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Crustal structure in southern and central West Bengal using deep seismic sounding explosion data

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सार – स्रोत (रसायन विस्फोट) के स्थान और आरंभ होने के समय के तथ्य के उपलब्ध होने की स्थिति में गहन भूकंपी परिज्ञापित (डी.एस.एस.) आँकडें किसी निश्चित क्षेत्र की भूपृष्ठीय संरचना के ठीक–ठीक से प्रस्तुत करने के अच्छे अवसर प्रदान करता है। भारत मौसम विज्ञान विभाग 1970 के प्रारंभ से ही इस प्रकार के सर्वेक्षण कर रहा है। इस शोध–पत्र में 1987 से 1990 के दौरान किए गए डी.एस.एस. क्षेत्र के तीन सर्वेक्षणों से दक्षिणी और मध्य पश्चिम बंगाल में पर्पटी के ऊपरी भाग में भूकंपीय तरंग वेगों को आकलित किया गया है। इन आँकडों के विश्लेषण से यह पता चला है कि इस क्षेत्र की तलछटी सतह में मुख्यतः दो सतहें होती है। पहली सतह की मोटाई, 2.85 से 2.88 कि.मी. / सें. का पी. तंरग वेग और 1.71 से 1.77 कि.मी. / सें. के एस–तरंग वेग के साथ 1.25 से 1.49 कि.मी. है। धरातल तरंग आँकड़ों से यह ज्ञात होता है कि बर्दवान के निकट तलछटी सतह में सबसे ऊपर 250 मी. की मोटाई की सतह महीन कम वेग की होती है। सबसे निचली तलछटी सतह की मोटाई 2.32 कि.मी. से 3.73 कि.मी से दक्षिण की ओर बढ़ती है – इस सतह में पी.–तरंग वेग 3.9 से 4.1 कि.मी / से. के बीच है। तलछटी सतहों पर 5.73 से 5.83 कि.मी. / से. की पी.–तरंग वेग के साथ ग्रेनाइटी सतहें ऊपरी फैली होती है।

ABSTRACT. Deep seismic sounding (DSS) data provides an excellent opportunity to accurately delineate the crustal structure of a given region owing to the fact that the location and origin time of the source (Chemical explosion) are available. India Meteorological Department is carrying out such surveys since early 1970's. In this paper. seismic wave velocities in the upper part of the crust in southern and central West Bengal are estimated from three DSS field surveys conducted during 1987-1990. From the analysis of the data it is noted that the sedimentary layer in the region consists of mainly two layers. The first layer is of thickness 1.25 to 1.49 km with P wave velocity of 2.85 to 2.88 km/s and S-wave velocity of 1.71 to 1.77 km/s. Surface wave data show that near Burdwan, the sedimentary layer includes a thin low velocity layer of thickness 250 m at the top. The thickness of lowest sedimentary layer increases southward from 2.32 km to 3.73 km : in this layer the P-wave velocity is between 3.9 & 4.1 km/s. The sedimentary layers are overlying a granitic layer with P- wave velocity of 5.73 to 5.83 km/s.

Key words – Deep seismic sounding, P-wave, S-wave.

