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RESEARCH ARTICLE

Interpretation of gravity anomalies over the eighty-five East Ridge in the Bay of Bengal

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Abstract: Several profiles of the negative gravity anomaly over the submerged 85° E ridge in the Bay of Bengal of the Indian Ocean have been interpreted in two dimension and results are combined together to give a detailed picture of its morphology and thickness of surrounding sediments. The observed negative gravity anomaly has been explained as the combined effect due to the positive mass anomaly caused by the replacement of sediments by high dense igneous rocks of the ridge, and the negative mass anomaly caused by replacing the high dense upper mantle material by the oceanic crust, which has been bended and sunk into the upper mantle due to the pressure exerted by the ridge. Downward migration of the oceanic crust has been also calculated assuming that the oceanic crust is behaving as a thin infinite elastic plate resting on inviscid fluid half space and is found to closely agree with the results of the gravity study. Both studies indicate that the thickness of the ridge vary from 11 km to 16 km while the oceanic crust has undergone a depression of 9 km to 14 km.

Keywords: Bay of Bengal, eighty-five East Ridge, gravity anomaly, Indian Ocean, Sri Lanka.

INTRODUCTION

Interpretation of gravity anomalies provides a relatively inexpensive way of revealing the shallow crustal structure of the Earth. A gravity anomaly is a manifestation of mass anomalies inside the Earth. Low dense sediments in sedimentary basins surrounded by high dense country rocks give rise to negative anomalies, while high dense igneous intrusions emplaced in an environment of relatively low dense country rocks give rise to positive anomalies. Most of the gravity anomalies that we have observed adhere to this general principle. An apparent exception to this general principle can be observed along the 85° E longitude in the Bengal Fan in the Indian Ocean. Existence of a buried ridge known as 85° East Ridge of high dense volcanic material within the sediments in this region has been established by Curray and Moore (1971), and Moore *et al.* (1974).

One of the most prominent features of the satellite gravity anomaly map of the Indian Ocean east of Sri Lanka (Figure 1) is a series of elongated negative anomalies running over the region suspected to occupy the 85° E Ridge. This anomaly, which appears around 20° N in the northern Bay of Bengal continues as a near linear feature up to 5° N and then curves towards west and continues to do so up to 2° N. The length of the anomaly is about 1850 km and it covers an approximate area of 2×10^5 km^2. The intensity approximately varies from - 60 mGal to -15 mGal. The bathymetry of the region is generally smooth with a gentle north to south gradient, reflecting the northward increasing sediment thickness and southerly transport of the turbidities comprising the fan. A positive free air anomaly is expected to observe over the buried ridge reflecting high density of the ridge relative to surrounding sediments. However, as indicated above the satellite gravity anomaly depicted in Figure 1 shows a negative gravity anomaly over the region of the ridge. The only possible way to have a negative anomaly over the region is depression of the oceanic crust below the ridge due to the weight of the ridge replacing high

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dense upper mantle material by relatively low dense oceanic crust (Liu *et al*., 1982). Negative anomaly caused by this density difference may outweigh the positive anomaly resulting from the positive density contrast between the ridge and the sediments giving rise to the observed negative anomaly. In this study, this hypothesis has been tested by interpreting gravity anomalies over the ridge and also by studying the flexural deflection of the oceanic crust due to the pressure exerted by the ridge.

As explained above, gravity anomalies over the 85° E Ridge have two source regions. The first is the part of the ridge, which is buried inside low dense sediments and the second is the part of the oceanic crust, which has migrated downward into the high dense upper mantle due to the pressure exerted by the ridge. The first produces a positive anomaly while the second produces a negative anomaly. In this interpretation of gravity anomalies, both these sources have to be considered. Two dimensional interpretation of gravity anomalies is sufficient in this case as the anomaly is a linear feature indicating that it is due to a body with one horizontal dimension that is much larger than the other.

METHODOLOGY

A two dimensional interpretation of seven profiles (Figure 1) of satellite gravity anomalies over the 85° E Ridge has been carried out using the method of Talwani *et al*. (1959). In the interpretation it was assumed that the thickness of oceanic crust is 6.0 km and densities of seawater, oceanic sediments, oceanic crust and upper mantle are 1030 kgm^{-3}, 2100 kgm^{-3}, 2900 kgm^{-3} and 3300 kgm^{-3}, respectively (Woollard, 1959; Bott, 1982). Further, it was also assumed that there is a regional level of - 60 mGal over the 85° E Ridge in the Bay of Bengal.

