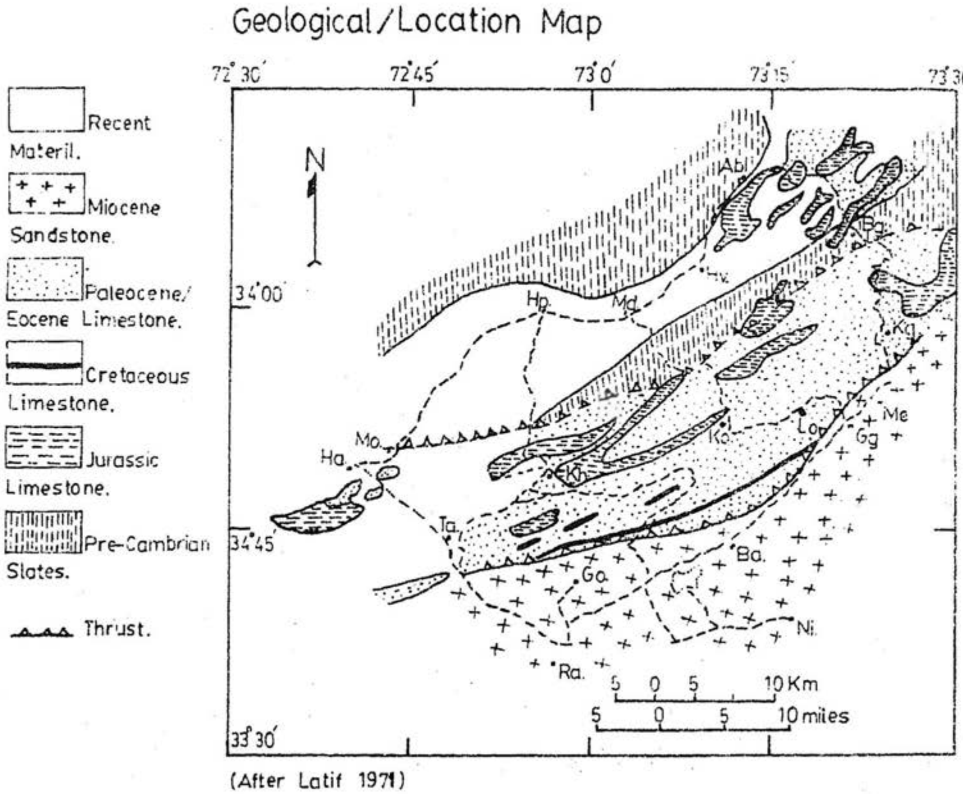

Fig. 1. Geological map of the area showing litho-structural zoning caused by MBT and the Langrial Fault. Sites on map are abbreviated. Ra = Rawalpindi; Lo = Lora; Ha = Hassanabdal; Go = Golra; Kg = Kheragali; Md = Maqsood; Ni = Nilore; Bg = Baragali; Hp = Haripur; Ba = Barakoh; Ko = Kohala; Hv = Havelian; Gg = Choragali; Kh = Khanpur; Ab = Abbottabad; Me = Murree; Ta = Tarnol.

12'N and longitude 72° 30' to 73° 27'E. Langrial fault brings Precambrian slates over Mesozoic to Tertiary limestone, and MBT pushes limestones over the Murree Formation.

The objective of this study was to explore the deep structural elements in the area to supplement the geodynamical studies of northern Pakistan. The MBT is a feature of interest regarding its orientation, subsurface attitude, and its inter-relationship with the basement.

ACQUISITION OF DATA

The studied area being a part of western lmb of the Hazara-Kashmir Syntaxis shows topographic and structural variation. Elevation varies from 450m in the south to 2750m in the north chronology ranges from Subrecent/ Pleistocene to Precambrian, and structures demonstrate intense folding, faulting and imbrications. The major thrusts, i.e., the Langrial fault and the Main Boundary Thrust, apart from repeated faulting, divide the area into three main rock units: slates, limestones, and sandstone. The average density estimates for these lithologies are 2.55gm/cc, 2.65gm/cc and 2.60gm/cc, respectively, similar to those of Malinconico (1982). Thus, MBT and Langrial fault corresponding to lithological divisions generate three density zones, and it is obvious from Figure 1 that the density contrast across Langrial fault (=0.10) is greater than that across the MBT (=0.05). This distribution gives an impression that the gravity signal across Langrial fault should be relatively sharper.

