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CONCEALED SUB SURFACE STRUCTURES BELOW PUNJAB ALLUVIUM : A GEOPHYSICAL EVIDENCE

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ABSTRACT

Forward gravity modelling along two profiles (one across Punjab Plains and Himalayan foothills through the drilled wells and another along Batala-Pathankot) is attempted to delineate the sedimentary thickness to confirm the known structures and ascertain sub-surface configuration in the Punjab Plains. The available refraction and drilled data has been used to construct the geological model. The gravity highs and lows are mostly obscure in the Bouguer gravity anomaly map, therefore, residual gravity map has been used for extracting the information about the sub-surface structures for the preparation of geological model. The residual gravity and magnetic anomaly map indicate that most of the anomalies are oriented parallel to the Siwalik trend. Highs and lows trending NW-SE alternate. There is striking resemblance of features in the magnetic anomaly map with the gravity residual anomalies. These characters seem to indicate the rolling nature of the subsurface strata. The observed morphological pattern suggests that tectonic forces which gave rise to Bharwain and Soan anticlines in the Himalayan foothills also caused minor undulations in the adjoining foredeep. The alternate residual gravity and magnetic highs and lows seem to be the reflection of the folded nature of the subsurface.

The signatures of the concealed Himalayan Frontal Thrust (HFT) and Bharwain anticline have been delineated under the Punjab alluvium. It appears that the thrust related tectonic loading as well as sub-thrust basement differentiation have influenced the potential field data in varying degrees. The subsurface strata are folded and axis of the folds runs parallel to the Himalayan front. The models indicate that thrusting has not ceased at HFT but progressed further beyond HFT towards the foredeep which is manifested by the presence of concealed thrust propagated anticlines. The folding of the subsurface rocks may enhance the probabilities of finding structural traps below Punjab alluvium.

Keywords: Punjab Plains, Himalayan Frontal Thrust (HFT), Gravity modelling, Siwaliks, Sub-Surface structures.

INTRODUCTION

The western part of Himalayan foredeep known as Punjab basin is demarcated by Aravali ridge and its subsurface extension to the east, Jhelum syntaxis (Jhelum Transverse uplift) to the west and north-west. Delhi-Sargodha ridge marks the southern margin whereas the Main Boundary Thrust (MBT) marks the northern extremity of the basin (fig.1). Tectonically it can be divided into two specific belts viz: (1) The undisturbed homoclinal foredeep below Indo-Gangetic alluvium and (2) The Tertiary thrust fold belt to the north of Himalayan Frontal Thrust. The Punjab plains occupy an area of 30000 sq. km in the states of Jammu & Kashmir, Himachal Pradesh and Punjab.

Exploration was initiated in this basin from 1956 onwards, which covered detailed geological mapping of the adjacent foothill belts supplemented by aeromagnetic (Agocs, 1957), gravity-magnetic (Guha, 1959), and seismic refraction studies (Nath, 1966; Pandey, 1973, 1974). Single fold seismic survey (Glinkin, 1957; Awasthi *et al.*, 1959; Datta; *et al.*, 1964) is also

