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43. The Mechanism of the Deep Earthquake that Occurred South of Honshu, Japan, on February 18, 1956.

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Abstract

The mechanism of the deep earthquake that occurred south of Honshu, Japan, on February 18, 1956, has been studied by several seismologists. In the present paper, all the available data on the condensation and rarefaction of the *P* waves and the polarization angle of the *S* waves are presented. The ample data gives a fine example for the study of the source mechanism. And it is confirmed clearly that the mechanism of the earthquake can be explained by the double couple hypothesis.

1. Introduction

Either or both of the two alternative models i.e. a single couple (type I source) and a double couple (type II source) have been adopted in the study of earthquake mechanism by many seismologists for many years. As is well known, the distinction between the two types of force systems is recognized in the difference of the patterns of *S* waves. And it has been found that in the earthquakes which occur in and near Japan the patterns of *P* and *S* waves agree with a double couple model, use of the dense network of seismological stations in Japan being made (Honda, 1962; Stauder, 1962; Hodgson et al., 1964). Recent studies from the observational (e.g. Stauder and Bollinger, 1964; Ritsema, 1965) as well as the theoretical (e.g. Maruyama, 1963; Haskell, 1964; Burridge and Knopoff, 1964) points of view also have shown that the mechanism of earthquakes, in general, can be explained by use of the double couple model. But it may be useful to give further examples of the study of

Table 1. Initial motion of *P* waves.

Station	Δ	α_E	θ		Station	Δ	α_E	θ	
Tori-shima	1°6	72°	24°	D	Inawashiro	7°7	10°	79°	C
Hachijo-jima	3.3	19	43	(C)	Fukuoka	7.8	299	80	C
Shionomisaki	4.2	327	52	C	Fukushima	7.9	11	81	C
Owashi	4.5	335	56	C	Aikawa	8.0	359	82	C
Omaezaki	4.6	357	56	(D)	Sendai	8.5	13	88	C
Murotomisaki	4.9	312	59	C	Tomie	8.7	290	90	C
Shizuoka	5.0	359	60	(D)	Izuhara	8.9	301	91	C
Mishima	5.1	4	61	(D)	Akita	9.8	7	96	C
Kameyama	5.1	341	61	C	Morioka	9.9	12	97	C
Osaka	5.3	332	62	C	Miyako	10.0	16	97	C
Sumoto	5.3	326	62	C	Hachinohe	10.8	12	100	C
Nagoya	5.3	346	62	C	Mori	12.2	7	103	C
Abuyama	5.5	334	63	C	Sapporo	13.2	9	106	C
Shimizu	5.5	302	64	C	Nemuro	14.5	21	109	C
Funatsu	5.5	2	64	D	Aberdeen	87	340	154	C
Yokohama	5.5	10	64	D	Alicante	102	328	156	(C)
Kochi	5.5	311	64	C	Almeria	104	329	156	(C)
Kyoto	5.5	336	64	C	Apia	65	125	144	C
Gifu	5.6	345	65	C	Ashkhabad	65	301	145	D
Hikone	5.6	342	65	C	Astrida	108	277	156	(C)
Takamatsu	5.7	320	65	C	Auckland	75	151	149	D
Tokyo	5.8	10	66	C	Bandung	47	224	135	D
Matsuyama	6.2	310	69	C	Basel	91	329	155	(C)
Toyooka	6.3	332	70	C	Belgrade	87	321	154	D
Miyazaki	6.4	289	70	C	Berkeley	79	53	151	C
Maebashi	6.4	4	70	C	Bombay	60	276	142	D(*)
Matsushiro	6.5	358	71	C	Bouldercity	85	51	153	C
Mito	6.6	14	72	C	Bozeman	82	41	152	C
Utsunomiya	6.6	10	72	C	Butte	81	42	152	C
Nagano	6.7.	358	72	C	Cheb	87	328	154	D
Oita	6.7	300	72	C	Christchurch	80	156	151	D
Hiroshima	6.7	312	73	C	Cleveland	100	29	156	(D)
Toyama	6.8	351	73	C	College	56	29	140	C
Yaku-shima	6.9	275	74	D	Collmberg	86	329	153	D
Kagoshima	7.0	285	75	C	Copenhagen	83	337	152	D
Onahama	7.2	15	76	C	De Bilt	89	333	154	D
Kumamoto	7.2	295	76	C	Djakarta	47	226	135	D
Hamada	7.3	314	77	C	Durham	89	338	154	C

