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Pg and Sg Wave Velocities in Delhi and the Surrounding Region from Microseismicity Data

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ABSTRACT The seismic network in and around Delhi operated by the Centre of Georesources, University of Delhi South Campus and India Meterological Department, has recorded a large number of locatable microearthquakes during the period 1990-95. The epicentres of these have been determined by us. The coda magnitude for these ranges from 1.5 to 3.5. Out of these, 18 events have been used to study the velocity structure. Using the arrival times of these events, crustal velocity structure for the top 10 km of crust in and around Delhi has been determined. The Pg and Sg wave velocities are found to be 6.0 ± 0.003 km/sec and 3.47 ± 0.003 km/sec, respectively. These are somewhat higher than those proposed by the Jeffreys and Bullen (1940) for the top 10 km crust on the basis of world wide data.

INTRODUCTION AND HISTORICAL PERSPECTIVE

Delhi and the adjoining region has experienced earthquakes of magnitude ≥ 6.0 since historical times. The Indian Meterological Department (IMD) has been operating a four station seismic network in the region since 1964 to study the seismicity (Kamble and Chaudhary, 1979). This network has reported several events of magnitude ≥ 4.0 which have occurred in the region since 1964. The high level of seismicity is attributable to northward movement of the Indian plate at the rate of 3-5 cm/year (Minister et al., 1974).

In view of the importance of Delhi and its surrounding region from seismic point of view, the University of Delhi, South Campus (UDSC) has established a three-station seismic network using digital as well as analog instruments under a project sanctioned by the Department of Science and Technology, Govt. of India, to study the region in detail.

This seismic network has generated very useful seismic data for the period 1991-95. Figure 1 shows geology of the area and some historical events as well as microevents of magnitude 3.1-4.0 recorded during the period 1964-1994. An attempt has been made to determine the seismic wave velocities for Pg and Sg phases recorded for Delhi and the surrounding region using the recently acquired data for micro earthquakes.

GEOLOGY AND TECTONICS OF THE REGION

The city of Delhi is located at the northern end of the Aravalli mountains and is surrounded by Gangetic alluvium practically from all sides. Fig. 1 shows the major geological formations in the area which include rocks belonging to the Delhi Supergroup (Alwar and Ajabgarh Series) and