The gravity and magnetic measurements taken with Worden Gravitymeter (model 111)

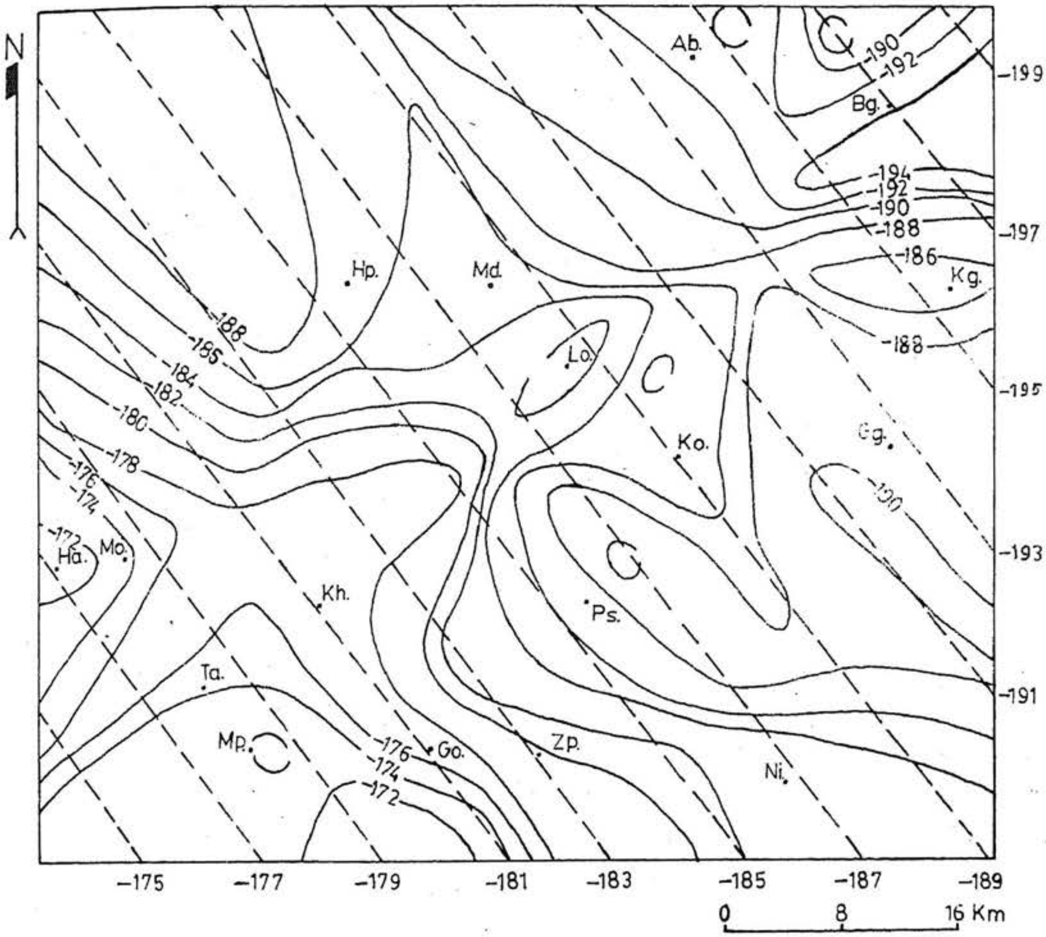

Fig. 2. Bouguer anomaly map of the area. Solid and dashed contours (in mgals) represent respectively the Bougeur anomaly and regional gravity effects.

and Fluxgate Magnetometer (model MF-2) are concentrated on easily accessible routes, two of which are along and four are across the regional geological structures. The heights of the observed 360 stations spaced at an interval of 1 to 2km, were obtained with American Pauline Aneroid type altimeter within an error of ± 3 meters. The gravity data have reduced to the mean sea-level using surface density 2.65 gm/cc, and magnetic data to the main base Islamabad.