1. Introduction

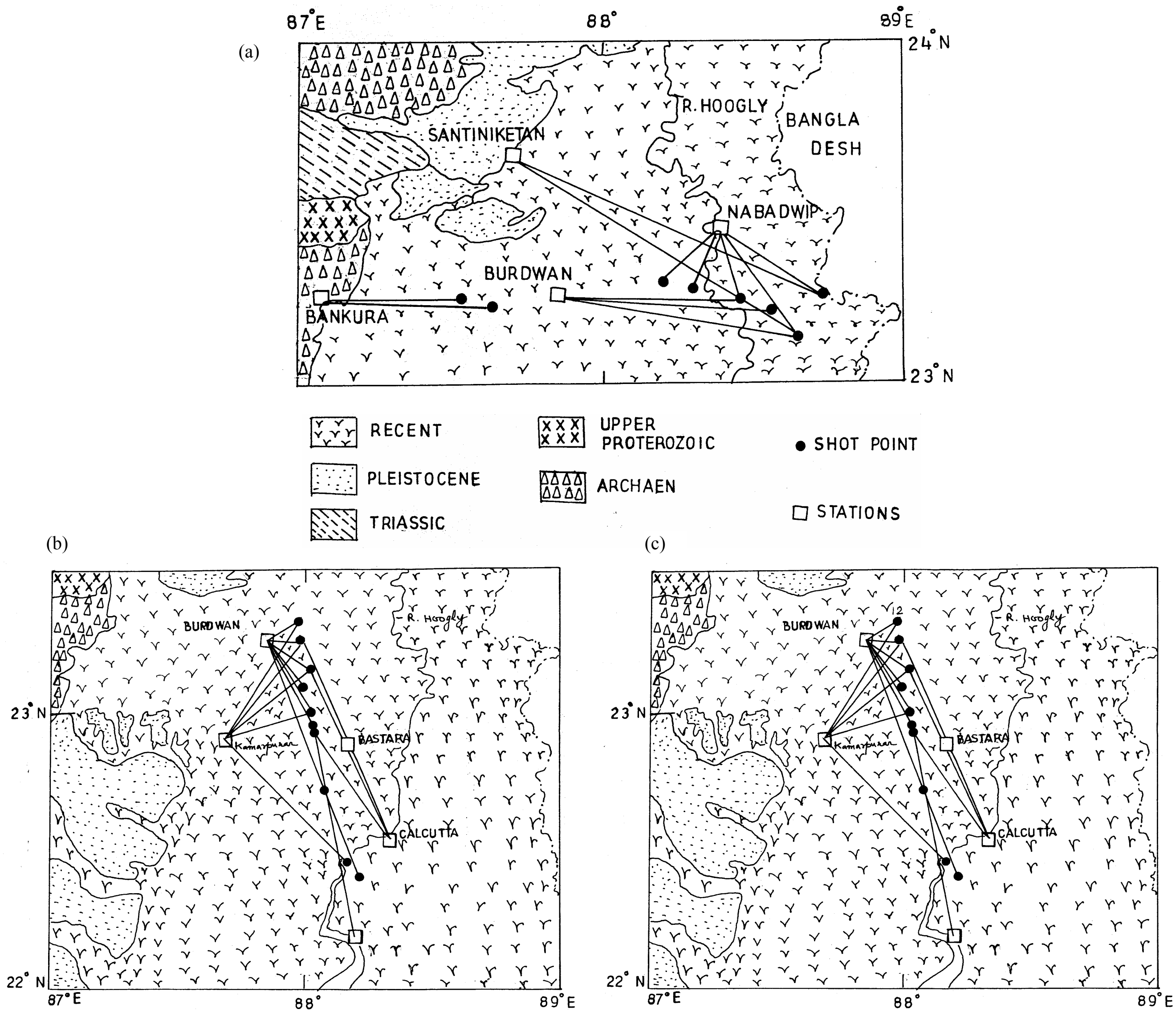
Deep Seismic Sounding (DSS) uses controlled explosions for evaluation of the crustal structure. Such evaluation is superior to earthquakes because of exactness of source parameters. During the years 1987-90, three deep seismic sounding surveys (DSS) were carried out along different profiles of southern and central parts of West Bengal.

(*i*) In 1987-88, the survey was along east-west profile running from Beliator (Bankura) to Bongaon through Burdwan. Another eastwest profile was along Gopali (Kharagpur) to port canning through Tamluk.

(*ii*) In 1988-89 a north-south profile from Bishnupur to Burdwan was considered.

(*iii*) In 1989-90, the profile of 1988-89 was continued northward to Kandi.

The shot points during these three field surveys are shown in Figs. 1(a-c). The DSS experiments along with controlled explosions were carried out by National Geophysical Research Institute (NGRI). India Meteorological Department (IMD) also participated in this experiment and recorded the seismic waves from these explosions using the seismographs used to record local earthquakes. The results of NGRI methodology were given by Kaila *et al.* (1992, 1996). The DSS results of IMD give a broad crustal structure which is useful for determining earthquake location (Chaudhury *et al*. 1984). Further records of IMD seismographs also enabled us to evaluate S-wave velocities.



