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IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE.

震災豫防調査會　觀測錄

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SEISMOLOGICAL NOTES.

No. 1.

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TOKYO.

Nov., 1921.

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PREFACE.

The new series of "Seismological Notes" has for its principal object the publication of preliminary reports on the Tokyo seismographical observations and of short accounts of the volcanic eruptions and tsunami (tidal waves) in Japan. It is intended to reproduce the more important of the seismograms from time to time.

F. Omori, Acting President,

Imperial Earthquake Investigation Committee.

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On the Duration of the Ist Preliminary Tremor of the Trans-Asiatic Seismic Propagation.

By **F. OMORI,** Member of the Imperial Earthquake Investigation Committee.

(*With Plate* I.)

The mean transit velocity of the first preliminary tremor of the Guatemala earthquake of April 19, 1902, across the Pacific and Atlantic ocean beds was 16.02 km./sec., while that of the Kangra (India) earthquake of April 4, 1905, across the great Asiatic continent was much smaller and only 11.36 km. per sec. Discrepancies like these are probably due to the difference in the values of the rigidity and bulk moduli of the earth's crust in suboceanic and continental portions.* Thus it would be legitimate to assume that the durations of the successive phases, or stages, of the earthquake motion of a distant origin also depend to a certain extent on the nature of the paths of the seismic propagation. Confining our attention to the propagation across Asia, the relation of the duration of the first preliminary tremor of the earthquake motion to the arcual distance of the seismic origin is found to be as in Table I. The transcontinental arcual distance of an earthquake origin corresponding to a given duration of the 1st preliminary tremor can be estimated from the diagram (fig. 1), which embodies the mean results contained in Table II.

Table I. Continental Propagation of Large Earthquakes.

Earthquake.	Place of Observation.	Duration of 1st Preliminary Tremor.		Arcual Distance.	
Kangra (India) Eqke. April4, 1905.	Colaba, Calcutta.	3^m	20^s	$13°35' = 1509^{km.}$	
	Kodaikanal, Tiflis, and 5 Caucasus Stations.	4	33	26 10	2907
	Taihoku, Taichu, Tainan ; Batavia, Manila.	6	27	40 45	4528
	18 Japanese and European stations.	7	11	50 12	5578
	2 British stations.	8	20	59 10	6574

* See the Bulletin of the Imp. Earthquake Inv. Comm., Vol. III (1909).

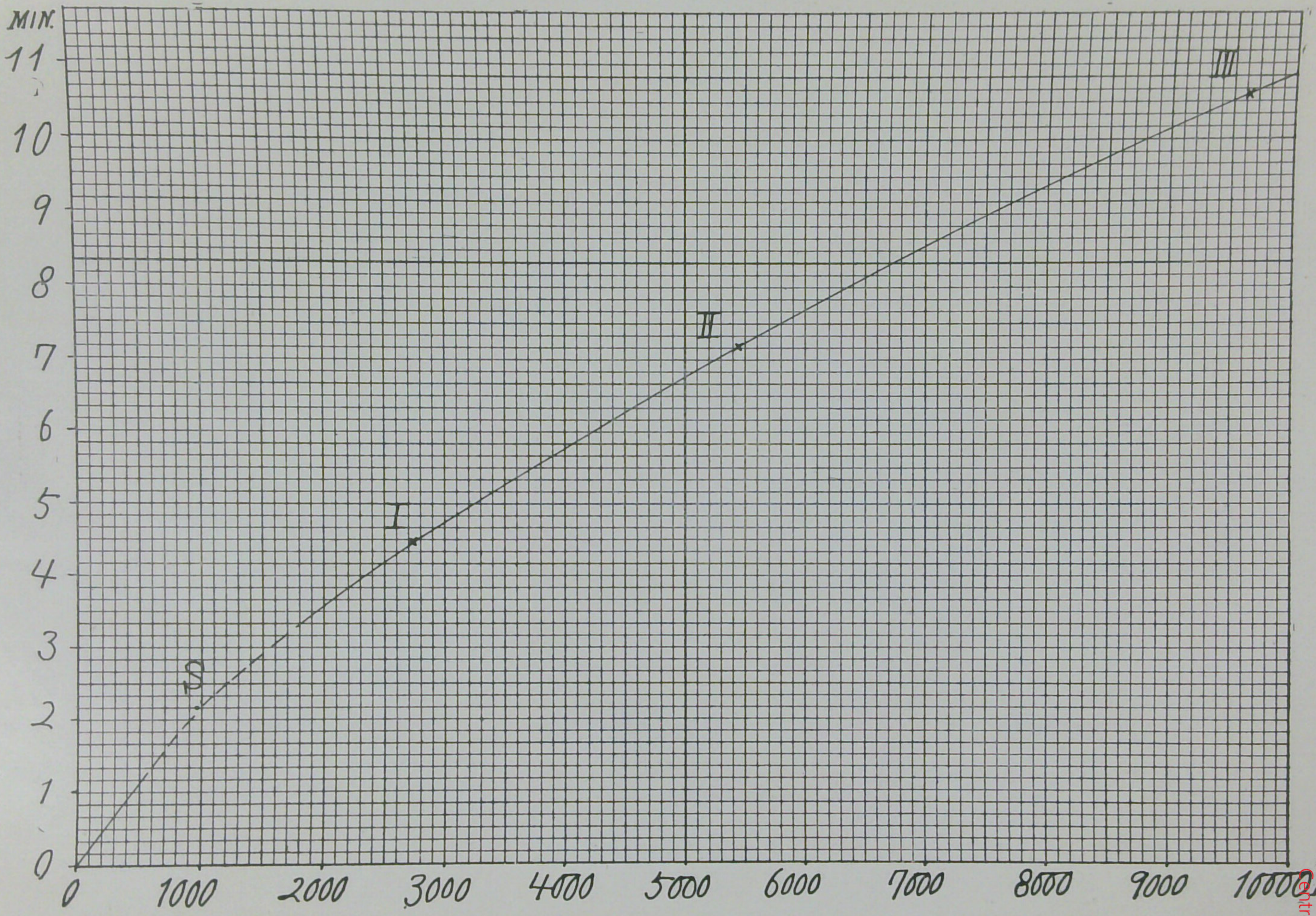
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Earthquake.	Place of Observation.	Duration of 1st Preliminary Tremor.	Arcual Distance.
Turkesten Eqke. Aug. 22, 1902.	Colaba.	3m 54s	20° 59′ = 2331km.
	Kodaikanal, Pavlousk.	5 36	32 03 3561
	Leipzig, Florence, Tokyo, Osaka.	7 18	47 02 5226
	Edinburgh, Batavia.	8 00	53 10 5907
10 Japanese Eqkes. (1894—1898.)	Italian Stations.	10 34	86 54 9650
9 Japanese Eqkes. (1899—1901.)	Stations in Central Italy.	10 36	85 54 9544
Messina. Eqke. Dec. 28, 1908.	Tokyo.	11 39	89 06 9900
Sakura-jima Eqke. Jan. 12, 1914.	Tokyo.	2 11	8 37 958

Table II. Mean Values of the Duration of the 1st Preliminary Tremor and of the Arcual Distance.

Group.	Earthquake.	Place of Observation.	Duration of 1st Preliminary Tremor.	Arcual Distance.
I	Kangra Eqke.	Colaba ; Calcutta.	3m 20s	1509km.
	Turkestan „	Colaba.	3 54	2331
	Kangra „	Kodaikanal, Tiflis, and 5 Caucasus stations.	4 33	2907
	Turkestan „	Kodaikanal ; Pavlousk.	5 36	3561
		Mean	**4 28**	**2735**
II	Kangra Eqke.	Batavia, Manila, and 3 Formosa stations.	6 27	4528
	„ „	18 Japanese and European stations.	7 11	5578
	Turkestan „	2 Japanese and 2 European stations.	7 18	5226
	„ „	Edinburgh ; Batavia.	8 00	5907
	Kangra „	2 British stations.	8 20	6574
		Mean	**7 12**	**5450**
III	10 Japanese Eqkes.	Italian stations.	10 34	9650
	9 „	Stations in Central Italy.	10 36	9544
	Messina Eqke.	Tokyo.	11 39	9900
		Mean	**10 37**	**9610**

TO THE TRANS-ASIATIC DISTANCE OF SEISMIC PROPAGATION.



I, II, III.....Mean Group Relations (Table II)

S.....Observation in Tokyo of the Sakura-jima Eqke. of 1914.

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The three points, I, II, and III in the diagram indicate respectively the three group mean values in Table II. The point S, put on for the sake of reference, represents the Tokyo observation of the strong Sakura-jima earthquake on Jan. 12, 1914, for which the arcual distance was 958 km., and the duration of the total preliminary tremor was $2^m\ 11^s$. It will be observed that the point S falls in very well with the prolongation of the curve III II I. In fact the line connecting S with the coordinate origin O represents the relation of the arcual distance of the seismic origin to the *total duration* of the preliminary tremor for near earthquakes. (See the Bulletin of the Imp. Earthq. Inv. Comm., Vol. IX, No. 1.) It follows, therefore, that what has been taken as the preliminary tremor, namely, the *total preliminary tremor*, of the near earthquake motion corresponds only to the 1st preliminary tremor of the distant earthquake motion.

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Note on the Kansu Earthquake of Dec. 16, 1920.

By **F. Omori**, Member of the Imperial Earthquake Investigation Committee.

(*With Plates* II–VII.)

The North China earthquake on the evening of Dec. 16, 1920, was a very great disturbance and caused considerable amount of damage in the province of Kansu. The seismic wave was sensible even in the city of Peking some 1,000 km. distant from the origin. Mr. Ch'en Kuan, a 3rd year student in the Civil Engineering Department of the Tokyo Imperial University, who happened to be in Peking at the time, felt some dizziness, which was imagined at first to be the effect of the heat and the gas emanation from a burning stove in the room, but which was ascertained to be due to a slow earthquake motion as the electric lamps were simultaneously set in oscillations.

According to the tromometer registers in Tokyo the earthquake in question was one of the greatest observed there during the course of the last two dozen years, being not less than even the Kangra (North India) earthquake of April 4, 1905.

TOKYO OBSERVATION. The time ($=t_1$) of commencement in Tokyo (Seismological Institute) of the great Kansu earthquake on Dec. 16, 1920, was 9. 11. 41 P.M., or 0. 11. 41 P.M., G. M. T. The duration ($=y_1$) of the preliminary motion stage, which was here very well defined and corresponds to the 1st preliminary tremor, was $4^m\ 44^s$, from which the approximate time ($=t_0$) of occurrence* at the origin may be inferred to be 0. 05. 54 P.M., G.M.T., as follows :—

$$t_0 = t_1 - 1.222\ y_1 = 0^h\ 05^m\ 54^s \text{ P.M., G.M.T.}$$

This is equivalent to $7^h\ 09^m\ 54^s$ P.M. of the local time of the 106° meridian near the earthquake origin.

According to Plate I, the arcual distance of Tokyo from the origin, corresponding to the above-mentioned duration of the 1st preliminary tremor, is 3,000 km. From the duplex pendulum tromometer diagram (fig. 2), which gives the resultant horizontal motion ($=2a$) with a magnification of 20, the general direction of motion in Tokyo during the same phase of motion is seen to be the west slightly north and the east slightly south, as follows :—

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* Based on the observation of the Kangra earthquake of 1905, the Bulletin of the Imp. Earthq. Inv. Comm., Vol. I, No. 1.

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1st four small vibrations (2a=1.5 mm)..... E. 15°S.—W.15°N.
5th and 6th larger vibrations (2a=4.3 mm) ...E. 17°S.—W.17°N.