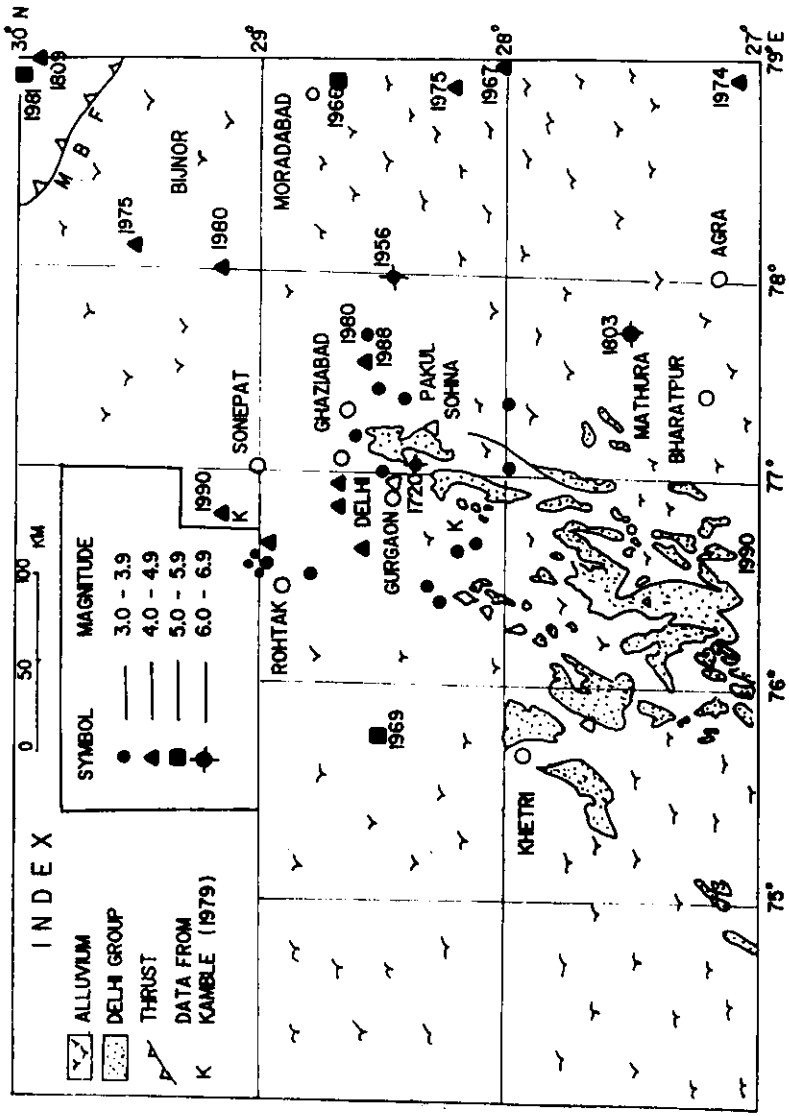

Fig.1 The figure shows a simplified geological map of the area. Historical as well recent events having mag. 3.0-4.0 till 1991 are also shown in the figure. Data reported by Kamble and Chaudhury (1979) has been included.

alluvium. The presence of Delhi Hardwar Ridge is a significant tectonic feature which lies in the area (Valdiya 1976; Raiverman 1983).

SOURCE OF DATA FOR ANALYSIS OF Pg AND Sg WAVE VELOCITIES The data generated by UDSC and IMD networks operating in the area for the period 1991-95 has been used for the present study. Figure 2 shows the location of seismic observatories and the events used for the present analysis. Table 1 gives the locations of observatories operating in this region. These include three digital and two analog instruments (Kinematrics) at University of Delhi South Campus (DLC), Jhajjar (JHI) and Kasan (KAS) and analog instruments at Rohtak (ROH), Sonepat (SON) and Sohna (SOH). The Ridge (RDG) observatory is equipped with WWSSN short period as well as long period instruments.

Table -1 Parameters of Seismic observatories operated by IMD and UDSC network Delhi Region

Station	Lattitude (° N)	Longitude (°E)	Instruments
Ridge (IMD)	28.68	77.22	Analog, S.P. and L.P.
Rohtak (IMD)	28.90	76.60	Analog, S.P.
Sonepat (IMD)	29.01	77.03	Analog, S.P.
Sohna (IMD)	28.25	77.08	Analog, S.P.
Dhaula Kuan (UDSC)	28.57	77.13	Analog, S.P. and Digital, S.P.
Jhajjar (UDSC)	28.60	76.65	Analog, S.P. and Digital, S.P.
Kasan (UDSC)	28.35	76.88	Digital, S.P.

The epicentral data used for the analysis of Pg and Sg phase velocities lies between Lat. 28-29^0 N and Long. 76-78^0 E. The location of epicentres are shown in Figure 2. Table 2 gives the arrival times of different phases and hypocentre locations used for the present study.

