623·454·8 : 614·83(47) : 550·34

A seismometric study of the Russian Nuclear Explosion on 30 October 1961

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(Received 20 March 1962)

Tandon (1961) has reported recently the recording of the surface waves by the long period Press-Ewing seismographs at Delhi and has made available some items of information. This had led the writer to examine the Shillong records in the light of the above information. In the past, this station has recorded seismic P-waves from a number of explosions in the Pacific (Tandon 1958). In the case of the above Russian explosion it has been possible only to record the surface waves at Delhi but apparently no P-wave has been reported. This is quite reasonable as the explosion was in the upper atmosphere when on account of atmosphere-crust coupling, most of the energy incident at the surface of the earth is likely to be concentrated in the crust and would propagate as surface waves. But a minor fraction is likely to propagate as body waves in the form of P-waves and it is quite likely that the recording of the P-wave will remain confined to near stations only. On account of large energy release due to above Russian explosion a very critical examination of the Shillong seismograms was considered necessary. The Shillong seismograms, in general, have a very quiet background and they are very suitable for such purposes. It was observed that the Sprengnether microseismograph ($T_o - T_g = 6^s{\cdot}8$) oriented in the E-W direction has recorded surface waves of the type reported by Tandon at about $09^h\ 04^m\ 40^s$ GMT. The record of the surface wave is reproduced in Fig. 1.

On a critical examination of the record of the Benioff short period vertical seismograph ($T_o = 1^s{\cdot}0$ and $T_g = 0^s{\cdot}18$) at Shillong it is noticed that there is some long period movement (compression) in the background of short period noises at $08^h\ 42^m 38^s$ GMT. The indication of this long period movement is supported by the presence of the long period feeble oscillations following the principal movement indicated by an arrow in Fig. 2 which represents the section of the Benioff record. The observed characteristics of the movements are very similar to the usual recording of the P-wave from distant earthquakes in the Benioff records. This led the writer to make a critical examination of the records of Indian stations equipped with sensitive instruments. The results of the examination indicate that some clear P-movements were recorded at Chatra and Delhi by the short period Benioff seismographs at those stations. The times of incidence at Delhi and Chatra are respectively $08^h\ 42^m\ 00^s$ and $08^h\ 42^m\ 25^s$. The records of the short period Benioff at Delhi and Chatra are reproduced in Figs. 3 and 4 respectively.

On a critical examination of the record of the long period Press-Ewing vertical seismograph ($T_o = 15$ sec, $T_g = 85$ sec) at Delhi, it is noticed that there are two clear movements recorded preceding the appearance of the surface waves reported by Tandon (1961). The record is reproduced in Fig. 5. The time of

