On the transit velocity of the earthquake motion originating at a near distance.

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With Plates XXV—XXVI.

1. *Introduction.*

The assumption of the existence of a stratum of the quickest earthquake propagation near the earth's surface parallel to the latter is very important in the study of the mode of propagation of the seismic motion. In fact, the linear relation which exists between the arcual epicentral distance of a distant station and the time taken in transit by the 1st preliminary tremor is well explained by considering the depth of the stratum to be a few hundred kilometres.[1]

It is a well-known fact that the mean velocity between the *origin* and a *near station* is comparatively small, becoming larger with the increase of the distance. For instance, the Kyushu, Formosa, and Manila earthquakes, which occurred in 1899–1902, had the velocities of 8·2, 10·6, and 10·9 km per sec. for the epicentral distances of 900, 2200, and 3050 km. respectively.[2] To see how the first phase is propagated from a *near station* to *another* in similar case, I have first examined the observations at Tokyo and Osaka of the earthquakes, which originated in NE Japan or in Kyushu, and obtained a transit

1 The *Publications*, No. 16, p. 116.

2 See Dr. Omori: The *Publications*, No. 13, p. 141.

velocity as high as 12 km. per sec., the result of similar examination made afterwards of the observations at the Mizusawa Astronomical Observatory being nearly the same. It must be remarked that, the origin of each earthquake having been comparatively near the observing stations and approximately in the direction of the straight line connecting the latter, the difference of the epicentral distances is but little affected by an inaccurate determination of the epicentre, whether the path be acual or chordal.

The earthquakes taken into consideration are given in the following table:—

Earthquake No.	Date.	Time of occurrence. at epicentre.			Epicentre.	
					Latitude.	Longitude.
		1902.				
		h	m	s		
1	Jan. 29.	23	24	50	34°.5 N	139°.8 E
2	Jan. 30.	23	0	0	41.0	142.5
3	Jan. 31.	10	41	30	41.5	142.5
4	Feb. 21.	0	37	40	40.8	142.8
5	May 2.	20	31	0	40.5	144.0
6	May 8.	11	19	0	30.7	131.6
7	May 28.	18	1	40	42.8	144.8
8	June 13.	9	21	20	42.7	144.3
9	June 23.	7	42	20	35 5	139.8
10	July 1.	17	16	20	40.0	144.0
11	July 8.	23	5	—	41.5	142.5
12	July 10.	19	56	20	41.7	142.0
13	Aug. 3.	10	40	—	42.5	146.5
14	Aug. 7.	18	19	—	39.8	143.7
		1903.				
15	March 21.	19	35	50	33.7	132.0
16	April 1.	23	8	30	38.0	142.0
17	Aug. 10.	13	38	—	36.0	137.1
18	Aug. 10.	13	45	—	36.0	137.1
19	Aug. 14.	0	46	—	42.8	144.8
20	Oct. 11.	1	41	0	32.3	132.0
21	Dec. 3.	17	52	40	32.0	132.0
		1904.				
22	March 18	22	—	—	42.7	144.3
23	April 13	14	37	40	38.7	142.0
24	May 27	5	40	0	35.0	139.6

The positions of the epicentres and times of commencement at the latter were determined from the result of instrumental observations at the Meteorological Stations and observations of the seismic intensity by the meteorological reporters in the different parts of the country. The observations depending on the 1st category are given in the *Publications,* No. 16, or in the appendix to the present note. The numbers of observations of the 2nd category were 205 and 156 in Eqkes. Nos. 2 and 3 respectively. These two earthquakes are specially discussed later on.

II. Observations at Tokyo and Osaka.

The diagrams examined were given by Omori's H. P. Seismographs at the Seismological Institute and Osaka Meteorological Observatory. The following is the list of the instruments which gave the Tokyo register.

Instrument.	Orientation.	Magnification.	Free vibration period.
			s.
No. 1.	E-W component.	10	26
A	Do.	15	62
B	N-S component.	10	30

The instrument at Osaka was less sensitive and had a magnification of 6 times and a period of 25 sec.

The time which is marked every minute on the smoked paper, is kept at Tokyo by a chronometer, but at Osaka by a clock whose daily change of clock rate amounted seldom to 20 sec., being commonly one-half of the latter. The clock and chronometer are daily compared with the standard time at noon, the former by means of an electric signal sent directly from the Tokyo Astronomical Observatory, but the latter indirectly by the report of a cannon at a distance of 2.3 km.