The subsequent motion of the phase in question was smaller and executed in nearly similar directions. The two strong vibrations, which occurred immediately after the termination of the 1st preliminary tremor stage were as follows :—

1st Displacement :	2a = 2.6 mm,	toward	E. slightly S.
2nd ,, :	2a = 6.3 ,, ,	,,	W. slightly N.
3rd ,, :	2a = 9.5 ,, ,	,,	E. slightly S.
4th ,, :	2a over 12.2 ,, ,	,,	W. slightly N.

The writing pointer then jumped out of the smoked paper, toward the W. slightly N.

The average direction of motion in the earlier portion of the earthquake may be taken to be N. 77° W. and S. 77° E., the very first displacement being westward and accompanied by a downward motion. The position of the earthquake origin* computed from the arcual distance and the azimuth determined in Tokyo is as follows :—

$\varphi_0 = 37° 05'$ N. $\quad \lambda_0 = 106° 05'$ E.

The centre thus located is in the N.E. part of the province of Kansu about 160 km. to the south of Ning-hsia Fu (寧夏府), and not far from Ping-liang (平凉府), Koo-yuen-chow (固原州), Ning-yuan (甯遠), Tunwei (通渭), Tsing-ning (靜甯), Tiensui (天水), Hai-yuen (海原) and other places where the shock was reported to have been disastrous. According to Father Gherzi, the area of destructive motion, corresponding to the X. grade of the Mercalli scale of seismic intensity, extends from the vicinity of Hai-cheng (海城縣) in the north to the confines of the Tsin-ling-shang range (秦嶺山) in the south.†

In the Tokyo seismograms, the most active portion composed of large and comparatively quick vibrations began about $9^m\ 35^s$ after the commnecement. Owing to the exceptional greatness of motion, the major-arc propagation as well as the repetition of the minor arc propagation were clearly registered.

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* The latitude (φ_0) and the longitude (λ_0) of the earthquake origin may be calculated from the arcual distance (s) and the azimuth (A) determined at the observing place (φ, λ) by the formulae

$$\sin \varphi_0 = \cos s. \sin \varphi + \sin s. \cos \varphi. \cos A$$

$$\sin (\lambda - \lambda_0) = \frac{\sin s. \sin A}{\cos \varphi_0}$$

† See the Zikawei Observatory Publication, "Note de Sismologie": Le Tremblement de Terre du Kan-sou (Chine), 16 Decembre 1920, par le R. P. E. Gherzi, S. J.

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Thus the first indication of the W_2 wave, or the earthquake motion propagated to Tokyo along the great circle between the origin and Tokyo through Europe, the Atlantic, America, and the Pacific, already appeared at $2^h\ 52^m\ 14^s$ P.M., became more distinct at $3^h\ 12^m\ 43^s$ P.M and most active at $3^h\ 19^m\ 03^s$ P.M. The W_3 wave, or the earthquake motion propagated along the shortest path, which went further on, and came back to Tokyo after making one complete circuit of the globe, appeared somewhat indistinctly at $3^h\ 28^m\ 15^s$ P.M.,* becoming a little better defined $3\frac{1}{2}$ min. further on. (See fig. 6, A and fig. 6, B.) These movements continued more or less distinct for about 24 min. The total earthquake duration was about 5 hours.

Pls. II to VI give the earlier portions of the Tokyo registers furnished by the different tromometers, while Pl. VII gives a slightly reduced reproduction of the complete diagram from the long-period N.–S. component horizontal pendulum tromometer.

EARTHQUAKE DISTRICTS OF CHINA. Speaking generally, destructive earthquakes are more frequent in the northern regions along the Hoang-ho, and in Yunnan and Szechen at the S.W. part of China. Especially the three northern provinces of Kansu, Shense, and Shanse have often been seats of extensive and violent earthquakes. The two principal interior seismic districts of (a) Kansu-Shense and of (b) Yunnan have been indicated on the map given in the Bulletin of the Imp. Earthq. Inv. Comm., Vol. I. (1907), reproduced in fig. 1.

The greatest earthquake recorded in Chinese history took place on Feb. 2, 1556, and shook the three provinces of Shanse, Shense, and Honan, killing more than 830,000 people. The meizoseismal area was a narrow zone at the S.W. corner of Shense, in the E.W. direction along the river Wei-ho (in Shense), a tributary of the Hoang-ho. Again, the earthquake of Aug. 18, 1561, which shook the northern portions of the province of Kansu, Shense, and Shanse, and was especially destructive at Ning-hsia-fu (寧夏府) and Koo-yuen-chow (固原州), in the northern part of Kansu, originated in the valley of the river Tsing-chooi, a tributary of the Hoang-ho running from south to north. The recent great disturbance, which originated in the district contiguous to and midway between the centres of these two great shocks, must be related to the latter, and also belong to the (a) Kansu-Shense group.

The Pacific branch (I) and the Himalaya-Mediterranean branch (II) of the great earthquake zone peripheral to the Asia-Europe continent were assumed to be continuous and to pass through the southern portion of China,

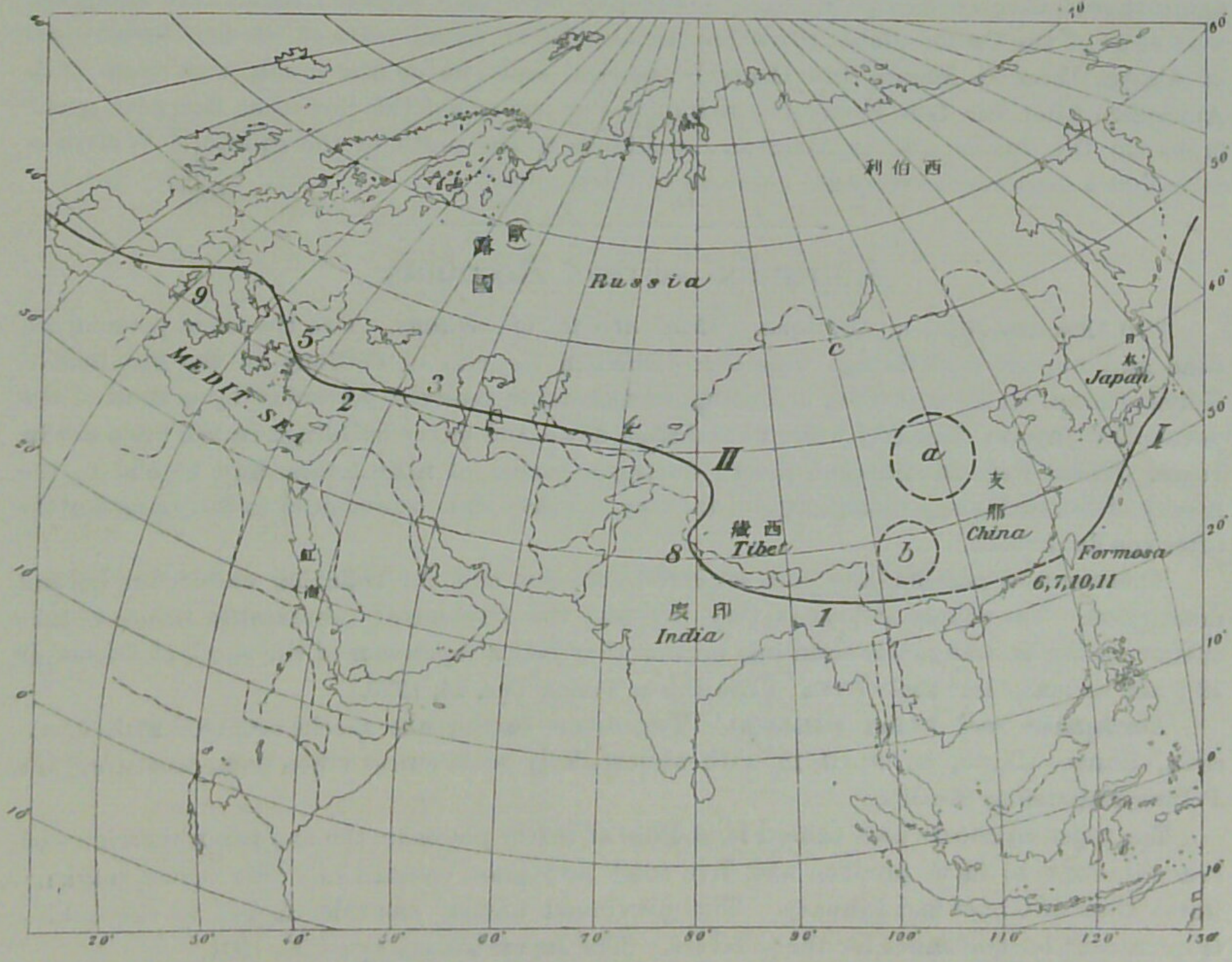
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* These times are expressed in G. M. T.

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and has been indicated by a dotted line on the map (fig. 1), although the provinces of Fokien and Kwang-tung were historically among the least disturbed districts of China. The assumption of the seismic zone has, however, been justified by the occurrence on Feb. 13, 1918, of the strong earthquake which proved destructive in and about Swatow, and originated 65 km. to the W. N. W. of the latter, at $\varphi = 23° 45'$ N., $\lambda = 115° 55'$ E., exactly on the dotted line shown in the map. The supposition in regard to the production of destructive shocks from those parts of an earthquake zone hitherto free from such disturbances, has also recently been fulfilled by the occurrence, amongst the others, of the Avezzano earthquake of 1915, of the Aleutian and Valparaiso earthquakes of 1906, and of the Kagi earthquake of March 17, 1906, respectively in the earthquake zones of Italy, of the Pacific coast of America, and of Formosa. I reproduce below a paragraph bearing on

Fig. 1. Map showing the Recent Seismic Activity along the Mediterranean and Himalayan Zone.



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this point from the report of the Director of Royal Hong-Kong Observatory on the Swatow earthquake of 1918, published in the South China Morning Post of March 8, 1918:—

"*Prediction of the Swatow Earthquake.* In connection with this disturbance it is of peculiar interest to note that a severe earthquake was due sooner or later, according to a diagram published in 1907 by Professor Omori, the Secretary of the Imperial Earthquake Investigation Committee of Japan. This distinguished seismologist, writing on the distribution of seismic activity along the Mediterranean-Himalayan zone, (Bulletin, Vol. I, No. 2) shows on a map (reproduced above) the position of 11 destructive earthquakes which had occurred in recent years. Of these earthqukes Nos. 1, 2, 4, 5, 8 and 9 were very great disturbances and happened at different places along the zone in question. Severe earthquakes had also occurred along the line from N. Japan to Formosa. But none had occurred between Formosa and Burma. Professor Omori therefore drew a dotted line from Formosa to Burma, passing over Swatow. This may be considered as his modest way of predicting one of more severe earthquake for this region. It remains to be seen whether the recent disaster at Swatow has sufficiently restored the equilibrium, or whether other severe earthquakes will occur between Swatow and Burma. It may be remarked that after a really severe quake a given spot is considered to be immune for perhaps a generation. Up to the present I have been unable to obtain any information as to the actual fracture of the earth's crust at the epicentre.

"In connection with the San Francisco earthquake of 1906, April 18, Professor Omori again showed that a severe quake might reasonably have been expected somewhere along the west coast of the United States, three having occurred in recent years off the south-west coast of Alaska, three in Mexico and Central America, and one on the north west coast of S. America. After the San Francisco earthquake he expressed the view that the next great shock on the Pacific side of America... would be to the south of the equator. Within a fortnight a disastrous earthquake occurred at Valparaiso."

Appendix. Press Accounts.

Two Thousand killed in Earthquake Shock at City of Peiliang. Two thousand persons are dead and numerous buildings were demolished in the city of Peiliang in the province of Kansu, China, on December 16, according to dispatches received yesterday by several of the vernacular papers. The city walls were shaken down and many buildings in the town are in ruins. There were 25 different shocks during a period of nine hours, and to add to the misery of the surviving inhabitants of the city, a heavy rain commenced to fall immediately after the final shock.

