32. *The Ratio of the Velocity of P and S Waves.*

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1. Introduction

In a previous paper[1], "Magnitude of the hypocentral region of an earthquake" was estimated from a time-distance curve analysis of seismic waves, and its seismological significance was studied in connection with earthquake energy to give a quantitative and seismometrical definition of the "hypocentral region of an earthquake." Practically, the estimate is greatly affected by the assumed values of V_P/V_S, the velocity ratio of the P and S waves, in the calculation. Therefore, and also from the following view point, the ratio is studied in this paper. So far, structures of the earthcrust were studied and classified in relation to the velocity of seismic waves, chiefly of P waves. While the determination of velocity is only made slowly, because of local difference and local complexity of the structure as classified from P-wave velocity: it is as yet difficult to find out a resolute seismological meaning of such a classification. Thereupon the velocity ratio of P and S wave, being directly related to the Poisson's ratio, comes to our attention as another measure of the classification. If the result here obtained, which implies an abrupt increase of the ratio V_P/V_S (to 1.78 from 1.67 in the earthcrust) at the Mohorovičić boundary, while nothing remarkable at any other boundary in the crust, be ascertained by further investigation, another geophysical significance will be added to the Mohorovičić boundary.

In due course, a method of examining the accuracies of the observed arrival time of P wave in Japan is presented.

2. Formula of calculation

The velocity ratio V_P/V_S is computed directly from a diagram of P–S interval (τ) against arrival time (T) of P, a linear relation between the two being presumed by many authors. Of course, strictly speaking,

1) R. YOSHIYAMA, "The Hypocentral Region of Earthquakes," *Bull. Seism. Soc. Am.*, **39** (1949), 187–188; **43** (1953), 153–158.

V_P/V_S should be computed from the respective analysis of time-distance curve of P and S waves. The method herein adopted is somewhat an expedient one to get a mean estimate of V_P/V_S, and, for that purpose, will be superior to the above mentioned strict method, because local complex structure only slightly affects the T–τ diagram to be computed: theoretically, if the ratio V_P/V_S is constant, the linear relation between T and τ is not affected at all either by the local difference of the velocity, or by the topographical or geological differences among the observatories, which give much trouble in the time-distance curve analysis. Putting,

$$V_P/V_S=1+\frac{1}{a} \tag{1}$$

where a is a certain constant, we get

$$a\tau+b=T \tag{2}$$

where b means the time when $\tau=0$, and, being denoted by T_0', was distinguished by the writer in the previous paper from the origin time, T_0, of P in the time-distance curve analysis.

The formula (2) being linear, and only two quantities being unknown, calculation of V_P/V_S, is far easier than the analysis of a time-distance curve. Assuming one a-value in several earthquakes, b being particular to each, and taking all the equations of observations of the form of (2) together in one scheme of the least square calculation, we can raise the accuracy of the computed a. According to the writer's rough estimation heretofore obtained, V_P/V_S in the earthcrust is 1.66∼1.70, while that below the Moho.-boundary is larger than 1.77.

In the following, studies of shallow focus earthquakes with the observations at short distances will give the V_P/V_S in the earthcrust, while those of deep-seated ones that below the Moho.-boundary. As to the shallow focus earthquake, particularly in Japan, observations of sufficiently high accuracy are difficult to obtain, because small earthquakes, which would otherwise give a distinct P and S phase, are not observed across sufficient distances owing to the short-coming of magnification of seismograph; on the other hand, P and S phase of a large earthquake are too complicated to be duly identified owing to the complicated earthquake mechanism.

3. Shallow focus earthquakes in Japan (1)

To avoid an undercrustal effect, calculation based on short distance observations, that is, observations of as small a P–S interval (τ) as possible is advisable, while, to get sufficient accuracy in the calculation by the T–τ diagram, we must have for each earthquake a sufficient number, some four or five at least, of observations distributed over some range of τ in the T–τ diagram. The extent of the range, or, in other words, the upper limit of τ to be adopted in the calculation, and the requisite number of observations for each earthquake should be determined taking the accuracy of observations into consideration.

In the Kinki district of Japan, shallow focus earthquakes arise frequently and geographical distribution of observatories are favourable for observation of these earthquakes. Therefore, eight shallow focus earthquakes in this area in 1953 and 1954, tabulated in Table I, are first

Table I.

