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ON AZIMUTHAL DISTRIBUTION OF THE CRUSTAL POISSON'S RATIO IN CASE OF EARTHQUAKE OCCURRENCES (Preliminaries)

BY

Akira KAMITSUKI

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ABSTRACT

Applying the *P–S* diagram analysis to some shallow earthquakes, it was found that the crustal Poisson's ratio in case of earthquake occurrence has different values in the push- and pull-zone of initial motion of seismic wave. This may be related to the state of stress accumulation causing the earthquake occurrence in the Earth's crust.

1. Introduction

By what causes an earthquake occurs is one of the most interesting problems in geophysics. Many investigators have been trying to solve this problem, but the essential of this problem still remains unsolved to the present time.

In general, the following process of earthquake occurrence may be accepted. First the stress energy is accumulated in a certain confined region of the Earth's interior, and the amount of accumulated stress approaches the limit of the strength of material in the particular part. As soon as the stress exceeds this limit, the fracture occurs and the stored energy is released in the form of elastic waves, crustal deformation, etc. (**1**, **2**, **3**, **4**). In most cases, it is assumed that the stress is accumulated uniformly in the confined region of the Earth's interior and the stored energy is released instantaneously with the emission of elastic waves.

Practically, some models of stress distribution varying azimuthally around the epicenter may be considered presuming from the data of push-pull distribution of initial motion, amplitude distribution of *P*- and *S*-waves, crustal deformation associated with the earthquake occurrence, etc. (see, e.g. **5**). Moreover, earthquakes are frequently accompanied by some aftershocks which occur in the same region with almost similar mechanism to that of the main shock. From this fact, it may be supposed that the stress accumulation is not always released instantaneously and the stored energy remains for the duration of earthquake occurrences. Recently the variation of elastic constants associated with the seismic activities has been reported in some cases (**6**, **7**).

In order to clarify the cause and mechanism of earthquake occurrences, it is very important to investigate the crustal Poisson's ratio in relation to earthquake occurrences. In the present paper, the *P–S* diagram method is applied to some earthquakes which occurred in the Earth's crust and the azimuthal distribution of Poisson's ratio is examined in some detail.

2. Case of the Daishoji-Oki earthquake on March 7, 1952

The Daishoji-Oki earthquake occurred on March 7, 1952 and was accompanied by many aftershocks. Its magnitude is reported to be 6.8 in the Bulletin of the Japan Meteorological Agency. The push-pull distribution of initial motion is shown in Fig. 1. The so-called quadrant-type pattern is ascertained in the neighbouring region of the epicenter.

The succeeding aftershocks have a similar pattern to that of the main shock. From this it may be inferred that the stress distribution causing the main shock may remain after its occurrence. The *P–S* diagram is shown in Fig. 2, and its data are given in Table 1.

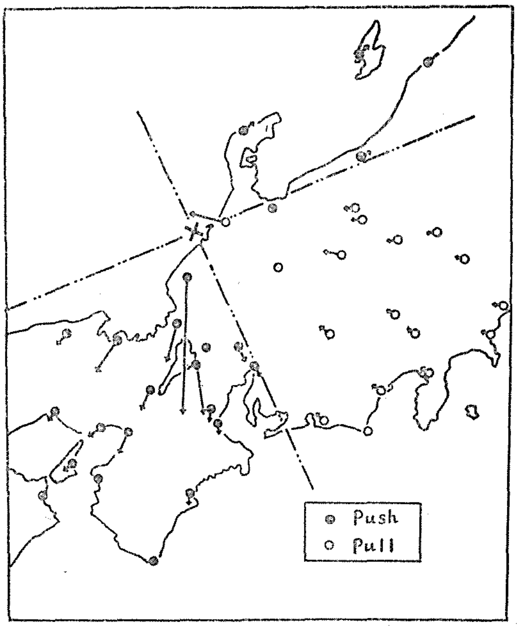

Fig. 1. The epicenter and push-pull distribution of the Daishoji-Oki earthquake on Mar. 7, 1952.