Thousands of persons have been rendered homeless and the suffering endured is beyond description. The supply of food is very low and the frightened inhabitants refuse to take shelter in the buildings left standing because they fear a repetition of the shock of December 16 when so many lost their lives. (The Japan Times, Dec. 24, 1920.)

Earthquakes rock China Settlement. Two severe earthquake shocks occurred at Rokhanshan, Kansu, China, on April 12 with almost daily recurrences since then, according to a Peking dispatch to the Jiji.

The repeated shocks have caused landslides at thirty places in the mountain district with heavy damage to farm produce and live stock and some casualities. The earthquakes are worse than the ones last January. The provincial tuchen has telegraphed to the Peking Government for assistance for the sufferers. (The Japan Times, April 29, 1921.)

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Earthquake Relief needed in China. A very serious situation has been caused in Kansu, China, by the recent heavy earthquake. Falling hills have blocked the watercourses in numberless places. If the obstructions resist the strain of the collected water then big floods will result and ruin the good land and houses. Should the blockage give way, under the heavy pressure of the water, it will carry destruction down its course.

An International Earthquake Relief Committee has been formed in Lanchowfu. Its first work will be to open the river courses. This work is urgent. Already in the Tsinchow district floods are destroying the villages. Money is needed urgently.

Mr. Mann is Chairman of the committee, Mr. Chan But-to, Postal Commissioner, vice-chairman and Mr. Geerts, foreign treasurer. With other members of the committee they have issued an appeal for assistance. (The Japan Times, May 21, 1921.)

新聞記事抜萃

陝西省邠州ヨリ達セル電報ニ曰ク十六日同地方ニ地震アリ西安府ノ西北ニ於テハ地辷リヲ惹起シ家屋ノ倒壊セルモノ若干アリト。(大正九年十二月十八日 北京國際ロイテル發)

北京ニ地震ガ起リ家屋震動大ニ人心ヲ驚カセリ。(大正九年十二月十八日 北京國際聯合通信發)

甘肅陝西兩省ノ大地震ニ就キ徐總統ハ十三日內務部及賑務處ニ憮恤方ヲ命ジタルガ最モ甚シキ災害地ハ甘肅省涇源道(舊隴東地方)陝西省ノ漢中道ニテ城壁家屋ノ倒潰セルモノ數限リナク人畜ノ死傷モ極メテ多シト。(大正十年一月十二日 北京特派員發時事新報)

客月十六日支那甘肅省平涼縣ヲ中心トシテ會甯、靜寧、通渭、天水、靜遠、海原、固原等ノ四十餘縣ニ亘レル大地震ノ報ハ當時上海特電ニテ傳ヘラレシガ、同地ハ僻遠ノ地トテ交通不便ノ爲メ詳細ノ報告ナカリシガ最近甘肅省城蘭州督軍ヨリノ通報ニ據レバ支那稀有ノ大震災ニテ山谷崩壞土地陷沒ノ地方多ク死傷ハ縣ニヨリテハ住民ノ半ニ及ビ生存者ハ住ムニ屋舍ナク食フニ食ナク北支ノ饑饉以上ノ慘狀ニテ大總統ハ救助ヲ命令シ居ル有樣ニテ北京甘肅同鄉會ハ勿論國際的ニ救濟ニ奔走シ日本留學ノ同省人モ遽ニ救濟事業ヲ劃セント來ル二十九日神田中華青年會館ニ慈善演藝會ヲ催シ在留中華人及ビ日本人ノ同情ニ訴フル由。(大正十年一月廿二日 東京朝日新聞)

客臘十二日支那西部甘肅ニ起レル未曾有ノ大地震ハ交通電信ノ破壞シタル爲未ダ詳カデハナイガ、警視廳外事課ヘ來タル報告ニ依レバ其ノ死傷者ハ一縣ニ二千餘名ヲ出シ、全部八十餘縣デ十五萬餘人ト云フ驚クベキ大慘害ヲ釀シテイル、

右ニ關シ在留支那留學生二千餘名ハ故國罹災民救濟ノ爲蹶起シ神田區神保町ノ中國基督教青年會館ヲ事務所トシ甘肅省出身學生漢坦張朝選外數名ガ專ラ其ノ任ニ當リ救濟金募集ニ努ムベク昨廿五日留學生滯宿ノ下宿ヤ學校等ニ檄ヲ飛バシ一方支那關係ノ名流富豪間ニ對シ運動スル事トシタ尙廿九日神田青年會館ニ慈善演藝會ヲ催スベク廿六日右次第ヲ警視廳外事課ニ幹事出頭届ケテ來タ。(大正十年一月廿七日 時事新報)

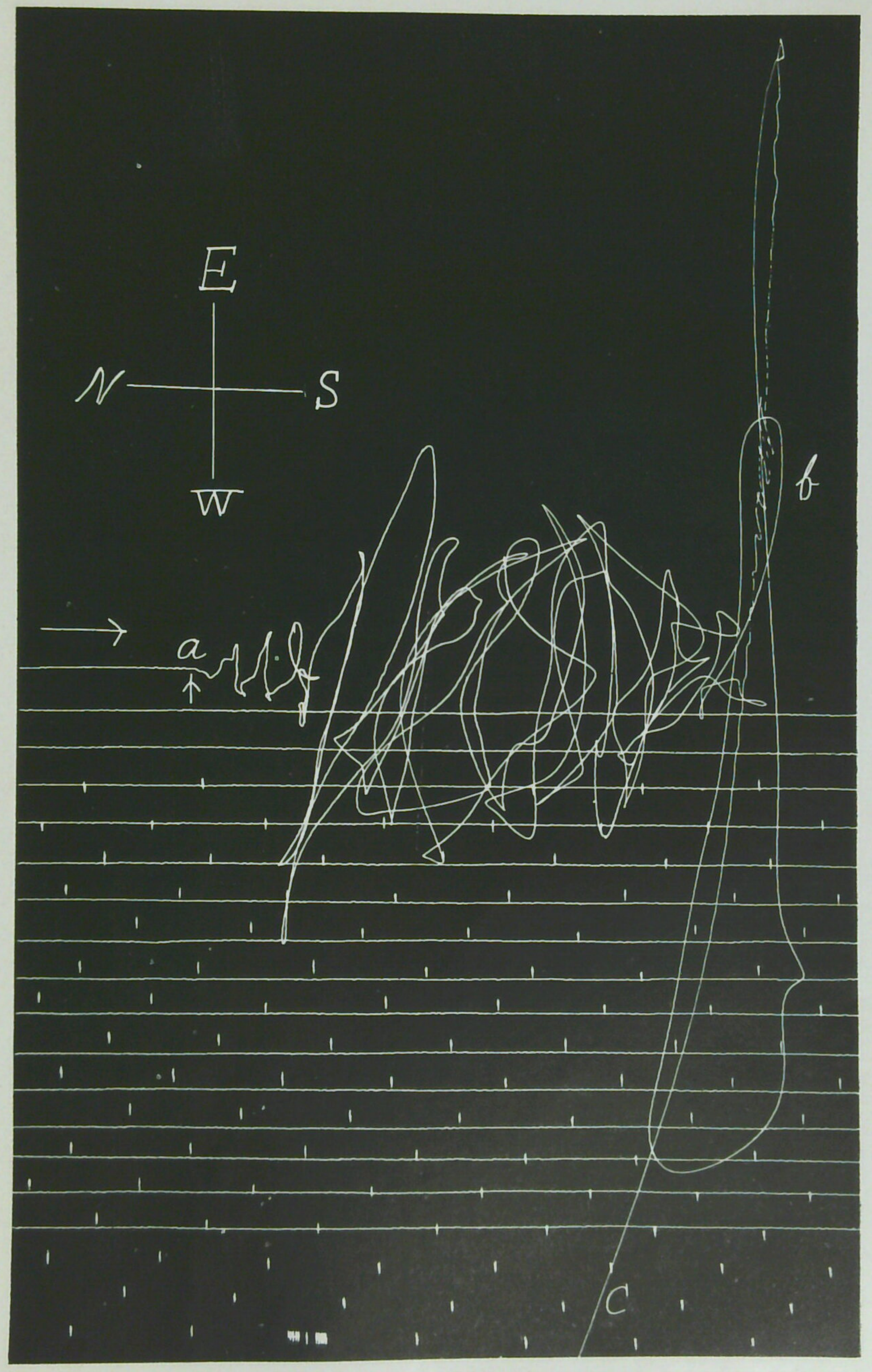
【北京一日發國際】 甘肅省カラノ報道ニ依ルト曩ニ回教徒蜂起ノ恐レガアッタガ遂ニ反亂的ニ擴大サレズニ熄ンダ革命計畫ノ放棄ハ最近ノ地震ニ驚駭シタ結果デアル由來回教徒ハ地震ヲ天ノ警告ト信ジテ居ルノデアル此ノ地震中洞窟、家屋、市壁ガ壓潰シテ シエン、ヂエム其他ノ回教首領等ノ斃レタノハ回教徒ノ中央政府反抗ノ計畫ヲ阻止スルニ與ッテ力アッタラシイ地震ノ當時五百餘ノ回教首領等ハ宗教會議ヲ開イテイタガ彼等ハ全部破壞建物ノ下敷トナッテ生埋ニサレタト云ハレ此悲劇ノ爲メ回教徒ハ舊來ノ反政府的猛ナ態度ヲ改メテ仕舞ッタノダト云フ。(大正十年二月三日 東京每夕新聞)

甘肅省六盤山ハ、十二日以來一時間二回ノ大震動ヲ示シ今猶熄マズ山嶽ノ崩壞三十餘ニ及ビ人心恟々タリ、數月前ノ大地震ニ比シ更ニ猛烈ニシテ農作物人畜等ノ損傷モ少カラザル如ク同督軍ハ北京政府ニ對シ目下救濟策ヲ電請中ナル由。(大正十年四月廿八日 時事新報)

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FIG. 2. DUPLEX PENDULUM TROMOMETER RECORD, SHOWING THE RESULTANT HORIZONTAL MOTION.

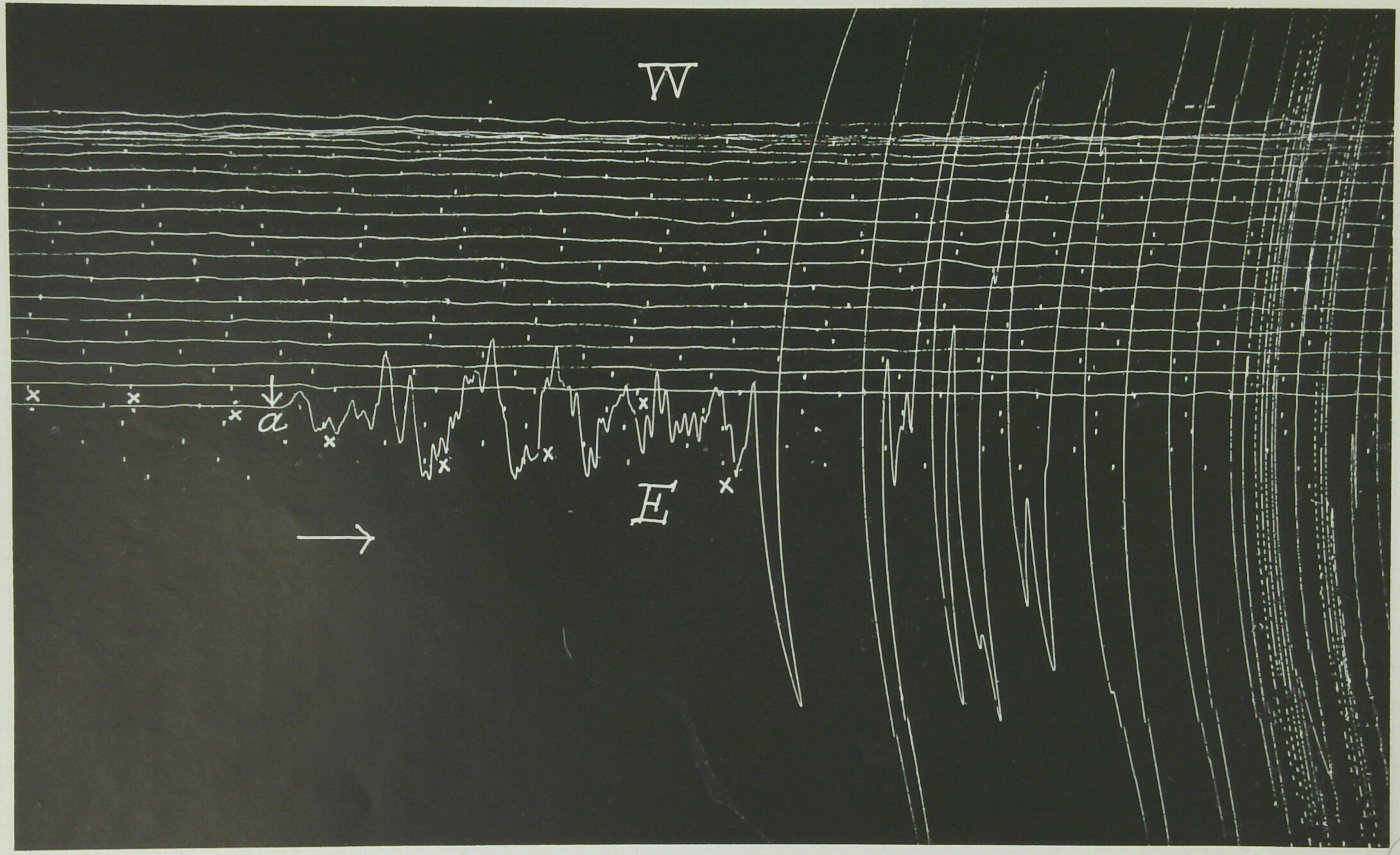
Multiplication=18. a.....Commencement. ab.....1st Preliminary Tremor.



