Determination of Optimum Average Density for Bouguer Correction – A Case Study in Tirasujanpur Area, Himachal Pradesh, India.

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Summary

Oil and gas seepages at various places and encouraging results in a well have raised optimism about the prospectivity of Himalayan foothills of Himachal Pradesh in the northern part of India. Poor quality of seismic data arising from tectonic complexities and rugged terrain common in thrust fold belt handicaps exploration in the area. Because of limitation of seismic imaging , there have been conserted efforts to extract as much sub-surface information as possible from seismic data.

Proper estimate of density for computation of Bouguer correction is crucial in areas of undulating topography. Direct determination of density by surface profiling or measurement in boreholes is not feasible. Hence, one has to rely on indirect method for estimation of density for computation of Bouguer anomaly. In the present study, we have estimated optimum density for Bouguer correction in indirect manner by correlating elevation and computed Bouguer anomaly with a suite of density values in Tirasujanpur area, in the western part of Himachal Pradesh, in the northern part of India.

Introduction

Jawalamukhi thrust and its adjacent area in the Himalayan foothills (fig 1) in Himachal Pradesh in the northern part of India have engaged much attention because of numerous oil and gas seepages in the area. Interest in the area is sustained by favorable results from two shallow objects in the well-1 and gas show in a few other wells. However, there has been neither commercial success nor the potential of the area is properly assessed mainly because of poor quality of seismic data. Subsurface tectonic complexities, rugged topography and rapidly varying near surface conditions, usual in thrust - fold belts, e.g. in Cachar –Tripura fold belt in the northeastern part of India (Dutta and Chatterjee, 1998). Moreover, seismic coverage is sparse in the area. Hence, there have been concerted efforts to elicit as much sub-surface information as possible from gravity and by integrating it with existing seismic data.

Gravity anomaly data can be confidently correlated with the causative if the effects of the factors influencing the gravity values are properly accounted for. The anomaly value having significance in hydrocarbon exploration is a small fraction of absolute gravity value and also of the variation caused by latitude, elevation and other factors. Hence, proper corrections to reduce the observed anomaly values to a common datum are crucial. Because of inverse square dependence of gravity on distance, the correction for the elevation of the observation point is very important

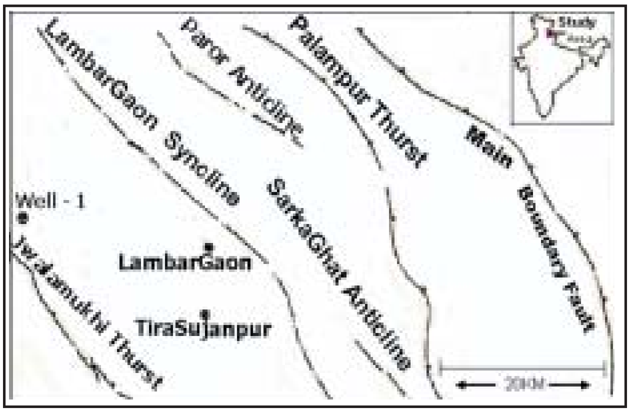

Fig. 1: Location Map of the area.

particularly in areas with high degree of variations in topography. In this paper we present the results of Bouguer correction in Tirasujanpur area in the western part of Himachal Pradesh.

Elevation Correction

Gravity value (g) at a height H from the sea level is given by,
$g = GM(R+H)^{-2} = (GM/R^2)*(1+2H/R–3H^2/R^2 + \ldots)$

Neglecting the higher order terms which are significant only for very high value of H, the above equation becomes

$$g = g_0 * (1+2H/R)$$

or $g_{\%}\, g_{0\,=}\, g_{f\,=}\, (2H/R)* g_0 = 0.3086* H$ mGal …… (1),
if H is in meter.

where $g_0 = (GM/R^2)$, G is the universal gravitational constant, R is the radius of the curvature of the earth, and M is the mass of the earth .

The factor g_f is called free air correction which assumes that there is no medium between the observation point at height H and the sea level. The effect of the attraction of the material between the observation point and the sea-level, which increases the gravity value, is taken care of by Bouguer correction. This effect is calculated by assuming (i) the observation point is located on a horizontal plain of infinite extent and (ii) the density of the slab lying between the plain and the sea level is uniform.

The error caused by the first assumption can be taken care of to a good extent by terrain correction, which requires a good knowledge of topography surrounding the observation points. Removal of the second effect is rather troublesome because it demands detailed information about the densities of the local rocks.