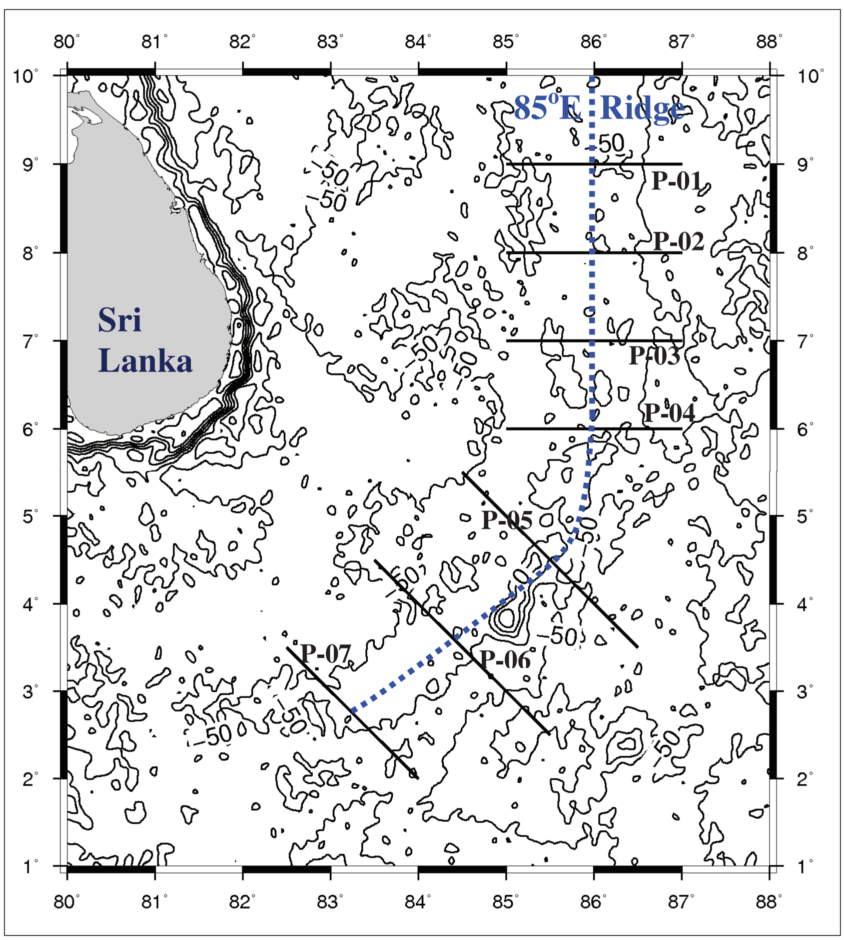

Figure 1: Gravity anomalies in mGal over the 85° E Ridge. Line segments give the position of the gravity profiles interpreted

Downward migration of the oceanic crust due to the pressure distribution acting on the 85° E Ridge has also been derived following a method similar to Liu *et al.* (1982). In this derivation it has been assumed that the oceanic crust is behaving as a thin infinite elastic plate resting on inviscid fluid half space. Downward migration z(*x, y*) of an elastic plate due to a pressure distribution of *p*(*x, y*) can be written as (Liu *et al*., 1982),

$$D\left(\frac{\partial^4 z}{\partial x^4}+\frac{\partial^4 z}{\partial y^4}\right)=p(x,y)$$

where, D is the flexural rigidity of the oceanic crust, which is a measure of its resistance to bending. The following expression for z(*x, y*) can be obtained by solving the equation using Fourier transforms,

$$z(x,y)=F^{-1}\left[\frac{-(\rho_c-\rho_w)H(k_x,k_y)-(\rho_s-\rho_w)S(k_x,k_y)}{\left\{\frac{D}{g}k^4+(\rho_m-\rho_c)\right\}}\right]$$

where, $S(k_x,k_y)$ is the Fourier transform of the thickness of sediments, $H(k_x,k_y)$ is the Fourier transform of the topography of the ridge, *k* is the wave number and ρ_w, ρ_s, ρ_c and ρ_m are the densities of seawater, oceanic sediments, oceanic crust and upper mantle, respectively. Details of the derivation can be found in Tantrigoda (2004) and Fernando (2005).