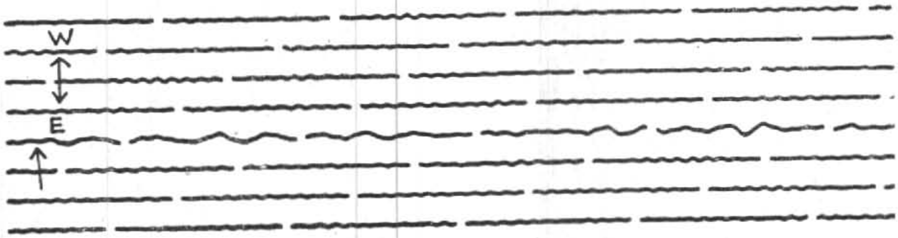

FIG. 1

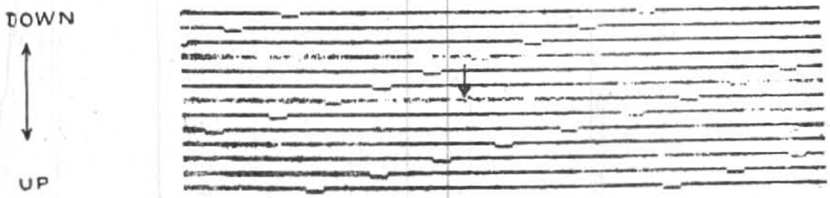

FIG. 2

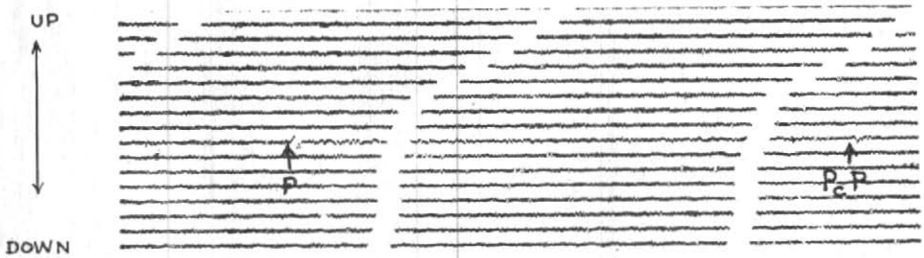

FIG. 3

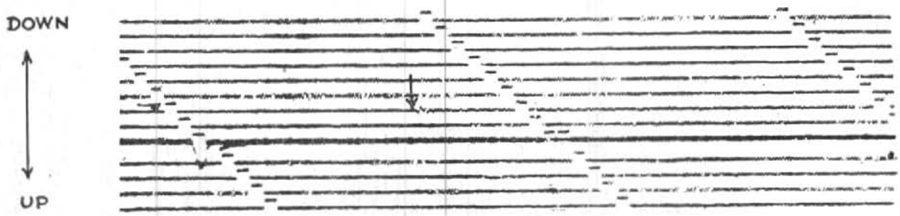

FIG. 4

Fig. 1. Section of Shillong Sprengnether (E-W) of 30 October 1961 ; paper speed 30 mm/min
Fig. 2. Section of Shillong Benioff Vertical (S.P) of 30 October 1961 ; paper speed 60 mm/min
Fig. 3. Section of Delhi Benioff Vertical (S.P) of 30 October 1961 ; paper speed 60 mm/min
Fig. 4. Section of Chatra Benioff Vertical (S.P) of 30 October 1961 ; paper speed 60 mm/min

TABLE 1

Station	Time of P-phase (GMT)			P—O		△
	h	m	s	m	s	
Shillong	08	42	38	9	05	51·0
Chatra	08	42	25	8	52	49·2
Quetta	08	41	39	8	06	43·4

incidence of the first movement exactly coincides with the time of recording P-phase by the Benioff seismograph at Delhi mentioned earlier. If the second movement after an interval of 1^m 48^s from the fir t movement is taken as the surface reflected PP-phase, the distance △ works out to be 46°·0 and the origin time based on △ =46°·0 becomes 08^h 33^m 33^s . Table 1 gives the distance based on this origin time. The common point of intersection of these distances from Shillong, Delhi, Chatra, and Quetta has the co-ordinates Lat. $73\frac{1}{2}$° N and Long. $62\frac{1}{4}$°E. Tandon (1961) has, however, assumed that the explosion took place in the neighbourhood of Lat. 77°N and 70°E. It may be mentioned that the origin time arrived at from Quetta data alone is 08^h 33^m 18^s on the observation of PP and S phases recorded at Quetta.

At Shillong the first group of surface waves arrived at 09^h 04^m 40^s GMT giving a travel time of 31 min 7 sec. This would correspond to a group velocity of 3·0 km/sec for waves of 20-sec period. The first group of Rayleigh waves at Delhi was recorded at 08^h 57^m 09^s GMT giving a travel time of 23 min 36 sec. This would correspond to group velocity of 3·6 km/sec for waves of 52-sec period. The observed velocities of surface waves of 3·0 km/sec (T=20 sec) and 3·6 km/sec (T=52 sec) are in good agreement with the dispersion curve for continental Rayleigh waves reproduced in Fig. 6. The higher velocity of 3·6 km/sec for waves of 52-sec period observed by Tandon and lower velocity of 3·0 km/sec for waves of 20-sec period observed by the author very clearly indicate normal dispersion. Normal dispersion means waves of higher period would have higher group velocities. The observed velocity of surface waves at Delhi and Shillong could not, howevei, decide on the correctness or otherwise of the coordinates of explosion and the origin time arrived at from seismometric observations by the author and Upsala data used by Tandon (1961).

Cardar and Baily (1958) in their study on seismic wave travel times from nuclear explosion have observed PcP from Bikini sources on short period vertical records although no PcP was recognised from Enivetok sources, the respective distances being 34°·9 and 32°·9. Further the initial P on Matsushiro short period vertical is an impulsive compression. PcP on the other hand begins as a weak or barely noticeable compression followed by a strong dilatation. A similar effect except for phasing was observed in the College records. From Bikini sources PcP is nearly as large as the initial P and the first motions have the same phase. From Eniwetok sources it is hardly recognisable. In the present study a clear PcP phase (Fig. 3) on the short period record of the Benioff vetical seismograph (T_o =1^s·0 and T_g =0^s·2) at Delhi was observed. it would be seen that the recording of the PcP is very similar to those at the Matsushiro Observatory mentioned by the above authors. The initial P on Delhi record is an impulsive compression while PcP phase on the other hand records a strong dilatation. The distance of Delhi from the place of explosion is about 46° as found from the seismic data. The travel time of the PcP phase agrees well with the times of J. B. tables (1948). Although the phase was very well recorded at Delhi but the phase could not be recognised on the records of Shillong and Chatra observatories having very similar instrumental equipment. The distances of Shillong and Chatra are 51° and 49°·2 respectively. This probably supports the suggestion of the authors that the amplitude of the PcP is quite sensitive to the angle of incidence or to the point of reflection on the core. The possibility of an interference, from