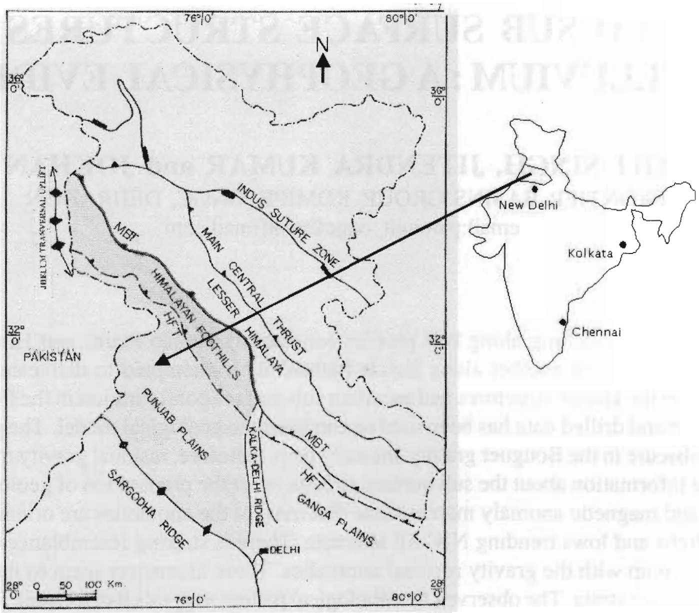

Fig. 1. Location map of Punjab plains

carried out in the selected areas of Punjab Plains, which does not give adequate information of the sub-surface. Five wells have been drilled in the plains (including H-1 and 2), without any commercial success. Multifold seismic reflection survey and geochemical survey data are not available at least in this part of the basin.

The fluorescence in well P-3 raised high hopes of striking oil in this region, but the area was abandoned without expending exploratory inputs in the area. The gravity-magnetic data depicts an interesting picture of the sub-surface. The refraction data also show the general deepening of the foredeep towards HFT and a considerable sedimentary thickness is available in the northern part of the Punjab Plains.

Forward gravity modelling is attempted by integrating the available refraction and drilling data to delineate the sedimentary thickness in the Punjab Plains and to confirm the known geological structures in the Siwalik hills. To ascertain how far the potential field data corresponds with the geology of the region and in addition to have additional information about the sub-surface structures gravity modelling has been carried out.

GENERAL GEOLOGY

As a part of Gangetic foredeep, Punjab plains is also a Proterozoic pericratonic pre-foredeep shelf superimposed by rapid subsidence and sedimentation by Tertiary foredeep molasse. The basinal area is about 30000 sq km, most of which is covered by recent alluvium (fig. 2). Airborne magnetic and ground gravity-magnetic data suggests a monoclinal northerly dipping slope having basinal neach around HFT, further off it is merged with thrust fold belt of Tertiary para-autochthon. Few basement controlled strike faults controlled the pre-foreland topography. Gravity–magnetic data indicates possibility of additional