Of the 41 earthquakes which were first taken into examination, the Osaka instrument did not record the time ticks in 20 cases, and gave 6 seismograms, 4 of which were too minute and the others were masked by pulsatory oscillations; besides, the correction of the clock was so uncertain in 2 cases that a reliable clock rate could not be obtained. In all, there were 13 earthquakes which were recorded tolerably well at the two stations.

Let P_1, P_2, and P_3 represent the initial waves of the 1st and 2nd preliminary tremors and principal portion, and V_1, V_2, and V_3 their respective transit velocities. The latter were calculated according to the formula

$$\text{Velocity} = \frac{d' - d}{t' - t},$$

where d and d' indicate the arcual epicentral distances of the two observing stations, and t and t' the times of arrival of each phase at the respective stations. The result is given in the following table.

Eqke. no.	Time of commencement at Tokyo.			Epicentral distance.			Diff. of times of arrival of P_1.	V_1	Duration.				Diff. of times of arrival of P_2	V_2	Diff. of times of arrival of P_3.	V_3.
				Nearer station.	Further station.	Diff.			Tokyo.		Osaka.					
									P_1–P_2	P_2–P_3	P_1–P_2	P_2–P_3				
	h	m	s	km	km	km	s	km/s	s	s	s	s	s	km/s	s	km/s
2	23	1	43	622	927	312	26	12.0	21	33	48	65	53	5.9	82	3.8
3	10	42	58	685	969	284	23	12.4	19	52	37	80	41	6.9	69	4.1
4	0	39	13	625	930	305	31	9.8	23	45	43	76	51	6.0	82	3.7
5	20	32	3	648	1005	357	33	10.8	29	56	48	89	52	6.9	85	4.2
7	18	3	43	898	1205	307	27	11.4	36	72	66	99	54	5.7	81	3.8
10	17	17	27	604	992	388	33	11.8	32	41	51	71	49	7.9	79	4.9
11	23	7	36	685	969	284	19	15.0	28	36	40	63	40	7.1	67	4.2
13	10	43	17	951	1285	334	26	12.9	78	72	103	99	53	6.3	80	4.2
14	18	20	50	571	917	346	28	12.4	27	35	48	66	49	7.1	80	4.3
15	19	37	36	341	743	402	35	11.5	41	56	18	18	58	6.9	96	4.2
16	23	9	24	324	688	364	24	15.2	20	23	48	56	52	7.0	85	4.3
20	1	42	38	420	810	390	36	10.8	56	69	27	30	56	7.0	95	4.1
21	17	54	38	442	826	384	28	13.7	52	79	28	36	52	7.4	95	4.0
Mean.	—			601	944	343	28.4	12.1	36	52	47	65	51	6.7	83	4.1

The values thus deduced do not much differ from those which are generally obtained in cases of large distant earthquakes, the formula adopted being the same.

Let us next compare these velocities with those which are obtained according to the formula

$$\text{Velocity} = \frac{d}{t - t_0},$$

where t_0 indicates time of commencement at epicentre, which was estimated with tolerable accuracy for the preceding earthquakes except Nos. 11, 13, and 14. In the following table only the mean values are given.

Place.	Epicentral distance.	Time taken in transit.			Transit velocity.		
		P_1	P_2	P_3	V_1	V_2	V_3
Tokyo.	679^{km}	91^s	124^s	177^s	7.5 $\frac{km}{s}$	5.5 $\frac{km}{s}$	3.8 $\frac{km}{s}$
Osaka.	792	101	142	204	7.9	5.6	3.9

The difference of the values of V_1 due to the two different methods may be explained, as has been noted previously, by assuming the stratum of the quickest propagation to have a depth of a few hundred kilometres. For the seismic motion radiating from the origin, which may be situated comparatively near the earth's surface, is propagated directly to observing station in the epicentral district, while the initial wave observed at a more distant station may be the wave propagated from the origin first downward to the stratum of the quickest propagation, next through that stratum to a position near the observing station, and then refracting to the latter. In so supposing, the transit velocity estimated according to the 1st formula relates particularly to the assumed stratum, the term depending on the depth being eliminated in the process of taking the difference. If the velocity determined according to the 2nd formula represent the mean value between the origin and a distant observing station, it seems more proper to introduce in the term of epicentral distance a correction, which, roughly speaking, is equal to double of the distance between the seismic focus and the stratum of the quickest propagation.

