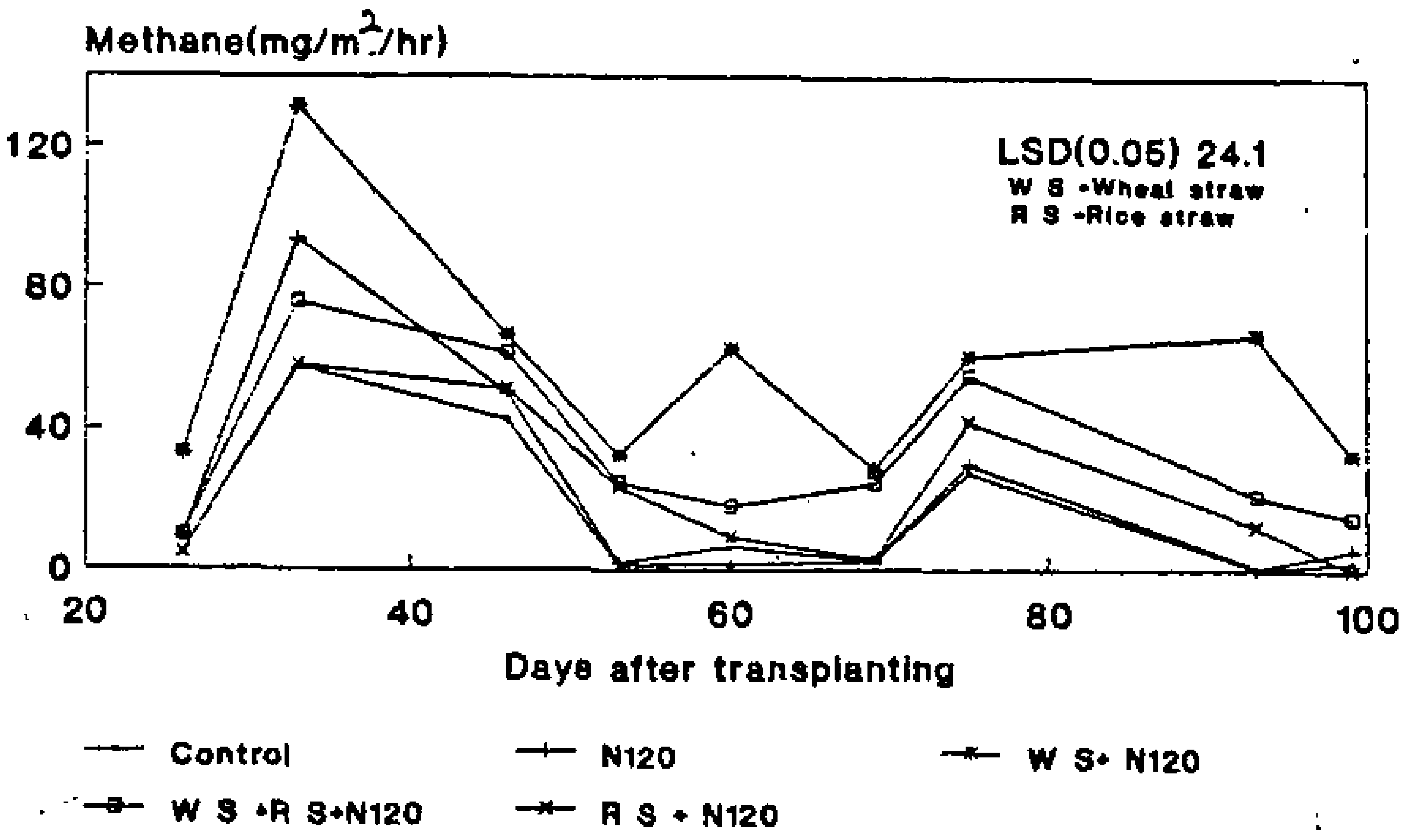

Figure 1. Methane emission as affected by different residues management practices.