Earthq. No.	Date	Epicentre		Depth
		N	E	km
1	Sept. 18, 1953	33°48′	135°36′	10
2	Oct. 8, 1953	33 48	135 06	20
3	Nov. 7, 1953	34 42	136 24	10
4	Mar. 22, 1954	34 12	135 12	10
5	Apr. 20, 1954	35 12	135 30	10
6	Apr. 26, 1954	36 00	136 18	10~20
7	June 24, 1954	35 24	135 45	10~20
8	Oct. 25, 1954	34 54	134 54	Shallow

(*from Scism. Bull. Centr. Meteor. Obs. Japan*)

studied. In the seismological Bulletin of the Central Meteorological Observatory (Japan) are reported the arrival times and the P–S intervals of these earthquakes except earthquake No. 8, about which the writer requested information as to observations.

There being nine unknown quantities, one a and eight b, the a-value common to the eight earthquakes was calculated based on 72 observations in all, in which the largest τ is 17 sec, with the result that $a=1.395$ and $V_P/V_S=1.72$.

However, the standard deviation of a single observation of arrival time reached 1.3 sec. Moreover, the upper-limit of τ as large as 17 sec, adopted in the above calculation, to get a sufficient number of observations for a required accuracy of calculation, is too large to study the earthcrust, because, in the time-distance curve of P, some undercrustal effect is apparent already at a distance of 100 km, where P–S interval is perhaps not more than 14 sec. And, by the writer's asking each observatory for the reexamination of the seismograms, it was ascertained that, as regards the earthquakes, No. 1, 2, 3, 4 and 7, many observations were unsatisfactory, partly because of the conditions of the observatories, and partly because of an undiscernible P and S phases. As to the earthquakes, No. 5, 6 and 8, some of the observations were revised and are given in the Table II, III and IV, and, on these three

Table II. Earthq. No. 5; $T_z=13^h13^m30^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Kyoto	30.7	6.0	3.2	+0.13	−0.97
Maizuru	29.8	7.9	4.4	+0.22	+1.08
Kobe*	64.2	11.6	8.0	−1.49*	−0.77
Nara	64.9	12.0	7.0	+0.41	−0.53
Osaka	61.0	12.0	7.5	−0.34	+0.16
Toyooka	71.2	13.9	8.9	−0.54	+0.33
Hikone	68.5	14.0	9.2	−0.90	+0.78
Himeji	83.4	16.3	9.9	+0.35	+0.62
Kameyama	96.2	17.1	10.3	+0.55	−0.87
Wakayama	111.6	19.2	12.0	+0.09	−1.61
Tsu	106.2	19.5	11.8	+0.69	−0.25
Sumoto	109.9	19.8	12.9	−0.66	−0.66

$a=1.504,\ b_5=+1.06$ sec.

Table III. Earthq. No. 6; $T_z=05^h20^m22^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Fukui*	7.4	3.5	1.8	+2.58*	+2.09
Tsuruga	44.2	6.4	4.9	+0.82	+0.24
Ibukiyama	68.8	9.2	8.0	−1.04	−1.17
Gifu	78.8	11.6	9.1	−0.29	−0.52
Takayama*	87.1	11.8	13.8	−7.16*	−1.72
Hikone	81.6	13.1	9.4	+0.75	+0.45
Maizuru	101.8	16.9	12.4	+0.04	+0.73
Nagoya	110.4	18.1	13.4	−0.26	+0.49
Kyoto	120.6	18.3	13.6	−0.36	−1.27
Kameyama*	126.7	19.3	15.2	−1.77*	−1.35
Toyama	111.9	20.5	14.6	+0.34	+2.54

$a=1.504,\ b_6=-1.79$ sec.

Table IV. Earthq. No. 8; $T_z=20^h22^m46^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Himeji	19.1	3.5	3.7	−1.04	±0.00
Kobe	34.0	5.7	4.6	−0.04	+0.37
Sumoto	59.2	10.8	7.6	+0.40	+1.21
Toyooka	70.7	11.1	8.3	−0.36	−0.20
Osaka	63.5	11.5	7.8	+0.80	+1.40
Wakayama	76.2	13.5	9.5	+0.24	+0.97
Kyoto*	77.1	15.1	8.8	+2.81*	+2.75
Takamatsu	100.1	16.8	11.8	+0.08	−0.13
Hikone	129.5	20.4	14.3	−0.08	−1.21

$a=1.504$, $b_8=-1.03$ sec.

earthquakes, the following was computed. For convenience of tabulation and calculation, arrival time (T) of P are measured from a certain arbitrary time, which is denoted by T_z and is given at the top of each table. From these observations of T and τ, except five observations (Kobe in No. 5; Fukui, Takayama and Kameyama in No. 6; Kyoto in No. 8), a, common to the three earthquakes, and three b are calculated.