Density and Bouguer correction

It can be shown that Bouguer correction (B_f) a top of a slab of height H above see level and having density ρ is

$$B_f = 2\pi G\rho H = 0.04192\ \rho\ H \text{ mGal} \qquad \ldots\ldots\ldots (2)$$

if ρ is in gm/cc and H is in meter, error “B_f in the computed Bouguer correction because of error “p in density is given by

$$“B_f = 0.04192\ “\rho\ h\ \ldots \qquad (3).$$

Since the error is exaggerated by the factor H, it becomes appreciable at higher elevation. The error in Bouguer correction because of the erroneous values of ñ used in Bouguer correction would amount to a dc shift in a level or near level topography but would lead to erroneous estimate of depth of the causative. However, it will mislead interpretation of Bouguer anomaly data in areas of undulating topography and discussed below.

Spurious lateral change in Bouguer anomaly between two points having elevation H_1 and H_2 because of error $|\Delta p|$ in density is

$$|\Delta BA| = 0.04192\Delta\rho\,|(H_2 - H_1)| = 0.04192\,\Delta\rho h$$

where $h = |(H_2 - H_1)|$, the elevation difference between the two points.

If the contour interval in a Bouguer Anomaly map is C mGal, error in Bouguer correction should not exceed 0.5C, i.e. $|\Delta p|$ should be less than 0.5C/0.04192h = 11.92C/h;For C = 1 mGal and h = 100 m, $|\Delta p|$ should be less than 0.1192 which is about 5% of densities of average rocks.

Estimation of density for Bouguer correction

In areas of homogeneous or nearly homogeneous near surface, density measured directly from outcrop samples, core cuttings or borehole samples can be used for computing Bouguer correction. In areas of rapidly changing near surface lithology because of outcrops of various formations a phenomenon common in thrust fold belt (Dutta and Chatterjee, 1998), usage of average density for Bouguer correction will lead to considerable error. There are cases where multiple densities have to be used in a small area for Bouguer correction.

In areas where direct measurement of density is not feasible or borehole data not available, optimum density for Bouguer correction can be estimated indirectly by Nettleton's method (1939, 1976). The Bouguer effect will be under-corrected with density less than the actual, i.e., the effects of the rocks lying between the observation station and the datum will partially remain in the data, and the Bouguer anomaly will be correlated to topography. On the other hand, if the density used for Bouguer correction is greater than the actual, Bouguer anomaly will have inverse correlation with elevation. The density for which Bouguer anomaly curves is least correlatable with elevation is the correct density for Bouguer correction.

We have used this method in Tirasujanpur area in the western part of Himachal Pradesh. The area lies between

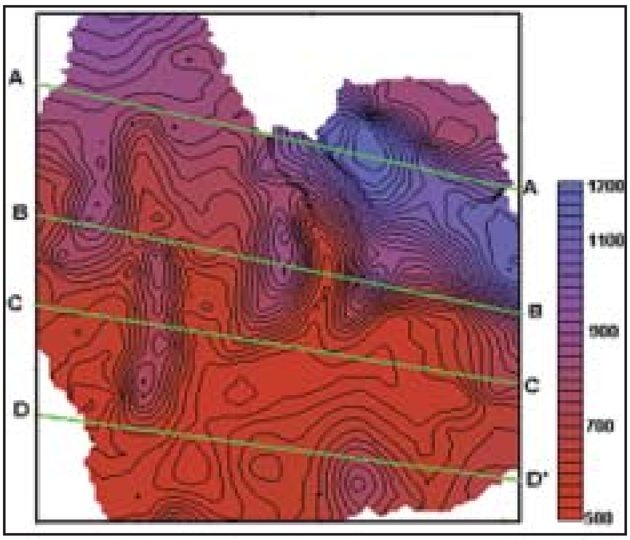

Fig. 2: Elevation map of the area

Palampur thrust to the east and Jwalamukhi thrust to the west. Elevation in the area ranges from 500m to 1100m. There is no seismic data in the area. Elevation map of the area is shown in Fig. 2 and Free-Air gravity anomaly map in Fig. 3.

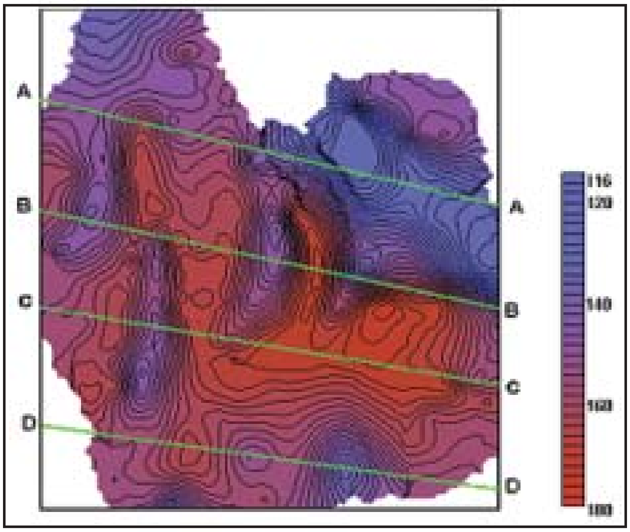

Fig. 3: Free-air gravity anomaly map of the area

Study in Tirasujanpur area

Bouguer anomaly maps of the area were prepared with a suite of density ranging from 2.0 gm/cc to 3.0 gm/cc in interval of 0.2 gm/cc. Bouguer anomaly map with ρ = 2.0,