Assuming the state of propagation of the 1st preliminary tremor as discussed above, the time which would have been taken by the wave-front in its transit from the seismic focus to the assumed stratum is calculated in the preceding 10 earthquakes to have been 20 sec. on the average. In the Kyushu, Formosa, and Manila earthquakes, previously cited, the times amount to 23, 25, and 31 sec. rerpectively. For the Aomori earthquake of Aug. 9, 1901, in which the focal depth was probably very shallow,[1] the value amounts to 60 sec. The time calculated in such a way may probably be used for the determination of the depth of the seismic focus and the stratum of the quickest propagation.

The path of P_3 seems, as usually accepted, to be superficial, for the velocities deduced by the two different methods do not much differ from each other. As regards P_2, the path may be inferred to lie between the two others.

III. Observations at Tokyo and Mizusawa.

The instruments at Mizusawa consist of a pair of Omori's H. P. Seismographs, that which registers E-W component motion being of the same type as that at Osaka but so adjusted as to have a free vibration period of 13 sec, while the other which records N-S component motion being of the same type and about equal period as the Tokyo instrument No. 1.[2]

The clock keeping the time tick was at first compared with the standard chronometer at the start and end of each smoked paper which lasts about 24 hours; but since the end of 1902, it was more frequently compared so that an accurate clock correction could be obtained whenever earthquake occurred. Hence, in the calculation of

1 The *Publications*, No. 16, p. 75.

2 See also Annual Report of the Meteorological Observations at Mizusawa for the year 1903.

the mean values of transit velocity, the weight of the data relating to the former epoch is assumed to be one-half of that relating to the latter.

Many earthquakes, which originated near one of our stations, have been grouped against those which originated at distances greater than 400 km. The result for the different groups will be understocd from the following tables.

OBSERVATIONS OF NEARER EARTHQUAKES.

Eqke. no.	Epicentral distance. Nearer station.	Further station.	Difference.	Time of commencement at Tokyo.	Diff. of times of arrival of P_1	V_1
	km	km	km	h m s	s	km/s
1	139	529	390	23 25 10	39	10.0
2	237	622	385	23 1 43	45	8.6
3	287	685	398	10 42 58	43	9.3
4	233	625	392	0 39 13	41	9.6
5	287	648	361	20 32 3	41	8.8
9	22	420	398	7 42 39	45	8.8
10	264	604	340	17 17 27	45	7.6
11	287	685	398	23 7 36	27	14.7
12	294	694	400	19 57 53	35	11.4
14	235	571	336	18 20 50	44	7.6
16	148	324	176	23 9 24	13	13.5
17	243	496	253	13 40 9	27	9.4
18	243	496	253	13 46 12	27	9.4
23	88	388	300	14 38 30	34	8.8
24	92	479	387	5 40 34	39	9.9
Mean.	196	522	327	—	34	9.6

OBSERVATIONS OF REMOTER EARTHQUAKES.

Eqke. no.	Epicentral distance. Nearer station.	Further station.	Difference.	Time of commencement at Tokyo.	Diff. of times of arrival of P_1	V_1
	km	km	km	h m s	s	km/s
6	944	1275	331	11 1 19	28	11.8
7	510	898	388	18 3 43	39	9.9
8	475	871	396	9 3 39	34	11.6
13	586	951	365	10 43 17	32	11.4
15	743	1015	272	19 37 36	21	13.0
19	510	898	388	0 48 8	25	15.5
20	810	1120	310	1 42 38	22	14.1
22	475	871	396	22 48 33	36	11.0
Mean.	633	984	351	—	28.4	12.4

Thus we arrive at nearly the same result as that deduced from the observations at Tokyo and Osaka, the value relating to the earthquakes which originated in near distances approximating to that calculated according to the 2nd formula in the previous case.

IV. Earthquakes of Jan. 30 and 31, 1902.

The 1st preliminary tremor of Eqkes. Nos. 2–3 were also recorded at several seismic stations in Europe and other parts of the world. The following is the result of those observations.

Eqke. No. 2.

Place of observation.	Epicentral distance.	Time taken in transit by P_1.	Place of observation.	Epicentral distance.	Time taken in transit by P_1
	°	m		°	m
Mizusawa.	2.1	1.0	Nikolajew.	72.7	11.5
Tokyo.	5.6	1.7	Hamburg.	76.9	11.9
Osaka.	8.4	2.2	Strassburg.	82.0	12.2
Irkutsk.	28.1	5.6	Trieste.	82.0	11.8
Calcutta.	49.0	8.0	Pola.	82.6	12.6
Taschkent.	53.3	9.8	Padova.	83.0	12.7
Batavia.	57.3	10.0	Shide.	83.4	12.3
Madras.	60.9	10.6	Firenze.	84.5	11.4 (?)
Bombay.	62.8	10.1	Roma.	85.6	13.0
Victoria.	62.8	10.2	Rocca di Papa.	85.6	13.2
Jurjew.	67.3	11.8	Ischia.	86.3	12.9
Tiflis.	68.8	11.4	Catania.	88.0	13.0

Eqke. No. 3.