The results are that

$$a=1.504\,, \qquad \text{i.e.}\quad V_P/V_S=1.665\,,$$

$$b_5=+1.06\text{ sec}\,, \qquad b_6=-1.79\text{ sec}\,, \qquad b_8=-1.03\text{ sec},$$

residuals (obs.-cal.) of T being calculated and denoted by $\varepsilon_T(\tau)$,

$$\sum_{27}\varepsilon_T^2(\tau)=7.62\text{ sec}^2$$

excluding the five observations stated above.

The standard deviation of a single observation of T is 0.6 sec and the standard deviation of a is 0.03, so that V_P/V_S is 1.65∼1.68. The resulting T–τ diagram of the three earthquakes is

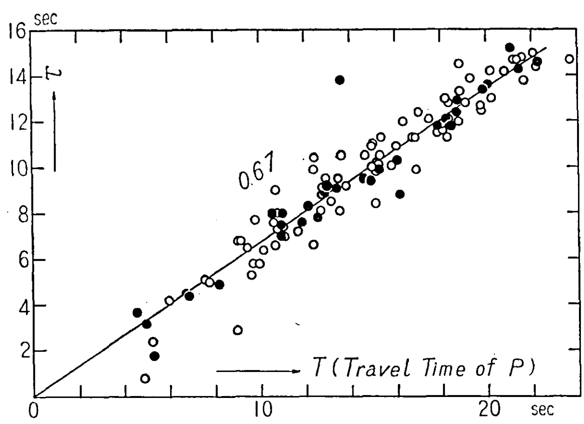

Fig. 1. T (Travel time of P)∼τ (P–S interval) relation of the earthquakes in the Kinki district, origin time of P being assumed at the time when $\tau=0$. And ●··Earthq. No. 5, 6, 8; ○··Earthq. No. 9∼14.

shown in Fig. 1 by filled-up circles ●; open circles ○ in the same figure are concerned with the six earthquakes studied in the following paragraph.

4. Shallow focus earthquakes in Japan (2)

In the above calculation, from a somewhat presumptive consideration by the writer of the accuracy of each observation, only three earthquakes of the eight were available. Therefore, six more earthquakes in the same district, given in Table V, were studied. The arrival times

Table V.

Earthq. No.	Date	Epicentre		Depth
		N	E	km
9	Nov. 24, 1953	35°12′	135°48′	20
10	Dec. 21, 1954	35 06	135 42	20
11	Feb. 13, 1955	33 54	135 12	10
12	Feb. 17, 1955	36 00	136 18	20∼30
13	Nov. 4, 1955	34 42	136 06	60
14	Nov. 17, 1955	33 57	135 33	20

(*from Seism. Bull. Centr. Meteor. Obs. Japan*)

Table VI. Earthq. No. 9; $T_z = 14^h 53^m 19^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Kyoto	21.3	0.3	4.2	−0.25	+1.43
Hikone	41.6	2.1	5.0	+0.37	+0.14
Tsuruga	55.5	4.3	5.8	+1.38	+0.01
Maizuru	48.1	5.0	6.6	+0.90	+2.06
Osaka	65.7	6.7	9.9	−2.28	+0.71
Kameyama	72.0	7.2	9.1	−0.59	+0.17
Gifu	90.8	9.3	10.0	+0.17	−1.06
Tsu	85.7	9.5	10.2	+0.08	+0.02
Kobe	80.1	9.6	10.1	+0.33	+1.17
Toyooka	96.9	11.2	11.3	+0.15	−0.23
Fukui	102.3	11.8	12.1	−0.43	−0.50
Himeji	108.0	14.1	12.7	+0.98	+0.72
Owashi	131.0	15.7	14.7	−0.37	−1.79
Wakayama	121.9	15.9	14.8	−0.32	+0.02
Sumoto	125.4	16.4	15.0	−0.12	−0.03

$a = 1.478$, $b_9 = -5.66$ sec.