RESULTS AND DISCUSSION

A gravity anomaly map and bathymetry map over the 85° E Ridge is given in Figures 2 and 3, respectively. Results of the interpretation of gravity profiles over the ridge are depicted in Figures 4 and 5. Maps of depression of the lower layer of the oceanic crust and sediment thickness have been compiled combining the information given in the above figures (Figures 6 and 7, respectively). In the contour map, variations of sediment thickness far away from the ridge, which are of the order of 200 m have been ignored to enhance its clarity. Flexural deflection of the lower surface of the oceanic crust has been depicted in Figure 8 using a 3-D surface map and a contour map.

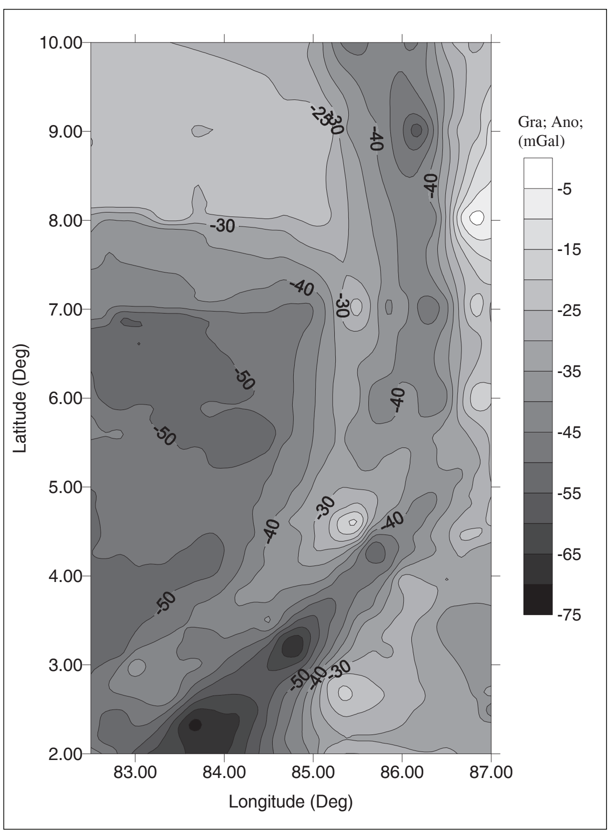

Figure 2: Free air gravity anomaly map over the 85° E Ridge and the surrounding area. Contours in intervals of 5 mGal

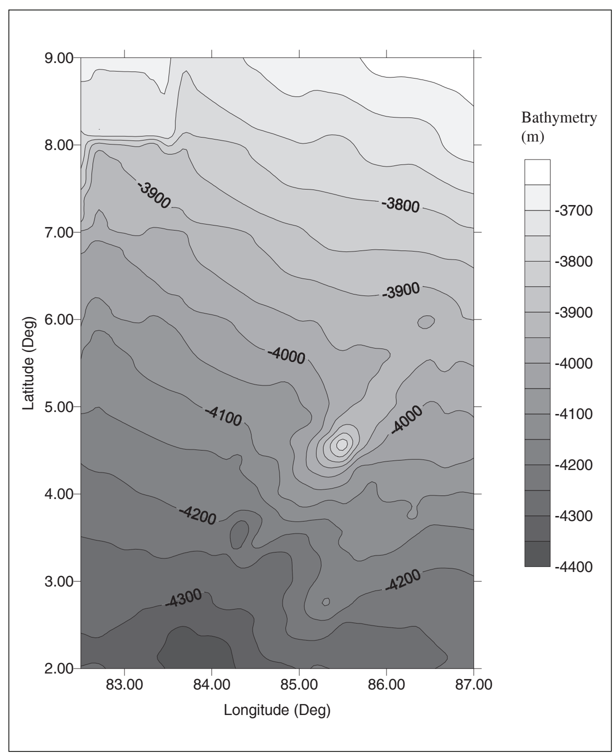

Figure 3: Bathymetry map over the 85° E Ridge and the surrounding area. Contours in intervals of 50 m

An isopach map over the 85°E Ridge has been compiled using the results of two-dimensional interpretation of seven profiles of satellite gravity anomalies (Figure 1). As can be seen from this map, sediment thickness over the ridge at the extreme north is very low and is about 200 m. It goes up to about 3 km within a short distance of 50 km along the profile.