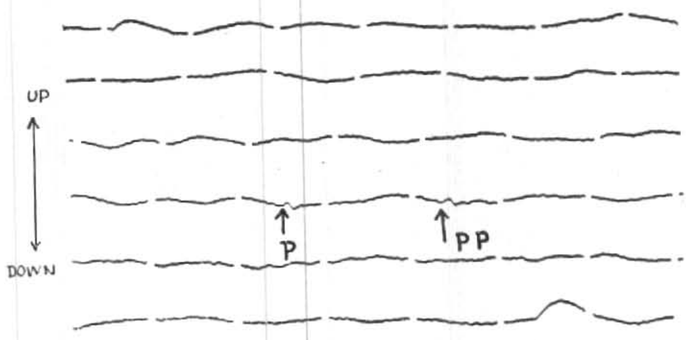

Fig. 5. Section of Delhi Press-Ewing Vertical (L.P.) of 30 October 1961; Paper speed 15mm/min

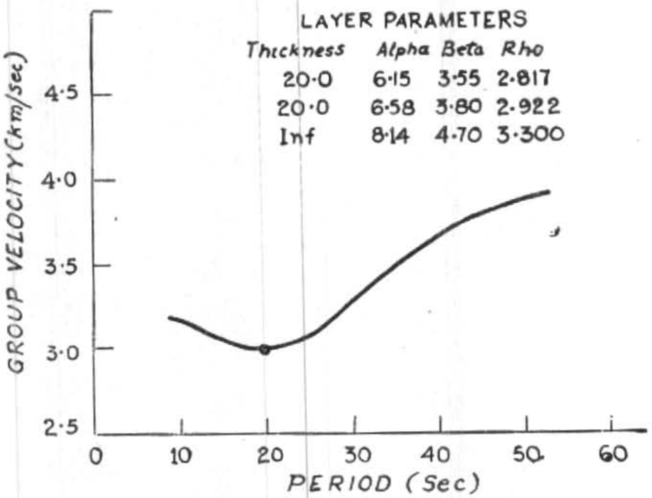

Fig. 6. Dispersion curve for continental Rayleigh waves

two reflecting surfaces at the core boundary, close enough together to bring it about the reflected waves alternately interfere and reinforce each other as a result of slight variation in the angle of incidence is not ruled out. The recordings of the PcP phase from nuclear explosions are too meagre and the present observation would support the conclusion of the authors.

There is another very interesting feature of the Shillong observations of surface waves with reference to the dispersion curve for continental Rayleigh waves. The minimum value of the group velocity curve for continental Rayleigh waves corresponds to periods of waves having values near about 20 sec. Theory predicts that large amplitudes should be associated with the minimum of the group velocity of the dispersion curve. These periods are probably excited by the atmospheric oscillations of the same period. The observations of 20-sec period waves at Shillong clearly supports the above theoretical prediction. This also suggests that the atmospheric oscillations induced by the nuclear explosion are coupled to the crust through the air inspite of their large contrast in acoustic impedances. The agreement of the observed period of 20 sec with the period corresponding to the minimum value of the group velocity atonce suggests that the entire crust is involved in the propagation of these surface waves.

The above observations of atmosphere-crust coupling might have significance on the mechanism of the generation of microseisms. In the case of microseisms, the period of the microseisms would correspond to the minimum of the group velocity curve appropriate to the structure of the ocean bed consisting of water layer plus the thickness of the unconsolidated sediments overlying the crystalline bottom. Pomeroy and Oliver (1960) have correctly suggested that the transfer of energy from atmosphere into seismic waves in the earth is possible at least without the intervening process of interfering gravity wave trains that has been discussed extensively in current literature on microseisms.

No indications of the shock waves observed by Tandon are, however, available in the Shillong records. The possibility that these are air coupled Rayleigh waves appears to be remote because these waves also show a normal dispersion. In the case of air coupled Rayleigh waves, constructive interference is possible only for those waves whose phase velocity equals the speed of the travelling disturbance. The energy thus transferred will form a train of constant frequency waves. They might be however Stoneley waves at fluid-solid interface in the case of fluid half space in contact with semi-infinite elastic solid medium. Theory would show that for fluid and solid half spaces with a simple harmonic point source in the fluid half space, the period equation corresponds to waves propagating with a velocity less than that of compressional or shear waves in either medium. The observations of this type are very rare and accordingly no detailed data are. however, available to justify the above suggestion.

P.S. It is interesting to note that Walter Dieminger and Harry Kohl of Max-Planck-Institut für Aeronomie, Institut für Ionosphären -Physik Lindau/Harz, Germany, have quoted exactly the same origin time of $08^h 33^m 33^s$ (*Nature*, **193**, p. 963, March 10, 1962). Although the authors have not mentioned the source of information the very fact that the time has been given in odd seconds certainly indicate an authentic source.

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