Table VII. Earthq. No. 10; $T_z=19^h32^m07^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Kyoto*	9.6	−3.3	0.8	+3.72*	+1.50
Hikone	54.5	0.9	6.8	−0.95	−0.66
Osaka	52.2	1.2	6.5	−0.21	+0.13
Nara	47.9	1.4	5.3	+1.76	+1.00
Maizuru	50.0	1.9	6.4	+0.64	+1.17
Kobe	65.9	2.8	7.0	+0.65	−0.65
Ibukiyama	69.7	4.2	10.4	−2.97	+0.09
Tsuruga	69.6	5.3	8.1	+1.53	+1.19
Kameyama	75.1	5.6	9.2	+0.20	+0.58
Tsu	86.6	6.9	9.8	+0.61	−0.21
Himeji	95.6	7.6	10.1	+0.87	−1.11
Wakayama	107.7	8.1	12.0	−1.44	−2.74
Toyooka	93.8	8.7	9.9	+2.26	+0.35
Sumoto	111.0	8.8	12.4	−1.33	−2.58
Gifu	102.7	10.0	13.0	−1.02	+0.05
Owashi	123.4	11.1	13.9	−1.25	−2.43
Nagoya	115.4	12.6	14.2	−0.19	+0.51
Fukui	116.0	14.0	14.4	+0.91	+1.73

$a=1.478$, $b_{10}=-8.20$ sec.

Table VIII. Earthq. No. 11; $T_z=02^h27^m48^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Wakayama*	37.2	0.4	2.9	+4.29*	+2.12
Sumoto	54.8	0.5	6.8	−1.01	−0.72
Tokushima	59.8	2.5	7.4	+0.11	+0.42
Shionomisaki	72.2	4.5	9.1	−0.41	+0.35
Owashi	94.0	6.1	10.5	−0.88	−1.91
Kobe	87.0	6.8	11.3	−1.36	+0.03
Osaka	88.8	8.2	11.3	+0.04	+1.07
Nara	104.7	9.8	12.8	−0.57	−0.17
Himeji	113.4	11.7	13.0	+1.03	+0.31
Murotomisaki	118.2	12.8	14.7	−0.39	+0.52
Takamatsu	115.6	13.1	13.8	+1.24	+1.17
Kyoto	133.4	15.4	14.7	+2.22	+0.43

$a=1.478$, $b_{11}=-8.54$ sec.

Table IX. Earthq. No. 12; $T_z=17^h06^m16^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Fukui	8.0	0.5	2.4	+1.67	+1.97
Tsuruga	44.4	2.8	5.1	−0.02	−0.43
Ibukiyama	68.5	7.6	6.6	+2.56	+0.16
Gifu	79.5	8.0	8.8	−0.29	−1.37
Hikone	81.4	8.4	8.5	+0.55	−1.13
Kanazawa	69.3	8.7	9.5	−0.63	+1.26
Takayama	87.0	10.2	10.9	−1.20	−0.39
Maizuru	101.7	13.1	11.5	+0.82	−0.14
Nagoya	111.0	14.1	13.3	−0.84	−0.76
Kyoto	120.2	14.1	14.5	−2.62	−2.36

$a=1.478$, $b_{12}=-4.72$ sec.

Table X. Earthq. No. 13; $T_z=08^h32^m42^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$
	km	sec	sec	sec
Nara	24.2	0.9	5.8	+1.11
Tsu	37.9	1.0	7.7	−1.60
Hikone	64.4	1.9	9.0	−2.62
Kyoto	48.5	2.0	8.0	−1.05
Kameyama	37.2	2.9	7.2	+1.03
Osaka	52.0	3.9	8.1	+0.70
Owashi	70.9	4.8	10.5	−1.94
Kobe	83.4	6.5	10.5	−0.24
Nagoya	94.4	9.3	11.6	+0.93
Gifu	98.6	9.3	11.9	+0.49
Tsuruga	105.5	9.4	12.0	+0.45
Wakayama	99.5	9.5	11.3	+1.57
Maizuru	107.3	10.0	12.0	+1.04
Sumoto	115.1	10.3	12.8	+0.16

$a=1.478$, $b_{13}=-8.78$ sec.

of P and P–S intervals, reported in the Seismological Bulletin of the Central Meteorological Observatory, are given in the Tables VI to XI, T being measured from a certain arbitrary time T_z and were used in the calculation without any revision in this case, but two observations, Kyoto and Wakayama, denoted by *, are omitted. The results of the calculation based on these 75 observations for the six earthquakes are that

Table XI. Earthq. No. 14; $T_z=03^h53^m08^s$ J.S.T.