INTERPRETATIONS

The processed Bouguer anomaly data subjected to an error of ± 1.5 mgal is correlated with second degree regional surface (corr. coeff. =0.9) is dominated by northeast directed strong regional gradient 0.25 mgal/Km (Fig.2). Upon this regional field are superimposed the lŏcal or residual gravity effects pertaining to upper crustal lateral density variations caused by major thrusts of the area, i.e., MBT and Langrial fault. The recovery of these effects has been made by subtracting simply the regional component from Bouguer anomaly values, and smoothed version of residual gravity picture of the area is shown in Figure 3.

The regional effects as mentioned by Malinconico (1986) and Lillie et al. (1986), are also considered here as the response of deepening Moho in conjunction with the overall thickening of the overthrusted crustal wedge (Farah et al., 1977). In order to find out crustal thickness or trace out the Moho-surface along northeastern line in the area

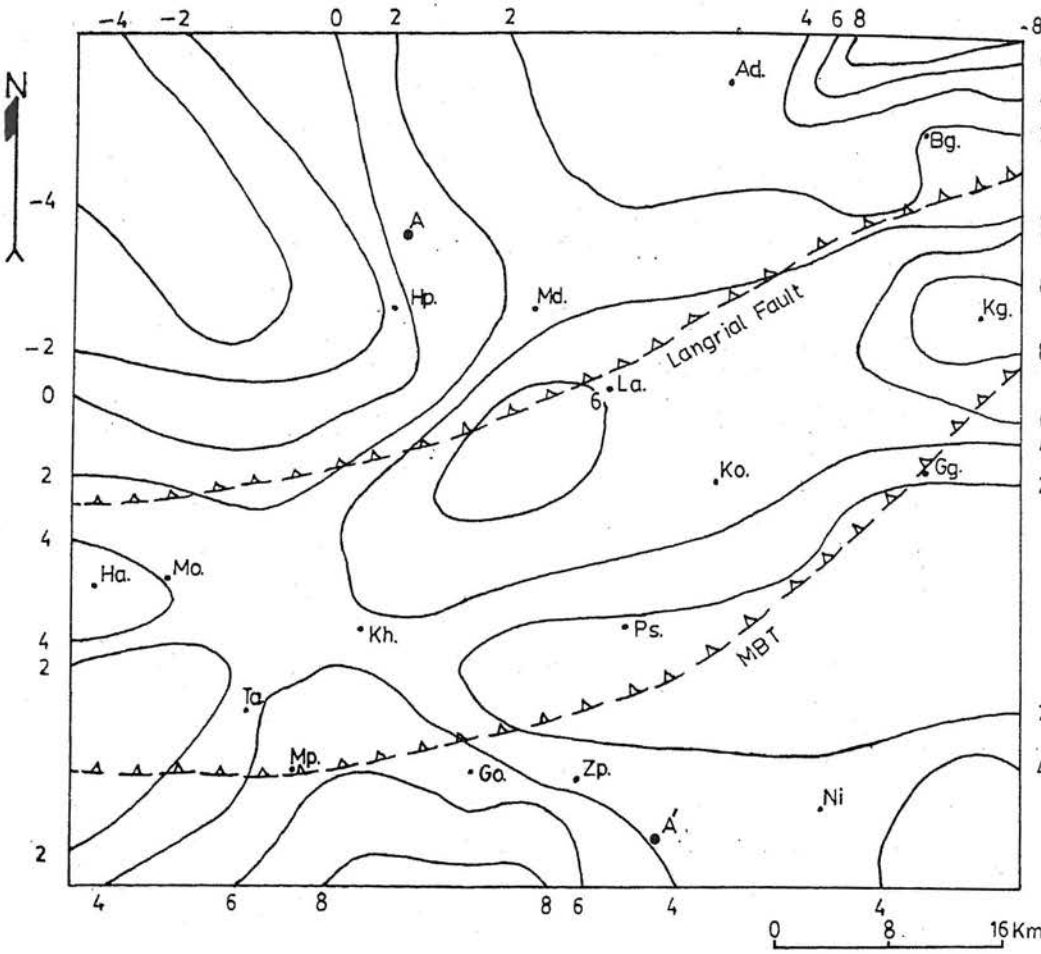

Fig. 3. Second degree residual gravity map of the area.

the schemes of Andreev (1958), and Wollard (1959) have been relied upon and the results obtained are given in the Table 1. The crustal thickness in the area seems to vary from 45km in the southwest to 47km in the northeast, within a distance of 80km, giving 1.5° as the average dip of Moho towards northeast. This estimate is drastically different from information of the foreland thrust belt (cf. Lillie et al., (1986). For example, gravity decreases from -70 mgal in northern Jehlum plain to -160 mgal in northern Potwar within a distance of 120km (gradient 0.75 mgal/km), the crustal thickness varies from 37km to 45.5km giving Moho dip of about 4°. If this finding is true, then in conjunction with the assumption that full thickness of the continental crust is being underthrust, it is logical to think that the change in dip from 4° to 1° within a short distance across Kalachitta and Margala ranges might have developed some sort of crustal deformation in the MBT zone.