Isopach map compiled in this study closely agrees with the isopach map compiled by Levchenko *et al.* (1993) based on seismic studies. This ridge may have influenced the sediment distribution around Sri Lanka. There is a crescent shaped rich sediment distribution, which has a thickness in the order of 2.0 – 3.0 km. The 85° E Ridge may have blocked the free flow of sediments forcing them to get accumulated around Sri Lanka.

Normally, most of the oceanic ridges produce positive gravity anomalies (Bott, 1982). A good example for this is the 90° E ridge (Mukhopadhyay & Krishna, 1994) situated close to the 85° E ridge. This is because the outcropping part of a ridge, buried in low dense sediments gives rise to a positive anomaly due to the positive density contrast between the sediments and

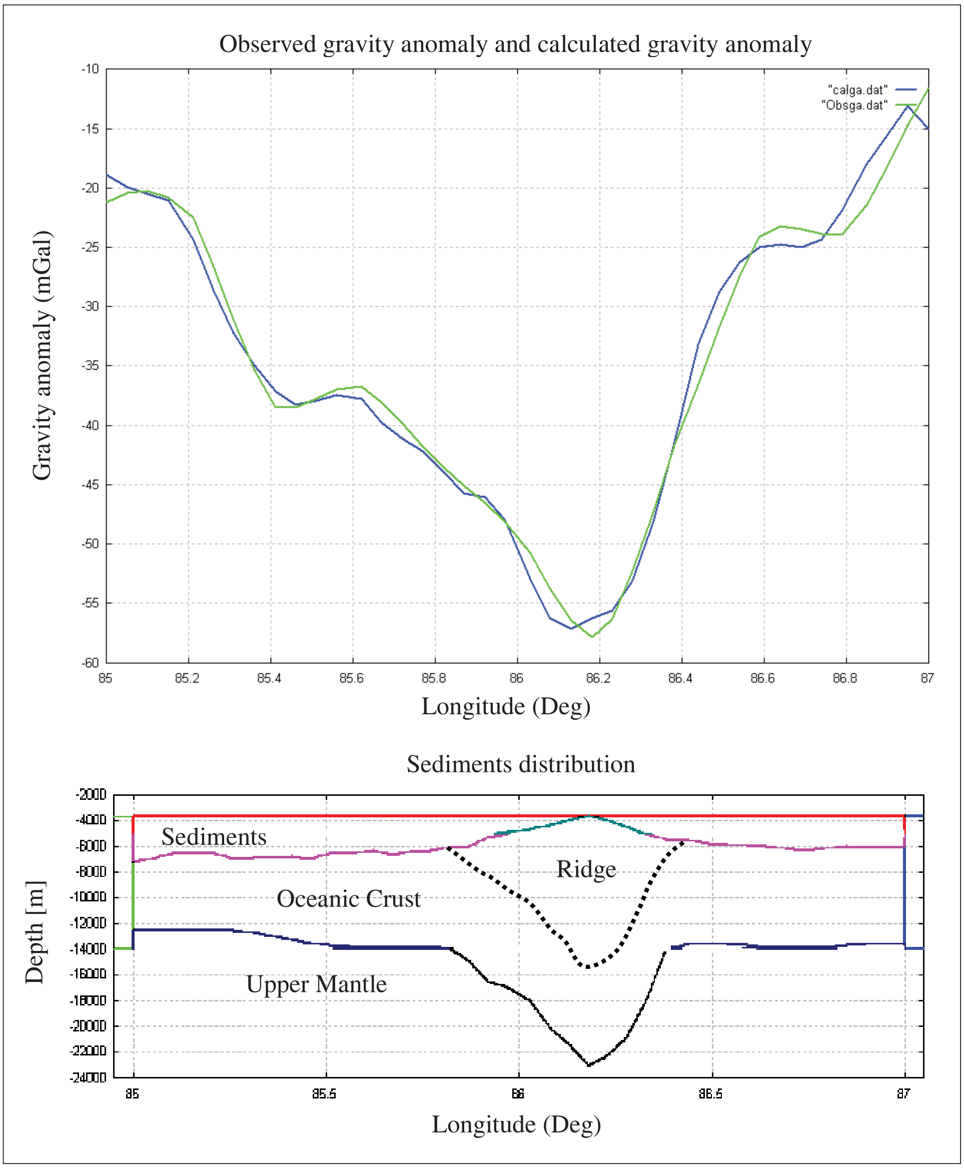

Figure 4: Interpretation of the profile P-01 of Figure 1