Figs. 1(a-c). Shot points used and locations of field observatories during the field seasons (a) 1987-88, (b) 1988-89 and (c) 1989-90. Wave paths used are shown by joining shot points and recording observatories

2. Geology and tectonic of the study area

The West Bengal Basin (WBB) forms the western part of the larger Bengal geosyncline province, limited to the west and north by the rocks of the Indian shield and to the east by geosyncline Surma Basin. Just below the western boundary of WBB the Indian shield rocks disappear below a blanket of alluvium. During Permian and early Mesozoic time, the western fringe of the West Bengal Basin were believed to be the part of the Gondwana land. Classic sediments were deposited under deltaic environment during early Miocene-Pliocene time. General stratigraphy of WBB shows that the lower Gondwana formations overlie Archaean basement (Tiwari, 1983).

3. Observational network and data

In each of the three field seasons five observatories were commissioned. The locations of the observatories are shown in Figs. 1(a-c) for the seasons 1987-88, 1988-89, 1989-90 respectively. The surveys were conducted during Feb-Apr 1988, May-Jun 1989 and Feb-Mar 1990. Each station was equipped with a short period vertical seismometer (Sprengnether L4C) connected to smoked paper recording system (Sprengnether MEQ-800). The speed of record was 120 mm/min. Digital seismograph with short period vertical seismometer (Sprengnether S-7000) connected to DR-200 recorder was installed at Burdwan during 1989-90 season.

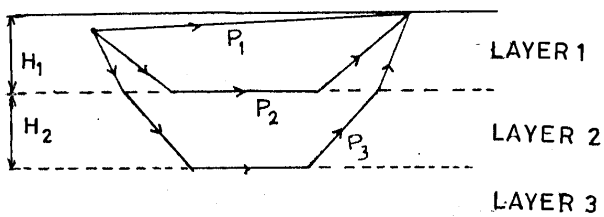


Fig. 2. Ray paths of phases P_1, P_2 and P_3

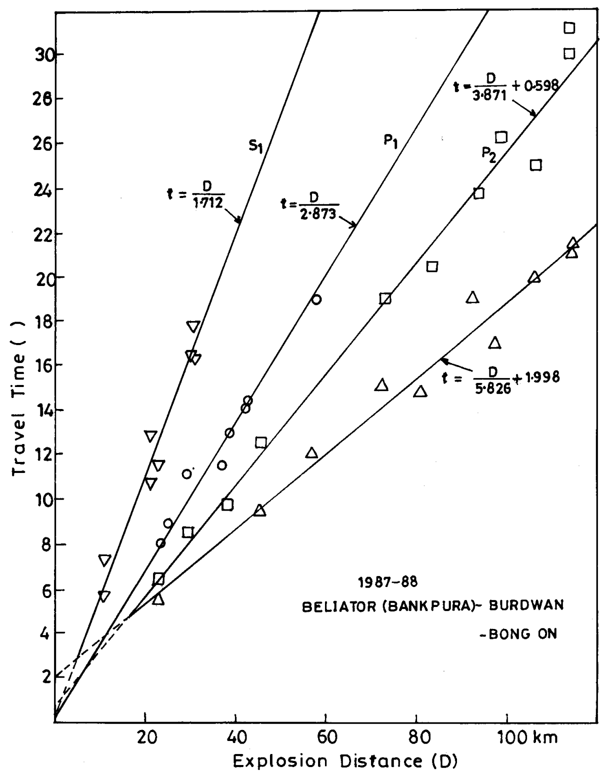


Fig. 3. Travel time of phases during 1987-88

The explosions were conducted by National Geophysical Research Institute and were of charge ranging from 20 kg to 350 kg. Low yield shots were used apparently because of alluvium soil which could render damage to buildings and other structures due to ground vibrations during explosions. Due to low charges, amplitudes of phases were small and were recorded at short distances. Further S phase were rarely recorded. The arrival times of phases recorded by the observatories were obtained. One direct p phase (P_1) and two refracted P phases (P_2 and P_3) were obtained. The ray paths of these three phases are shown in Fig. 2. In some cases direct S phases (S_1) were also obtained.