(to be continued)

Table 1. (continued)

Station	Δ	α_E	θ	
Eureka	82°	49°	152°	C
Florence	92	325	155	(C)
Fresno	81	53	152	C
Frunse	52	303	138	(C)
Goris	73	306	148	(C)
Hawaii	60	83	142	(C)
Hong Kong	23	256	123	D
Horseshoe Bay	73	42	148	C
Hungry Horse	79	40	151	C
Hyderabad	56	271	140	D(*)
Irkutsk	34	321	129	C
Jerusalem	85	304	153	(C)
Jujhno-Sakhalinsk	17	10	115	C
Kaimata	78	156	150	(C)
Karapiro	76	151	149	D
Karlsruhe	90	330	154	D
Kew	91	336	155	D
Kirkland Lake	95	25	155	C
Kiruna	72	339	148	C
Ksara	83	305	152	D
La Paz	152	67	172	D_1'
La Plata	165	114	176	D_1'
Lembang	47	224	135	D
Lwiro	108	278	156	D
			170	(C_1')
Macquarie Island	86	168	154	(C)
Manila	22	230	122	D
M'Bour	130	328	170	D_1'
Melbourne	68	174	146	D
Messina	94	319	155	D
Mineral	78	50	150	C
Moscow	71	324	147	C
Mount Hamilton	76	53	149	C
Neuchatel	92	329	155	D
Noumea	59	149	141	D
Ottawa	99°	24°	156°	C
Pasadena	84	54	153	D
Perth	65	201	145	D
Prague	86	328	154	D
Quetta	61	290	143	D
Rabaul	36	157	130	C(*)
Rathfarnham	92	340	155	D
Reno	80	50	151	C
Resolute	70	13	147	C
Reykjavik	85	351	153	C
Riverview	65	168	144	D
Saint Louis	98	36	156	C
Salt Lake City	84	46	153	C
Santa Clara	79	53	151	C
Scoresby Sund	79	353	151	C(*)
Seattle	74	44	149	C
Shasta	77	50	150	C
Shawinigan Falls	99	22	156	(D)
Simferopol	79	316	151	D
Skalnate Pleso	84	325	153	D
Skalstugan	78	338	150	C
Stara Dala	86	324	153	D
State College	102	27	170	(C_1')
Strasbourg	90	330	155	D
Stuttgart	89	329	154	D(*)
Sverdlovsk	59	321	142	C(*)
Tananarive	100	254	156	(C)
Tashkent	56	302	140	D
Tbilisi	73	309	148	D
Tuai	77	150	150	D
Tucson	90	52	154	D
Uppsala	78	334	150	C
Uvira	108	277	156	D
Victoria	73	44	148	C
Wellington	78	153	151	D
Weston	103	22	156	(D)

Δ: Epicentral distance.
α_E: Direction of the great circle path at the epicenter.
θ: Angle of incidence at the focus.
C or D: Compression or dilatation. C_1' and D_1' relate to PKP_1.
( ): Inconsistence with the obtained solution.
(*): Data given by Ritsema (1965).

Table 2. Initial motion of S waves.

Station	α_S	θ	γ_{ob}	γ_{th}	Station	α_S	θ	γ_{ob}	γ_{th}
Shionomisaki	325°	52°	6°	9°	Hiroshima	309°	72°	−84°	−56°
Owashi	334	56	−9	20	Toyama	351	72	52	40
Omaezaki	357	56	25	44	Yaku-shima	270	72	−138	−115
Oshima(1)	9	58	62	53	Onahama	17	75	75	55
Murotomisaki	310	59	−56	−27	Kumamoto	291	75	−110	−91
Shizuoka	359	60	44	46	Hamada	310	75	−90	−60
Tomisaki(2)	13	60	49	54	Fukuoka	295	78	−99	−90
Mishima	4	61	57	49	Niigata(4)	4	78	69	52
Kameyama	340	61	4	27	Fukushima	13	78	71	55
Osaka	331	62	−29	12	Aikawa	358	79	46	50
Sumoto	324	62	20	−1	Tomie	285	82	−96	−104
Nagoya	346	62	12	33	Morioka	14	87	80	59
Shimizu	299	64	−65	−60	Miyako	18	88	92	60
Yokohama	10	64	51	53	Hachinohe	14	91	67	62
Kochi	309	64	−59	−39	Nemuro	25	107	69	74
Kyoto	334	64	1	17	Berkeley	119	148	164(*)	134
Gifu	344	65	38	32	Bombay	246	140	−84(*)	−93
Takamatsu	318	66	−42	−19	Christchurch	150	149	115(*)	143
Kumagaya(3)	7	69	62	51	De Bilt	219	153	−174(*)	−142
Matsuyama	307	69	−70	−54	Kiruna	234	146	−157(*)	−153
Toyooka	330	70	0	6	Riverview	168	142	146(*)	137
Miyazaki	286	70	−118	−93	Scoresby Sund	197	148	−158(*)	−168
Maebashi	4	70	42	50	Simferopol	239	148	−116(*)	−126
Nagano	358	71	46	46	Stuttgart	222	153	−167(*)	−138
Oita	297	72	−128	−78	Sverdlovsk	262	140	−153(*)	−134