Place of observation.	Epicentral distance.	Time taken in transit by P_1	Place of observation.	Epicentral distance.	Time taken in transit by P_1.
	°	m		°	m
Mizusawa.	2.6	0.8	Nikolajew.	72.3	11.5
Tokyo.	6.2	1.5	Hamburg.	76.6	11.7
Osaka.	8.7	1.9	Strassburg.	81.5	12.3
Irkutsk.	27.8	5.3	Trieste.	81.6	12.1
Taschkent.	53.1	8.4	Shide.	82.7	11.6
Bombay.	62.5	10.1	Firenze.	84.1	11.1 (?)
Jurjew.	66.8	10.6	Roma.	85.2	12.8
Tiflis.	68.5	11.2			

The mode of propagation of the earthquake motion may be understood from the graphical representation given in Fig. 1. The curves in the figure have been drawn according to the following method:— Marking down as usual on a section paper so many points corresponding to the different sets of the epicentral distance (x) and the time taken in transit (y), a continuous free-hand line was drawn connecting the 4 left-hand points and thence a straight line determined by the method of Least Squares from the 5 points for Irkutsk, Calcutta, and the 3 mean places for the stations whose epicentral distances are 53°–63°, 67°–77°, and 82°–88°[1] in Eqke. No. 2, and from the 4 points for Irkutsk, Taschkent, and the 2 mean places for the stations whose epicentral distances are 62°-77° and 81°–86°[2] in Eqke. No. 3 The linear relation seems to hold approximately for a distances as near as 10°, but the observations at comparatively near distances having been scanty, this part of investigation must be reserved for a future occasion.

The transit velocity comes out from the above mentioned straight line to be 14·3 and 14·1 km. per sec. in Eqkes. Nos. 2 and 3 respectively. These values are nearly equal to those obtained by Prof. Omori as a result of his more recent investigation.[3]

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1-2 Firenze is omitted.

3 Prof. Omori: The *Publications*. No. 13.

APPENDIX. EARTHQUAKE OBSERVATIONS AT THE METEOROLOGICAL OBSERVATIONS.* (THE TIMES ARE GIVEN IN THE FIRST NORMAL JAPAN TIME).

Eqke. No. 1. Jan. 29th 1902; 23h.

Mera. ···	···25^m 0^s.	Weak.	Gentle.
Yokosuka.	···25 30.	Do.	Duration long.
Tokyo. ···	···25 9.	Slight.	
Kanayama.	···25 10.	Do.	Duration short.
Maebashi.	···25 15.	Do.	
Mito ···	···25 42.	Do.	Gentle.
Choshi. ···	···25 45.	Do.	Duration short.
Nagano. ···	···26 0.	Do.	
Kumagae	···26 28.	Do.	
Miyako. ···	···27 15.	Do.	Gentle.
Matsumoto	···27 55.	Do.	
Akita. ···	···27 58.	Do.	
Fukushima.	···30 54.	Do.	
Utsunomiya.	···34 48.	Do.	Gentle.

Eqke. No. 7. May 28th 1902; 18h.

Kushiro. ···	··· 1^{m}53^s.	Strong (rather violent).	Sharp, houses shaken.
Tokachi. ···	··· 2 15.	Weak.	Sharp.
Nemuro. ···	··· 1 18.	Weak (rather slight).	Duration long.
Abashiri. ···	··· 1 5.	Slight.	
Sapporo. ···	··· 2 50.	Do.	Gentle.
Aomori. ···	··· 3 6.	Do.	Sharp.
Miyako. ···	··· 3 12.	Do.	Sharp, accompanied by vertical movement.
Wajima. ···	··· 4 8.	Do.	
Mito. ···	··· 4 30.	Do.	Sharp.
Ishinomaki.	··· 3 10.	Slight (unfelt).	
Fukushima.	··· 4 12.	Do.	

* Observations of Eqkes. Nos. 2, 3, 4, 5, 6, 8, and 10 are given in the *Publications*, No. 16.

Akita. ...	... 4 47.	Do.
Kumagae.	... 5m11s.	Do.
Tokyo. ...	... 5 20.	Do.

Eqke. No. 9. June 23rd 1902; 7h.