Time Scale: Interval between successive time marks=1 minute.
At c, the pointer got out of the smoked paper.
Natural Pendulum Period=19 sec.

FIG. 3. E.W. COMPONENT HORIZONTAL PENDULUM TROMOMETER RECORD.

Multiplication = 10.3 a.....Commencement.

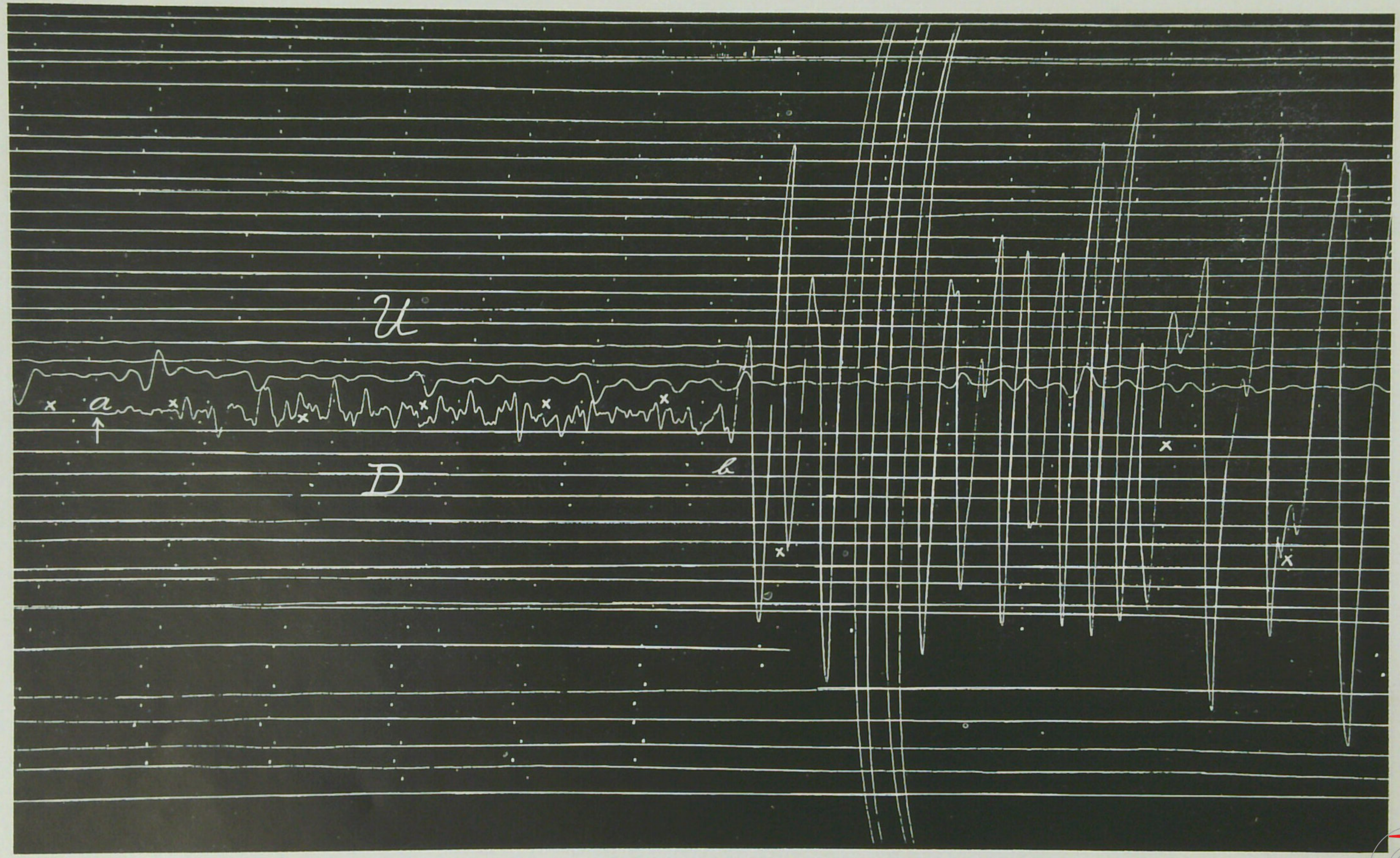


The short cuttings indicated by the small crosses (×) mark the successive minutes. (The time is also indicated by small ticks whose successive interval is 1 minute.) Natural Pendulum Period = 61.5 sec.

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FIG. 4. VERTICAL COMPONENT TROMOMETER RECORD.

Multiplication = 15.2 a.....Commencement. ab.....1st Preliminary Tremor.



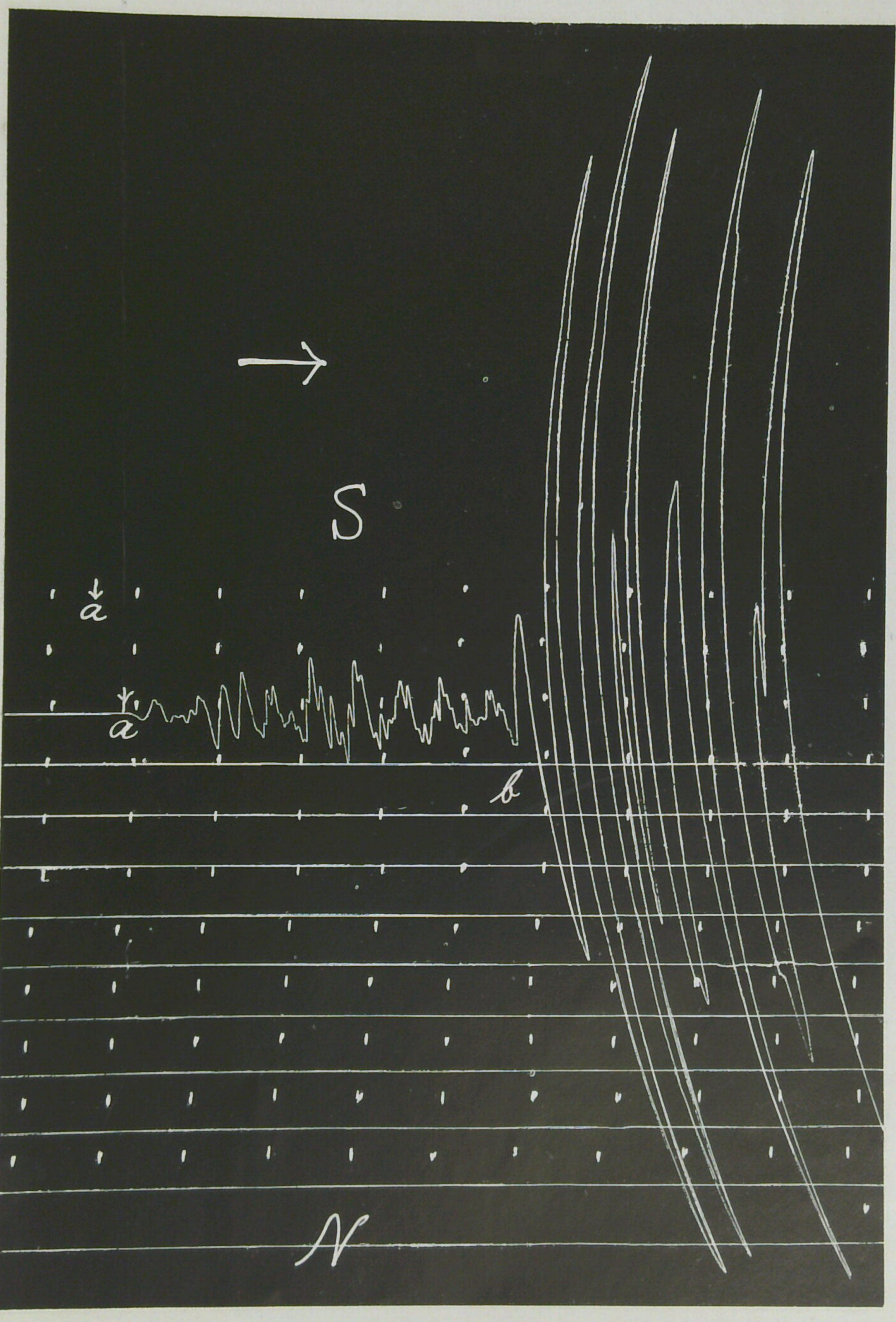
Short cuttings marked by small crosses (x) indicate successive minutes of time. (The interval between the successive small dots, which are also time ticks, is 1 minute.) Natural Pendulum Period = 16 sec.

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FIG. 5. E.-W. N.S. COMPONENT HORIZONTAL PENDULUM RECORD.

Multiplication = 10. a.....Commencement. ab.....1st Preliminary Tremor.



Time Scale: Interval between the successive marks = 1 minute.