Table 1. The Daishoji-Oki earthquake
1952 Mar. $7^d\,16^h\,32^m$ (36°28′.1 N, 136°12′.3 E; $H=20$ km)

Station	Push or pull	*P*-wave		*S*-wave		Δ
		Phase	Time	Phase	Time	
			m s		m s	km
Fukui	+	iP_{NE}	32 46.7	*S*	32 51.5	46.3
Kanazawa	−	iP_{E}	46.8	*S*	54.7	40.8
Toyama	+	*P*	54.3	*S*	33 6.2	92.6
Tsuruga	+	*iP*	54.7	*S*	6.7	91.5
Takayama	−	*eP*	56.0	*S*	10.6	100.1
Wajima	+	*iP*	58.5	*S*	14.1	119.6
Maizuru	+	*iP*	33 0.0	*S*	17.2	133.4
Hikone	+	*iP*	1.4	*S*	24.7	133.4
Gifu	+	*iP*	1.9	*S*	—	128.8
Nagoya	+	*iP*	4.2	*S*	23.1	161.2
Toyooka	+	*iP*	4.2	*S*	25.1	157.5

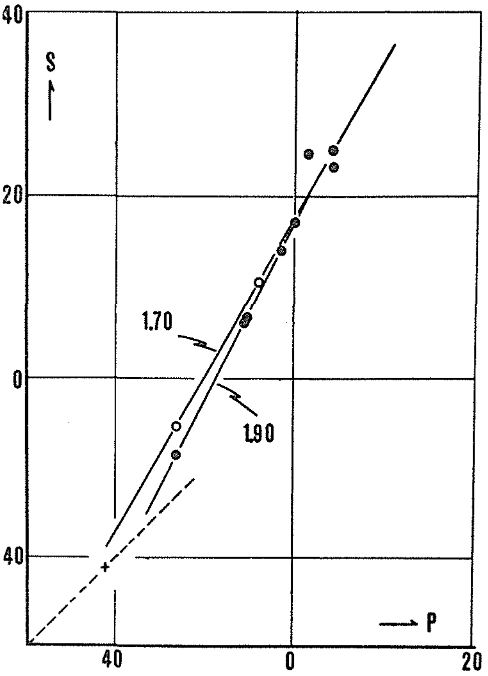

Fig. 2. The *P*–*S* diagram of the Daishoji-Oki earthquake.
(Solid circle : push, open circle : pull)

In Fig. 2, the points are separated into two groups according to the initial motion being either push or pull, and they are arrayed on the two branched lines. The points of stations in the pull-zone are arrayed on the upper line while the points of stations in the push-zone are arrayed on the lower line. These two lines coincide at the further part corresponding to the epicentral distances of over 150 km. The gradient of the upper line is 1.70, while that of the lower line is 1.90. Compared with the normal value of V_p/V_s in the Earth's crust (≒1.67), it is found that the former is a little larger and the latter is much larger than the normal value. It can be safely said that this effect is attributed to the variation of crustal Poisson's ratio, because the distribution of points in the *P*–*S* diagram is not affected by any other condition than the elastic properties of the Earth's crust (8). Moreover, the two values mentioned above must be considered to be the apparent ones of V_p/V_s, reflecting upon the drawing method of the *P*–*S* diagram. And so if the origin time at the hypocenter is known, the variation of the value of V_p/V_s can be immediately obtained. Assuming that the origin time at the hypocenter is only one, being common to *P*- and *S*-waves, it slides on a straight line with 45° gradient passing through the origin of diagram. The two intersection points of this line with the two branched lines mentioned above will give the origin times of the push- and pull-motions respectively. But the difference of about 5 sec in the present case is too large to correlate with the dimension of the hypocenter. From the analysis of time-distance curve as shown in Fig. 3, the origin time is estimated to be about $32^{m}39^{s}$ and is plotted on the segment between two branched lines. Considering that the value of V_p/V_s in the Earth's crust must have its upper and lower limits corresponding to the state of stress accumulation, the linearity of the two branched lines will be broken at the part of left end, and the upper line will be convex upward, and the lower one downward respectively. Finally, their end points converge to one origin time. For the lack of points close to the origin-time point, this breaking of linearity is not yet ascertained.