Yokohama	.. 42m58s.	Strong (rather weak).	Sharp, accompanied by vertical movement, houses shaken.
Tokyo. ...	...42 20.	Weak.	Sharp.
Yokosuka.	...42 35.	Do.	Sharp, accompanied by vertical movement.
Kumagae.	...42 40.	Do.	Gentle.
Mito. ...	.. 42 40.	Do.	Do.
Numazu. ...	...43 40.	Do.	Do.
Mera. ...	...45 40.	Do.	Houses shaken.
Choshi. ...	.. 40 0.	Weak (rather slight).	Accompanied by earthquake sound.
Kofu. ...	...43 11.	Do.	Houses shaken.
Nagano. ...	...42 58.	Slight.	Duration long.
Utsunomiya.	.. 44 20.	Do.	Gentle.
Wajima. ...	..45 20.	Do.	
Matsumoto.	...42 17.	Slight (unfelt).	Duration long.
Maebashi.	...43 10.	Do.	
Fukushima.	...43 11.	Do.	
Nagoya. ...	...43 17.	Do.	Gentle.
Iida.	.. 43 24.	Do.	
Hikone. ...	...43 40.	Do.	
Ishinomaki.	...43 49.	Do.	
Fukui. ...	...44 0.	Do.	
Yagi. ...	...44 45.	Do.	
Gifu. ...	...47 23.	Do.	

Eqke. No. 11. July 8th 1902; 23h.

Tokachi. ...	... 6m 0s.	Weak.	Gentle.
Hakodate.	... 5 13.	Weak (rather slight).	Sharp.
Aomori. ...	.. 8 42.	Do.	Windows rattled.
Miyako. ...	... 3 39.	Slight.	

Sapporo. ...	... 5 39.	Do.	
Ishinomaki.	... 7m29s.	Do.	
Akita. ...	... 7 41.	Do.	
Nemuro. ...	... 7 56.	Do.	Gentle.
Wajima. ...	... 8 23.	Slight.	
Kumagae.	... 4 12.	Slight (unfelt).	
Mito. ...	... 8 0.	Do.	
Tokyo. ...	... 8 36.	Do.	
Yokohama.	... 9 29.	Do.	Gentle.

Eqke. No. 12. July 10th 1902; 19h.

Hakodate.	...56m35s.	Weak (rather slight).	Sharp.
Miyako. ...	...55(?)38.	Slight.	
Aomori. ...	...57 6.	Do.	Sharp.
Nemuro. ...	.. 57 27.	Do.	Gentle.
Wajima. ..	.. 58 12.	Do.	
Sapporo. ...	...58 30.	Do.	Gentle.
Akita. ...	.. 57 30.	Slight (unfelt).	
Fukushima.	...57 55.	Do.	
Tokyo. ...	...59 30.	Do.	
Mito. ...	...60 27.	Do.	

Eqke. No. 13. Aug. 3rd 1902; 10h.

Nemuro. ..	.. 38m 0s.	Slight.	Gentle.
Fukushima.	...42 40(?).	Slight (unfelt).	
Kanayama.	...44 55.	Do.	
Akita. ...	...47 36(?).	Do.	

Eqke. No. 14. Aug. 7th 1902; 18h.

Aomori. ...	...19m17s.	Weak (rather slight).	Gentle.
Wajima. ...	.. 21 6.	Slight.	
Akita. ...	...18 52.	Slight (unfelt).	
Kanayama.	...20 13.	Do.	
Ishinomaki.	...21 37.	Do.	

Mito. ...	...22^m 3^s.	Do.	
Tokyo. ...	..22 18.	Do.	
Iida.	...23 5.	Do.	Gentle.

Eqke. No. 15. March 21st 1903; 19 h.

Kure. ...	...$36^m 10^s$.	Strong.	
Ashizurizaki.	...35 0.	Strong (rather weak).	Sharp, houses shaken.
Oita. ...	...35 38.	Do.	Accompanied by vertical movement, clocks stopped.
Murotozaki	.. 35 40.	Do.	Houses shaken.
Niihama ...	...36 6.	Do.	Duration long.
Hiroshima	...36 25.	Do.	Windows rattled.
Miyazaki...	...37 0.	Do.	Sharp, houses shaken.
Tadotsu ...	...41 58.	Do.	Accompanied by vertical movement, houses shaken.
Hamada ...	...32 0.	Weak.	Houses shaken.
Ajino ..	...32 3.	Do.	Clocks stopped.
Kochi ...	...35 7.	Do.	Duration long.
Matsuyama	...35 50.	Do.	Accompanied by vertical movement, houses shaken.
Sakai ...	...36 0.	Do.	Houses shaken.
Besshi ...	...36 0.	Do.	Accompanied by earthquake sound, houses shaken.
Okayama	...36 25.	Do.	Houses shaken.
Kyoto ...	...37 10.	Weak (rather slight).	Gentle.
Kumamoto	...37 6.	Do.	Duration long.
Miyazu ...	...37 10.	Do.	Do.
Fukuoka ...	...37 20.	Do.	Do.
Saga ...	...37 25.	Do.	Windows rattled.
Shimonoseki	...37 32.	Do.	Accompanied by vertical movement, houses shaken.