(1) $\Delta=4^\circ.8$, $\alpha_E=9^\circ$ (2) $\Delta=5^\circ.0$, $\alpha_E=13^\circ$
(3) $\Delta=6^\circ.2$, $\alpha_E=7^\circ$ (4) $\Delta=7^\circ.9$, $\alpha_E=3^\circ$.

α_S: Direction of the great circle path at the station.
γ_{ob}: Observed polarization angle (cf. Figure 1).
γ_{th}: Polarization angle expected theoretically from the type II hypothesis.
Observed polarization angles of the last ten stations are given by Ritsema. Since there is a little difference between the epicenter adopted by Ritsema and that by the present authors, Δ and α_E are slightly changed from those given by Ritsema.

source mechanism which are clearly solved. In the present paper, the results of the study of the deep earthquake which occurred south of Honshu, Japan, on February 18, 1956, will be given as a fine example of the mechanism solution, as comparatively numerous data both on P and S waves of the earthquake have been obtained.

Table 3. Initial motion of *ScS* waves.

Station	θ	γ_{ob}	γ_{th}	Station	θ	γ_{ob}	γ_{th}
Shionomisaki	178°	−83°	−77°	Toyooka	176°	−68°	−70°
Owashi	177	−53	−69	Miyazaki	176	−99	−115
Murotomisaki	177	−50	−91	Utsunomiya(3)	176	−49	−33
Shizuoka	177	−36	−45	Nagano	176	−32	−44
Kameyama	177	−68	−62	Hiroshima	176	−92	−90
Nagoya	177	−55	−58	Yaku-shima	176	−127	−130
Shimizu	177	−88	−101	Kumamoto	176	−81	−108
Kochi	177	−82	−92	Hamada	176	−80	−87
Kyoto	177	−63	−67	Fukushima	176	−40	−29
Gifu	177	−64	−57	Aikawa	176	−46	−41
Hikone(1)	177	−44	−52	Akita(4)	175	−69	−32
Kofu(2)	177	−6	−42	Miyako	175	−34	−24
Takamatsu	177	−70	−82	Hachinohe	174	7	−26
Matsuyama	176	−76	−92	Nemuro	172	−41	−15

(1) $\alpha_S=340°$. (2) $\Delta=5°.7$, $\alpha_E=1°$, $\alpha_S=1°$.
(3) $\alpha_S=10°$. (4) $\alpha_S=8°$.

2. Patterns of P and S Waves

The epicenter of the earthquake of February 18, 1956, was located at 30°.0 N and 138°.5 E with focal depth of 480 km. The magnitude was $7\,^1/_4$ to $7\,^1/_2$ as determined by the Seismological Laboratory, Pasadena. The fault plane solution given by Hodgson and Stevens (1958) is

Plane *a*	Strike: N 20°E	Dip: 56°
Plane *b*	Strike: N 76°W	Dip: 68°.

Ichikawa (1961) studied the pattern of *P* waves of the earthquake. Kasahara (1963) investigated the polarity and the relative amplitude of *S*, *SS*, *sS* and *ScS*. Hirasawa and Stauder (1964) examined the Fourier spectra of *S* and *ScS*, and Ritsema (1965) studied the patterns of *P* and *S* waves. Honda (1962) gave a preliminary report on the study of the mechanism of the earthquake with the cooperation of Hirasawa and Ichikawa.