Obs.	Δ	T	τ	$\varepsilon_T(\tau)$	$\varepsilon_T(\Delta)$
	km	sec	sec	sec	sec
Shionomisaki	59.0	0.4	7.6	−0.64	+0.14
Owashi	61.2	0.6	7.3	−0.01	+0.01
Sumoto	72.2	2.7	9.5	−1.15	+0.20
Kobe	88.2	4.8	11.0	−1.27	−0.50
Osaka	77·7	4.9	8.4	+2.67	+1.36
Tokushima	89.9	5.8	10.9	−0.12	+0.15
Kyoto	119.5	9.6	12.5	+1.31	−1.39
Kameyama	130.8	10.0	14.2	−0.80	−2.96

$a=1.478$, $b_{14}=-10.19$ sec.

$$a=1.478\pm0.05 \text{ (M.E.)}, \qquad \text{i.e.} \quad V_P/V_S=1.676 ,$$

$$b_9=-5.66 \text{ sec}, \quad b_{10}=-8.20 \text{ sec}, \quad b_{11}=-8.54 \text{ sec},$$

$$b_{12}=-4.72 \text{ sec}, \quad b_{13}=-8.78 \text{ sec}, \quad b_{14}=-10.19 \text{ sec},$$

$$\sum_{75} \varepsilon_T^2(\tau)=105.50 \text{ sec}^2 .$$

The standard deviation of a single observation of arrival time T is 1.2 sec and that of the calculated a is 0.05, therefore V_P/V_S is estimated between 1.70∼1.65. The T–τ diagram, T being measured from each "b", of the six earthquakes is given by open circles in Fig. 1. That V_P/V_S is about 1.68 is also concluded from a calculation based on 102 observations of 11 earthquakes which occured in swarm in Tokusima and Kooti Prefecture of the Sikoku district in 1955, Fig. 2 being the T–τ diagram of these earthquakes, but the mean of $\varepsilon_T(\tau)$ is as large as 1.8 sec; the dispersion of observations are too large to study in more detail. Since the effect of the inner part, whose V_P/V_S is no less than 1.78 as shown later on, increases the apparent V_P/V_S of the earthcrust, 1.67 may be perhaps

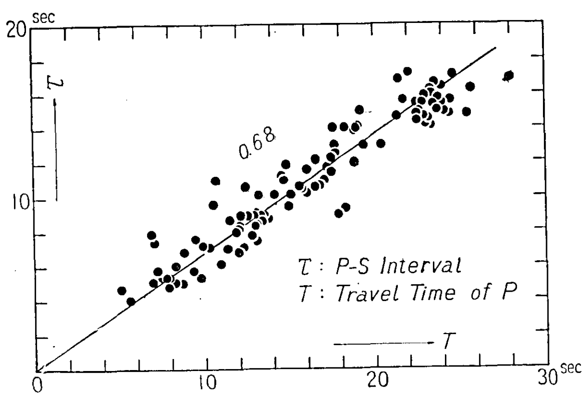

Fig. 2. T–τ relation of 11 earthquakes in the Sikoku district in 1955.

the most probable value thereof. Results of a computation with the seven earthquakes studied in the "Velocities of P at short distances"[2] by Dr. C. F. Richter gives also $V_P/V_S \doteqdot 1.67$, provided the observations whose P–S intervals are less than 8 sec are used.

5. Some remarks on the accuracies of observations

Fig. 3 is the time-distance relation of the above studied eight earthquakes in the Kinki district, the earthquake No. 13, since clearly deeper focussed than the others, being excluded. The time when $\tau=0$, which is given by respective "b", is adopted for the origin time of each earthquake. In the figure, not only the observed travel time of P, given in the tables and measured of course from "b", but also $a\tau$, that is, calculated travel time from the P–S intervals are plotted. In this way, if not always advisable, observations of S are added to the computation of the P-wave velocity, when the accuracies of observations of arrival times are doubtful compared with those of the P–S intervals.