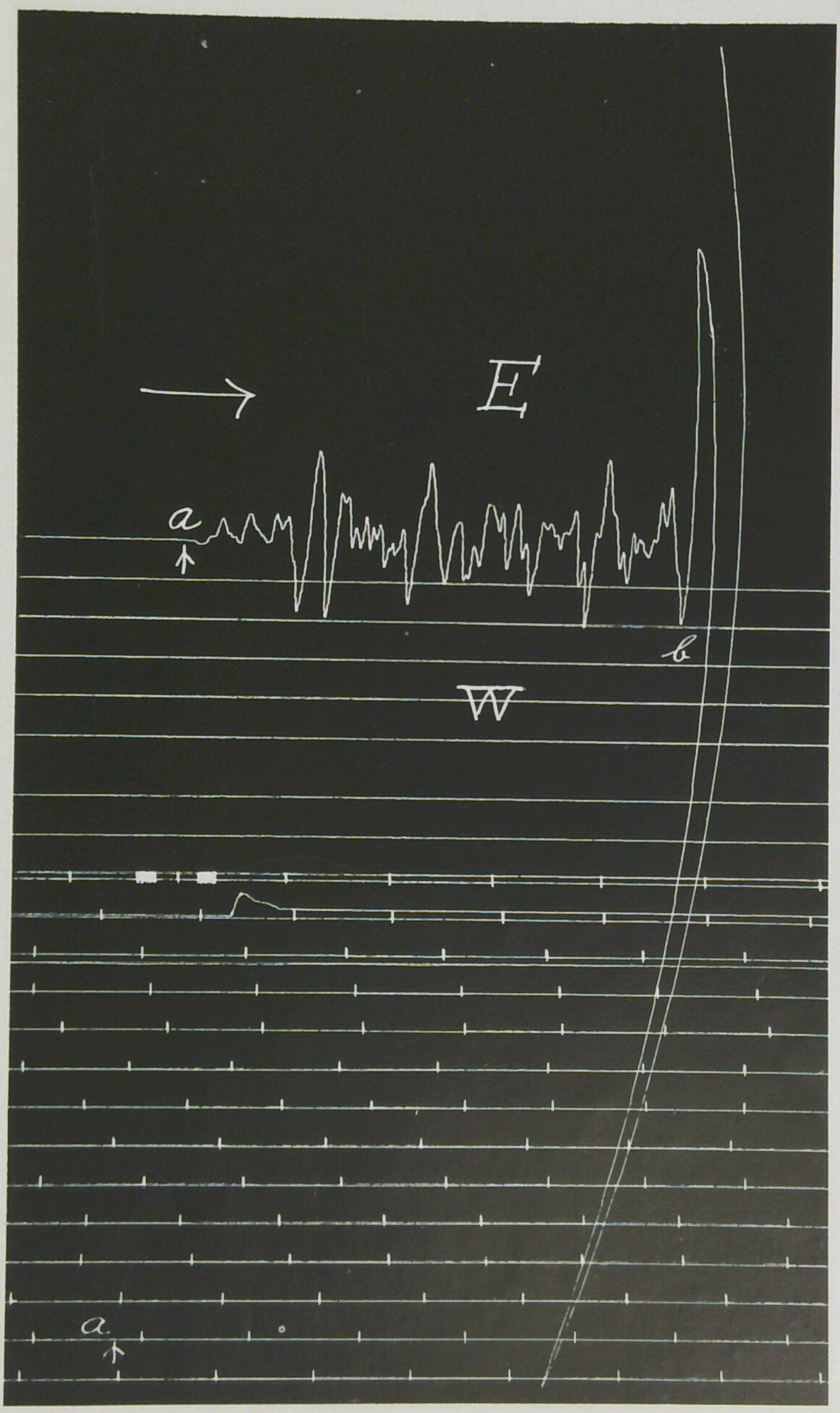
Natural Pendulum Period = 32 sec.

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FIG. 6. E.W. COMPONENT HORIZONTAL PENDULUM TROMOMETER RECORD.

Multiplication = 11.6

a.....Commencement. ab.....1st Preliminary Tremor.



Time Scale Interval between the successive marks = 1 minute.

Natural Pendulum Period = 28 sec.

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IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE

震災豫防調査會　　彙報　　錄

大正十三年三月　　第四號

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TOKYO

March 1924

International Seismological Centre

Tokyo Observation of the Strong Earthquake on Jan. 14, 1923.

By **F. Omori.**

With Plates I—IX.

1. ***Introduction.*** The two semi-destructive earthquakes experienced in Tokyo on Dec. 8, 1921 and on April 26, 1922, were followed by a strong shock on Jan. 14, 1923. This third earthquake was much smaller than the two former, and caused no serious demage except a few cases of wooden houses slightly thrown out of the vertical in the low soft-soil portions of the Fukagawa and Honjo wards. The casuality consisted of only one woman timber-dealer wounded in consequence of the overthrow of the timbers piled in the front of the house, out of which she was rushing. The duration of the sensible motion at Hongo (Tokyo) was about 42 sec. The earthquake, whose total duration on the tromometer registers did not exceed 20 minutes, belonged to the category of a local strong shock.

2. ***Time of occurrence.*** The time of the earthquake occurrence in Tokyo (Seismological Institute) was 2. 51. 44 P.M. At the Tokyo Astronomical Observatory (Azabu), the clock Dent No. 1588, facing toward the west, stopped at 2. 52. 01 P.M., namely, about 17 seconds after the earthquake commencement, or 8 seconds after the maximum vibration.

In the preliminary report on the severe earthquake of Dec. 8, 1921, (the Seismological Notes, No. 2), I have pointed out that the stronger shocks felt in Tokyo show a marked diurnal frequency variation and have a tendency to occur either, (i), at 8–10 A.M. and P.M., or (ii), about 2 A.M. and P.M. The present earthquake belongs to the (ii) category while the severe shock on April 26, 1922, at 10. 11. 41 A.M. was of the (i) category.

In the subsequent description of the seismograms, the symbols 2a and T are used to denote respectively the range of motion and the complete period of vibration.

[SEISMOGRAPHIC OBSERVATION AT THE SEISMOLOGICAL INSTITUTE, HONGO. §§ 3–7.]

3. ***Horizontal strong motion seismograph,*** composed of two horizontal pendulums in the E. W. and N. S. direction (Fig. 6.). *Instrumental constants.* In each component instrument, the distance between the point of support of the horizontal

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pendulum and the heavy bob (15 kg. in weight)=1 metre: the pointer prolongation=50 cm., with the resulting magnification of 1.5 times; the rate of motion of the smoked paper recorder=5.5 cm. per min. in the E. W., and 2.5 cm. per min. in the N. S. component; the proper pendulum period=32 sec. in the E. W. and 26.2 sec. in the N. S. component. *E. W. Component.* In the preliminary tremor: T=0.67 sec., 2a=0.32 mm. The principal portion began with the maximum vibration of T=1.46 sec. composed of the 1st eastward displacement=10.5 mm. and the 2nd westward displacement=13.1 mm. The subsequent motion was much smaller, the successive group of vibrations being as follows: T=0.62 sec., 2a=4.2 mm.; T=0.84 sec., 2a=3.2 mm., (with superposition of quicker movements); T=0.66 sec., 2a=2.0 mm. (regular movements). *N.S. Component.* The maximum vibration at the commencement of the principal portion, of T=1.3 sec., was composed of the 1st southward displacement=8.1 mm., and the 2nd northward displacement=13.9 mm. For the next 7 sec., the motion was of T=0.6 sec., 2a=3.5 mm.; and for the succeeding 7 sec., of T=0.81 sec., 2a=2.0 mm. The motion

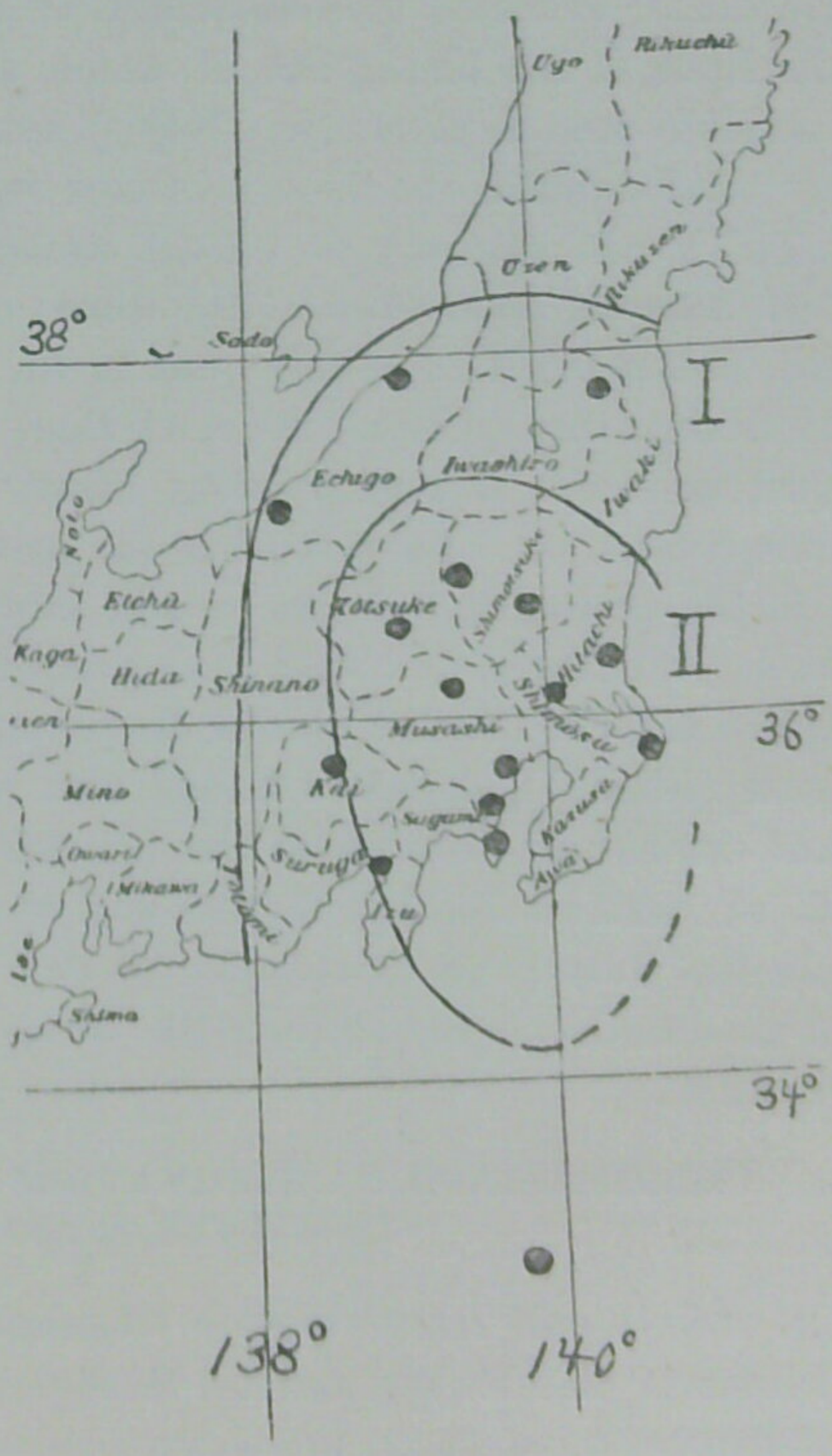


Fig. 1.

Area of Sensible Motion of the Eqke. on Jan. 14, 1923.

I.....Area of Slight Motion.

II.....Area of Moderate or Strong Motion.

(•).....Met. Obs. where the motion was sensible.

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between 50 sec. and 2 min. after the commencement was as follows:—

T=1.7 sec., 2a=1.25 mm. T=2.3 sec., 2a=1.8 mm.
T=1.27 „ , 2a=1.05 „ T=1.4 „ , 2a=1.0 „

The resultant maximum horizontal vibration was as follows:—

{1st displacement=13.2 mm., toward S.65°E.
{2nd „ =19.1 „ , „ N.56°W.

4. *Vertical tromometer.* (Fig. 9.) *Instrumental Constants.* Length of the vertical spiral spring=1.14 m.; weight of the heavy mass=10 kg.; horizontal arm length=0.95 m.; natural oscillation period=14.2 sec.; rate of motion of the smoked paper=2.5 cm./min. The vertical component began with two downward displacements of the total amount of 0.24 mm. The motion in the preliminary tremor, 9.3 sec. in duration, and the next 7 sec., was composed of the movements of T=3.0 sec., 2a =2.2 mm., mixed with quicker ones of T=1.1 sec. and others still quicker. The pointer went out of the smoked paper downwards at 16.6 sec. after the commencement.

