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Crustal Structure of NW Himalaya through Gravity and Magnetic Data Analysis

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Summary

Here, our regional gravity and magnetic profiles spanning approximately ~1220 km and ~1120 km respectively along Delhi – Chandigarh – Kiratpur – Sundernagar – Kullu – Manali – Keylong – Sarchu – Pang – Rumtse – Upshi – Igu – Leh – Khardung La – Panamik, Igu – Karu – Chang la – Durbuk profiles (Fig. 1) across all major structural elements of NW Himalaya were duly processed and interpreted. Additionally, we include our gravity and magnetic profiles across Indus Tsangpo Suture Zone (ITSZ) along Mahe – Sumdo – Tso Morari (Fig. 2).

By considering all the inputs form Spectral analysis followed by data decomposition, Stabilized Analytical Signal algorithm and Continuous Wavelet Transform, crustal structure models were derived for gravity and magnetic data along Delhi – Panamik profile. Our gravity derived crustal structure emphasizes the deepening of Moho below Higher Himalaya to around 65 km and it shallows up under Aravallis to 40 km. The decollement in both sections (gravity and magnetic cases) is around 9 - 12 km on an average. Partially melt zone is inferred below Higher Himalaya zone in gravity derived crustal structure section.

The presence of ophiolites within Ladakh batholith is also inferred in our analysis of total field intensity anomaly data along Rumtse – Upshi –Igu – Leh – Khardung la – Panamik, Rumtse – Upshi –Igu – Karu – Chang la – Durbuk profiles.

Introduction

Himalaya is a unique geological feature in the entire world and it poses several geodynamic challenges before the earth science community at large and Indian earth scientists, in particular. Because of the highly rugged topography and complex geological setup, available geophysical data sets are not commensurate to tackle the intricate crustal structure at depth. However, in recent years, gravity (Chamoli et al., 2010), magneto-telluric (Gokarn et al., 2002; Li et al., 2003; Arora et al., 2007, Caldwell et al, 2009) and seismic profiles (Zhao et al., 2001; Haines and Klemperer, 2003; Wittling et al., 2004; Rai et al., 2006; Rehman et al., 2007) were undertaken by several national and international scientific groups. Prominent efforts by INDEPTH (Zhao et al., 2001; Haines and Klemperer, 2003) team are worth mentioning. Here, we report our own efforts in deciphering crustal structure beneath NW Himalaya stretching from Aravallis to Karakoram Himalaya based on our own regional gravity and magnetic data profiles cutting across all major structural elements. It may not be out of place to mention that ours is a maiden venture, which involves both gravity and magnetic profiles spanning 1220 km with a close sampling of 2 km in this region. The projected straight profile amounts to approximately 688 km.

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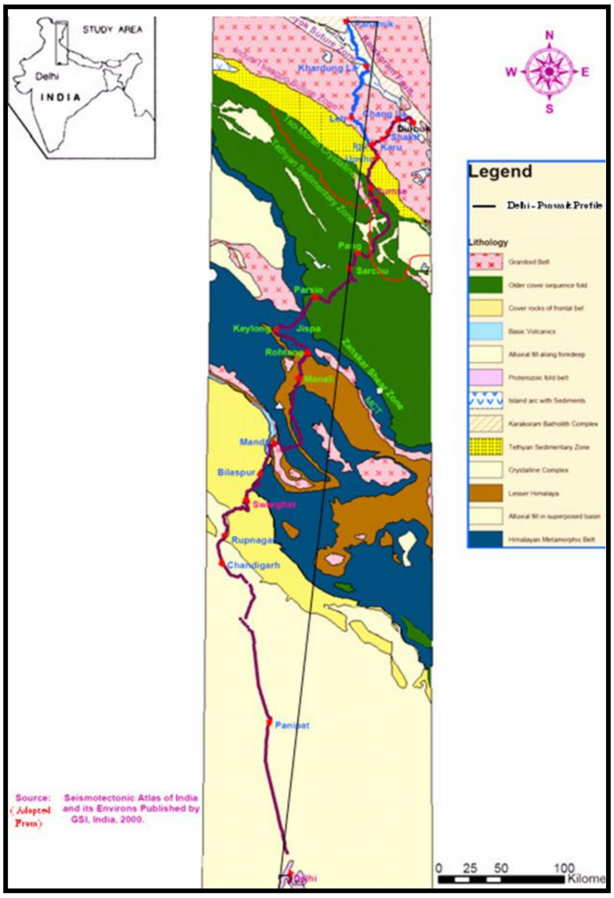

Fig. 1 : Our gravity and magnetic data projected onto Delhi-Panamik straight profile. The original profile is also shown on the geological map. (Adopted form Seismo- tectonic atlas of India and its Environs, GSI, 2000, India)