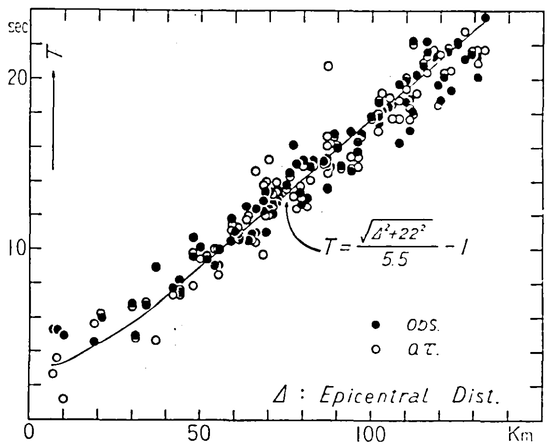

Fig. 3. Time-distance relation of the earthquakes No. 5, 6, 8, 9, 10, 11, 12 and 14.

For convenience in numerical computation, the following expression was assumed as a mean curve through the all, observed and calculated, points in Fig. 4. Δ being measured in km,

$$T=\frac{\sqrt{\Delta^2+(22)^2}}{5.5}-1 \text{ sec.} \qquad (3)$$

The formula (3) suggests an assumptive earthquake as a mean of the eight earthquakes, such that its hypocentral depth is 22 km, while radius of its hypocentral magnitude is 5.5 km, and the P-wave velocity in the earth-crust is 5.5 km/sec. Obviously, even to determine the P-wave velocity, too dispersive are the observations, but it does no matter in

2) C. F. RICHTER, "Velocities of P at short distances," *Bull, Seism. Soc. Am.*, **40** (1950), 281–289.

the present study whether these, plausible to the writer, implications are appropriate or not.

The last column $\varepsilon_T(\Delta)$ of the tables give the residuals of the observed T, measured of course from "b", from the calculated ones by the formula (3), that is

$$\varepsilon_T(\Delta) = (\text{"}T\text{" in the Table-}b) - (T \text{ cal. by } (3)).$$

Thus we have two kind of residuals of observed arrival time of P, respectively denoted by $\varepsilon_T(\tau)$ and $\varepsilon_T(\Delta)$, one from the T–τ diagram, and the other from the T–Δ diagram. And the correlation between the two are illustrated in Fig. 4.

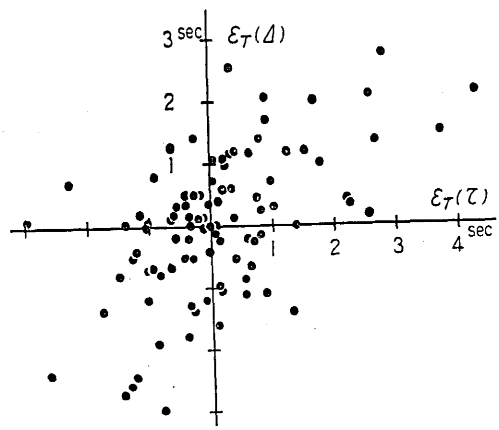

Fig. 4. Correlations between the two kind of residuals.

In Fig. 4, most of the observations are within a range of $|\varepsilon_T(\tau)| \leqslant 1$ sec and $|\varepsilon_T(\Delta)| \leqslant 1$ sec, and, as far as these points are concerned, any significant correlations between $\varepsilon_T(\tau)$ and $\varepsilon_T(\Delta)$ are not observed. On the other hand, for the observations whose $\varepsilon_T(\tau)$ or $\varepsilon_T(\Delta)$ is large, we can clearly see a positive correlation; that is, if we assume some corrections to the arrival time, not only the dispersions in the T–Δ diagram, but also those in the T–τ diagram, decrease altogether without any revision of the P–S intervals. Consequently it seems to the writer, there is much more to be improved in the observation, especially, of arrival time of P, to reduce the dispersions from the assumed linear relation between T and τ, previous to attributing them to some other seismological or geological causes.