5. *Strong motion seismograph,* composed of two horizontal pendulums and a vertical motion recorder, giving a continuous registration in natural size. (Fig. 7.) The two horizontal components were oriented in the directions of N′.S′. and E′.W′., as follows: N′=N.12°W.; S′=S.12°E.; E′=E. 12°N.; W′=W.12°S. (Instrumental Constants were equal to those for the similar instrument at Hitotsubashi, § 9.) In the N.S. component, the maximum vibration was composed of the 1st displacement=6.9 mm. towards the S′, and the 2nd displacement=21 mm. towards the N′. In the E.W. component, the maximum vibration, of T=3.1 sec., was composed of the 1st displacement=9.6 mm. toward the E. and the 2nd displacement=22.4 mm. The resultant 1st displacement of the maximum vibration was 11.8 mm. directed towards S.66°E. The maximum vertical motion was 4.0 mm.

6. *Duplex pendulum tromometer.* According to the Duplex Pendulum Tromometer register (fig. 5), the movement at the commencement of the earthquake took place in a general E.40°N.—W.40°S. direction. The motion at the commencement of the principal portion was in a S.E.—N.W. direction, and the pointer was thrown out of the smoked paper, toward the E.

7. *Ordinary Gray-Milne type seismograph.* In Pl. III is reproduced the ordinary Gray-Milne type seismograph register, magnifying the two horizontal components 5 times and the vertical component 30 times. The 1st displacement (*bc*) of the principal portion was 67 mm. directed towards S.56°E., accompanied by two complete vibrations in the vertical component. The next displacement (*cd*) was 21.4 mm. directed towards N.58°W. The 3rd large displacement (*de*) was 12.4 mm., S. and over 15 mm., E. The period corres-

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ponding to the two displacement (*cd*) and (*de*) was 1.3 sec. The subsequent motion was much smaller.

[SEISMOGRAPHIC OBSERVATION AT THE SEISMOLOGICAL STATION OF HITOTSUBASHI, §§ 8 AND 9.]

8. ***Ordinary Gray-Milne Type Seismograph.*** In Pl. II is reproduced the record furnished by an ordinary Gray-Milne type seismograph at Hitotsubashi with magnification ratio of 5 for the two horizontal components, and of 10 for the vertical component.

The maximum motion in the preliminary tremor was 0.5 mm. (vertical), 0.84 mm. (N.S.) and 0.5 mm. (E.W.). The 1st displacement (*bc*) of the vibration at the commencement of the principal portion was 6.2 mm. toward S. 5.8 mm. toward E.; Resultant 2a=8.5 mm. directed toward S.43°E., corresponding to two complete oscillations (2a=0.4 mm.) in the vertical component. Then there followed a complete and maximum N.S. vibration (*cd*), composed of the north displacement (=14.6 mm.) and the counter south displacement, accompanied by a complete vertical vibration (2a=0.9 mm.). To these there corresponded the single westward motion of 17.9 mm. in the E.W. component. To the next complete N.S. vibration (*de*) of 2a=11.3 mm.. accompanied by the complete vertical vibration of 2a=1.0 mm., there corresponded the single eastward motion of 2a=16 mm. The two prominent N.S. vibration (*cd* and *de*) had the average period of 0.85 sec., while the vibration (*ce*) in the E.W. component had a period of about 1.3 sec. The next vibration (*fg*), of T=0.81 sec., was as follows:

1st displacement····5.2 mm., N.; 12 mm., W.; 1.1 mm., up,
2nd displacement····4.1 mm., S.; 12 mm., E.; 1.45 mm., down.

The succeeding three vibrations in the N.S. component gave an average period of 0.88 sec. In the E.W. component, the pointer went out of the smoked paper towards the east, at 11½ sec. after the start of the recorder.

In the N.S. component, the motion was fairly pronounced till 29 sec. after the commencement: T=0.74 sec., 2a=5.2 mm.; T=0.90 sec., 2a=7.6 mm. About 15 sec. later on, the motion was: T=0.90 sec., 2a=2.8 mm.

In the later portion of the E.W. component, about 50 to 60 sec. after the commencement: T=1.08 sec., 2a=2.2 mm.; T=0.88 sec. 2a=1.9 mm.

In the vertical component, the maximum motion of 2a=2.0 mm. occurred 13 sec., after the start. Some of the later well-defined vibration were: T=0.7 sec., 2a=1.2 mm.

9. ***Strong motion seismograph with a continuous recorder.*** (Fig. 8.)
Instrumental Constants. For the E.W., N.S., and the vertical components, each recording in natural size, the distances between the steady point and the pendulum axis=18 cm., 18 cm.,

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and 22 cm. respectively. The natural oscillation period of the steady system = 4.9 sec. for the two horizontal components, and 6.7 sec. for the vertical component. Weight of the heavy bob = 3 kg. (E.W. and N.S.), and = 1 kg. (vertical). Rate of motion of the common continuous recorder = 4 cm. per minute. In the N.S. component, the maximum vibration at the commencement of the principal portion had a period of 1.5 sec., and was composed of the 1st displacement = 6.6 mm. towards the S., and the 2nd displacement = 17.2 mm. towards the N. This was followed by quicker vibrations of T = 0.84 sec., 2a = 14 mm. In the E.W. component the first 3 large displacements at the commencement of the principal portion were as follows:

1st	displacement =	7.8 mm.,	towards the	E.,
2nd	„	= 25.7	„ ,	„	W.,
3rd	„	= 19.0	„ ,	„	E.,

the 1st and 2nd displacements making up a complete vibration of period of 2.1 sec., and the 2nd and 3rd displacements of period of 1.9 sec. Then there followed quicker movements of T = 0.75 sec., 2a = 14.4 mm. The succeeding vibrations had a period of 0.92 sec.

The resultant 1st displacement of the maximum vibration was 10.2 mm. directed towards S.50°E.

10. ***Maximum motion in Tokyo.*** At Hongo, the 1st displacement of the maximum, or most active, vibration occurring at the commencement of the principal portion had the following direction:—

(i) S.65°E. . . . . Long Period Hor. Pend. (§ 3).
(ii) S.66°E. . . . . Strong Motion Seismograph (§ 5).
(iii) S.56°E. . . . . Ordinary Seismograph (§ 7).

Of these, (i) is to be regarded as being most accurate, the mean value being S.63°E. At Hitotsubashi, the direction in question was as follows:

(iv) S.50°E. . . . . Strong Motion Seismograph (§ 9).
(v) S.43°E. . . . . Ordinary Seismograph (§ 8).

(iv) is of a greater weight than (v), and the mean value is S.48°E. For the direction of the 1st displacement of the maximum vibration, I prefer to take that at the Seismological Institute, Hongo, where the ground is hard. At Hitotsubashi, situated 2.49 km. to the S.8°½W. the soil is soft and the direction of motion of destructive nature may possibly be modified to a certain extent. In the present instance, the discrepancy in the direction between the two Tokyo stations was about 13°, making an allowance for the mutual distance.

At Hongo, the maximum displacement, = 21.4 mm. (§ 7), had the period of 1.3 sec., with the corresponding maximum acceleration of about 250 mm./sec². At Hitotsubashi, the maximum N.S. vibration was 2a = 14.6 mm., T = 0.85 sec., max. acceleration = 400 mm./sec.²; and the maximum E.W. vibration was 2a =

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17.9 mm., T=1.3 sec., max. acceleration=210 mm./sec.^{2} At Hongo, the maximum vertical motion was 4.0 mm., or 1/5.4 of the maximum horizontal motion.

11. ***Observation at the Tsukuba Seismological Station,*** (φ=36°12′39″ N., λ=140°6′36″E.). According to the observations with a pair of horizontal pendulum tromometers of 120-time magnification, the preliminary tremor lasted about 6 seconds, and began with the displacement of 0.26 mm. directed towards N.1°½ E. Again, according to the ordinary Gray-Milne type seismograph, of 5 and 20 time magnifications for the horizontal and vertical components respectively (Pl. IX), the first displacement at the commencement of the principal portion was 1.8 mm. directed toward S.73°E. The 2nd and maximum displacement was 4.5 mm. directed towards N.71°W.; these two constituting a complete vibration of period of about 1.3 sec. The corresponding maximum vertical motion was 0.31 mm. The total duration was 14 minutes.

Mr. M. Fuya, observer at the Seismological Station, reported that the earthquake was initiated by a feeble rushing sound, immediately followed by a marked horizontal shaking, which became stronger after 5 or 6 seconds, causing the building to shake and the doors and windows to rattle. The motion was sensible for some 2 minutes. There was no seismic damage in and about Tsukuba, no people running out of doors. At the town of Hojo (北條町) situated on the low soft plain 4 km. to the south of the above named place, several clocks were stopped, and some people rushed out of the houses.

12. ***Observation at Mito.*** The observation at the meteorological observatory of Mito (φ=36° 22′ 44″N., λ=140° 28′ 18″E.), whose two Omori Horizontal Pendulums, each of 20-time magnification, had the natural oscillation periods of 27 and 38 sec. respectively in the E.W. and the N.S. component, was as follows. *N.S. Component.* The preliminary tremor, whose duration was 9.4 sec., began with a displacement of 0.53 mm. toward the N., followed by the counter displacement of 0.63 mm. toward the S., the two forming a slow oscillation of T=3.1 sec., with a superposition of quick movements. The maximum displacement, which occurred at the commencement of the principal portion was 4.2 mm. towards the S., with the corresponding T=1.2 sec. The subsequent motion was much smaller, although the vibrations remained more or less active for 2½ minutes. *E.W. Component.* The preliminary tremor lasted 9.4 sec. and began with slow vibrations of T=2.3 sec. appr., whose first two displacements were 0.23 mm. towards the E. and 0.25 mm. towards the W. The four movements at the commencement of the principal portion were respectively 2.24 mm. towards the E.; 3.43 mm. towards the W.; 3.58 mm. towards the E.; 4.1 mm. towards the E.

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The resultant motion at the commencement of the preliminary tremor was 0.58 mm. directed towards the N.23°.5 E., and that at the commencement of the principal portion was 4.8 mm. towards the S.36°E.

13. ***Observation at Choshi.*** According to the report from the Choshi meteorological observatory, the preliminary tremor lasted 12.7 sec., the mean value of the 1st displacement recorded by the four different tromometers of 20 to 120-time magnification, being 0.3 mm., directed towards S.60°E., and accompanied by an upward motion of 0.28 mm. Again, the maximum horizontal and the vertical movements indicated by the ordinary Gray-Milne type seismograph were respectively 4 mm. (period=0.64 sec.), and 0.57 mm. (period=0.36 sec.).

14. ***Observation at Kmagai.*** According to the report of the Kmagai meteorological observatory, the duration of the preliminary tremor was 6.8 sec., and the first displacement was 0.057 mm., directed toward E.4°S.

15. ***Area of sensible motion.*** The earthquake was sensible in the provinces of Musashi, Shimosa, Hitachi, Awa, Kazusa, Kotsuke, Shimotsuke, Iwashiro, Echigo, Kai, Sagami, Izu, and Suruga, namely, within the radial distance of about 250 km. to the north and the south-west, and about 170 km. to the west (fig. 1). To the south, it was sensible in the island of Hachijo-jima at the radial distance of 350 km. Thus it will be observed that the present earthquake was much smaller than the semi-destructive shocks on Dec. 8, 1921 and April 26, 1922, whose maximum radii of sensible motion area were respectively 1000 and 500 km. Accordingly the maximum range of motion in Tokyo (Hongo) was also smaller in the former than in the two latter cases. In the two earthquakes of Jan. 14, 1923 and of April 26, 1922, for which the duration of the preliminary tremor did not much differ, the comparison is as follows :—

Max. 2a		Max. Radial Distance of Sensible Motion Area.
21.4 mm / 63.0 mm	= 1 / 3	350 km. / 500 km. = 1 / 1.4

The comparatively large amount of max. 2a in the earthquake of April 26, 1922, may be due to the "seismic habit" explained in the Seismological Notes, No. 3.

16. ***Position of the epicentre.*** Combining the observations in Tokyo with those at Tsukuba, Mito, Choshi, Kmagai, and Nagano, (Table II), the position of the epicentre may be fixed at a point about 45 km. to the N.33°E. of Tokyo, namely, at $\varphi = 36°4'$N., $\lambda = 140°3'$E. (See fig. 2.)