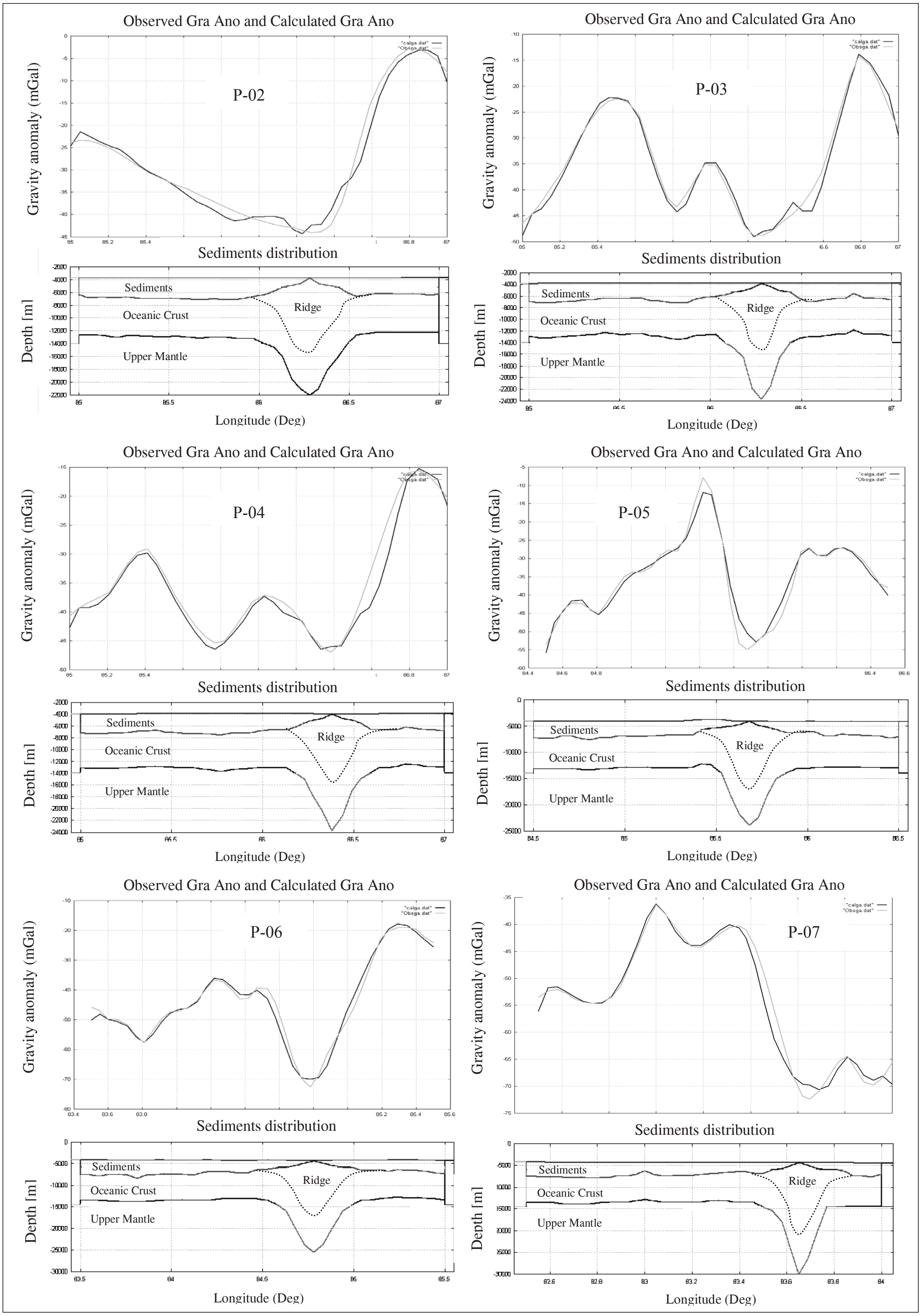

Figure 5: Interpretation of profiles P-02 to P-07 of Figure 1

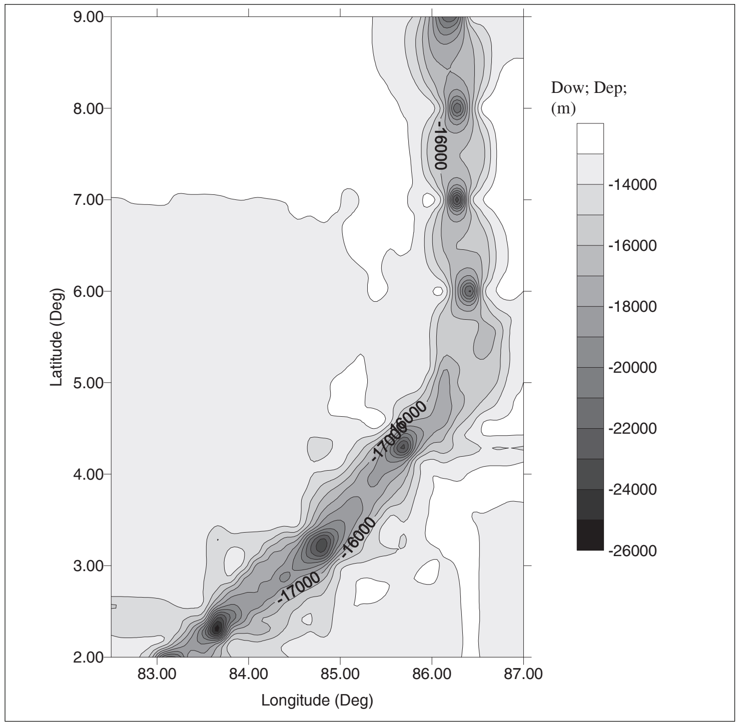

Figure 6: Map of downward depression of the lower layer of the oceanic crust over the 85° E ridge and the surrounding area. Contours in intervals of 1000 m

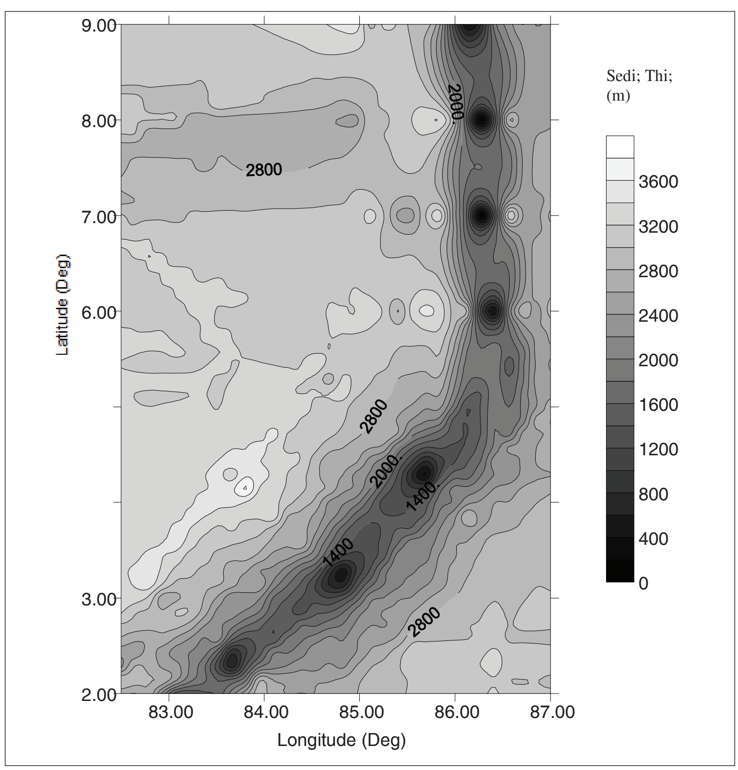

Figure 7: Map of sediment thickness over the 85° E ridge and the surrounding area. Contours in intervals of 200 m