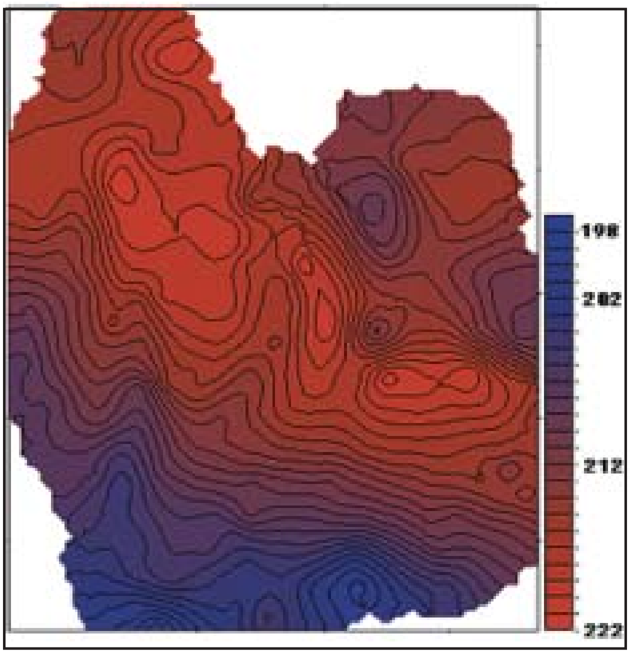

Fig. 4 : Bouguer anomaly map of the area with ρ= 2.0 gm/ cc

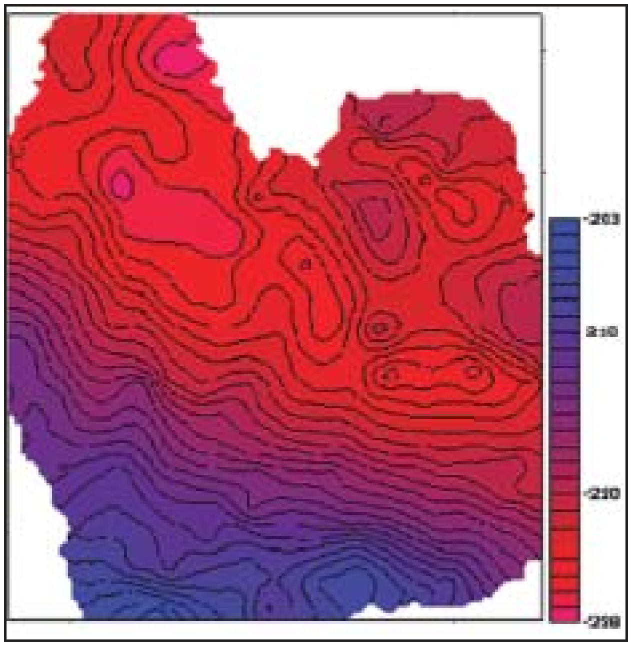

Fig. 5 : Bouguer anomaly map of the area with ρ= 2.2 gm/ cc

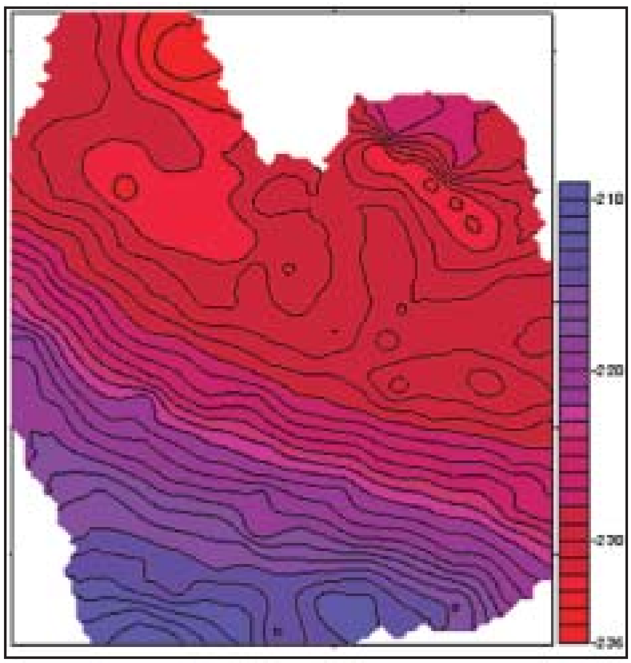

Fig. 6 : Bouguer anomaly map of the area with ρ=2.4 gm/cc

2.2, 2.4, 2.6, 2..8, gm/cc and ρ = 3.0 gm/cc are shown in Fig. 4 to Fig. 9 respectively. Comparing the Bouguer anomaly maps with elevation and free-air gravity anomaly maps it was found that least correlation between Bouguer anomaly and elevatio is observed around density 2.6gms/cc