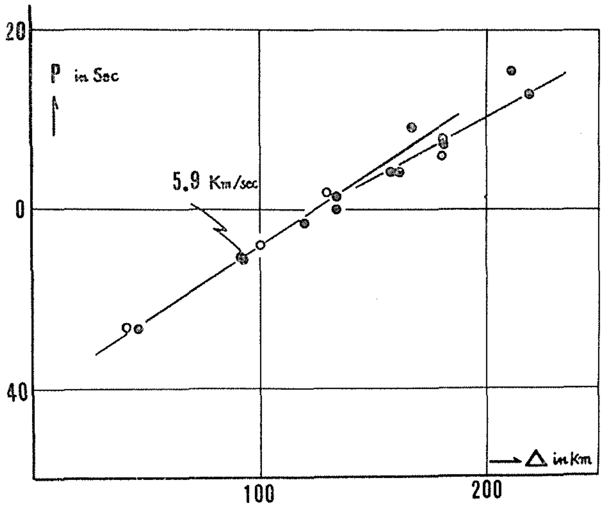

Fig. 3. The time-distance curve of the Daishoji-Oki earthquake.

From the above consideration it may be concluded that the mean value of V_p/V_s estimated along the path from the hypocenter to the station in the push-zone is at first about 1.60 and then increases with the increase of hypocentral distance, while in the pull-zone it is at first about 1.72 and then decreases with the increase of hypocentral distance, both two approaching to the normal value of 1.67. At the epicentral distances of over 150 km they coincide within the observation accuracy. The distance of the point of coincidence of the two branched lines and the deviation of the apparent value of V_p/V_s from the normal one may be correlated to the earthquake magnitude and the state of stress accumulation. This fact is ascertained by comparison of the case of Daishoji-Oki earthquake with that of Tokushima earthquakes treated in the next section.

In several aftershocks which occurred succeeding to the main shock, the above-stated effect still remains but its amount becomes considerably small. This may correspond to the releasing rate of stress accumulation after the occurrence of the main shock.

3. Some examples in other regions

In Shikoku, especially in the Tokushima Pref., shallow earthquakes have frequently occurred from about 1950. Their magnitudes are estimated to be from about 4 to 5. Among them the earthquake which occurred on July 27, 1955 has the largest magnitude of 6.0 Some earthquakes which occurred before and after this earthquake are examined concurrently.

Table 2. The earthquake on Apr. $10^{d}\,11^{h}\,9^{m}\,12^{s}$
($34.1°N$, $134.2°E$; $H=10$ km ca.)

Station	Push or pull	*P*-wave		*S*-wave		Δ
		Phase	Time	Phase	Time	
			m s		m s	km
Tokushima	–	*iP*	9 20.1	*iS*	9 24.8	35.2
Takamatsu	+	*iP*	23.6	*iS*	28.7	27.8
Sumoto	–	*iP*	26.9	*iS*	35.5	70.4
Wakayama	(–)	*eP*	29.8	*eS*	41.7	92.6
Okayama	+	*iP*	29.9	*iS*	39.4	68.6
Kochi	–	*iP*	30.0	*iS*	40.1	87.1
Murotomisaki	+	*iP*	32.1	*S*	42.4	96.4
Kobe	+	*P*	35.4	*iS*	48.4	111.2

Table 3. The earthquake on May $18^{d}\,13^{h}\,39^{m}\,24^{s}$
($33.8°N$, $134.3°E$; $H=0\sim20$ km)

			m s		m s	km
Tokushima	–	*iP*	39 31.8	*iS*	39 37.3	40.8
Takamatsu	+	*iP*	36.0	*iS*	43.4	61.2
Murotomisaki	+	*iP*	36.4	*S*	43.2	63.0
Kochi	–	*iP*	37.6	*iS*	46.9	76.0
Sumoto	–	*iP*	40.1	*iS*	50.7	83.4
Wakayama	(–)	*iP*	40.8	*iS*	52.9	92.6
Okayama	+	*iP*	43.0	*iS*	55.0	105.6
Shionomisaki	(–)	*eP*	43.9	*iS*	40 0.7	140.8

Table 4. The earthquake on July $27^{d}\,10^{h}\,20^{m}\,49^{s}$
($33.75°N$, $134.3°E$; $H=0\sim10$ km)

			m s		m s	km
Tokushima	+	*iP*	20 58.5	*iS*	21 3.6	44.5
Murotomisaki	+	*iP*	21 0.9	*iS*	6.6	57.4
Takamatsu	+	*iP*	2.6	*iS*	12.5	66.7
Sumoto	+	*iP*	3.6	—	—	87.1
Kochi	–	*iP*	3.9	*iS*	11.0	74.1
Wakayama	(–)	*iP*	8.7	*iS*	18.3	105.6
Okayama	+	*iP*	10.5	*iS*	24.5	109.3
Kobe	(+)	*iP*	14.1	*iS*	29.5	131.6

(Parenthesized data of *Push or Pull* were presumed from the horizontal motions.)