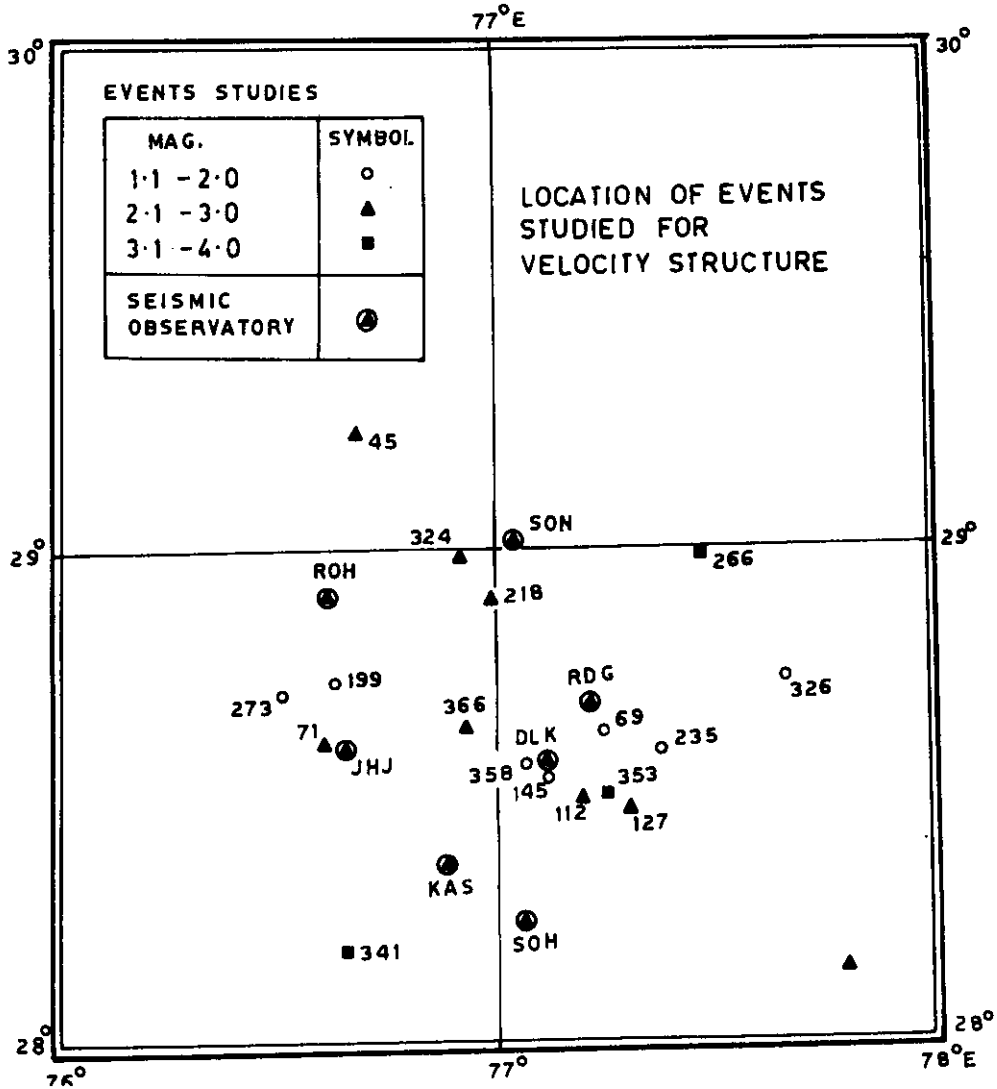

Fig.2 Locations of the events used in the analysis of Pg and Sg wave velocities are shown alongwith the recording stations. Abbreviations : ROH-Rohtak, SON-Sonepat, RDG-Ridge, SOH-Sohna (IMD network), JHI-Jhajjar, DLK-Daula Kuan and KAS-Kasan.