Methane emission during the rice growing season was highest twice during investigation, forming two peaks in most of the treatments (Figure 1). But the treatment with 8 t wheat straw ha^{-1} showed three peaks. The first peak was observed in June, 2nd peak in middle of July and 3rd in August by Yagi and Minami[7], but in the present studies first peak was observed in the middle of July. The first methane peak may be due to the enhanced availability of root exudates and development of root gas transport system[8,9], but the present investigations were carried out at the site under rice–wheat rotation where the rice and wheat residues have been managed and obviously making more availability of carbon substrate to anaerobes for maximizing methane production. Addition of straws to the flooded rice paddies has shown dramatic increase in methane emission with type, quantum and pattern of residues incorporated into the soil. This has also been observed by other investigators[8,10]. The second peak may be due to the decay of roots besides the remaining residue sources.

Methane emission rates ranged between –0.20 and 66 mg m^{-2} h^{-1} in kharif season[3], and the methane emission was 80 mg m^{-2} h^{-1} in the green leaf manure treatment[11]. In the present studies, control plots emitted methane @ 15.7 mg m^{-2} h^{-1} and in the treatments where different residues were incorporated at different rates and blends, it was in the range of 24.1 to 57.3 mg m^{-2} h^{-1}.

As is evident, methane emissions in most of the treatments were maximum in the first half of the growing season in Punjab. Some workers have assumed that active methane emission occurred during a 15-day period[12], while others have assumed 30 days[13] for calculating total methane emission from the area. Our study suggests that such assumptions are not appropriate. Methane emission varies with sites and different treatments are needed to be taken care of while computing total methane emission of the area. Further recycling of crop residues for substitution of nutritional requirements, and also inorganic fertilizer are needed to be evaluated for the methane production, so that emission of methane to the atmosphere is regulated, if not completely ceased.

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Layering of the Earth's crust and upper mantle – An evidence from gravity anomalies over India

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Studies on the propagation of seismic waves revealed that the Earth, in general, possesses a layered structure; the boundaries between successive layers being characterized by abrupt changes in seismic wave velocities and hence the densities. Local variations in the depths of these discontinuities, among other things, produce gravity anomalies whose wavelengths are dependent on their depths from the surface of the earth. Spectral analysis is a powerful tool to find the ensemble average depths of horizontal (approximately) boundaries between rock units of different

densities and has been used to analyse the gravity anomalies over India. The results show that the average depths of density interfaces beneath the Indian subcontinent are 17, 32 and 115 km corresponding to the boundary between the upper and the lower crust, the Moho, and the top of the low velocity zone respectively.

SEISMOLOGICAL evidences reveal that the Earth possesses a layered structure, mainly divided as the crust, mantle and core, differing from one another either in composition or physical state or both. The continental crust, whose average thickness is about 35 km is highly inhomogeneous and can be divided broadly into two parts: the upper and the lower. The Upper crust contains igneous/sedimentary/metamorphic rocks on the surface overlying the rocks mainly composed of felsic minerals. The boundary between the upper and the lower crust, usually referred to as the Conrad discontinuity, is characterized by an increase in seismic wave velocity. There is an abrupt change of seismic wave velocity at the Moho, the boundary between the crust and the mantle. The velocity of compressional seismic waves increases from about 6.8 km/s in the crust to about 8.1 km/s in the upper mantle. This change in seismic velocity is largely caused by a change in the composition of the medium. The mantle, extending up to a depth of 2900 km is solid. But within this, there is a relatively thin zone ranging from about 100 km below the surface to about 250 km, where the velocities of both P and S waves decrease, signifying partial melting of rock material. This zone is called the low velocity zone. The *p*-wave velocity changes significantly yet again at depths of 400 km and 650 km below the surface.