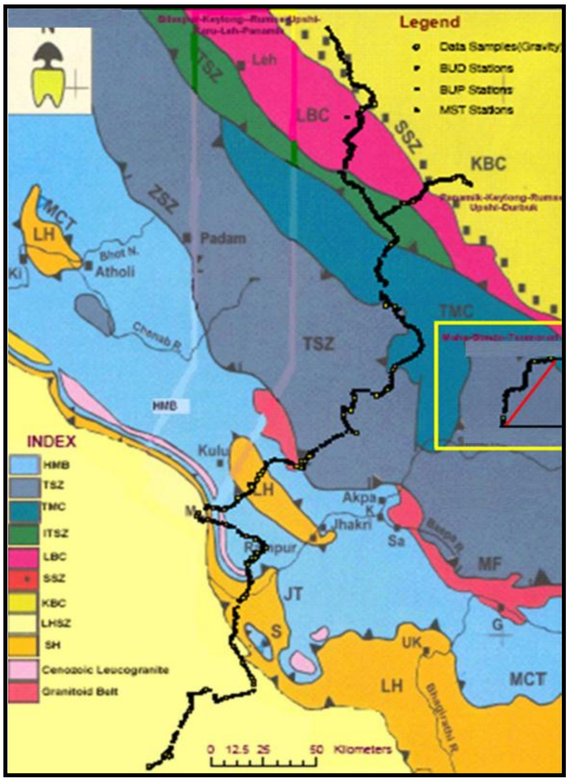

Fig. 2 : Our gravity and magnetic data projected onto Mahe – Sumdo – Tso Morari straight profile on the geological map. (Modified after Cover page of DST seminar abstract volume, Himalayan Tectonics, Singh & Jain, 2003)

Methodology

It entails in the following:

1. All regional gravity and magnetic data along Delhi-Panamik, Delhi – Durbuk and Mahe-Sumdo-Tso Morari profiles are processed as per norms and pseudo-gravity from total-field intensity data (Blakely, 1995) are obtained.
2. Then the gravity and magnetic stations are projected onto straight profiles in respective cases and the interpolation is carried out to yield gravity and magnetic data at a uniform interval.
3. Based on the data on straight profiles, spectral analysis is carried out on gravity, magnetic and pseudo-gravity to obtain average depth, frequency range of different density, magnetic and pseudo- density interfaces respectively.

4. Using our spectral decomposition software, gravity and magnetic anomaly resulting in Step 2 is decomposed into its components by considering inputs from Step 3.
5. Our Stabilized Analytic Signal algorithm is applied on potential field data (gravity, magnetic, pseudo- gravity) from Step 4 and by considering analytic responses of dipping sheet and dipping fault in both gravity and magnetic cases (Phillips, 2010), depth, dip and horizontal coordinates of anomaly sources are obtained.
6. Depth stack based on results achieved in Step 5 are prepared (Fig. 3).
7. Continuous Wavelet Transform (CWT) method is implemented on gravity and pseudo-gravity data leading to depth stack of results profile-wise (Fig. 4).
8. Based on information accrued from Steps 2-7, physical properties (density and magnetic susceptibility) of rock samples collected from different geological formations along different regional profiles and other geological and geophysical constraints from published literature, both density and magnetic susceptibility models of subsurface along regional gravity and magnetic profiles are framed.
9. 2-D forward responses of both density and magnetic susceptibility models arrived at Step 8 are computed and matched them with observed data resulting at Step 2. For better matching of these two responses, the density and magnetic susceptibility models arrived at Step 8 are modified suitably in an iterative manner.

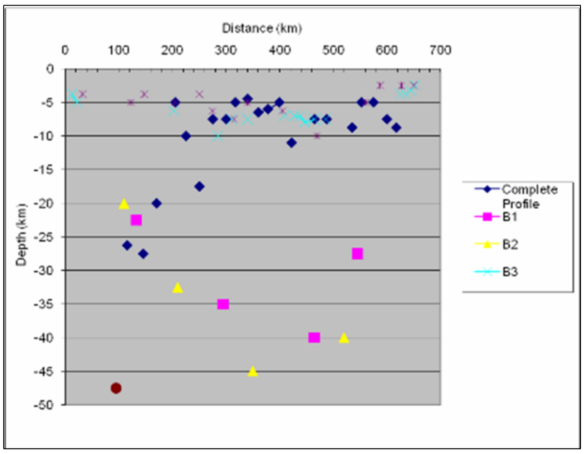

Fig. 3 : Depth stack of Bouguer gravity along Delhi- Panamik profile by Analytical Signal analysis.

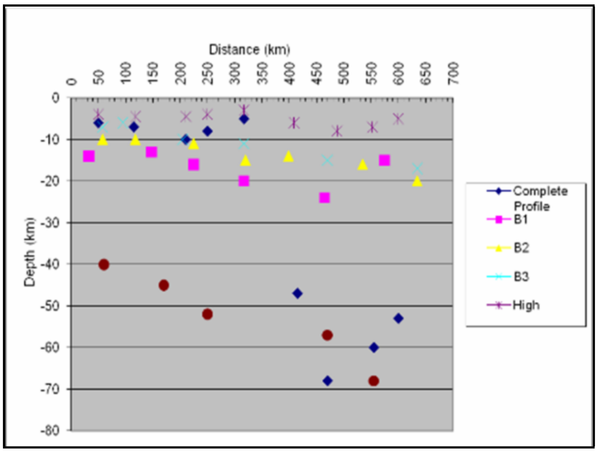

Fig. 4 : Depth stack of Bouguer gravity along Delhi- Panamik profile by Wavelet analysis.