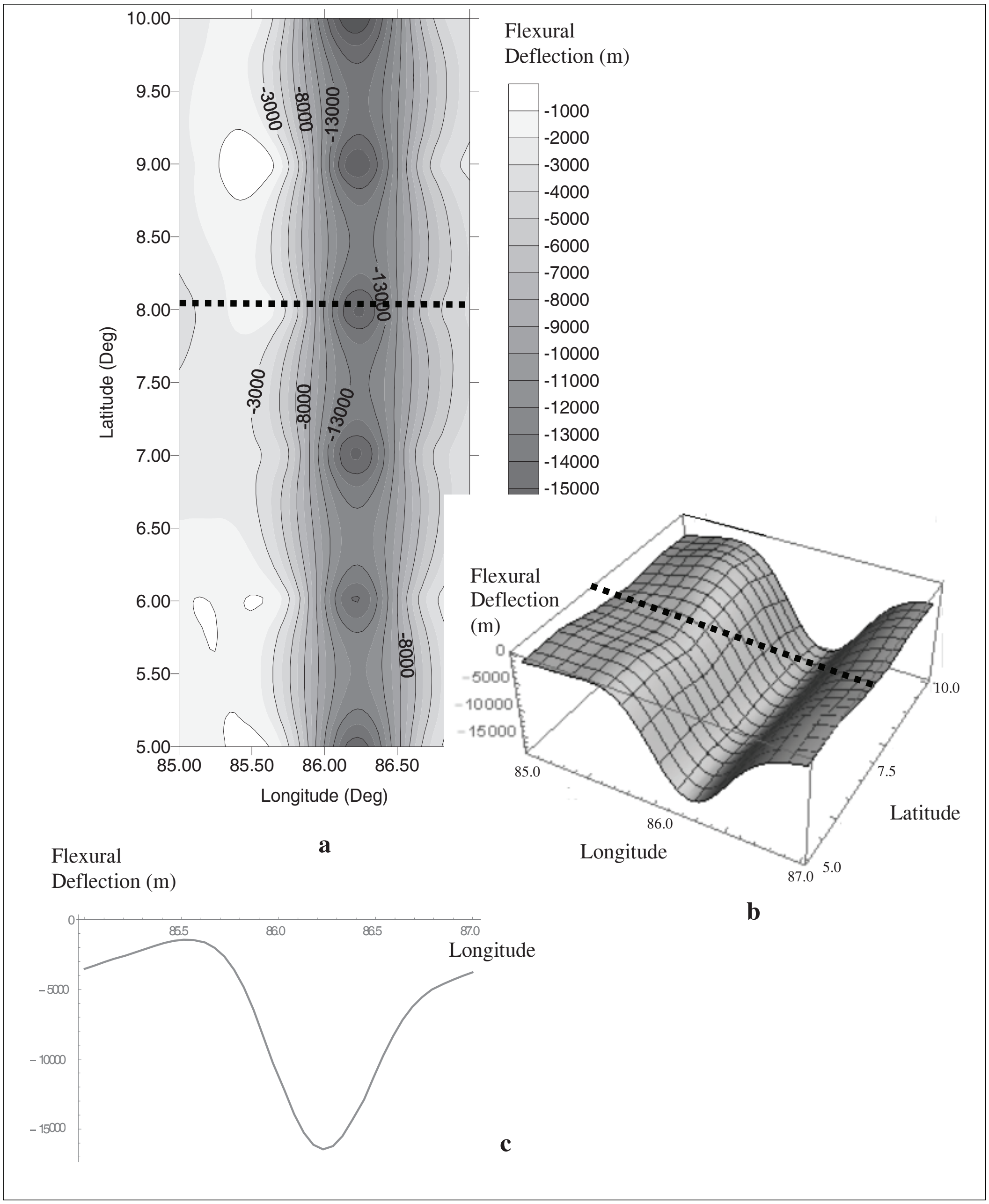

Figure 8: Downward deflection of oceanic crust below the 85^o E ridge when flexural rigidity of the oceanic crust is 1.8×10^{21} Nm (a : contour map; b : 3D map and c : cross section along 8^o latitude)

material of the ridge, which have a density more or less equal to that of the oceanic crust. It has been revealed in the gravity interpretation that oceanic crust has sharply migrated downward replacing high dense upper mantle material by low dense material of the ridge. As seen in Figure 8, the oceanic crust bends down as much as 9 – 14 km due to the pressure exerted by the ridge producing an intense negative gravity anomaly. This negative anomaly outweighs the positive anomaly due to the part of the ridge buried in the sediments making the resultant anomaly negative.

The downward migration of the oceanic crust below the ridge was also calculated using elastic properties of the oceanic crust approximating the oceanic crust to a very thin plate lying on a viscoelastic fluid. It has been also assumed that the region under investigation has reached vertical equilibrium by the combined effect of upthrust on the root of the seamount and support of stresses within the lithosphere.

CONCLUSION

The thickness of the 85° E ridge varies from 11 km to 16 km. The oceanic crust has undergone a depression of 9 to 14 km as a result of the pressure exerted on the oceanic crust by the ridge. The negative gravity anomaly observed over the 85° E ridge can be explained as a result of negative anomaly caused by replacement of high dense upper mantle material by downward migrated low dense oceanic crust, which exceeds the positive anomaly caused by igneous rocks of the ridge intruded into the oceanic sediments.

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