Laboratory studies of seismic wave velocities and densities of a variety of rock samples[1] revealed that the density of rocks normally increases along with the seismic wave velocity. Seismological studies over various parts of the earth also reveal that the depth of these discontinuities varies over a wide range from place to place on a global scale. These discontinuities which are also characterized by abrupt changes in density produce gravity anomalies of varying and usually large wavelengths which can be seen on maps of continental sizes. Spectral analysis is one way of identifying these anomalies of various wavelengths and is useful to deduce the average ensemble depths of interfaces from gravity and magnetic anomalies[2]. Based on this philosophy, an attempt has been made here to identify the density discontinuities in the crust and upper mantle beneath India from the spectral analysis of Bouguer gravity anomalies over India.

The Bouguer anomaly map of India[3] (Figure 1), which is based on over 31,000 gravity observations, has been interpreted in detail by various workers[4-6] to understand the relation of gravity with surface/subsurface geology and structure. In general, the Bouguer anomalies over India vary over wide limits; from about 75 mGal near Bombay to a value less than –375 mGal in the greater Himalayas. In general, gravity anomalies correlate well with the major geological and structural provinces of the Indian land mass.

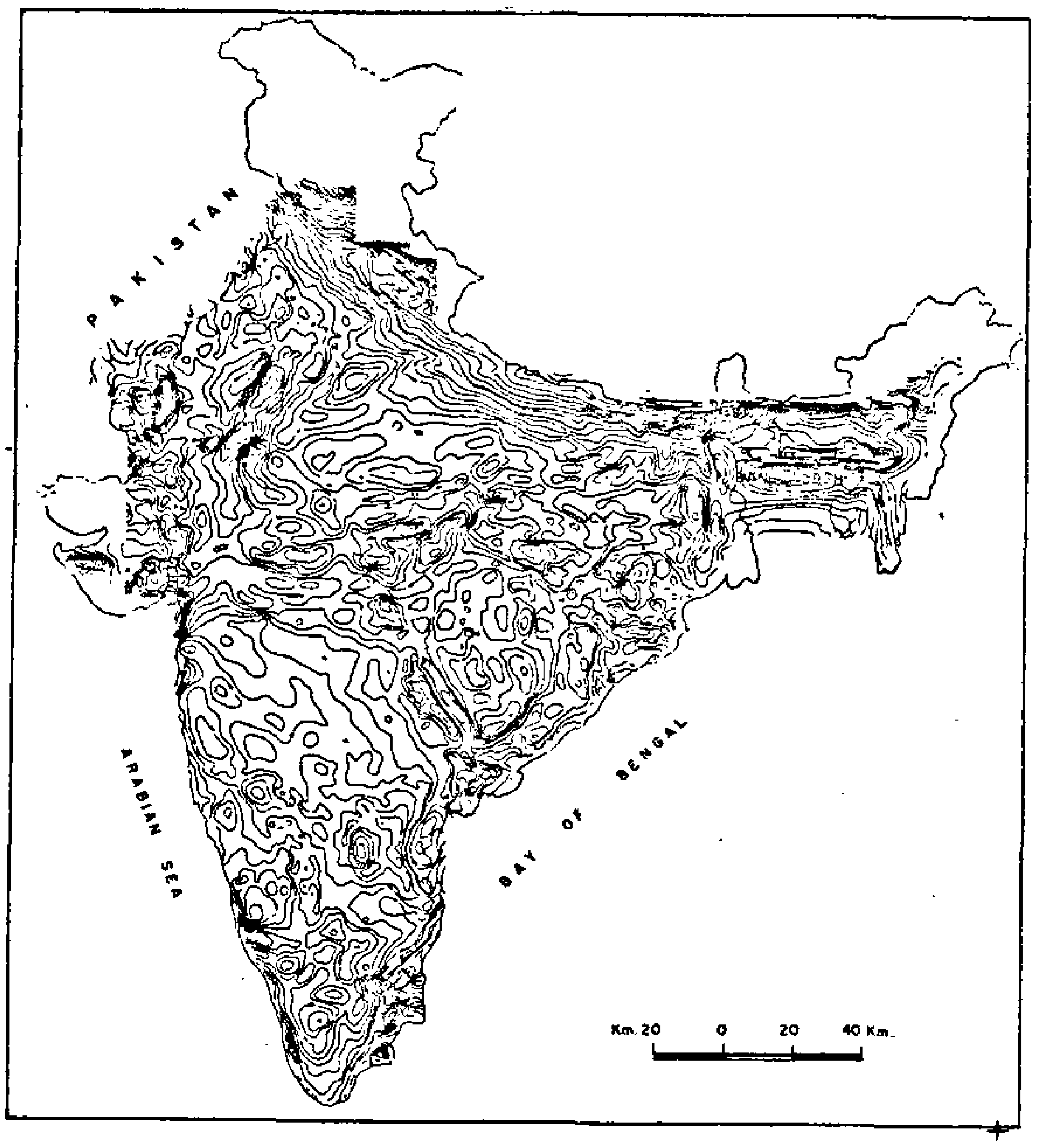

Figure 1. Bouguer anomaly map of India (after NGRI, 1975).

For the present study, the gravity anomalies have been digitized on a regular square grid of size 20 km and its 2-D FFT has been computed from a computer interpolated fine grid of size 2.5 km by using the MAGMAP[7] software. The maximum length of the data in north-south and east-west directions is about 2500 km. The radial spectrum (Figure 2) in which the log-amplitude of anomalies for various wavelengths are presented shows that the amplitudes in certain range of frequencies follow straight line segments. This indicates a change in the density of the subsurface; the depth of the boundary at which this change takes place is obtained from the slope of the straight line segment[2]. The radial spectrum presented in Figure 2 can be split into four line segments, giving four levels of density interfaces located at average depths of 17 km, 32 km, 58 km and 115 km.

To test the reliability of the spectral depth estimates, the radial spectrum was computed again by corrupting the data set with a noise level of ±5% which is approximately equal to the accuracy of the data set. The inclusion of noise did not change the overall characteristics of the spectrum but resulted in small changes in average depths which do not deviate more than ±4%. The line segments are defined by a large number of data points in the spectrum and the accuracy of estimated depth is within ±4%. The gravity anomalies due to sedimentary