The data on the compression and rarefaction of the initial motion of *P* waves and the polarization angle γ of the initial motion of *S* and *ScS* waves which are found in the papers of Hodgson et al., Kasahara and Ritsema and those which were collected by the present authors, are given in Tables 1, 2 and 3. The angle γ is defined by tan $\gamma=\bar{u}_H/\bar{u}_R$, where $\bar{u}_R$ and $\bar{u}_H$ are the components along and perpendicular to the great circle path at the station, of the linear particle motion diagram of the horizontal component of the surface motion produced by the incidence of S waves (Figure 1). The angle γ is assumed to be approximately equal to the real polarization angle ε of the incident S waves, which is defined by

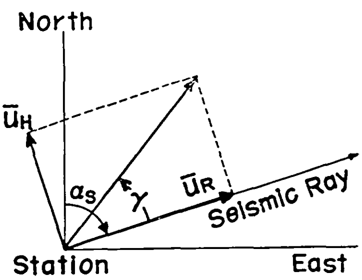

Fig. 1. Polarization angle γ.

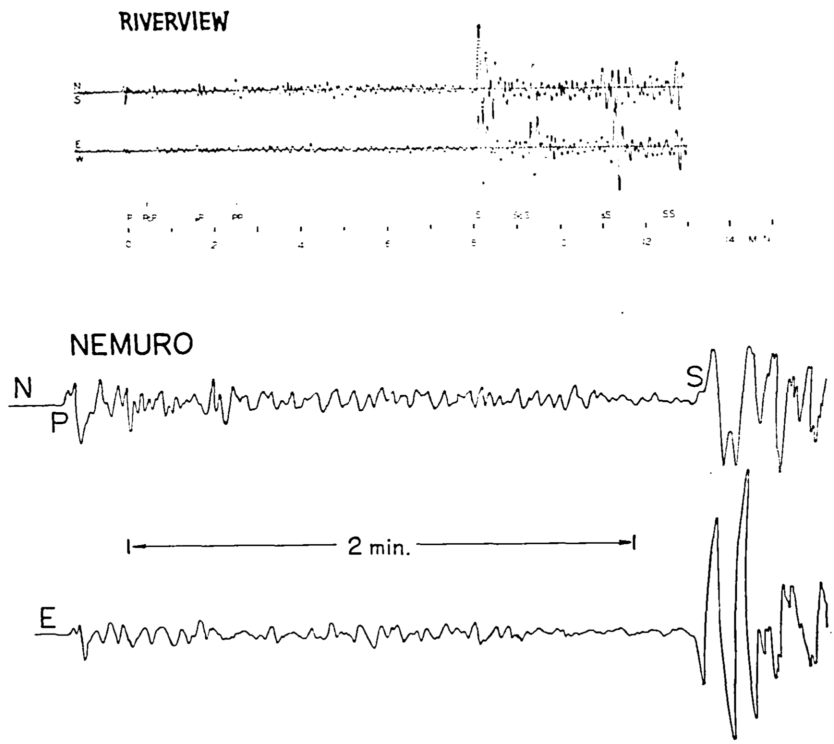

Fig. 2. Seismograms at Riverview (after Kasahara, 1963) and Nemuro.