Table - 2 Phase Data used for the analysis of Pg and Sg Velocities

S. N.	Event No.	Date	Origin Time (hms)	Recording station	Arrival Times Pg(sec)	Arrival Times Sg(sec)	Sg-Pg (sec)	Delta (Km)	Lat. (°N)	Long. (°E)	Depth (Km)
1.	45	20-09-91	07:21:06:11	DLK	22.5	32.5	10.0	85.0	29.20	76.67	5.0
				RDG	22.0	32.0	10.0	81.0			
				ROH	11.0	15.5	4.5	98.0			
2.	69	01-11-91	12:32:53:5	DLK	57.0	59.0	2.0	9.7	28.63	77.21	13.7
				SOH	62.0	66.9	4.9	43.9			
				RDG	56.0	58.0	2.0	5.9			
3.	71	08-11-91	16:40:33:0	RDG	44.0	52.0	8.0	60.9	28.61	76.60	10.0
				DLK	44.5	53.0	8.5	52.29			
				SOH	48.5	58.9	10.4	61.89			
4.	112	03-05-92	01:10:46:0	DLK	50.1	52.6	2.5	10.56	28.51	77.21	15.0
				RDG	50.7	53.9	3.2	19.02			
				SOH	52.5	56.9	4.4	31.66			
5.	127	22-07-92	10:59:24:43	DLK	28.3	30.8	2.5	20.09	28.47	77.30	5.3
				RDG	50.7	53.9	3.3	25.01			
				SOH	30.4	34.9	4.5	32.31			
6.	138	28-11-92	00:05:59:30	DLK	73.8	83.8	10.0	81.40	28.13	77.80	15.0
				RDG	74.8	85.0	10.2	83.24			
				SOH	72.0	81.5	9.5	71.20			
7.	145	01-01-93	23:53:06.73	DLK	10.2	12.7	2.5	4.80	28.53	77.13	15.0
				RDG	11.4	14.7	3.3	18.64			
				SOH	13.4	17.6	4.2	31.61			
8.	199	29.03-93	12:20:40.90	DLK	50.0	58.5	8.5	5.0.93	28.72	76.62	5.0
				SOH	54.5	67.0	12.5	74.10			
				RDG	51.5	59.5	8.0	40.22			
9.	218	29-04-93	04:33:52.00	DLK	59.0	65.0	6.0	38.33	28.90	77.00	5.0
				RDG	57.7	62.1	4.4	31.93			
				SOH	65.0	75.0	10.0	72.47			
10.	235	24-06-93	07:43:38.80	DLK	35.5	38.3	2.8	24.60	28.60	77.38	5.0
				RDG	34.6	36.6	2.0	18.46			
				SOH	39.2	46.2	7.0	48.45			
11.	273	11-10-93	15:25:33.25	DLK	45.0	53.7	8.7	62.27	28.51	76.51	10.0
				RDK	44.5	53.5	9.0	69.18			
				SOH	52.4	63.0	10.6	74.35			
12.	286	18.11-93	08:22:35.09	DLK	45.0	51.5	6.5	56.14	28.99	77.46	10.0
				RDG	43.2	48.5	5.3	41.5			
				SOH	51.0	63.0	12.0	89.90			
13.	324	13-01-94	6:25:49.90	DLK	59.0	65.0	7.0	49.34	28.97	76.90	20.0
				RDG	58.5	64.5	6.0	44.39			
				SOH	64.2	75.9	11.7	81.78			

14. 326	23-02-94	18:47:48.20	DLK	58.0	65.0	7.0	54.23	28.75	77.65	5.0
			RDG	57.2	63.0	5.8	43.06			
			SOH	62.8	74.0	11.2	78.41			
15. 341	01-06-94	11:22:13.10	DLK	25.5	34.8	9.3	63.7	28.18	76.66	10.0
			RDG	27.0	37.1	10.1	77.98			
			SOH	8.6	14.9	6.3	42.16			
16. 353	28-07-94	14:23:41.20	DLK	44.0	46.0	2.0	14.14	28.50	77.25	10.0
			RDG	44.8	47.2	2.4	19.70			
			SOH	47.6	51.5	3.9	33.30			
17. 358	20-09-94	22:47:45.56	DLK	48.5	50.8	2.3	5.93	28.56	7707	10 0
			RDG	50.0	53.0	3.0	19.41			
			SOH	52.3	57.0	4.7	34.55			
18. 366	15-10-94	02:24:08.5	DLK	13.0	15.3	2.3	20.08	28.6	76.9	10.0
			RDG	14.8	17.7	2.9	30.83			
			SOH	17.4	21.0	3.6	40.93			

DLK - Dhaula Khan; RDG - Ridge; SOH - Sohna

The reliability of the seismic data used for velocity analysis is of paramount importance. In order to maintain the reliability of the data, the events selected for the purpose were critically examined keeping in view the following points.

i) In order to pick true Pg and Sg phase, events having a focal depth of 10-15 km or less and epicentral distances of less than 1.2 were selected for analysis.

ii) Reliability of the event was checked by plotting (S-P) vs Tpg and Tsg (where Tpg and Tsg are arrival times in seconds, as given in Table 2). Figure 3 shows plots for some of these events used in the present study.

iii) The events were recorded at a minimum of three stations.