6. Deep-seated earthquakes in Japan

That $d\tau/dT$ of a deep-seated earthquake and also that of a distant earthquake are about 0.8 has been pointed out or implicitly given already by some senior authors in their studies of velocity of P and S waves. In this paper, $(d\tau/dT)$ of the three deep-seated earthquakes in the Table XII was computed, time-distance curve and earthquake mechanism of these earthquakes being long before thoroughly investigated by Kawasumi, the writer and others. Especially as regards earthquake No. 15,

Table XII.

Earthq. No.	Date	Origin time	Epicentre		Depth
		h m s	N	E	km
15	Feb. 20, 1931	5 33 24.0	44°29′	135°45′	325
16	June 3, 1929	6 38 36.1	34 20	137 08	353
17	June 2, 1931	11 37 52.3	35 55	137 23	240

Kawasumi and the writer[3] studied its earthquake mechanism and time-distance curve of P in some detail based on world wide observations. Fig. 5 is the T–τ diagram of the earthquake.

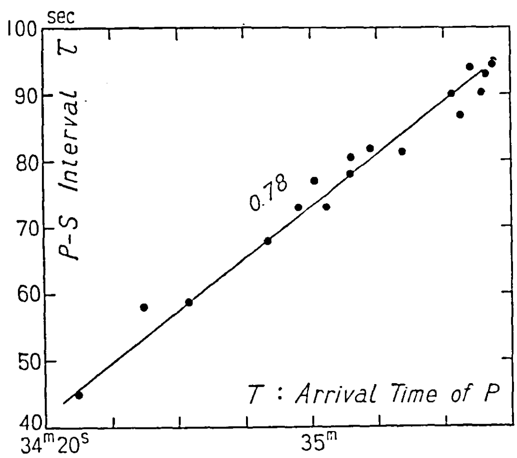

Fig. 5. T–τ relation of the deep-seated earthquake on 20, Feb., 1931.

According to the results of studies of earthquake mechanism, one of the four "nodal points of S wave" of this earthquake, where original S wave from the origin would not be observed theoretically at all, is close to Aomori in Japan.

Since the observations of P–S interval at observatories near the nodal points would be naturally inaccurate, observations at Aomori and some other observatories near the nodal point are not used. And also excluded are the observations at epicentral distances much greater than the inflexion point, $\Delta_i \doteqdot 7°$, of the time distance curve of P wave. In the T–τ diagram, Fig. 5, 18 points are plotted, but observation of arrival time at Haboro seems unreliable. Then the results of the calculation based on 17 points are,

$$a = 1.280 \pm 0.05 \text{ (M.E.)}, \qquad \text{i.e. } V_P/V_S = 1.781,$$

$$b = 26.5 \text{ sec} \pm 4 \text{ sec}.$$

Fig. 6 is the T–τ diagram of the earthquake No. 16 in which 49 points are plotted; 10 observations, Tsu, Shionomisaki and etc., whose residuals

3) H. KAWASUMI and R. YOSHIYAMA, "On the Deep-seated Earthquake of Feb. 20, 1931" [in Japanese], *Zisin* (*Jour. Seism. Soc. Japan*), **6** (1934), 415, "On the Mechanism of a Deep-seated Eapthquake", *Proc. Imp. Acad. Japan*, **10** (1934), 345-348.

are greater than 5 sec, being excluded. And the results of computation with 29 points whose residuals are smaller than 2 sec are,

$a=1.270$, i.e. $V_P/V_S=1.787$,

$b=37.4$ sec.

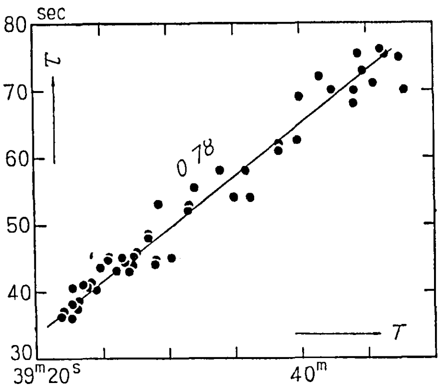

Fig. 6. T-τ relation of the deep-seated earthquake on 3, June, 1929.

Fig. 7 is the T-τ diagram of the earthquake No. 17. Calculations with 24 points out of 33 points in the figure gives a result that

$a=1.291$, i.e. $V_P/V_S=1.774$,

$b=53.5$ sec.