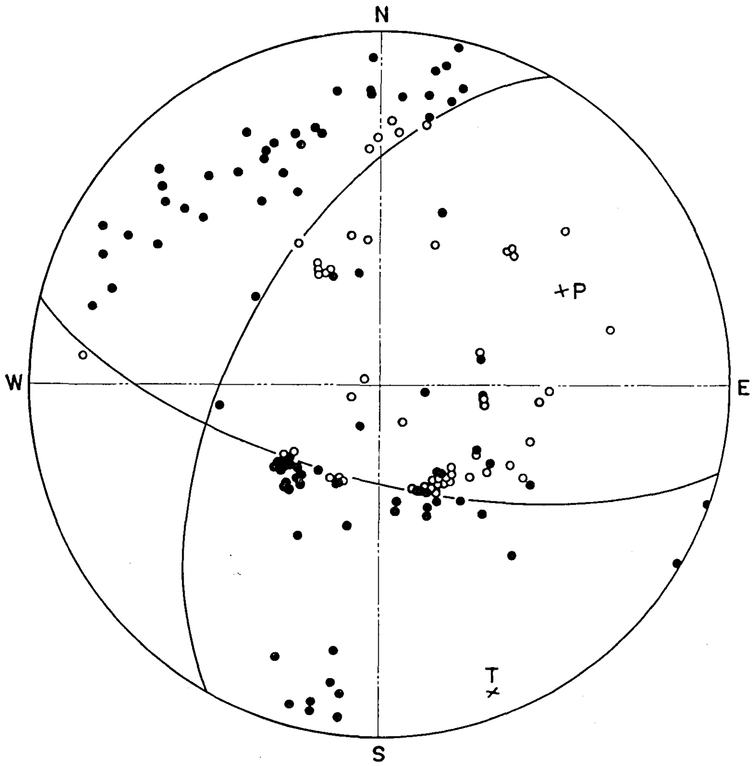

Fig. 3. Pattern of the initial motion of *P* waves by use of the equal area projection of the upper half of the focal sphere. Solid circles are compressions and open circles are rarefactions. *P* and *T* in the figure indicate the pressure and tension directions respectively.

$\tan \varepsilon = SH/SV$. The number of stations where the data on the *S* waves is obtained amounts to fifty.

The seismograms recorded at Riverview (after Kasahara) and Nemuro are given in Figure 2. It may be found that the direction of the initial motion of *S* waves at these stations can be read without ambiguity.

The pattern of the compression and rarefaction of the initial motion of *P* waves is shown in Figure 3 by use of an equal area projection of the upper half of the focal sphere, the observations related to the lower hemisphere being reduced to those of the upper hemisphere. The nodal lines are those given by Hodgson and Stevens.

The observed directions of the initial motion of *S* waves and those which are obtained by theoretical calculation from the double couple hypothesis, are illustrated by the arrows of thick lines and dotted lines

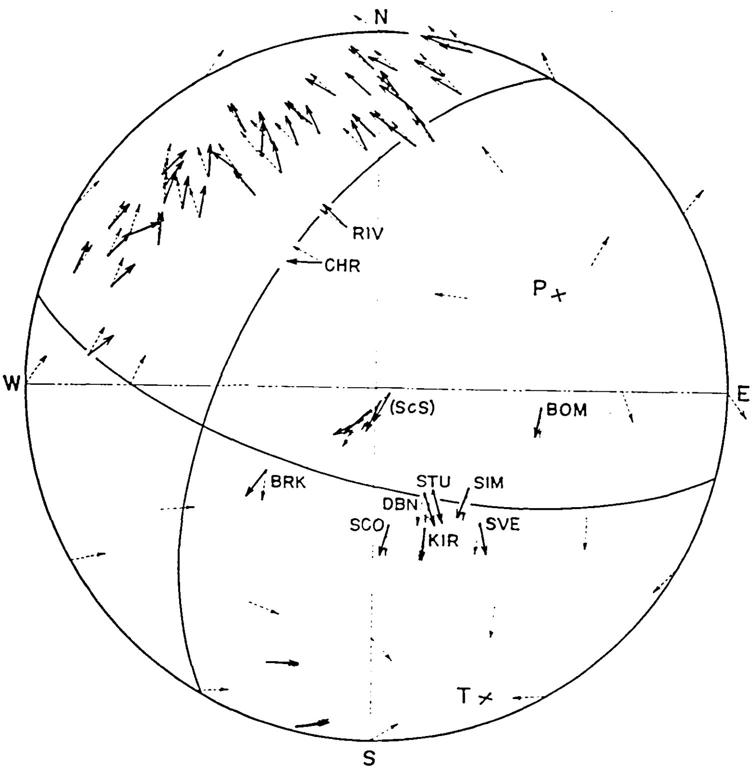

Fig. 4. Pattern of the initial motion of *S* waves. The arrows of thick lines are observed motion directions and the arrows of dotted lines are theoretical ones.

respectively in Figure 4. A little of the ample data on *ScS* waves listed in Table 3 is also illustrated in the figure. The results of observations and theoretical calculations of the initial motion of *S* waves agree well with each other. The figure thus gives a fine example of the study of the earthquake mechanism by use of ample data of *S* waves.

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43. 1956年2月18日本州南方沖の深発地震のメカニズム

東京大学理学部 地球物理学教室 { 本多弘吉 平沢朋郎
気象庁 市川政治

1956年2月18日に本州南方沖に起こつた深発地震のメカニズムはすでに多くの人々によつて研究されている．本研究においては本邦および外国の観測所におけるこの地震の *P* 波および *S* 波に関する観測結果をできるだけ多く集め，その豊富な材料に基いてこの地震のメカニズムは double couple (type II) の震原モデルによつて十分によく説明できることを確めた．