Tokushima	...37m 0s.	Slight.	
Kagoshima	...37 4.	Do.	Gentle.
Fukui ...	.. 37 15.	Do.	Duration long.
Hikone ...	...36 35.	Slight (unfelt).	Sharp.
Osaka ...	...37 17.	Do.	Gentle.
Iida	.. 52 35.	Slight.	

Eqke. No. 16. April 1st 1903; 23 h.

Ishinomaki	... 8m57s.	Weak.	Houses shaken.
Kanayama	... 8 37.	Weak (rather slight).	Duration short.
Miyako ...	... 6 1.	Slight.	Duration long.
Fukushima	... 8 38.	Do.	
Yokohama	... 9 52.	Do.	Gentle.
Kumagae	... 8 51.	Slight (unfelt).	
Matsumoto	... 8 53.	Do.	
Mayebashi	... 9 24.	Do.	
Yamakata	... 9 25.	Do.	
Choshi ...	... 9 57.	Do.	
Tokyo ...	...10 0.	Do.	
Iida	.. 10 8.	Do.	Sharp.
Utsunomiya	...10 53.	Do.	
Aomori ...	.. 11 15.	Do.	
Kinkwasan	..12 30.	Do.	Duration short.

Eqke. No. 17. Aug. 10th 1903; 13 h.

Takayama	...37m35s.	Weak (rather slight).	Sharp, accompanied by earthquake sound, houses shaken.
Kyoto ...	...34 19.	Slight.	Gentle.
Fushiki ...	...39 40.	Slight (unfelt).	
Katsumoto	...40 4.(?)	Slight.	
Hikone ...	...40 12.	Do.	Gentle.
Tsu	.. 40 15.	Do.	

Tokyo ...	...41^m 0^s.	Slight.	
Iida	...41 48.	Do.	
Nagoya ...	... 39 42.	Slight (unfelt).	
Fukui ...	... 41 0.	Do.	
Kobe ...	... 41 7.	Do.	

Eqke. No. 18. Agu. 10th 1903; 13 h.

Takayama	...48^{m}52^s.	Weak (rather slight).	Sharp.
Wajima ...	.. 46 20.	Slight.	Duration short.
Tokyo ...	...46 35.	Slight (unfelt).	
Fushiki ...	.. 47 28.	Slight.	
Nagoya ...	.. 45 47.	Slight (unfelt).	
Iida	.. 46 10.	Do.	
Matsumoto	...46 25.	Do.	

Eqke. No. 19. Aug. 14th 1903; 0 h.

Kushiro ...	...46^m 5^s.	Strong (rather weak).	Duration short.
Tokachi ...	.48 30.	Weak (rather slight).	Sharp.
Wajima ...	...47 10.	Slight.	Gentle.
Nemuro ...	...47 29.	Do.	Do.
Hakodate.	.. 48 5.	Do.	Do.
Ishinomaki.	.. 49 0.	Slight (unfelt).	
Mito. ...	...50 2.	Do.	Gentle.
Aomori. ...	.. 50 13.	Do.	

Eqke. No. 20. Oct. 11th 1903; 1h.

Toizaki.	.. 37^{m}25^s.	Strong.	Sharp, houses shaken.
Miyazaki.	.. 41 19.	Do.	Sharp, accompanied by vertical movement.
Kagoshima.	.. 41 30.	Weak.	Houses shaken.
Oita. ..	...39 0.	Do.	Clocks stopped.
Matsuyama.	. 52 22.	Slight.	Accompanied by vertical movement.

Kumamoto.	...41m42s.	Slight (unfelt).	Duration long.
Yagi. ...	...42 52.	Do.	
Fukuoka....	...44 50.	Do:	

Eqke. No. 21. Dec. 3rd 1903; 17h.

Miyazaki.	...53m 4s.	Weak.	Houses shaken.
Kagoshima.	...52 45.	Weak (slight).	Do.
Oshima. ...	...52 40.	Slight (unfelt).	Gentle.
Kumamoto.	...53 40.	Do.	
Oita. ...	...52 45.	Slight.	