Conclusions

1. The acquired gravity and magnetic data along Delhi – Chandigarh – Kiratpur – Sundernagar – Kullu – Manali -Keylong – Sarchu – Pang – Rumtse – Upshi – Igu – Leh – Khardung La – Panamik abbreviated as Delhi – Panamik profile is projected onto straight profile (Fig. 1) spanning 688 km.
2. The acquired gravity and magnetic data along Delhi – Chandigarh – Kiratpur – Sundernagar – Kullu – Manali – Keylong – Sarchu – Pang – Rumtse – Upshi – Igu – Chang la – Durbuk abbreviated as Delhi – Durbuk is projected onto straight profile (Fig. 1) spanning 600km.
3. Acquired gravity and magnetic data are processed as per norms.
4. Interpretation of processed data is carried out with the help of our Stabilized Analytical Signal algorithm and Continuous Wavelet Transform (CWT) methods. Both these interpretation methods are applied on complete anomaly (gravity, magnetic and pseudo-gravity) and its components along Delhi – Panamik, Delhi – Durbuk and Mahe - Sumdo –Tso Morari profiles.
5. By considering Analytical signal characteristics of dipping sheet and fault models (Phillips, 2010), we have worked out a scheme for computing dip information from both gravity and magnetic anomalies for complete profiles and their components (Low-pass, Band-pass and Hi-pass).
6. The zero crossings of IIAS plots along both Delhi – Panamik, Delhi – Durbuk and Mahe - Sumdo – Tso

Morari profiles for gravity, magnetic and pseudo-gravity coupled with depths and dip information provided by AAS helped in effective forward modeling to leading a reasonable crustal structures. Our crustal structure models derived from gravity (Fig. 5) and magnetic anomaly (Fig. 6) along Delhi – Panamik profile are initial attempts in this direction.

7. The depth stacks derived from CWT and Analytical signal method serve as good constraints for crustal structure determination.
8. In gravity derived crustal structure model, deepening of Moho to 65 km under Higher Himalaya and beyond, the decollement, the effects of thrust sheets and suture zones are clearly seen.
9. In crustal structre model derived from magnetic anomaly along Delhi-Panamik profile, effects of major thrust sheets and decollement are visible clearly. The depth range of decollement is 9 - 12 km.
10. Arrived crustal structure sections (Fig. 5 and 6) are non-unique by considering the fact that they are derived using potential field data.

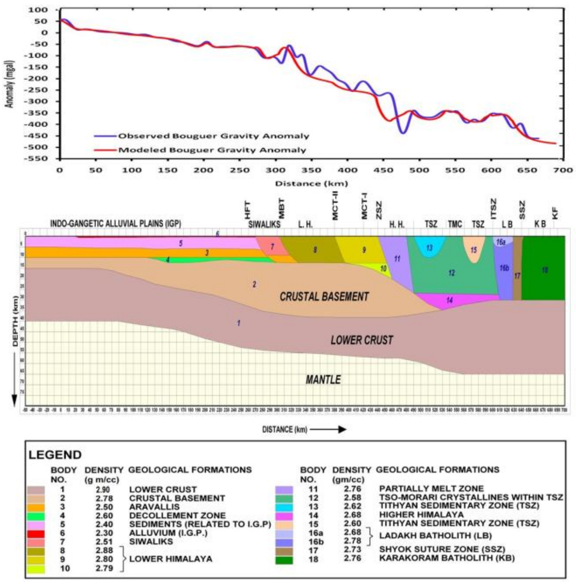

Fig. 5 : Crustal structure derived from projected Bouguer gravity anomaly along Delhi – Panamik profile.

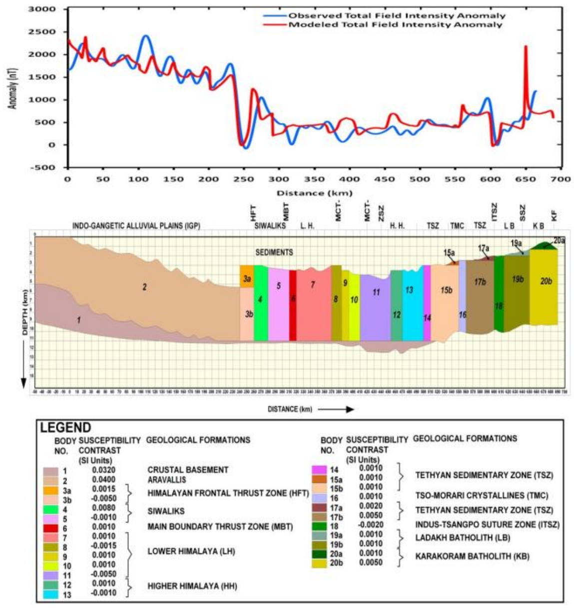

Fig. 6 : Crustal structure derived from projected magnetic anomaly along Delhi – Panamik profile.

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