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Table I. Observation of the Earthquake on Jan. 14, 1923, at the Different Meteorological Stations.

Place.	Time of Occurrence.	Intensity.	Place.	Time of Occurrence.	Intensity.
	h m s			h m s	
Tokyo.	2 51 44P.M.	Strong.	Numazu.	2 51 48P.M.	Moderate.
Choshi.	2 51 45	Slight.	Fkushima.	2 52 35	Slight.
Mito.	2 51 44	Moderate.	Nagoya.	2 51 00	Unfelt.
Tsukuba.	2 51 41	„	Fkui.	2 51 05	„
Kmagai.	2 51 44	„	Yokoska.	2 51 51	Moderate.
Nagano.	2 51 56	Unfelt.	Kofu.	2 51 52	Slight.
Niigata.	2 51 58	Slight.	Yokohama.	2 51 54	Moderate.
Takata.	2 53 06	„	Tsu.	2 52 02	Unfelt.
Mizusawa.	2 52 22	Unfelt.	Ashio.	2 52 07	Slight.
Utsunomiya.	2 51 48	Slight.	Fushiki.	2 52 15	Unfelt.
Kanazawa.	2 50 25	Unfelt.	Hikone.	2 52 33	„
Maebashi.	2 51 10	Slight.	Miyako.	2 52 54	„
Hachijo-jima	2 51 39	„			

Table II. Observation of the Earthquake on Jan. 14, 1923: Duration of Preliminary Tremor and Direction of Motion.

Place of Observation.	Time of Occurrence	Duration of Prel. Tremor.	Radial Disatnce.	Direction of the 1st Displt. of Prel. Tremor.	Direction of the 1st Displt. of Principal Portion.
	h m s	sec.	km.		
Tokyo (Hongo). $\varphi=35°42'35''$N. $\lambda=139°45'58''$E.	2 51 44 P.M.	9.0	67	E.40°N.	S.63°E.
Tsukuba. $\varphi=36°02'39''$N. $\lambda=140°6'36''$E.	2 51 41	6.0	45	N.1°½ E.	S.73°E.
Mito. $\varphi=36°22\ 44''$N. $\lambda=140°28'18''$E.	2 51 44	9.4	69	N.23°½ E.	S.30°E.
Choshi. $\varphi=35°44''11'$N. $\lambda=140°51''38'$E.	2 51 45	12.7	94	S.60°E.	
Kmagni. $\varphi=36°09'$N. $\lambda=139°23'$E.	2 51 44	6.8	50	E.4°S.	
Nagnno. $\varphi=36°40'$N. $\lambda=138°12'$E.	2 51 56	25.0	185		

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It will be noticed that the direction of the maximum vibration at each of the three observing places of Tokyo (Hongo), Tsukuba, and Mito, was approximately normal to the respective epicentral radii.

The origin of the earthquake under consideration as well as those of the strong shocks on Dec. 8, 1921 and on May 9, 1922, belong to the Tsukuba-san and Kasumiga-ura seismic district (Area II, in fig. 2, the Seismological Notes, No. 3).

17. ***Focal depth.*** According to the map (fig. 2) the epicentral distances of the three observing stations of Tokyo, Mito, and Choshi were respectively 48, 50, and 77 km. Comparing these surface radii with the focal distances corresponding to the duration of the preliminary tremor, the focal depth is found to be approximately 48 km. The unusually great depth of the focus is in accord with the intensity distribution in the seismic area, as the earthquake was felt very nearly with an equal strength within the district of radius of about 50 km., including Tokyo, Mito, and Tsukuba.

APPENDIX I. ***Notes on Jochi Daigak Building.**** By OMORI.

Earthquake Motion at Hongo (hard ground). Equivalent to that at the Jochi Daigak:

(1). Earthquake of June 20, 1894, at 2 P.M. was the strongest since the well known Yedo (Tokyo) catastrophe in the 2nd year of Ansei (1855). Maximum Motion=73 mm., Complete Vibration Period=1.8 sec.; Intensity, or destructive capacity=444 mm per sec.^{2}; Direction of Max. Motion=S71°W.

(2). Earthquake of April 26, 1922, at 10 A.M. was the severest since 1894. Maximum Motion=67 mm., Complete Period=2.0 sec.; Intensity=330 mm./sec.^{2}; Direction of Max. Motion=West.

Future Earthquake in Tokyo.

(3). The max. intensity of motion of the earthquake originating from the vicinity of Tokyo, i.e., from the Musashi Plain or the Tokyo Bay, may be taken to be equal to that of (1). More or less strong earthquakes of this type

* The main building of the Jochi Daigak, a Catholic University in the Kojimachi Ward, Tokyo, is a large 3-story brick structure, which had high parapets along the roof edges, and received slight damage on the occasion of the strong earthquake of April 26, 1922. The present note has been written for the benefit of the authorities of the university in properly repairing the building,

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may be repeated in the course of every half a dozen years or so.

(4). Tokyo may be assumed to be free in future from the visitation of a violent earthquake like that of 1855, as the latter shock originated right under the city itself, and as destructive earthquakes do not repeat from one and the same origin, at least not in the course of 1,000 or 1,500 years.

(5). In case of occurrence of a great suboceanic earthquake off the coast of Izu or Awa-Kazusa peninsula, the intensity of motion may be 1,000 mm./sec.^{2} or more over at the hard ground portions of the city. Such an event is not likely to occur for at least some 60 or 70 years to come.

Brick Buildings.

(6). One-story or two-story brick buildings, if properly built, can withstand fairly well an earthquake whose intensity is 2,500 mm./sec.^{2}, or some 8 times stronger than (2), that is to say, a shock, equivalent to that in the city of Nagoya in 1891, and that in Messina in 1908.

Methods of Reducing the Seismic Damage.

(7). The building must be simple in construction and uniform in strength. Hence there must be no combination of tall and low structures as portions with different modes of oscillation cause mutual destruction.

(8). Gable, pediment and parapet must be avoided.

(9). The height of the building must be reduced as much as possible, as the seismic stability varies inversely as the square of the height of the centre of gravity.

Damage to the Jochi Daigak Building.

(10). Crack of the back (south side) wall of the Central Portion at its junction with the east block, caused by the separation of the former in consequence of the strong westerly motion.

(11). Separation of the front (north side) corridor wall off from the main structure, the amount of separation being greatest at the middle of the length.

(12). Crack in the walls of the tower, due to its height and to the peculiar construction of the staircase supported against the walls.

Repaires to be recommended.

(13). All the parapets are to be taken down.

(14). The east wing is to be reduced in height by about 16½ feet (including the parapets), making its height equal to that of the central block. This would increase the seismic stability of the block by about 50%.

(15). The height of the tower is to be reduced by about 21′½ to 27′ (Including the parapets). This would increase the seismic stability of the structure (tower) by about 50 %.

(16). It is better to reduce also the height of the west wing more or less.

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(17). The front (north) side corridor wall of the middle portion must be tied suitably to the main structure, so as to prevent its outward separation.

(18). Tower staircase is to be properly modified in construction so as to relieve the walls of its pushing pressure.

(19). The doorway must not be made under the Tower, neither must it be situated at the middle of the long central portion.

(20). The repair works must be executed very carefully, with good mortar.

If the above repairs be properly executed, the building will be able to resist future strong earthquakes likely to occur in Tokyo. It will be cracked more or less, but the walls will not fall down.

APPENDIX II. ***Report relating to the Semi-destructive Earthquake of April 26, 1922.*** *(From the Japan Times of April 27 to May 6, 1922.)*

Old Outer Moat Wrecked and Peace Exposition is Damaged by Earthquake.

Fifty feet of the stone wall of the historic old Outer Moat, built more than 800 years ago to protect the stronghold of General Ota Dokan, military dictator of what was then Yedo, now one of the show places of the Imperial Palace grounds, collapsed this morning when the most severe earthquake in Japan's seismograph records shook this part of the Empire.

The temblor lasted only a short time but was unusually violent and did considerable damage to buildings at the Peace Exposition, in Uyeno Park, besides causing several deaths here and at Yokohama and starting a number of small fires. Prompt action of the fire departments prevented any considerable damage from fames.

Some damage was done to the Marunouchi Building, under construction by the Fuller Construction Company, opposite the Tokyo Station. The front was cracked but it is understood that there was little other loss there.

Walls surrounding the palace of Prince Higashi Fushimi are reported to have been shaken down but the palace itself is said to have suffered little damage. The palace is at Awoicho, Akasaka.

Damage at Yokohama.

The first shock was felt at 10.12 o'clock this morning and lasted for only ten seconds but was so violent that people rushed into the streets in alarm, fearing that the buildings in which they had been would collapse. Several structures did fall under the force of the quake here and many more were wrecked in Yokohama. The greatest damage in the Port City, however, was in the Chinese district where several deaths are said to have occurred. One Chinese girl is known to have lost her life. She was Ah-sui, 18 years old, and was crushed by a falling wall.

Mount Asama: the only "live" volcano on Japan Proper, resumed activity yesterday after a long dormant interval and it is surmised that this has some bearing on today's unheaval in this

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district. Huge columns of smoke are said to be issuing from the crater of the volcano and showers of ashes are falling for many miles around. Whether there has been an eruption of lava today in connection with the temblor felt here is a matter of speculation.

Reports from Yokohama says that buildings at Numbers 188,189 and 191 were wrecked, that the Chinese Temple at Number 145 was badly damaged, the ceiling caving in and the interior decorations being ruined, a godown at Number 218 collapsed, a dye works at Number 160 was destroyed.

A bean merchant at 36 Itchome, Ishikawa, is reported to have been killed by falling tiles.

Ten Deaths, Scores Hurt, Two Million Yen Damage, Earthquake Toll Estimate.

Latest reports indicate that the death toll from the earthquake which rocked the centre Tokyo-Yokohama vicinity yesterday will not exceed ten persons, although a score or more are known to have been seriously injured. Accurate estimates of the property loss are unobtainable but it is believed the total will not exceed two million yen.

The death list includes Gorokichi Ishii, a carpenter in Fukagawa, who was killed by the fall of a pile of lumber, Miss Ah-Sui, 18-years-old daughter of a Chinese restaurant keeper in Yokohama, who was killed by a falling wall; and Kiyoshi Karibe, aged 16, who was crushed by a chimney while fleeing from his home in China Town, Yokohama. K. Kaneko, of Yokohama, sustained injuries which may prove fatal when he was struck by a flying tile. Miss Mary White, teacher in the Yokohama Foreign School, is recovering from injuries received while escaping from the building.

Started Near Uraga Channel.

The seismograph department of the Tokyo Imperial University announces that the earthquake which shook Tokyo and neighbourhood yesterday morning and worked an extensive havoc to houses and other properties originated in the neighbourhood of Uraga channel, seventy-nine kilometres south of Tokyo, in the seabed outside of Tokyo Bay.

The central meteorological observatory published a statement according to which the origin of the shock is located in the vicinity of Mount Nokogiri or Nokogiriyama in Awa province, a point about fifty kilometres south-east of Tokyo. Dr. Nakamura and other experts of the central meteorological observatory went to Uraga and Awa today to inspect conditions in those places to ascertain the origin of the shock.

Observatory Damaged.

The building of the meteorological observatory at Mera point, situated at the southern extremity of Awa province at the entrance of Tokyo Bay, which is the most important point for ascertaining the real origin of the shock, is reported to have been badly damaged by yesterday's shock and partially demolished. The observatory belongs to the central meteorological observatory of Tokyo. Officials of the station were not injured.

According to later reports yesterday's shock seems to have worked the worst damage at Uraga, Yokosuka and neighbourhood, where many houses and other buildings were demolished or partially destroyed, besides a number of stone walls and wooden walls collapsed through the shock. The cases of the walls and ceilings of houses which cracked are numberless. Fortunately no casualties occurred.