On the hand, the residual gravity effect represented by short wavelength anomalies is correlated appreciably with litho-structural division of the area (Fig.3). It appears to be maximum (4 to 8 mgal) over Mesozoic to Eocene limestone, decreases to moderate values (2 to 4 mgal) in the south of MBT over the molasse sediments (Murree Formation) of mid-Oligocene to Miocene, and reaches minimum (2 to -4 mgal) in the north of Langrial fault over the Precambrian low density slates. This is an overall generalisation with the exception of two localities found northeast of Baragali-Abbottabad line, and near Islamabad, where the gravity value in-

TABLE 1. CRUSTAL THICKNESS AND MOHO DIP

	Formula	Reference	Abbreviation
1	Z=33-0.555 g	Worzel & Shurbet (1955)	WS
2	Z=30-0.100 g	Andreev (1958)	AD
3	Z=32-0.080 g	Wollard (1959)	WD

A-Crustal estimates from our data

SW Corner	NE Corner	Distance	Gradient
g=-175 mgal	g=-199 mgal	80 km	0.25 mgal/km
1 WS 42.6 km	43.9 km		
2 AD 47.5 km	47.9 km		
3 WD 46.0 km	47.9 km		= 1.0° dip
AV 46.8 km	47.9 km		

B-Crustal estimates based on data from Lillie et al . (1986)

Northern Jhelum plain	Northern Potwar	Distance	Gradient
g=-70 mgal	g=-160 mgal	120km	0.75 mgal/km
1 WS 36.9 km	41.8 km		
2 AD 37.0 km	46.0 km		
3 WD 37.6 km	44.8 km		=4.0° dip
AV 37.3 km	45.4 km		

Since AD and WD estimates are significantly closer than those of WS, the averages (AV) are based on AD and WD (AV=(AD+WD/2).

creases to 8 mgal. These gravity anomalies apparently would be referred to limestone simply because of the reason that the magnitude of anomaly in both cases is equivalent to the observed gravity effect of limestone. But the situation is different. The magnetic results do not support the candidature of limestone. Figure 4 shows clearly that magnetic highs are developed exactly on gravity highs and this association demands dual property of the causative source, i.e., denser as well as susceptible. Limestone does not qualify as such because it is less susceptible than the sandstone and slates. Thus, the alternative interpretation that can be proposed to explain both gravity and magnetic results is the piling or stacking of ultrabasic slices or portion of the basement at the shallow depths. This opinion, however, needs to be certified with the help of more work, particularly deep seismic studies in the area. Although Lillie et al. (1986) have detected high seismic velocities in northern Potwar, they prefer to relate them with hard limestone and seem reluctant to invoke another possibility.