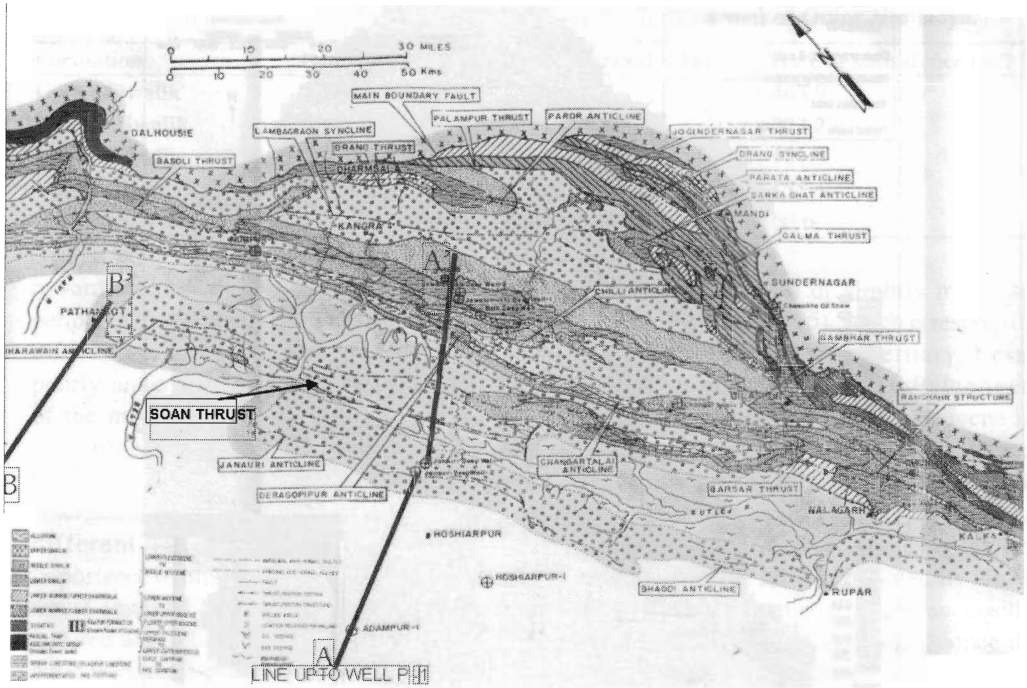

Fig. 2. Geological map of Punjab plains and Himalayan foothills

sedimentary thickness within fault bound depressions, which were basically controlled by linear boundary faults parallel to the Himalayan front. One such low is located in Dasuya-Pathankot sector having a sediment pile of more than 5 km Pre-Tertiary stratigraphy in this belt is highly conjectural due to lack of data. However, Riphean carbonate strip of Vaishnodevi and the Janauri group of limestone meta-sediments encountered in well H–2 is the representative of pre-foredeep sediments on Indian pericratonic margin.

METHODOLOGY

Bouguer gravity anomaly map (fig. 3), magnetic anomaly map (vertical component, fig. 4), a few refraction lines shown on the gravity anomaly map and drilling data in the Punjab Plains and foothills have been used for determination of the sub-surface configuration in this study.

Well P-1, P-2 in the Punjab Plains and H-2 in the Himalayan foothills are drilled to the basement. The thickness and lithology of sediments is known in these wells. The gravity anomaly generated by this pack of sediments is calculated considering the effective density contrast of the sediments by using Bouguer infinite horizontal slab method. It is also realised that the massive root of the Himalayas located in the northeast of the Punjab Plains, dominantly cause general lowering of the Bouguer anomaly values towards northeast. By considering basement lowering towards northeast, a strong gradient of gravity anomalies due to deep crustal faulting and realizing the influence of the Himalayas, which gives rise to strong regional anomaly in this area, a regional field is estimated. Residual component of the Bouguer anomaly along a

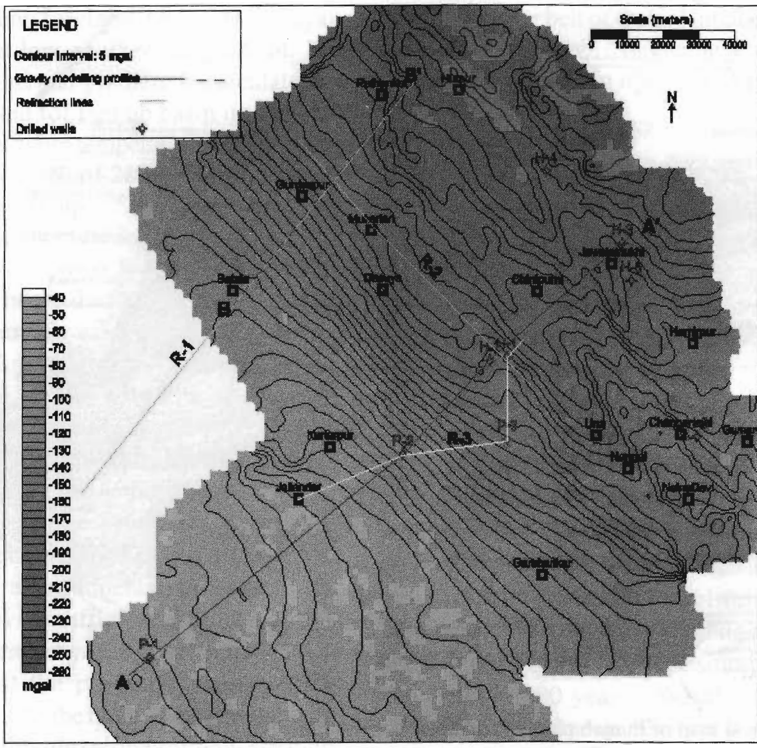

Fig. 3. Bouguer anomaly map of Punjab Plains and adjoining Himalayan foothills

profile AA' (fig. 3) passing over the wells P-1, P-2, H-2 and H-3 is obtained by subtracting the regional component from the Bouguer anomaly values by graphical method. A seismo-geological section is generated by incorporating the well data and refraction data along wells P-2 & 3 in Punjab Plains and well H-1 in Himalayan foothills (fig. 5) for preparing the geological model in the Punjab Plains along line AA'.

