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Upper Mantle Structure in and around the Indian sub-continent (from *S*-waves)

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ABSTRACT. Upper Mantle Structure of the Indian sub-continent has been studied from the *S*-wave observations of shallow focus earthquakes, using $T-\triangle$ method. The *S*-wave velocity below the Mohorovicic discontinuity is found to be 4·54 km/sec, whereas this seems to be lesser under Himalayas. The depth of the top of the low velocity layer in the Upper Mantle is found to be about 140 km and its thickness about 50 km. *S*-wave velocity increase with depth from the Mohorovicic discontinuity to the top of the low velocity layer has been observed. A steep velocity gradient below the low velocity layer has also been observed. Lehman's model for the continental Upper Mantle has been fitted with the observations and its deviations discussed.

1. Introduction

Several studies relating to the Upper Mantle structure of the continents and oceans, notably by Gutenberg (1948, 1954, 1959a, 1959b), Dorman *et al.* (1960), Lehman (1961), Aki and Press (1961), Dowling and Nuttli (1964), have been made from body as well as surface waves data. Various standard models of the upper mantle structure for continental and oceanic regions have been suggested by Gutenberg (1953), Lehman (1955, 1961), and Dorman *et al.* (1960). Existence of the low velocity layer in the upper mantle, hitherto, controversial but gaining strong support in many studies of Gutenberg, has been concluded and the effects of mountains and oceanic regions have been studied extensively. Tandon (1967) investigated the upper mantle structure of Hindu Kush region from the data of earthquakes having different depths of focus. He utilised the Guntenberg's method of velocity determination and obtained the velocity distribution for both *P* and *S*-waves. The depth of the top of the low velocity layer was found to be about 160 km by the author (Dube 1969) while studying the upper mantle structure of the Indian sub-continent from *P*-wave observations of shallow focus origins observed a strong evidence for the low velocity layer. The present investigation is also an attempt to study the Upper Mantle structure of the sub-continent from the *S*-wave observations of shallow focus earthquakes.

2. Data and method of analysis

The *S*-wave study was made for the same seventy earthquakes as were used in the *P*-wave study (Dube 1969). The division of the shocks into two groups (Gr. I and II), originating north and south of the Himalayas and the analysis of the results are identical to those in the *P*-wave study.

3. Results

The analysis gave the following results, upto $\triangle = 10$ degrees.

$$T = 24\cdot47 \triangle + 10\cdot02 \quad (1) \quad \text{for Group I}$$

$$T = 24\cdot57 \triangle + 10\cdot92 \quad (2) \quad \text{for Group II,}$$

indicating *S*-wave velocity of $4\cdot54 \pm 0\cdot01$ km/sec and 4·52 km/sec respectively for the region south of the Himalayas and to the north. They thus clearly bring out the effect of the mountains, the higher intercept time of 10·92 sec as against 10·02 sec pointing to the deeper Mohorovicic Discontinuity to the north—the mountain root propounded by Airy (1855).

The results are also shown in Figs. 1 and 2. A scrutiny of these shows the presence of a discontinuity in the *S*-wave travel time curve around 11-degree distance, the same as was found for the *P*-waves. The plot of reduced travel times shown in Fig. 3 brings out the above discontinuity more clearly.

4. Interpretation and Discussion

The results presented in the preceding section seen in the light of the calculated curves of Dowling and Nuttli (1964) and the earlier *P*-waves result (Dube 1969) confirm the presence of a low velocity in the upper mantle. The identical distance $\triangle = 11$ degrees when the discontinuity occurs in both the *P* and *S*-wave travel times additionally points out to the same depth of the layer for *S*-waves as for

