apparent from Figs. 1 to 4 and Table 2 that most of the phases of body waves are clear in general and in good agreement with J.B. Tables. It is interesting to note that S wave has been poorly recorded compared to P waves in all the components of Colaba seismograms. It is clear in Sprengnether seismogram which may be due to its high magnification, but poor in Milne–Shaw N—S and E—W components, where PS and PPS phases have been recorded with bigger amplitude and clearness than S wave. The possible reason for S to be poorer than P may be lack of well developed shearing stress and strain in the earthquake. S wave is poorer in Milne–Shaw N—S component than in Milne-Shaw E—W component which may be due to lack of transverse motion in N—S direction.

It is clear from Table 2 that there are two waves other than body phases recorded in all the components of Colaba seismograms. The first wave appears at $12^h 15^m 00^s$ GMT in both Sprengnether and Benioff seismograms as an oscillatory wave with period of 4 sec. It is poor in Milne-Shaw due to the instrument's lower magnification. The velocity of travel of this wave works out to 7·90 km/sec. Because the difference in times of arrival between PcP and Pa for this epicentral distance is 23 sec, and from PPP it is 12 sec, this wave cannot be misunderstood to be body phase like PcP or PPP. The identification of this wave is thus easier due to its oscillatory nature, lower amplitude and different appearance from body phases (Figs. 3 and 4). Taking all these into consideration this wave may be identified as Pa wave of Caloi (1953).

The second wave appears as pulse-like on the seismograms of all the horizontal as well as vertical components and has been recorded on vertical Benioff seismogram (Fig. 3) at $12^h 23^m 12^s$ GMT and in Milne-Shaw and Sprengnether seismograms (Figs. 1, 2 and 4) at $12^h 23^m 09^s$ GMT. This wave has been recorded 3 sec earlier in the horizontal component than in the vertical component with velocity of travel 4·40 km/sec in the period

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Pa AND Sa WAVES IN TAIWAN EARTHQUAKE OF 18 JANUARY 1964

While examining the seismograms of Colaba Observatory of Taiwan earthquake of 18 January 1964 two interesting phases of seismic waves having similarity with Pa and Sa Waves of Caloi (1953) were noticed. Particulars of the Formosa (Taiwan) earthquake including phases recorded on Colaba seismograms with their arrival times and clearness are given in Tables 1 and 2. The epicentre, origin time and magnitude of the earthquake have been taken from the epicentre cards issued by the U.S. Coast and Geodetic Survey.

The epicentral distance obtained from (S—P) interval using Jeffreys–Bullen (J.B.) Tables (1948) is in good agreement with the origin time, O, as issued by U.S.C.G.S. Other phases in Table 2 are also in good agreement with J. B. Tables. The epicentral distance from (S—P) interval is 43·9° but from (P—O) interval it is 44·1°. Since the P phase is clear in all the components, the epicentral distance obtained from (P—O) has been used. It is

TABLE 1

Date	Origin time (GMT)	Location of epicentre	Magnitude	Focal depth F and epicentral distance $\triangle$ from Bombay
18 Feb 1964	$12^h\ 04^m\ 40^s$	23·1°N, 120·5°E	6¾(Pas) $6\frac{3}{4\text{–}7}$ (EKS) 6·1 (CGS) 6½–6¾ (Pal)	F = 33 km $\triangle$ = 44·1° = 4901 km

TABLE 2

Phase symbol	Arrival time (GMT) h m s	Clearness of Phases: Milne-Shaw (N—S)	Milne-Shaw (E—W)	Sprengnether (E—W)	Benioff (Vertical)
P	12 12 52	clear	clear	clear	clear
PP	12 14 35	—	—	— } mixed	clear
PcP	12 14 42	clear	clear	— } mixed	clear
Pa	12 15 00	poor	poor	clear	clear
PPP	12 15 12	clear	clear	clear	clear
PcS	12 18 30	clear	clear	clear	—
S	12 19 24	poor	poor	clear	po
PS	12 19 29	clear	poor	poor	—
PPS	12 19 39	clear	clear	clear	—
SS	12 22 32	poor	poor	clear	—
ScS	12 22 50	poor	clear	clear	—
Sa(H)	12 23 09	clear	clear	clear	—
Sa(Z)	12 23 12	—	—	—	clear
SSS	12 23 29	—	clear	clear	—

range of 15 to 16 sec. Press and Ewing (1955), Tandon and Chaudhury (1963) have also observed Sa wave to be recorded earlier in the horizontal component. As is clear from Figs. 1 to 4, the wave has been recorded with bigger amplitude and longer period than body phases. The chance of the wave to be misinterpreted from ScS or SSS phases is also less because ScS comes 23 sec earlier and SSS 6 sec after this wave, for this epicentral distance which cannot be accounted for as due to error. The difference in appearances of the wave from body wave is also uggestive.