Forward gravity modelling is attempted along two profiles based on Manik Talwani's (1959) polynomial technique. The model is validated on the profile having full stratigraphic and sedimentary thickness control. The regional for second profile BB' (fig. 3) passing through Batala-Pathankot, is estimated from the refraction data. Southeastern part of BB' is along the refraction line R-1 (fig. 6) from Batala to almost end of the line and also crosses the refraction line R-2 (fig. 7) in between Gurdaspur and Pathankot. The rock density information is taken from well log of H-3 in Himalayan foothills and the densities are adjusted towards the Punjab Plains area by considering the lithology, degree of compaction and velocity information from the refraction data.

ANALYSIS

The gravity map of the area shows that the regional gravity surface is almost a plane striking NW-SE and dipping towards NE (fig. 3). This indicates a NW-SE trend of the geosyncline in this region which conforms well to the Himalayan strike observed at Janauri, Bharwain and Jwalamukhi structures. In view of above, it is considered to explain the gravity anomalies of Punjab Plains in conjunction with the Siwalik hills. This also well conforms with the magnetic anomaly map (fig. 4). It appears that gravity picture is in full accord with the regional geology.

Vertical magnetic anomalies vary from -500 to 500 gammas (fig. 4). The zone southwest of Jalandhar is characterized by positive magnetic anomalies and low gradient of magnetic variations, whereas, northeast of Jalandhar-Batala is characterized by sharp magnetic anomalies and seem to be associated with undulations of the basement topography. The polarization of the rocks seems to be vertical.

The gravity lows and highs are mostly obscure in the gravity map and needs to be resolved by residual gravity map. The residual anomaly map (fig. 8) indicates that most of the anomalies are oriented parallel to the Siwalik hills, the lows and highs are alternate with each other in the NW-SE direction. The significant character of the magnetic map in Punjab Plains is that the belts of magnetic lows and highs are oriented parallel to the Siwalik strike and its striking resemblance is seen in the gravity residual anomalies.

The geological model along line AA' (fig. 9) is prepared from the sub-surface information from the wells. The gravity response computed from the geological model is very well matched with the graphical residual gravity anomaly. A small mismatch is observed in the northeastern end of the profile where Lower Siwalik is exposed. The mismatch may be due to the under estimated Bouguer density. The density of Lower Siwalik is of the order of 2.5-2.55 gm/cc whereas the Bouguer density used for reducing the data to MSL is 2.4 gm/cc. The model is in full accord with the available seismic data in the NE part of the line from Soan