Since one degree distance changes from equator to the poles epicentral distances were calculated from given latitude and longitude using Richter's (1969) formula.

$$\Delta^2 = \Delta X^2 + \Delta Y^2$$

where, $\Delta X = A\Delta\lambda$, $\Delta Y = B\Delta\phi$

Where, Δ is the required distance in km and $\Delta\lambda$ and are $\Delta\phi$ the differences in longitude and latitude between source and the station. A and B are the constants given by Richter (ibid)

Pg AND Sg WAVE VELOCITIES Figure 4 shows a plot of (Tpg-To) vs epicentral distance in km., where Tpg and To are the Pg wave arrival times and the origin time, respectively. The inverse of slope of the best fit line through this data set gives the Pg wave velocity of 6.06 ± 0.12 km/sec. The equation of the least square fit for Pg is :

$$Y = (0.164 \pm 0.003)\, x + 1.190$$

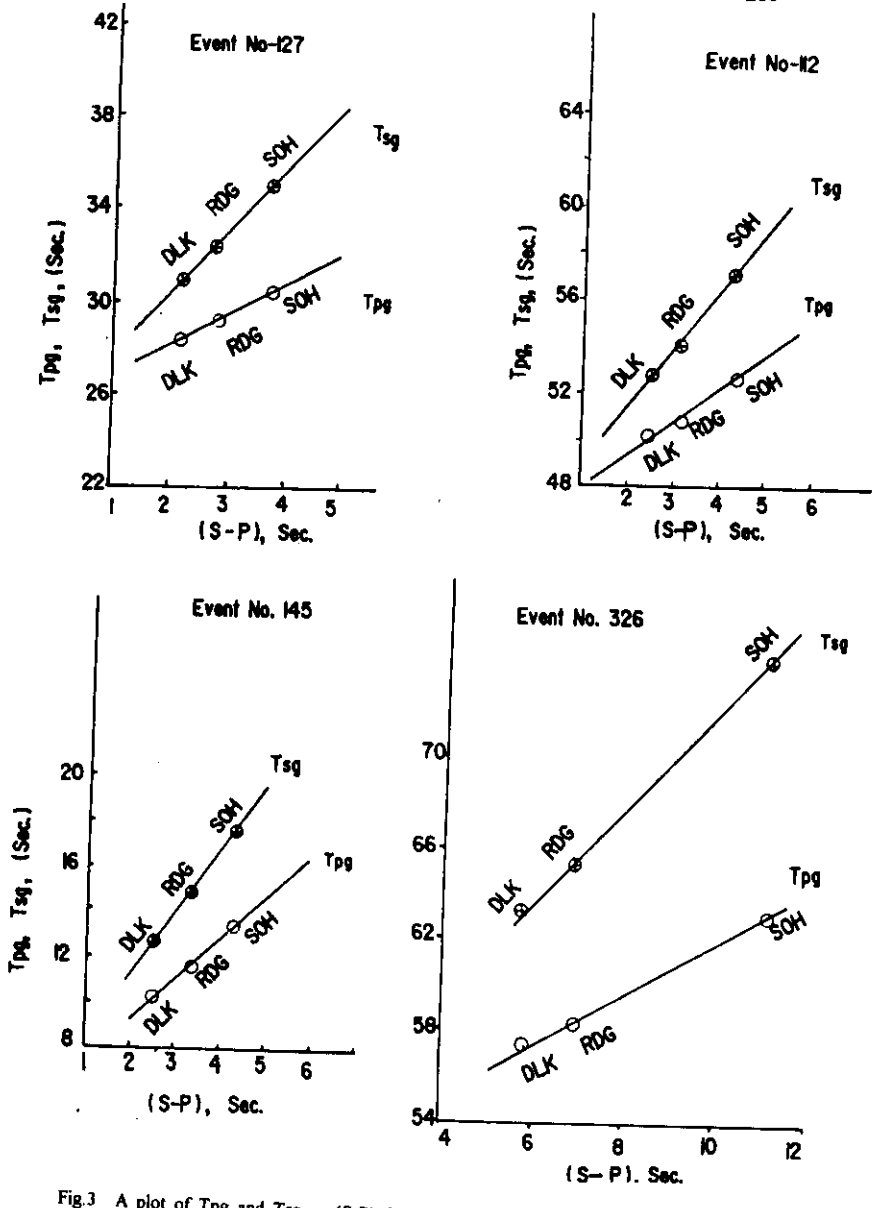

Fig.3 A plot of Tpg and Tsg vs (S-P) for some events used for the present study for determination of reliability of the data.

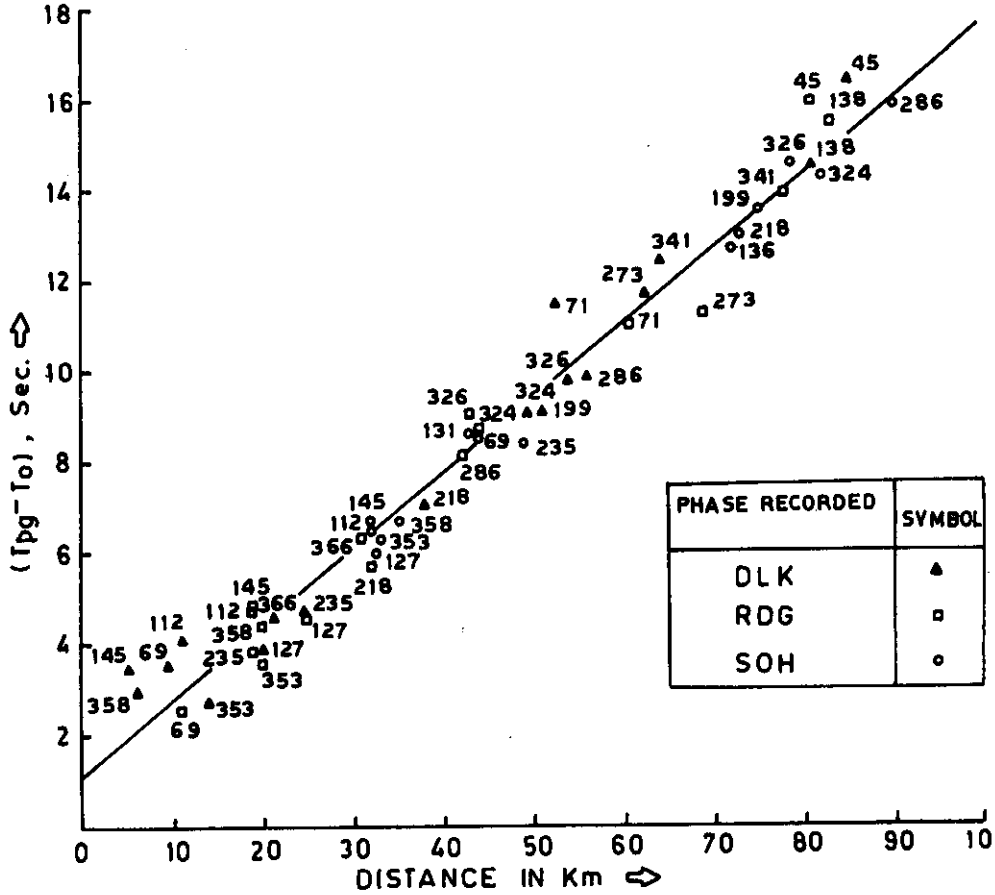

Fig.4 A plot of (Tpg-To) vs epicentral distance (km) for the ata used. The inverse of slope of least square fit gives the Pg wave velocity of 6.06±0.12 km/sec.