During field survey, explosion time was obtained. Using this explosion time, the travel time (t) of each of the

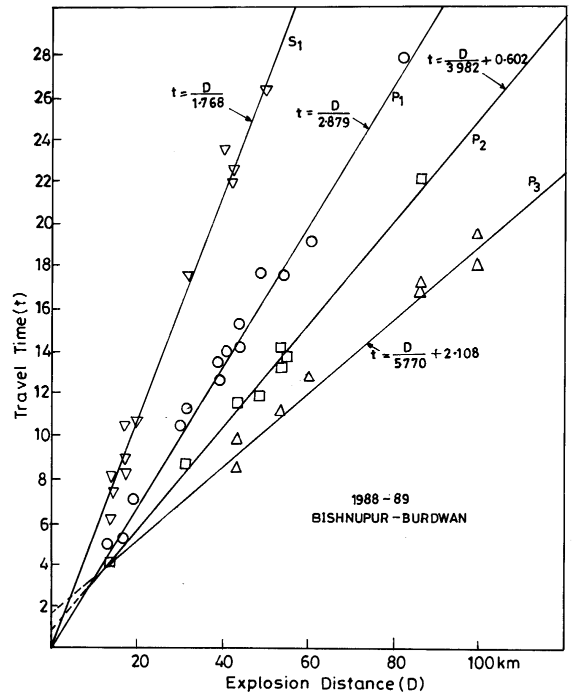


Fig. 4. Travel time of phases during 1988-89

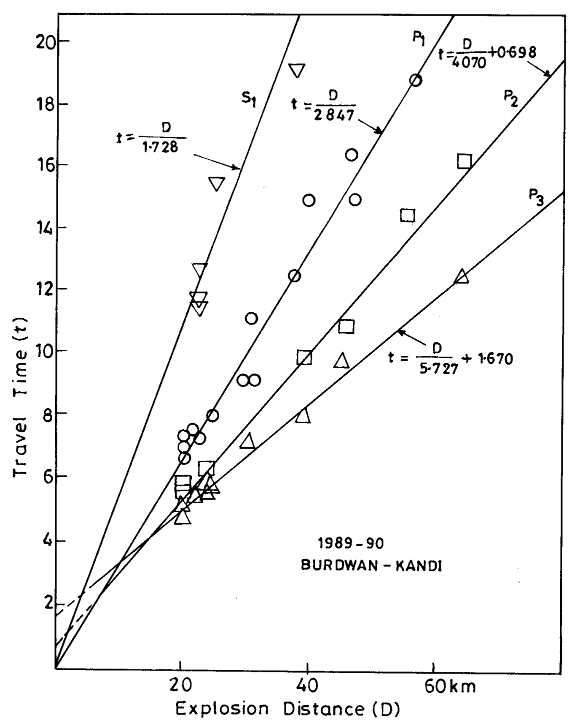


Fig. 5. Travel time of phases during 1989-90

observed phases were obtained and plotted against the distance (D) of the recording station from the shot point. The Figs. 3-5 show these plots for the field seasons 1987 - 88, 1988 - 89 and 1989 - 90 respectively.

TABLE 1

Crustal structure obtained from direct and refracted body waves

Season	Layer No.	P-wave vel. (km/s)	Thickness (km)	S-wave vel. (km/s)
1987-88	1	2.873	1.28	1.712
	3	3.871	3.17	-
	3	5.826	-	-
1988-89	1	2.879	1.25	1.768
	2	3.982	3.73	-
	3	5.770	-	-
1989-90	1	2.847	1.49	1.728
	2	4.070	2.32	-
	3	5.727	-	-

4. Method of analysis

The travel time of direct P-phase *i.e.* P_1 -phase is

$$t_l = D/V_l \quad (1)$$

and travel time of the refracted phases P_2 and P_3 are

$$t_2 = D/V_2 + 2H_1 * \sqrt{\left(1/V_1^2 - 1/V_2^2\right)} \quad (2)$$

$$t_3 = D/V_3 + 2H_1 * \sqrt{\left(1/V_1^2 - 1/V_3^2\right)} + 2H_2 * \sqrt{\left(1/V_2^2 - 1/V_3^2\right)} \quad (3)$$

Here V_l, V_2, V_3 are P-wave velocities in first, second and third layer: H_l and H_2 are thickness of first and second layer. Travel time of S_1- phase is given by right hand side of equation (1), but V_l is then the S-wave velocity of the first layer.