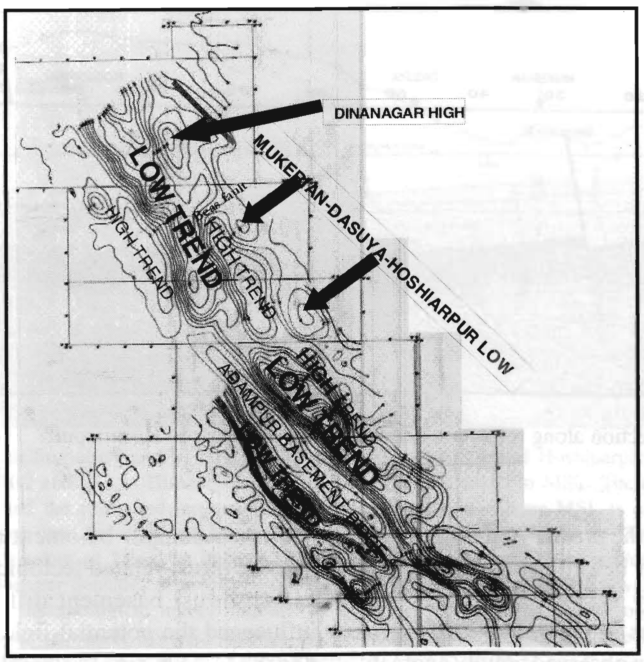

Fig.4. Magnetic anomaly map (vertical component) of Punjab Plain

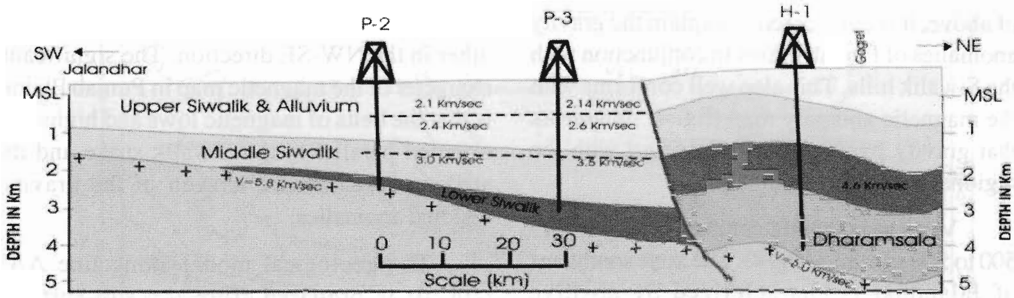

Fig. 5. Seismogelogical section interpreted from refraction and well data

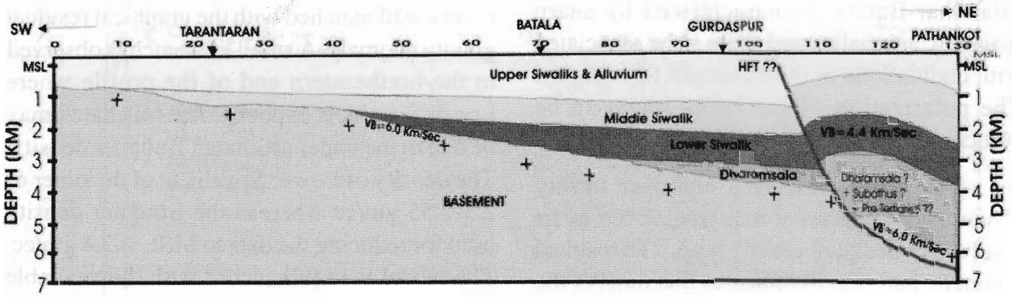

Fig. 6. Depth section along refraction profile R-1 from Tarantaran to Pathankot

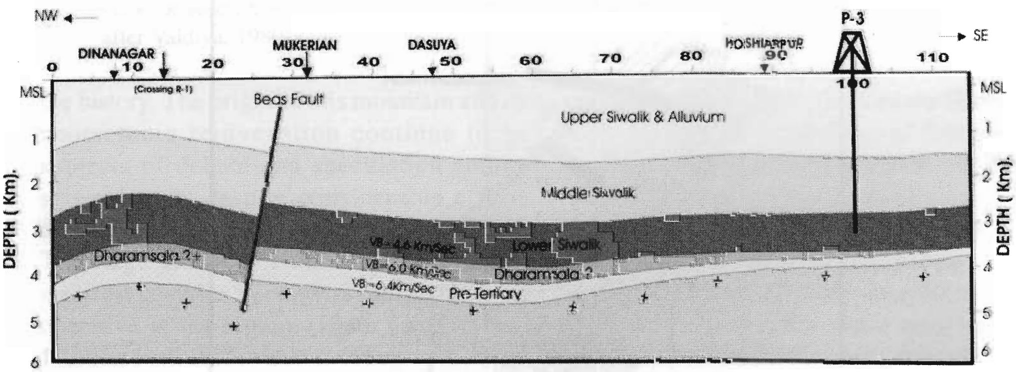

Fig. 7. Depth section along refraction line R-2 from Dinanagar to Hoshiarpur

thrust to the end of the profile and a number of thrusts emerge just before the well H-3. The computed gravity response of Soan and Bharwain anticlines in the geological section are matched with the observed gravity anomaly. The well P-2 is drilled on the northern flank of Ambala-Adampur basement ridge. It appears that the thrust related tectonic loading as well as sub-thrust basement differentiation have influenced the potential field data in varying degrees. The small variation in gravity anomalies towards the Punjab Plains are the