As shown in Figs. 4 and 5, similar effects to the case of the Daishoji-Oki earthquake are found clearly. The rate of V_p/V_s-variation with the increase of hypocentral distance is smaller than that discussed in section 2. And the distance at which two branched lines coincide is also smaller. This is reasonably accepted, considering the difference of magnitudes of the earthquakes concerned.

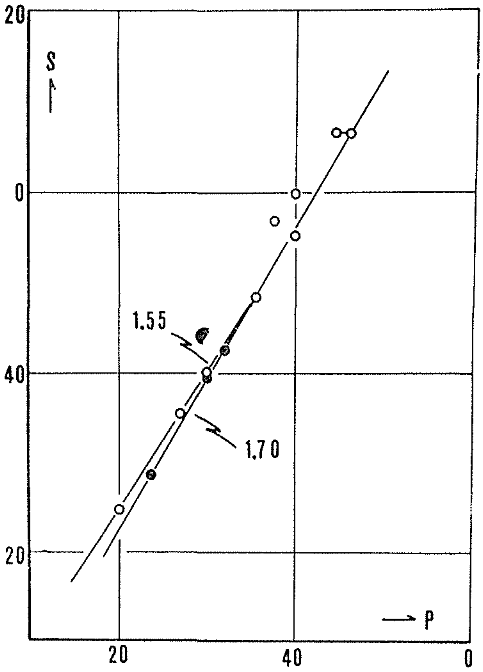

Fig. 4. The *P–S* diagram of the earthquake on Apr. $10^{d}\,11^{h}\,9^{m}\,12^{s}$.

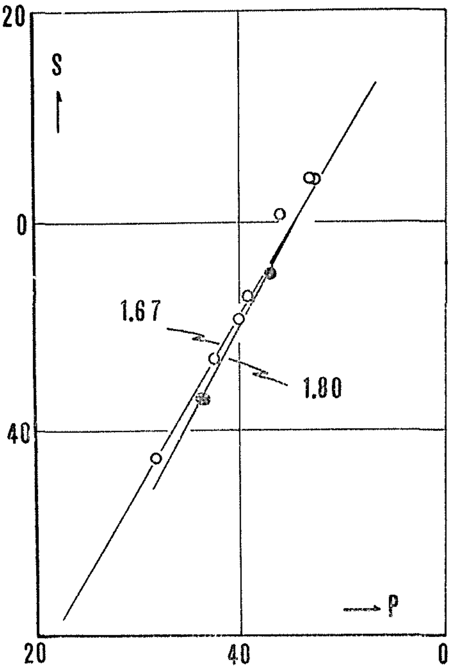

Fig. 5. The *P–S* diagram of the earthquake on May $18^{d}\,13^{h}\,39^{m}\,24^{s}$.

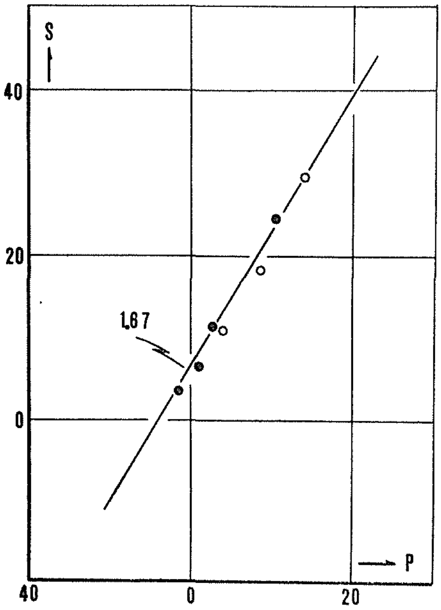

Fig. 6. The *P–S* diagram of the earthquake on July $27^{d}\,10^{h}\,20^{m}\,49^{s}$.

The *P–S* diagram of the earthquake occurred on July 27, 1955 is shown in Fig. 6. Owing to the deficiency of good observation condition, the data are not favourable, and its seems probable that the effect is inverse in regard to push- and pull-zones as compared with the previous cases. This tendency is frequently seen in the cases of some earthquakes which occurred after this main shock. This fact must be investigated in future with more abundant data.