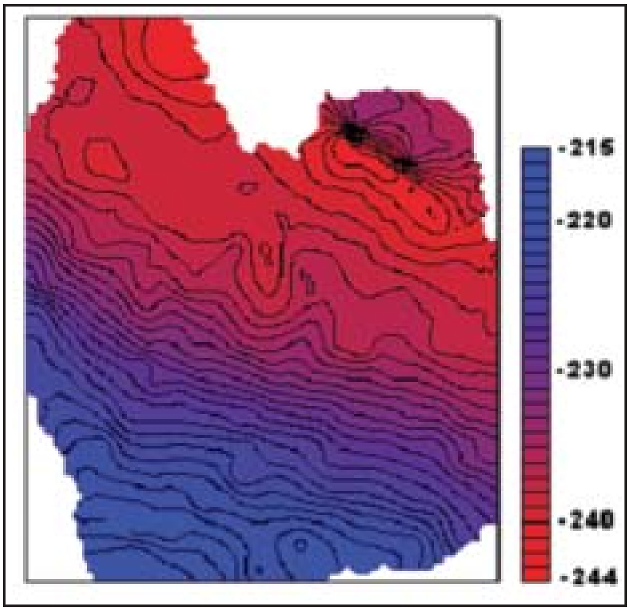

Fig. 7 : Bouguer anomaly map of the area with ρ=2.6 gm/cc

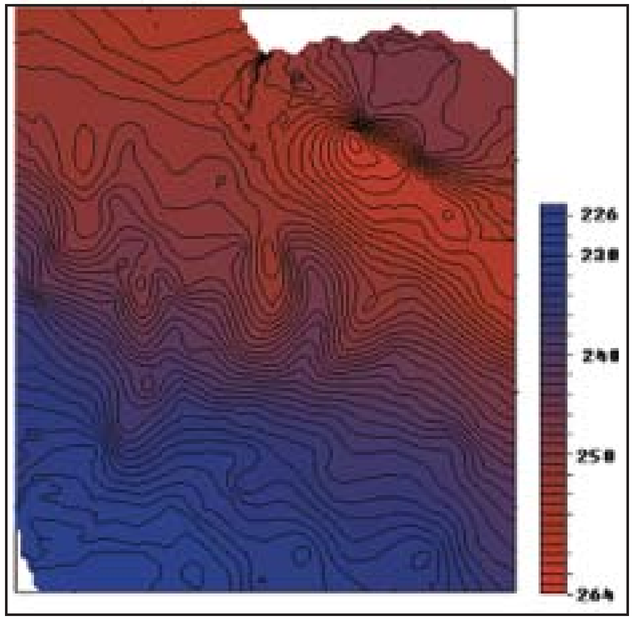

Fig. 9 : Bouguer anomaly map of the area with ρ=3.0 gm/cc

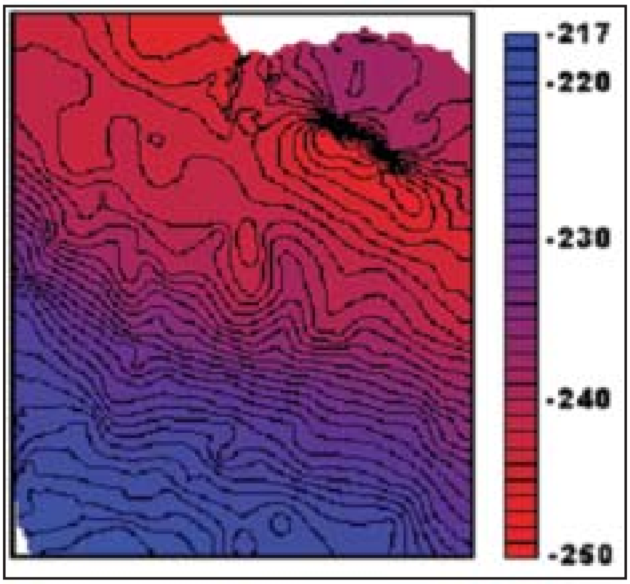

Fig. 8 : Bouguer anomaly map of the area with ρ=2.8 gm/cc

For better analysis, a few gravity profiles straddling important topographic features and having sufficient number of gravity observation points were generated. Four such profiles AA, BB, CC, and DD from north to south are shown in figure 2 and 3. Gravity anomalies along these profiles for various densities are shown in figure 10-13. It can be seen that for all the profiles Bouguer anomaly is the least correlatable with elevation or free air anomaly at density of 2.6 gm/cc after which Bouguer anomaly and elevation shows reverse correlation.