Observations about the waves are not sufficient to draw a very definite conclusion, but due to lower velocities obtained for the waves than that of Press and Ewing, *i.e.*, 8·24 km/sec for Pa and 4·58 km/sec for Sa, and being of the same order to that of Caloi, *i.e.*, 8·0 km/sec for Pa and 4·4 km/sec for Sa, it may be said that this observation supports Caloi's (1953) view of propagation of these waves in the low velocity channel of the mantle below Mohorovicic discontinuity, *i.e.*, "Sofar Propagation". Press and Ewing also supported this view if velocities obtained for these waves are equal to that obtained by

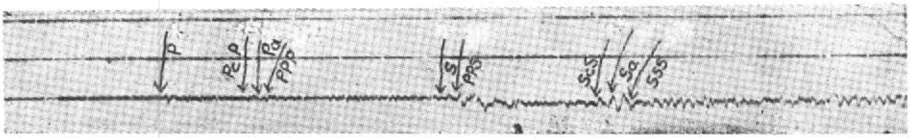

Fig. 1. Milne-Shaw seismogram — E-W component (T=12 sec; Damping=15 : 1; Magnification=250)

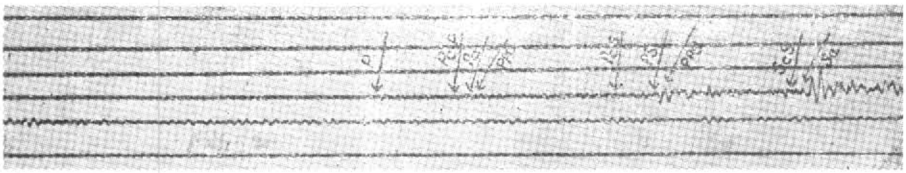

Fig. 2. Milne-Shaw seismogram — N-S component (T=12 sec; Damping=20 : 1; Magnification=350)

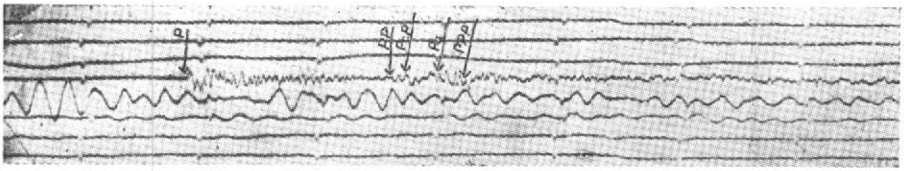

Fig. 3 (Left half)

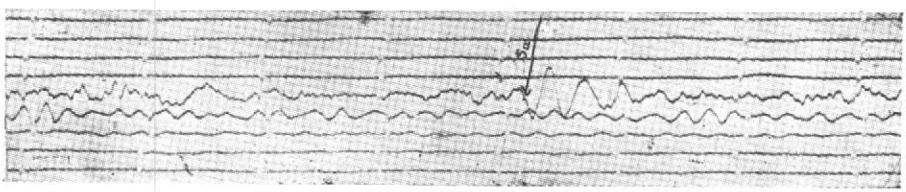

Fig. 3 (Right half). Benioff seismogram—vertical component (T_g=87, T_0=1 sec)

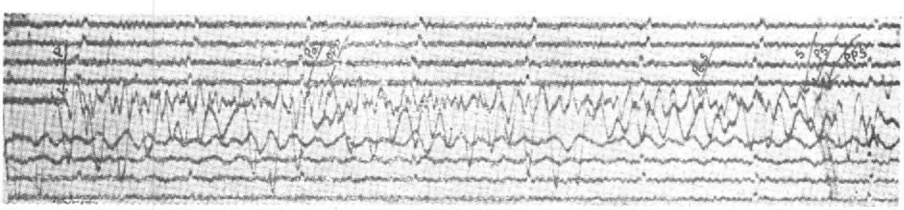

Fig. 4 (Left half)

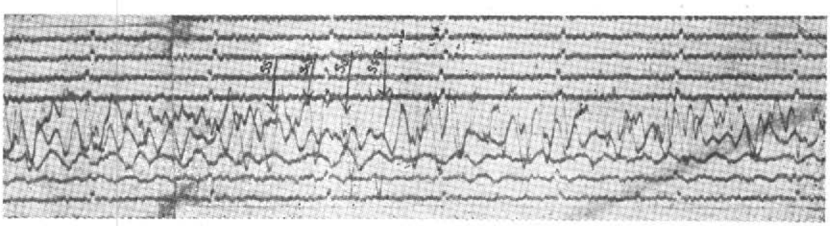

Fig. 4 (Right half). Sprengnether seismogram—E-W component
(T_g=7·4 sec; T_0=7·4 sec; Damping=2·3 : 1; Magnification=5000)

Caloi (1953). Thus the waves could be interpreted as Pa and Sa waves of Caloi.

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