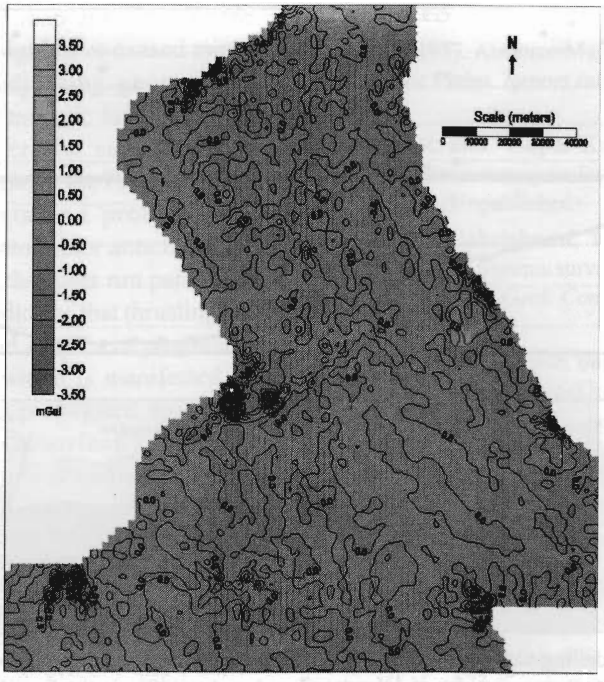

Fig. 8. Residual Gravity anomaly map of Punjab Plains

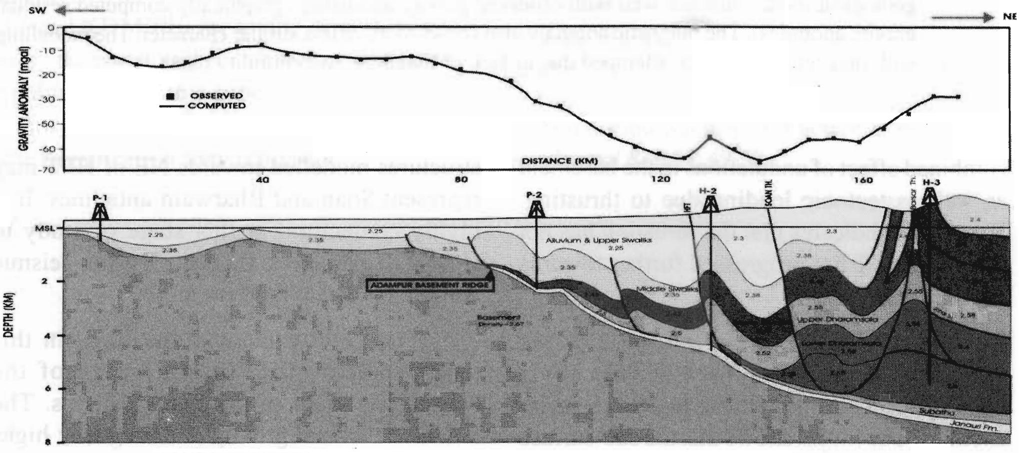

Fig. 9. Gravity modelling along profiel AA' passing over wells P-1, P-2 and Hoshiparpur low in Punjab Plains and weels H-2 and H-3 in Himalayan foothiils. The data is reduced to MSL. The elevation are projected separately and the computed response of sedimentary thickness above MSL is not taken into account. The densities used for different lithologies are appended in every horizon. The density for Bouger correction is taken as 2.3gm/cc in the foothils upto Barsar Thrust and 2.4 gm/cc beyond that towards NE. The Bouguer densities seems to be correct upto exposed Upper/Middel Siwaliks and the computed response of the geological model matches well. The slight mismatch in the observed and computed response over the Lower Siwaliks may be due to the application of under corrected Bouguer reduction density as the density of Lower Silwaliks is between 2.5-2.55gm/cc as per the density log of well H-3.