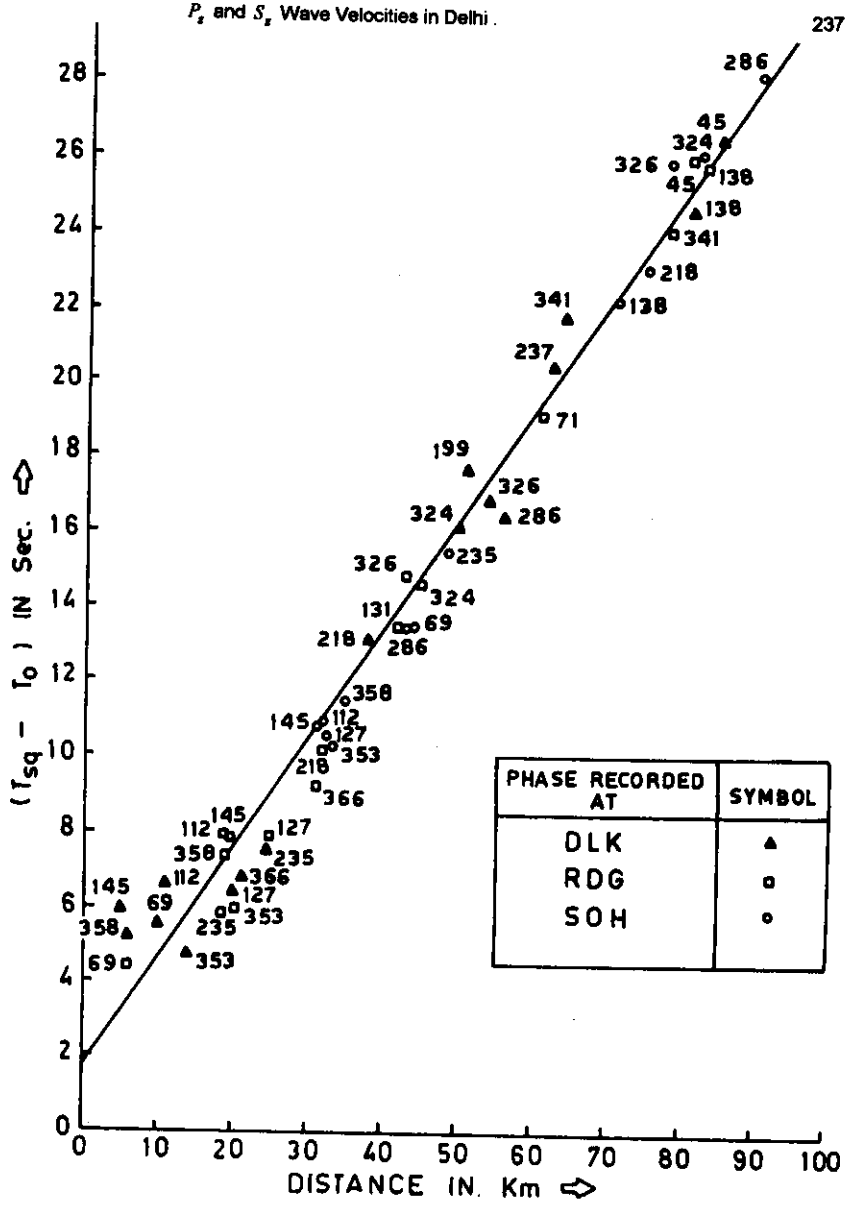

Fig.5 Figure shows a plot of (Tsg-To) vs epicentral distance (km) for the purpose of determination of Sg wave velocity. The inverse of least square slope through the data set gives the velocity of 3.47± 0.07 km/sec.

that the continental crust in Delhi and the surrounding region consists mostly of gneisses and schists upto a depth of about 10 km.

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