The density modelling we tried across major geological structures, particularly along Islamabad-Haripur section (Fig.3) using Talawani method (Talawani et al., 1959) gives a good agreement between the observed and calculated gravity effects (Fig.5), and suggests the following possibilities in litho-structural configuration of the area.

(i) The fault planes of the major thrusts (MBT and Langrial) may become steeper (more than 25°) at shallow depths instead of retaining gentle dips of the outlying region (15°).

(ii) High density material (=2.85 gm/cc) may be present near Islamabad at an approximated depth of 5km.

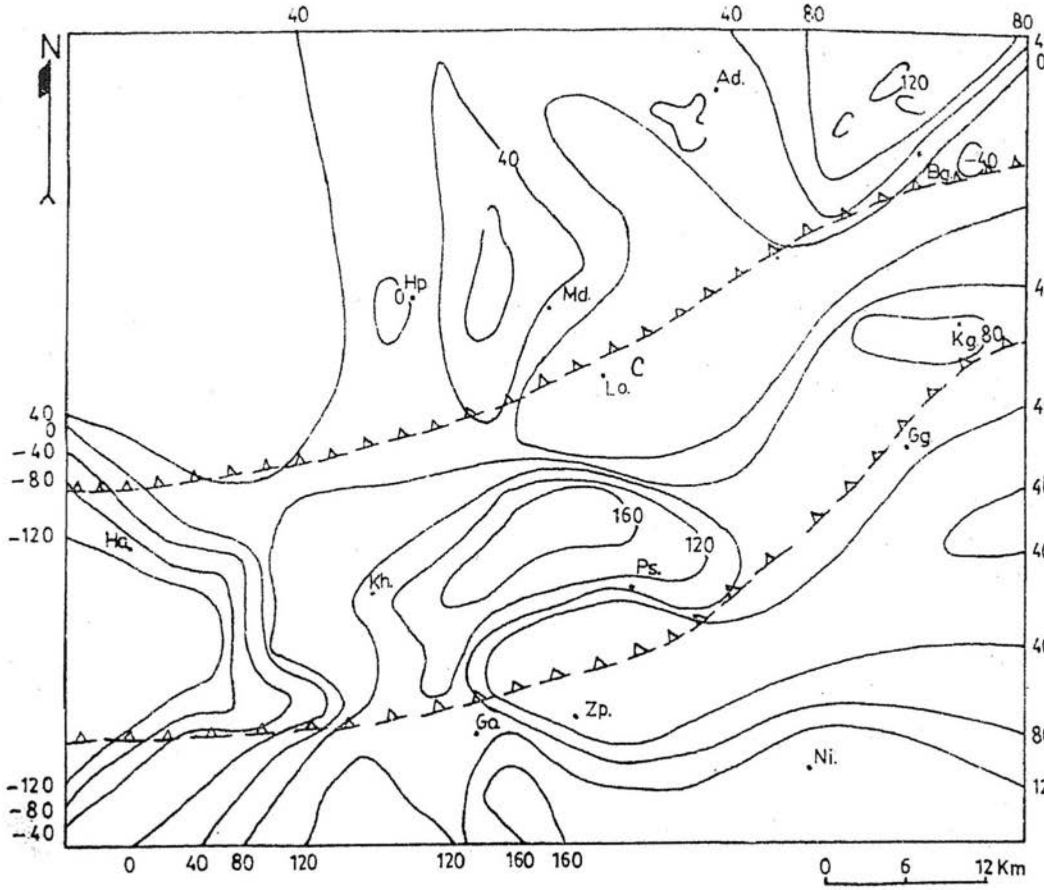

Fig. 4. Resudual vertical magnetic anomaly map of the area (magnetic values in gammas)