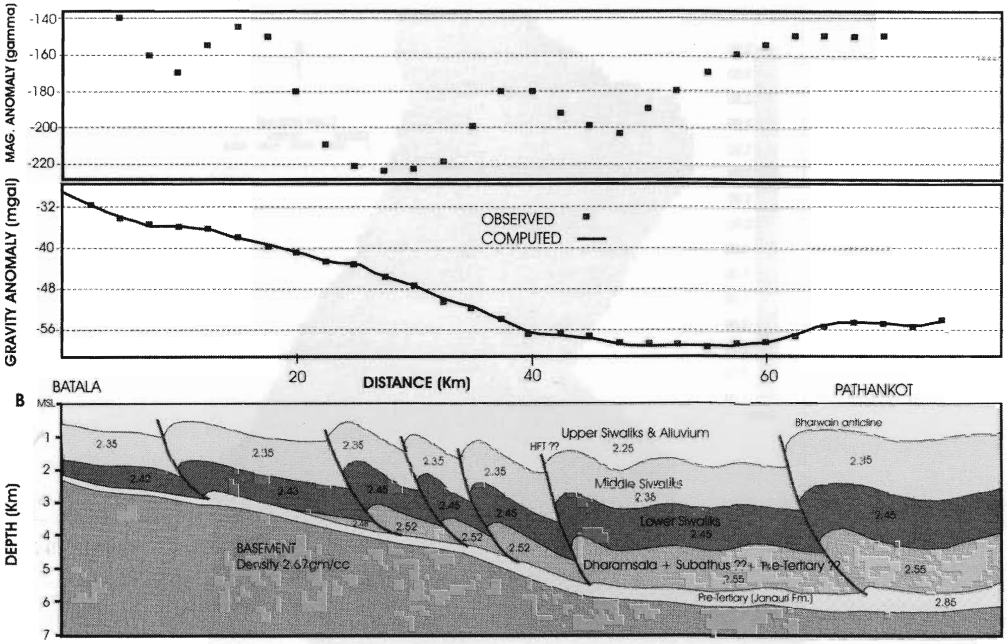

Fig. 10. Gravity modelling along profile BB' from Batala to Pathankot, Punjab. The density for Bouguer correction is taken as 2gm/cc and the data is reduced to MSL, in the Punjab plains. The densities used for different lithologies are appended in every horizon. The computed response of the geological model matches well with observed gravity anomalies (graphically computed residual gravity anomiles). The magnetic anomaly also shows more or less similar character. The modelling with magnetic data is not attemped due to lack of magnetic susceptibility data.

combined effect of undulations in the basement as well as tectonic loading due to thrusting. The model indicates that the thrusting has not ceased at HFT but progressed further towards the foredeep.

Similarly the gravity response of the geological model along line BB' (fig. 10) is matched with the graphical residual gravity anomaly. The model shows that the sub-surface strata are of a rolling nature. The fault at northeast of Gurdaspur seen in refraction section (fig. 5) has its representative response in the gravity model. It seems that the fault south of Janauri is continuing towards northwest under the cover of alluvium of Punjab and the signatures of HFT are between Gurdaspur and Pathankot and plunging towards Pakistan. The structures modelled towards NE of HFT may represent Soan and Bharwain anticlines. It is highly conjectural at this stage of study to clearly demarcate anticlines. Further seismic work is needed to confirm these.

The gravity models discussed in this paper indicate the rolling nature of the subsurface strata in the Punjab Plains. The alternate residual gravity and magnetic highs and lows seem to be the reflection of the folded nature of the subsurface.

CONCLUSIONS

The signatures of the concealed Himalayan Frontal Thrust (HFT) and Bharwain anticline have been delineated under the Punjab alluvium. The tectonic forces which have given rise to Bharwain and Soan anticlines in the Himalayan foothills might have caused minor undulations in the adjoining geosyncline region. There may be tectonic loading due to thrusting and minor crustal sags owing to basement lows and highs in the Punjab Plains. The subsurface strata and probably the basement are folded into minor anticlines and synclines and axes of the folds run parallel to the Siwalik range. It indicates that thrusting has not ceased at HFT and may have progressed further beyond HFT which is manifested by the presence of thrust propagated anticlines. The folding of the subsurface rocks may enhance the probabilities of finding structural traps in the region.

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