Eqke. No. 22. March 18th 1904; 22h.

Nemuro. ...	...24m32s.	Weak.	Liquid in vessels overflowed.
Akita. ...	...44 52.	Do.	Duration long.
Aomori. ...	.. 45 1.	Do.	Windows rattled.
Kushiro. ...	.. 49 40.	Do.	Clocks stopped.
Tokachi. ...	.. 54 12.	Do.	Houses shaken.
Abashiri....	.. 44 40.	Weak (rather slight).	Accompanied by earthquake sound.
Ishinomaki.	...57 31(?).	Do.	
Shana. ...	.. 44 50.	Slight.	Gentle.
Kumagae.	...45 12.	Do.	Duration long.
Tokyo. ...	.. 46 15.	Do.	Gentle.
Nagano. ...	...46 40.	Slight (unfelt).	Duration long.
Iida.... ...	...46 53.	Do.	Gentle.
Maebashi.	...47 31.	Do.	
Matsumoto.	...47 48.	Do.	Gentle.
Miyako. ...	...43 56.	Slight.	Accompanied by earthquake sound.
Hakodate.	...45 6.	Do.	
Mito. ...	...45 0.	Do.	

Eqke. No. 23. April 13th 1904; 14h.

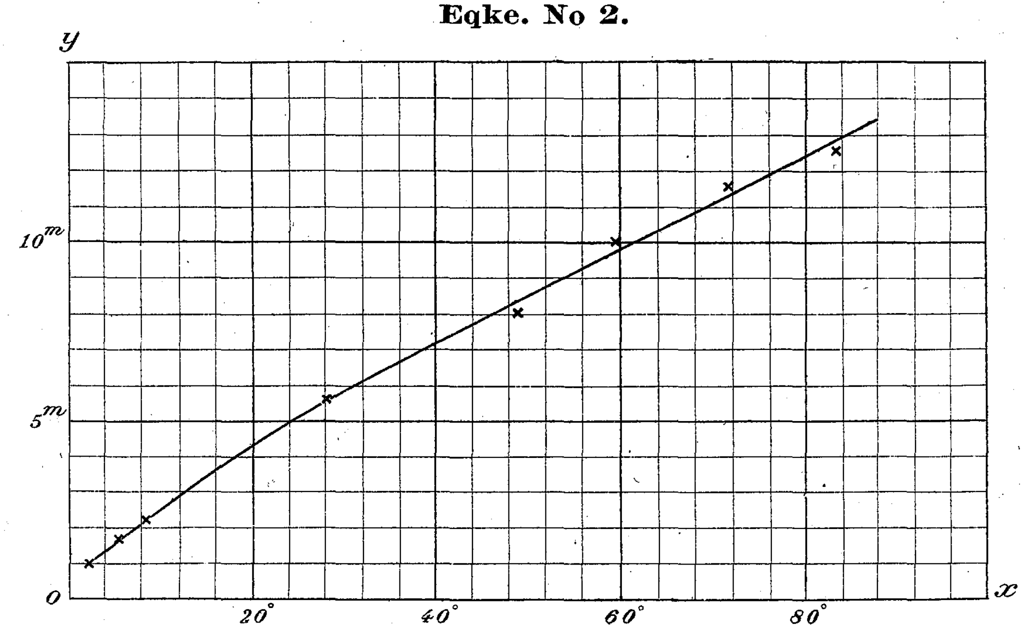
Miyako. ···	···37m52s.	Slight.	Accompanied by vertical movement.
Ishinomaki.	·· 38 8.	Do.	Gentle.
Akita. ···	··38 16.	Do.	Do.
Kumagae.	·· 38 54.	Slight (unfelt).	
Aomori. ···	··38 54.	Do.	
Utsunomiya.	··39 6.	Do.	
Tokyo. ···	···39 42.	Do.	Gentle.
Fukushima.	···38 23.	Do.	

Eqke. No. 24. May 27th 1904; 5h.