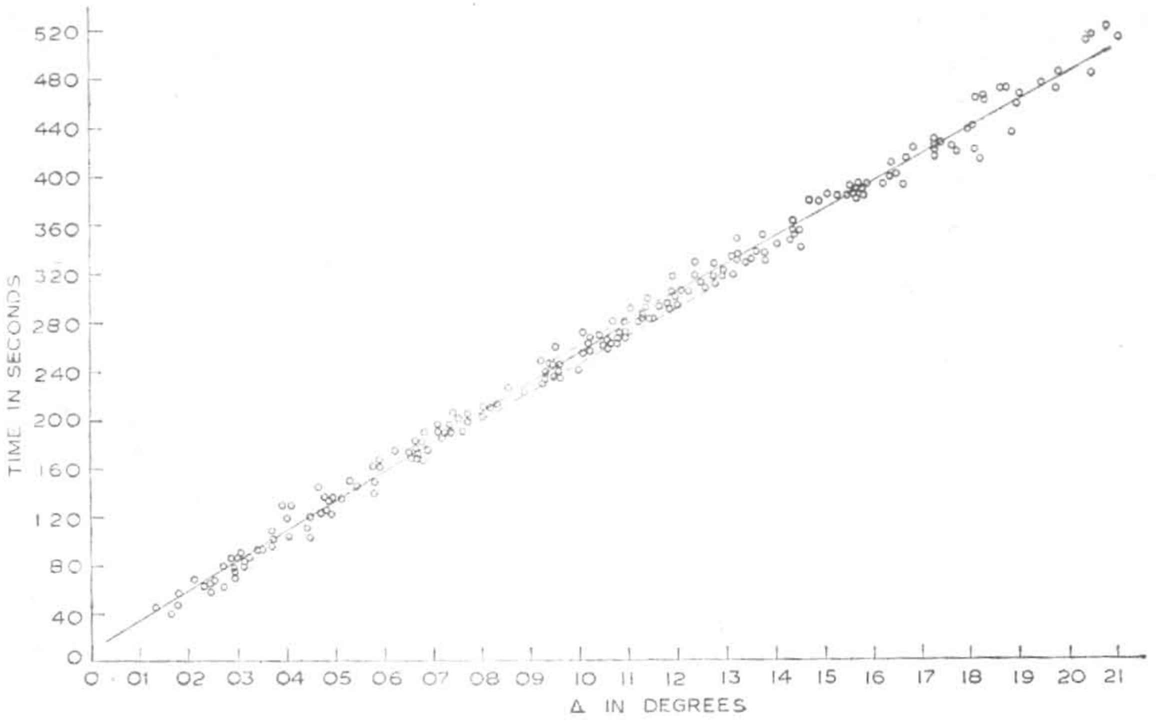

Fig. 1. T-$\triangle$ curve for S-waves (as in Group I)

P-waves. The overlapping of the two branches of the travel time curve also shows that below the low velocity layer the velocity gradient is steep.

Lehman (1961) has prepared a model for the upper mantle under continents for S-waves. This model consists of a crust 35-km thick with S-velocity of 3·55 km/sec, over the mantle when the velocity changed from 4·60 km/sec to 4·65 km/sec upto a depth of 120 km. In the low velocity layer the S-wave velocity is 4·30 km/sec and below it, it increases to 4·70 km/sec. The results of the present study have been compared with the travel-time for Lehman's model in Fig. 4. The observed points fit satisfactorily on the Sd branch in the distance range between 3 and 9·5 degrees but lie well below it between 10·3 and 11 degrees. An abrupt increase to higher values at a distance of 11 degrees is also clearly seen. Further the observed points lie below the model curve at larger distances. From these it can be concluded that the Upper Mantle velocity distance for S-waves in the area of study is more or less similar to Lehman's model for depth ranges of 10 degrees. Higher velocities than in the model are likely for depth ranges 10·3 to 11 degrees. The earlier observed arrivals at the larger distances could be due to higher velocities than in the model both in and below the low velocity layer. Tandon (1967) got the depth of the low velocity layer in the Hindu Kush region as 160 km and the minimum velocity 4·4 km/sec which are both higher than in Lehman's model. This also supports the conlusions mentioned earlier.

5. Summary and Conclusions

(1) The velocity of S-waves just below the Mohorovicic discontinuity of the Indian sub-continent is 4·54 km/sec, but it increases with depth upto the top of the low velocity channel. Slightly lower velocity has been obtained beneath Himalayas.

(2) The presence of a low velocity layer for S-waves in the Upper Mantle has been clearly indicated, the depth of the top of which appears to correspond to the maximum depth penetrated by ray emerging at an epicentral distance of 11 degrees.

(3) The almost identical similarity of the T—$\triangle$ curve of the S-waves to that of P-waves suggests for the Upper Mantle structure for S-waves to be similar to that of P-waves. Therefore, the depth of the top of the low velocity layer and its thickness can safely be taken to be about 140 km and 50 km respectively. A strong velocity gradient, below the channel is also indicated because of the overlapping of the two branches.