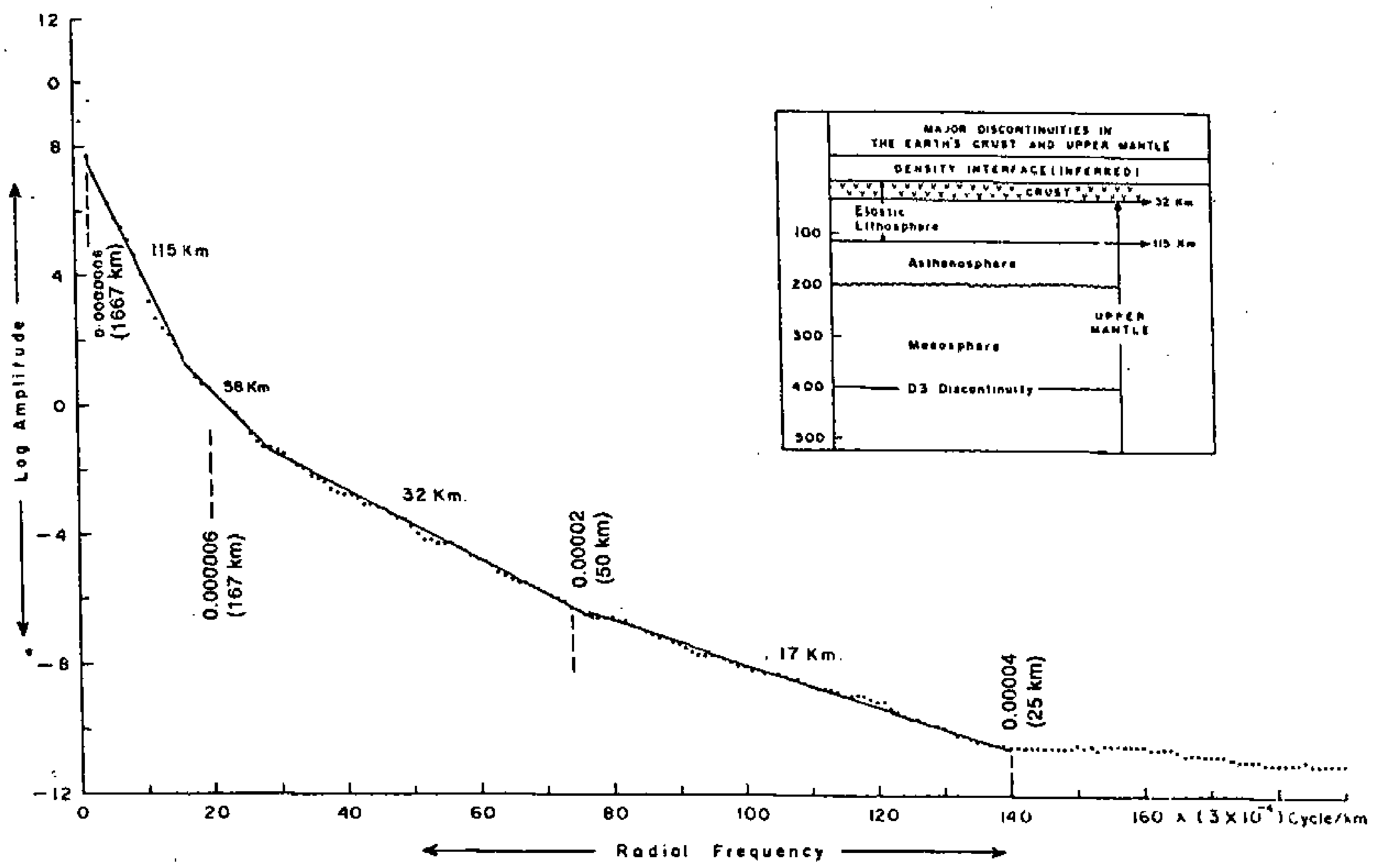

Figure 2. Radial spectrum of Figure 1. Inset shows a direct comparison of layers determined from seismological data with those obtained from the analysis of gravity data.

basins, rift valleys, granite massifs, etc. are of limited size when compared to the overall size of the study area. Moreover, these outcropping (zero depth) features appear to be represented as white noise in the spectrum. The average depth of interfaces obtained from this analysis can be attributed to the globally recognized seismic discontinuities (inset of Figure 2) situated at depths of 17 km (between the upper and the lower crust); 32 km and 58 km (Moho); and 115 km (top of low velocity layer). The interface located at an average depth of 58 km given by the second line segment does not correspond to any discontinuity that is recognized globally. However, a considerable part of the Himalayan foothills is covered by the gravity data where the crustal thickness exceeds 50 km. Therefore, this interface at 58 km depth might correspond to the average depth of the Moho in the sub-Himalayan region covering this data set. .

The spectral analysis of gravity data revealed the presence of four density interfaces in the crust and upper mantle zone beneath India. As there is close correspondence between gravity interfaces and seismic discontinuities, the present analysis also serves as direct evidence for the variation of density at these boundaries in addition to a change in the seismic wave velocity.

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Quaternary palaeolakes in Kumaun Lesser Himalaya: Finds of neotectonic and palaeoclimatic significance

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Movements in the geologically recent time on the North Almora Thrust; South Almora Thrust; on related subsidiary thrusts and faults caused blockade of the river Kosi west of Almora and of the Thuli Gad east of Pithoragarh in the Kumaun Lesser Himalaya. The fault movements resulted in the formation of lakes that have since vanished due to revival of neotectonic movements. Stretching more than 7 km in length, these palaeolakes are presumably the