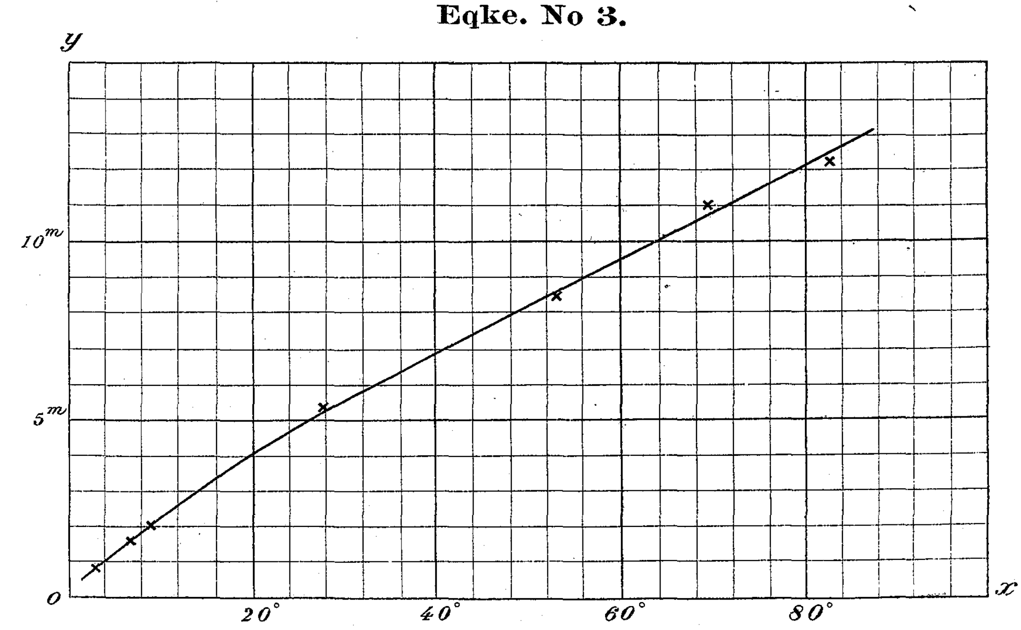
Mera. ···	·· 40m 0s.	Weak (rather slight).	Houses shaken.
Yokosuka.	···40 20.	Slight.	Windows rattled.
Tokyo. ···	···41 49.	Do.	Gentle.
Yokohama.	···32 26.	Slight (unfelt).	Do.
Kofu. ···	·· 41 3.	Do.	Do.
Kumagae.	···41 7.	Do.	
Ishinomaki.	···41 50.	Do.	
Mito. ···	···42 50.	Do.	

Fig. 1. Relation between arcual epicentral distance and time taken in transit by the 1st. preliminary tremor.

Eqke. No 2.



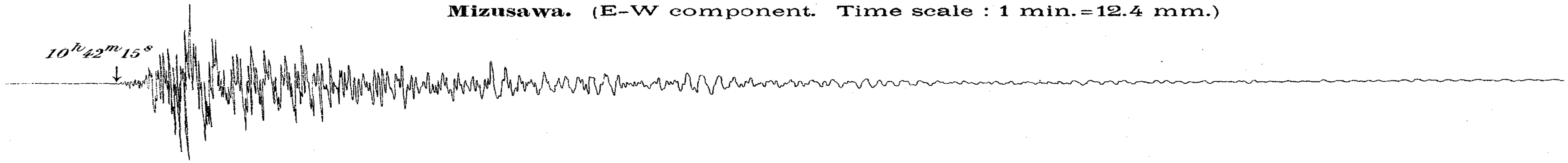
Eqke. No 3.



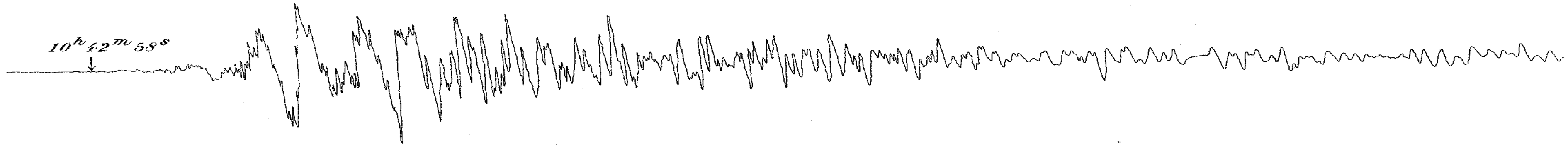
x = arcual epicentral distance.
y = time taken in transit.

Fig. 2. Eqke. No. 3.

Mizusawa. (E-W component. Time scale : 1 min.=12.4 mm.)



Tokyo. (Instrument No. 1. Time scale : 1 min.=16.1 mm.)



Osaka. (Time scale : 1 min.=13.9 mm.)

Fig. 3. Eqke. No. 13.

Mizusawa. (E-W component. Time scale : 1 min.=13.1 mm.)

Tokyo. (Instrument A. Time scale : 1 min.=14.2 mm.)

Osaka. (Time scale : 1 min.=12.6 mm.)