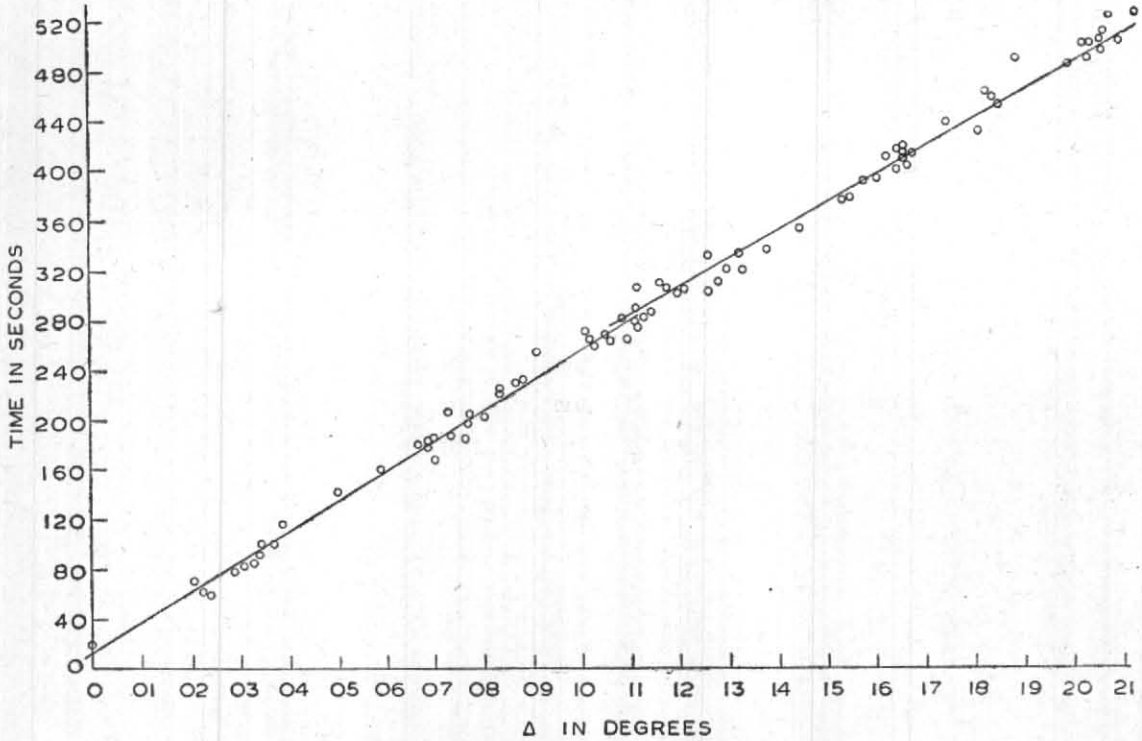

Fig. 2. $T-\triangle$ **curve for** S**-waves (as in Group II)**

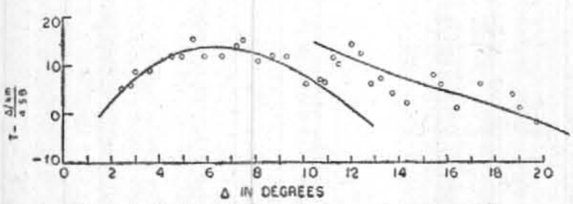

Fig. 3. Reduced travel times for S**-waves**

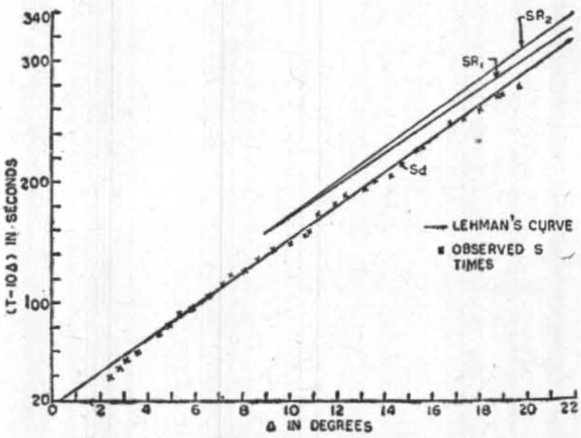

Fig. 4. Reduced travel times for S**-waves and Lehman's (1961) model curve**

(4) There appears to be a deviation as regards the depth of the top of the low velocity layer, its thickness and the velocity distribution in the channel and below from the Lehman's model of the Upper Mantle structure.

A similar study from deep focus earthquakes data is also under progress.

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