The results of b of these three earthquakes were already used in the studies of the "Hypocentral region of earthquake." A tendency that apparent V_P/V_S decreases with the origin depth of the earthquake concerned may be partly due to the effect of the earthcrust whose V_P/V_S is not greater than 1.68. However, some actual increase of V_P/V_S towards the inner part of the earth may be also expected.

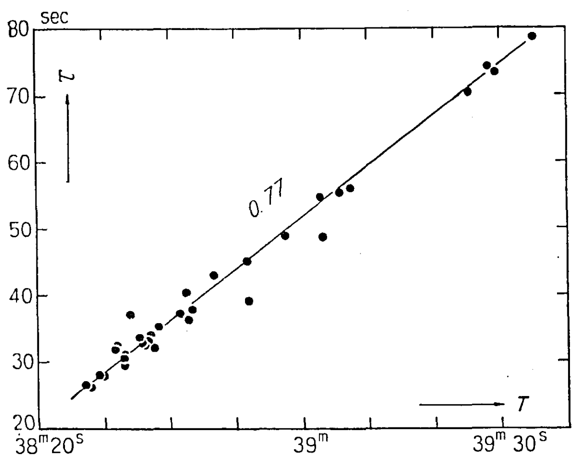

Fig. 7. T-τ relation of the deep-seated earthquake on 2, June, 1931.

7. Concluding remarks and acknowledgement

It is clear that in the earthcrust V_P/V_S is not much greater than 1.67 and that of inner part is about 1.78, the corresponding Poisson's ratio being 0.22 and 0.27 respectively. Since the T-τ diagrams and the T-Δ diagrams of the shallow focus earthquakes, for the range of distance $\Delta=130$ km$\sim$200 km, are extremely dispersive, presumed abrupt (in practical saying) increase of V_P/V_S at the Moho.-boundary was not confirmed in this paper. However, if the increase of

V_P/V_S is gradual, the apparent V_P/V_S of the deep focus earthquake, for example No. 17, will be far less than that here obtained. To get a more definite conclusion, a higher accuracy of observations, as regards time-keeping and driving rate of the recording drum, and, especially for shallow focus earthquakes, some established seismological and practical method to distinguish the original (directly coming from the earthquake centre) S-phase are necessary. Because, in the course of these studies, very often it seemed to the writer that, the incidence of S wave following a conventional method being assumed at a certain "remarkable phase" in the seismograms, P-wave generated by S wave at some inner-crustal boundary might have been mis-reported as the original S wave which comes out a few seconds later. Amplitudes of these P waves are too large to overlook for a certain range of angle of incidence of the S-wave.

If it were not a mere numerical appearance resulting from the calculation, accuracies of which are yet unsatisfactory, the fact that the Poisson's ratio of the two media, bounded by the Moho.-boundary, is almost equally larger in the one and less in the other than the generally adopted value of 0.25 predicted by Cauchy, is interesting to the writer, and leads to the expectation of throwing some light on our knowledge of the physical state at the boundary.

The writer is grateful to the members of the observatories for their kind information of observations, and to Miss Y. Satô and Miss S. Murata for their assistance in these laborious computations.

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32. P 波 S 波の速度比に就いて

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P 波と S 波の速度比は半ば習慣的に 1.73 とされているが，験震学的に“震源域”の大いさを計算するためにはこの比の値をも少し精度高くきめることが必要である．近畿地方の浅発地震によつて計算した結果，地殻内ではこの比が 1.73 よりは明かに小さく 1.67 に近く，深発地震で調査した結果,内部では 1.78 に近いのではないかと思われる．アメリカに於ける近地地震観測からも同地に於けるこの比の値は矢張り 1.67 に近く推定され，地殻内に於ける P波の速度が日本とアメリカに於いて，少くとも今迄のところ可成り異つているらしいことに比べて面白い一致である．即ち速度比が速度そのものよりも地殻とそれから内部の性質のちがいを一層端的に示しているものとすれば，モホロビチック不連続面の性質を明かにするために，或はまた，その辺りに最も多く地震が発生することをも考え合せて，この比の調査は冒頭の目的以外にも更にくわしく行わねばならぬと思われる．そのためには，装置の面からも，また複雑な地震記象の中から S 波をはつきり検出するための基本的な技術の面からも観測の精度を高める必要がある．