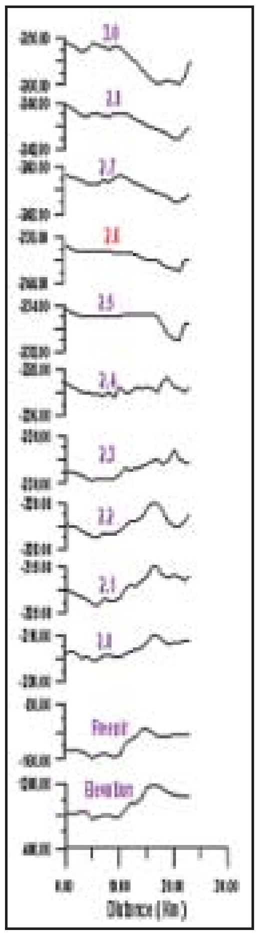

Fig. 10 : Profile AA

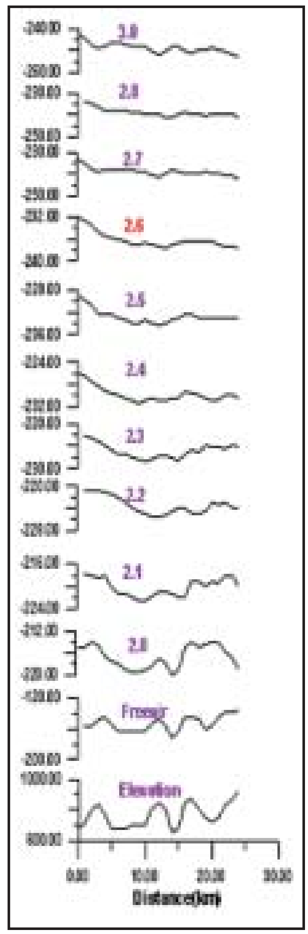

Fig. 11 : Profile BB

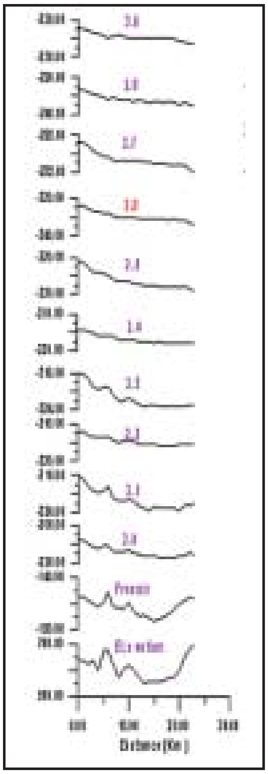

Fig. 12 : Profile CC

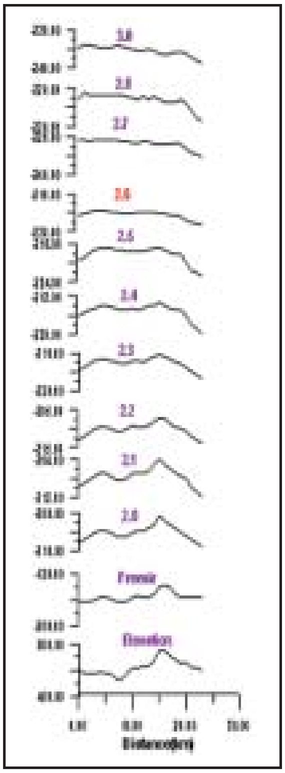

Fig. 13 : Profile DD

Conclusions

1. Indirect estimate of density for Bouguer anomaly computation is essential in the area because no density data either by surface profiling or measurement in bore hole is available.

2. Optimum density for Bouguer correction in the area is determined by indirect method by studying correlation between topography and Bouguer anomaly data. The optimum density in the area is 2.6 gm/cc.

Views expressed in this paper are that of the author only and may not necessarily be of ONGC.

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