CONCLUSIONS

1. The average crustal thickness or Moho depth in (Islamabad-Abbottabad) is about 47km.
2. MBT zone proves to be significant in the sense that northeast directed dip in Moho reduces drastically from about 4° to 1° in the region, causing probably a crustal deformation along northwest-southeast direction.
3. The basement structures are discordant to the surface geology, and the two are probably decoupled with the presence of salt.
4. The residual gravity corresponds reasonably with a generalised lithostructural division of the area, except for the locations near Abbottabad and Islamabad.
5. A strong association between gravity and magnetic highs on these locations infers the presence of basement or ultrabasic slices (rather than limestone) at shallow depth of 5km.
6. The faults of the area seem to be steepening downwards.
7. Deep seismic studies are needed for reviewing the tectonic model for northern areas.

Acknowledgements: We acknowledge Dr.I.R. Qureshi from University of New South Wales, Australia, for giving valuable suggestions and computer programme to calculate terrain correction. We also extend our appreciations to Masers Tariq. M. Tahir, M. Arshad, Saeed Ahmed Sarfaraz Abbasi, Riasat Hussain, and others for their active participation in the project.

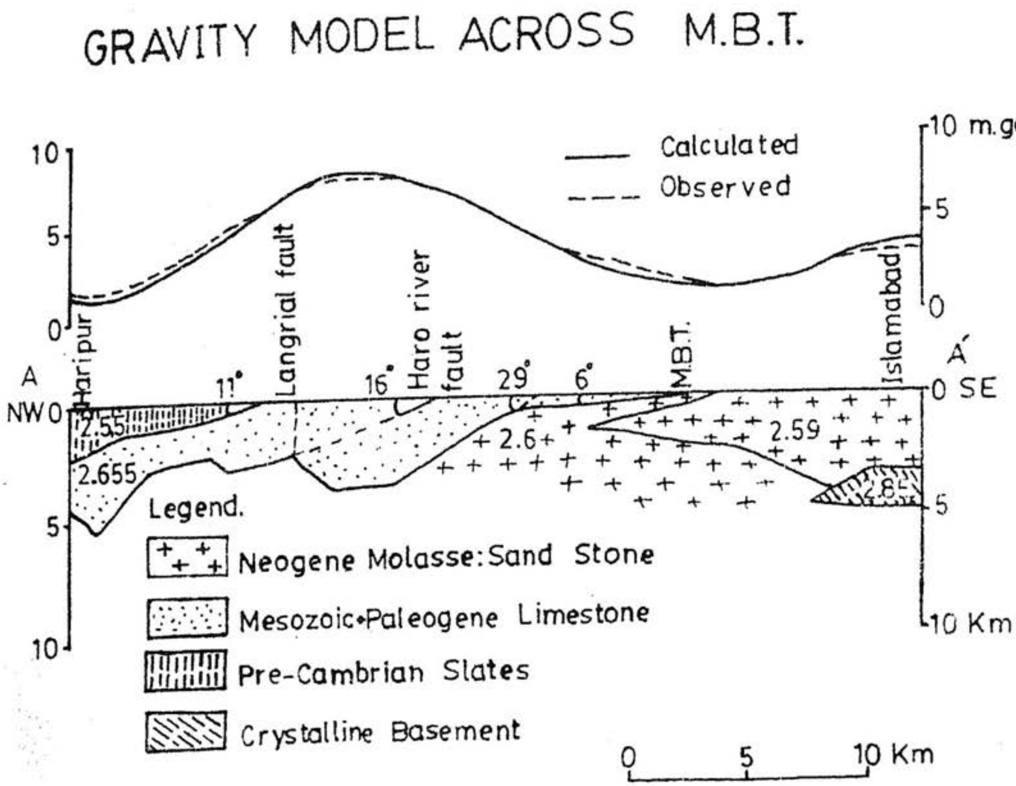

Fig. 5. Gravity model along Haripur-Islamabad section (across MBT).

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