A line is drawn through the data of each phase by least square method. These lines may be seen in Figs. 3-5. The inverse of slope of these lines gives V_l, V_2 and V_3. If I_2 and I_3 are intercepts on *t*-axis by the lines passing through travel times of phases P_2 and P_3 respectively, then

$$I_2 = 2H_1 * \sqrt{\left(1/V_1^2 - 1/V_2^2\right)} \quad (4)$$

$$I_3 = 2H_1 * \sqrt{\left(1/V_1^2 - 1/V_3^2\right)} + 2H_2 * \sqrt{\left(1/V_2^2 - 1/V_3^2\right)} \quad (5)$$

Thus noting these intercepts I_2 and I_3, we find the thickness H_1 and H_2 once V_1, V_2 and V_3 are known.

The results are shown in Table 1 and Fig. 7. The structures show two sedimentary layers over a granitic layer. The present P wave velocity structure to the east of Burdwan (1987-88 profile) may be compared with the results of Kaila *et al.* (1992) who obtained sedimentary layers with P wave velocities about 3.0 and 3.8 km/s which are close to our results. Below the sedimentary layers Kaila *et al.* (1992) obtained two layers with P wave velocities as 4.8 and 6.0 km/s. However, we obtained P wave velocity as 5.826 km/s below the sedimentary layers.

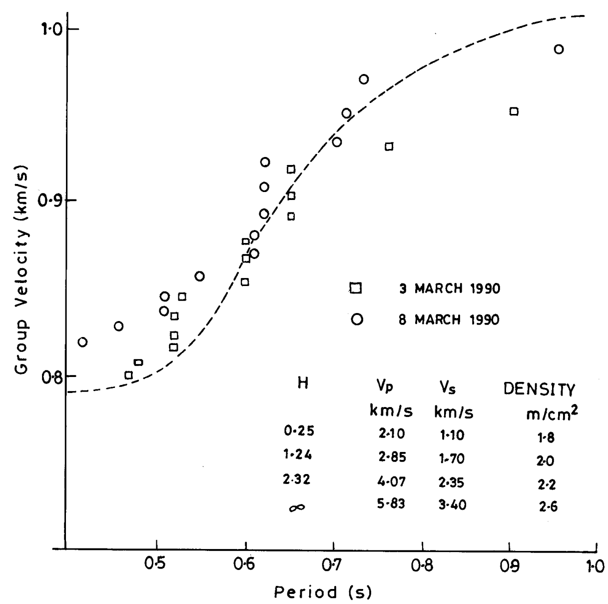


Fig. 6. Group velocity of Rayleigh from shot point 12 (Fig. lc) to Burdwan

The present P-wave velocity structure below the north-south profile across Burdwan (1988-89 and 1989-90 profiles) may be compared with results of Kaila *et al.* (1996) who obtained P wave velocity about 2.7 and 3.7 km/s for sedimentary layers. While we have obtained them as 2.879 and 3.982 km/s in the southern part and as 2.847 and 4.070 km/s in the northern part. Below the sedimentary layers, Kaila *et al.* (1996) obtained a thin layer of P wave velocity 4.6 km/s overlying a granitic layer of P wave velocity 5.9 km/s. However, our results does not support the thin layer and supports the existence of granitic layer with similar velocity below the sedimentary layer.

5. Surface wave dispersion data

Dispersive Rayleigh waves of period 0.4 to 0.95 were recorded from shot point 12 [Fig. l(c)] on 3 March 1990 and 8 March 1990 by vertical component digital