In the previous paper (8), some rather deep earthquakes were examined using the *P–S* diagram analysis and it was ascertained that the crustal Poisson's ratio shows no local anomaly in the Shikoku region. And so the above-stated effects must be attributed to the variation of crustal

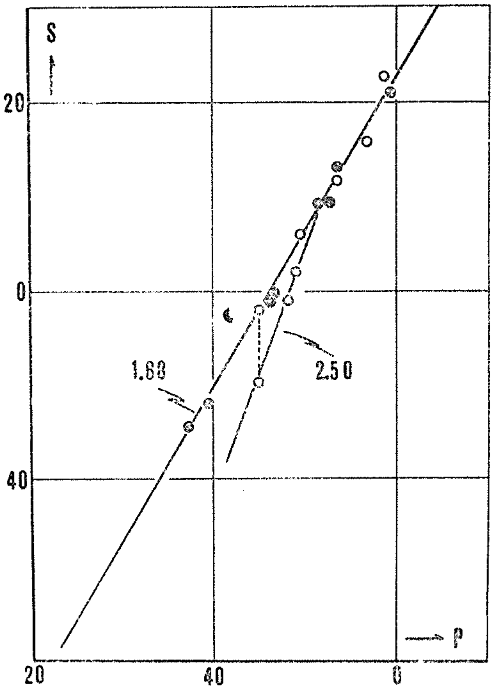

Fig. 7. The *P–S* diagram of the Fukui earthquake on June 28, 1948.

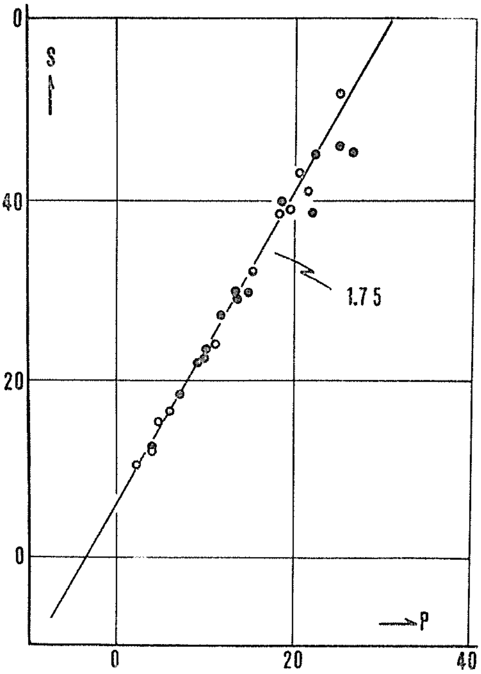

Fig. 8. The *P–S* diagram of the Yoshino earthquake on July 18, 1952.

Poisson's ratio in case of earthquake occurrences.

On June 28, 1948, the Fukui earthquake occurred. Its focal depth and magnitude are estimated to be about 20 km and 7.0 respectively. The *P–S* diagram is shown in Fig. 7. The two branched lines are drawn, but the effect is inverse in regard to the push- and pull-zones as compared with the case of the Daishoji-Oki earthquake. The point of Gifu station (pull) is on the line of push-zone station. It may perhaps be attributed to the ambiguity of *S*-phase identification.

On July 18, 1952, the Yoshino earthquake occurred. Its focal depth and magnitude (M_G) are estimated to be 70 km and 7.0 respectively. In Fig. 8, any conspicuous effect cannot be found in spite of its large magnitude. This may perhaps be due to its greater depth of origin and occurrence mechanism of another type.

4. Summary

Using the *P–S* diagram method, the azimuthal distribution of the crustal Poisson's ratio in case of earthquake occurrences is investigated. It is favourable that the value of Poisson's ratio obtained by this method depends only on the elastic preperties of the Earth's crust. Some shallow earthquakes which occurred with the so-called quadrant-type distribution of intial motion are examined and the value of Poisson's ratio is found to be considerably different in the push- and pull-zones. The correlation between its variation mode and the push-pull sense is, however, not decided uniquely. This may be related to the partition of stress energy causing the *P*- and *S*-waves.

In the last part of section 3, the Yoshino earthquake whose focus is situated below the Mohorovičić discontinuity is treated. But in this case any conspicuous effect cannot be found. This may perhaps be due to its greater depth and occurrence mechanism of another type.

The problem of stress accumulation in the Earth's crust is very interesting in relation to the earthquake occurrences and so it is desirable to investigate this problem in more detail with more abundant data.

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