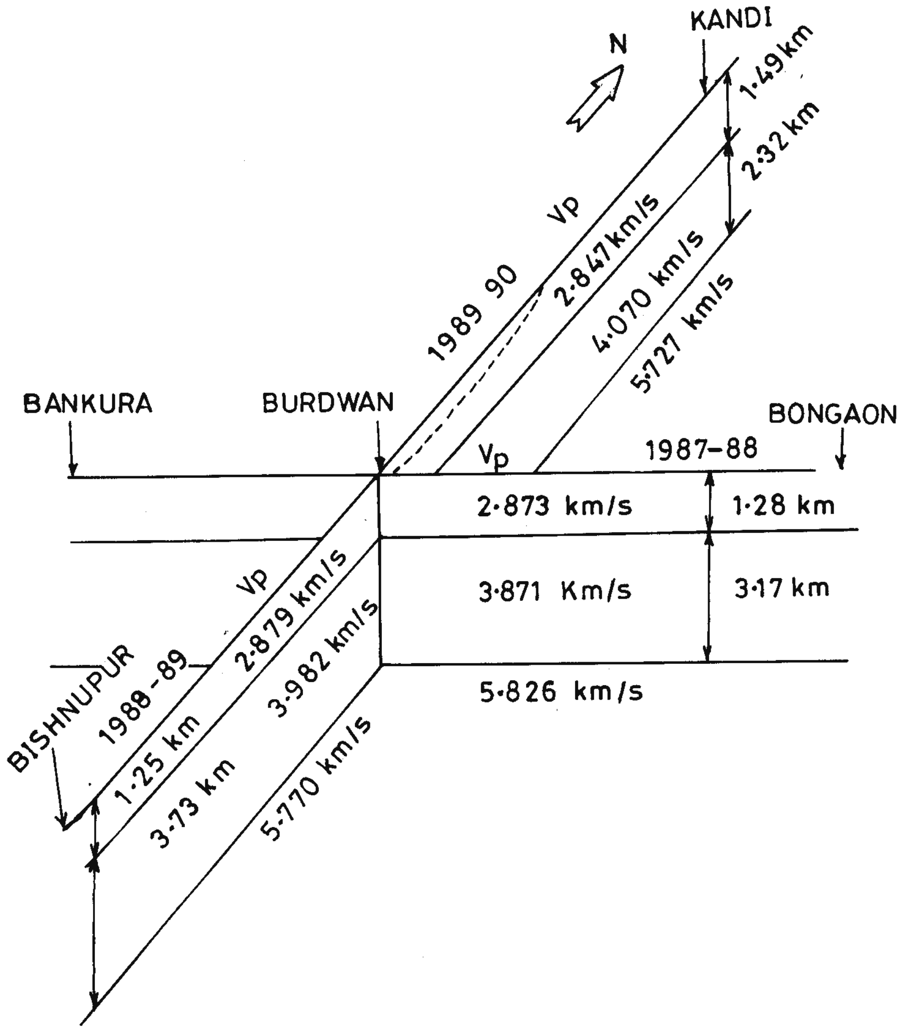


Fig. 7. 3-D crustal structure of the study area

seismograph at Burdwan. The group velocity data obtained from these records are shown in Fig. 6. The structure that fits the dispersion data is also shown in Fig. 6 alongwith the corresponding theoretical group velocity curve. A better fit could not be achieved presumably because of lateral heterogeneity. The data show a presence of a top thin sedimentary layer of very low P wave velocity 2.1 km/s. This thin sedimentary layer is present only in some parts and could not be traced by body wave refraction data. Such top thin very low P wave velocity 2.0 km/s also obtained by Kaila *et al.* (1996) under this region. In addition, our results on surface wave data gives a S wave velocity structure for this region.

6. Conclusions

The models obtained in the three field seasons are shown in Fig. 7. It is noted that the sedimentary layer consists of mainly two layers. The first layer is nearly 1.25-1.49 km with P-wave velocity as 2.85 -2.88 km/s and S-wave as 1.71 -1.77 km/s. Surface layer includes a thin low velocity sedimentary layer at the top with P wave velocity 2.1 km/s; this layer is of thickness 250 m only. The thickness of lowest sedimentary layer increases southward from 2.32 km to 3.73 km; here the P -wave velocity is between 3.9 & 4.1 km/s The sedimentary layers are overlying granitic layer with P-wave velocity

5.75-5.83 km/s. The present results show similarity with the structure obtained by NGRI (Kaila *et al*., 1992, 1996) except that a layer with P-wave velocity around 4.8 km/s just above the granitic layer was not discernible.

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