Warehouse Destroyed.

In Tokyo, besides those already reported, several persons were injured by the falling tiles or pieces of falling timbers in different sections of the city. A warehouse at Tamachi, Akasaka,

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was demolished and a little girl who was playing near by was injured at the head by a falling tile. The citizens were uneasy last night fearing a possible recurrent shock.

Timbers in the yards at Fukagawa, which is the center of the lumber industry, fell and blocked the roads. A carpenter working at Higashi Hiranocho was knocked down by a falling timber and killed. Two men walking on the street of Higashimachi, the same ward, were also knocked down by falling timbers and injured.

Phone Service Crippled.

Approximately 2,000 telephones in the city of Tokyo were put out of commission owing to the wires having been broken by the shock. The telephones belonging to the Shitaya exchange office, were almost entirely cut off.

Fifty-one telephone wires between Tokyo and other places outside the city, including seven wires to Osaka, five wires to Nagoya and one wire to Yokosuka via Yokohama, were also cut off. One telegraph line between Tokyo and Kyoto and several telegraph lines between Tokyo and other cities were damaged and out of service yesterday.

Railways Damaged.

The railway track between Ōnuki and Sanuki and at a point near Minato station of the Hōjō line, in Awa province, was damaged by the earthquake, the rails having been crooked. The train traffic on the section temporarily suspended.

The city water pipes were damaged at six places, namely at Nagatacho, Kojimachi-ku; Miyashitacho, Azabu; Kojimachi Hatchome; Kitajimbocho, Kanda; Tameikemachi, Akasaka; Hinokicho, Akasaka; but water supply was maintained as the damages were speedily repaired.

A large tank containing about 300 koku of beer in the cold storage shed of the Anglo-Japanese beer brewery company at Tsurumi, Kanagawa prefecture, was destroyed by the shock and the shed was flooded with the fragrant liquid.

Exposition Losses.

The exposition halls at Uyeno park were perhaps the centre of the greatest consternation caused by the earthquake. The noise of the cracking buildings and the articles falling from the shelves on the floor below presented a fearsome scene.

Part of the ceiling of the reception hall on the second story of the Tokyo Jichikan, built at a cost of 300,000 yen, gave way.

Four girl guards swooned but recovered after a short time.

Several visitors were slightly injured, but nothing serious happened.

Peace Tower Damaged.

The Peace Tower and the high tower were damaged.

The outer walls of the forbidden garden of Fukiage in the inner part of the Imperial Palace Grounds were demolished to the extent of about 600 feet and other damage was done in other parts of the palace grounds. Soldiers were detailed to protect the palace buildings.

Brewery Loses Heavily.

The Asahi glass company in the neighbourhood of the Anglo-Japanese beer brewing company near Tsurumi suffered a considerable loss. Three hundred cases containing glass panes in the company's warehouses were destroyed and the contents smashed to pieces. The loss is estimated at no less than 20,000 yen. The big chimney stack of the Masuyama brick yard at Miyukimura, near Kawasaki, 150 feet high, the largest chimney in that locality, broke and fell

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to the ground from a height of 70 feet with a tremendous noise. Part of the debris fell on the zinc roof of the workshop below and penetrated the roofing. Many operatives were in the shop and consternation ensued, but all escaped. Many factories in the neighbourhood of Kawasaki, and Tsurumi, including the Asano dockyards, sustained damage.

Two Men Buried Alive.

The earthquake caused a landslide on the side of Mukoyama mountain in Kimizu district, Chiba prefecture. Three houses at the foot of the mountain were buried under the debris and two men were buried and killed. Several houses were demolished at different villages in Awa province and several hundred houses in various districts of Chiba prefecture were more or less damaged. An embankment along the course of the Miyakogawa in the same prefecture was also destroyed through the shock caused by the earthquake. Large crevices were created at various points on the roads leading from Otakimachi to Hojo and other towns.

Modern Building and Earthquake.

If the reports in the vernacular papers and the talk on the street can be trusted, then the recent earthquake has demonstrated the folly of the cocksure Americanism of certain enterprising building contractors.

It has been said that the George A. Fullar Construction Company, American building contractors, who are at present engaged in erecting the Marunouchi Building facing the Tokyo Central Station, came here with great expectations that after a few demonstrations such as they are making now, they would construct all the large buildings in the Far East, thus controlling and monopolizing the business. That sounds rather natural for an ambitions American enterprise. In America one hears in almost every city he visits that something there is the largest in that city, and perhaps the greatest of the kind in the world. That's a typical American boast that is heard too often, and although one can really admire their spirit, it is frequently puzzling to know which after all was the largest in America and the greatest in the world.

But when that dauntless spirit is manifested without some control, a fall must be expected. What the American builders had to face unexpectedly in Tokyo was the recent earthquake which it is stated did more damage to the Marunouchi Building than to any other modern building in the city. Moreover it is said that the contractors of this building, the largest in Tokyo, involving some ¥ 5,000,000 in its construction, refused at the outset to have any Japanese advisors which all other foreign constructors have formerly engaged. The fact that the Nippon Yusen Kaisha and the Nippon Sekiyu Kaisha buildings in the neighbourhood have suffered the least damages ought to speak eloquently the wisdom of these concerns which engaged Japanese advisors.

To fight against the elements is certainly the hardest of battles, and it may be unjust to blame the builders, but in the present instance, if the reports are to be relied upon—and because there has not been any refutation in the press we are inclined to believe them—this demonstrates too plainly the truth that "virtue itself turns into vice when misapplied." It is not thought for a moment that foreign builders should not have their own ways in building a modern structure in Japan, because the modern architecture is their's and the Japanese are yet learning much from them. But, "every man's shoe must be made on his own last," and if a stranger in a strange land insists on following his own methods and disregards the wisdom and experience of the land and its people, he is bound to miss a step here and there, all to his own discredit, for at least he may not know "the last shoe" worn in that strange land.

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Echoes From the Earthquake.

How feeble is mere man in the face of Nature's mighty forces was strikingly exemplified by the earthquake which rocked Tokyo and the island on which it stands Wednesday morning. Men, women and children, startled by the shock, realized their helplessness and rushed like sheep in the path of an electrical storm.

Humanity can only pause and shudder when the Divine Elements assert their strength. The natural impulse is to seek the open spaces and higher levels, away from the danger of crumbling buildings, but this would prove of no avail in the event of giant upheaval such as that which originally created the islands of this archipelago.

The natural lesson which we learn from the intermittent upheavals of the earth's surface is to construct our buildings more firmly and refrain from erecting too lofty structures that will topple like a house of cards when the slightest temblor comes. But the real lesson which be impressed upon us is the importance of character building in order that we may be prepared if suddenly called to account for our earthly career.

Japan may feel fortunate that she has suffered no such volcanic catastrophe such as that which destroyed Pompeii, Italy, two thousand years ago or the awful disaster which over-took San Francisco, California, less than two decades ago still fresh in the memory of present residents of Japan. No part of the globe is entirely free from earthquake, which are due to contraction of the earth's crust and from volcanic or other causes. It is said that the sudden cessation of accustomed volcanic activity will often bring on earthquakes. This causes much speculation as to what may have been responsible for the temblor this week, as it is reported that Mount Asama had just resumed activity after a long dormant interval.

Science has made great progress in studying the causes and effects of volcanic action and the delicate seismograph accurately records disturbances of the earth's surface within a radius of thousands of miles but the science of volcanology still represents a vast unexplored field which will require many more centuries to completely fathom.

Japan is proud of possessing the world's seismographic authority in Dr. Omori whose profound knowledge and untiring research will disclose all mysteries of the earthquake and will add a great deal to the world's store of knowledge of what was once believed to be a symbol of God of Terror.

APPENDIX III. *Reports relating to the Effects on the Water Conduit at Yodobashi (Tokyo) of the Strong Earthquake on Dec.* 8, 1921. (*From the Japan Times of Dec. 10-15, 1921*)

Tokyo Faces Water Famine After Worst Earthquake In 28 Years; Death List Miraculously Small.

Tokyo is confronted by the possibility of a water famine today as a result of an earthquake, the most severe experienced here in 28 years, which rocked South Eastern Japan last night. The intake open conduit at Hatagaya Hommura, in the Western suburbs of Tokyo, collapsed at 5 o'clock this morning as a result of the temblor and as soon as one remaining reservoir supply

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is pumped out, the City's water supply may be shut off for two or three days, possibly longer, while repairs are being made. The supply may cease at any moment and the public is warned to draw enough water to meet its needs for that period.

Officials of the Water Department are making desperate efforts to avoid the necessity of shutting down the pumps and, this afternoon, said they had strong hope of being able to continue uninterrupted service, although they could not be certain.

Better Draw Your Water Supply Now!

Every person in Tokyo, is advised to draw a water supply sufficient to last for at least three days without a moment's delay. The intake open conduit that supplies the City with water from the Tama River has collapsed and Tokyo may be without service as soon as the one reservoir left full is emptied.

It is impossible to say how soon repairs on the tunnel can be made but officials of the Water Department are doing their utmost to get the work down in time to prevent interruption of service. They are uncertain, however, whether they will be successful. If the service is discontinued it may be two or three days before it can be resumed.

Water Supply Is Safe; Repairs On Tunnel Near End

Fear of a water famine in Tokyo as a result of the collapse of the Hatagaya Hommura intake open conduit from the Tama river to the City's pumping Station yesterday morning as a result of the severe earthquake of the night before vanished today when it was announced that there would be no necessity of temporarily discontinuing service. Officials of the Water Department met the emergency with promptness and efficiency and saved the city from what might have proved a very serious situation.

Gangs numbering many hundreds of workmen were rushed to the scene of the break in the intake line and are still working steadily on the necessary repairs. It was expected that water would be again flowing through the tunnel this afternoon.

Village Flooded.

Residents of Hatagaya Hommura probably had the narrowest escape, as a result of the collapse of tunnel. The village was slumbering peacefully when with a roar the open conduit collapsed for a distance of 100 feet and a torrent rushed over the community, reaching a depth of 10 feet in some places.

News of the disaster was dispatched to the City Water Works Station at Yodobashi and crews of men were immediately rushed to the scene in an effort to check the food and restore the open conduit. The water was out of control, however, and this afterncon efforts were also directed towards cutting off the open conduit supply at its source at Wadabori on the Upper Tama River.

Water for the city is being pumped today from the reservoir at Yodobashi. It is difficult to estimate how long this supply will last as normal figures are of no avail, the drain on the reservoir being greatly increased by the extra quantities being drawn for use during the possible repair period.

No Disastrous Panics.

That there were no disastrous panics in the theatres, which were crowded at the time of the earthquake is another remarkable feature. There was great disorder in many districts and some persons were hurt when the audiences scrambled for the open as the buildings began to sway and tremble but no fatalities have been thus far reported.

That Tokyo's big buildings will withstand earthquakes was demonstrated, none of them

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having been damaged so far as could be learned today. Mr. A. George, engineer in charge of mechanical appliances and steel construction on the Marunouchi Building which is being erected by the George A. Fuller Construction Company, said this afternoon that despite the fact that an uncompleted structure is naturally more suspectible to shock than one which is finished no damage was done to the buildings on which his company is working.

Some damage was done to the Kitadaimoncho Dynamo Station of the Tokyo Electric Light Company which caused the failure of the light service in the Southern half of Hongo Ward for half an hour.

A warehouse at Tatedaikucho, Kanda, partially collapsed and wrecked a number of electric poles, causing a temporary failure of the light service in that neigbourhood. Similar accidents were reported from other places throughout the city but in most instances the damage was slight.

Two persons were struck on the head by falling tiles at Iidamachi, Kojimachi Ward, and severely injured.

Lighter At Yokohama.

The shock was not felt so strongly in Yokohama as in Tokyo, but it furnished plenty of thrills. A large part of the foreign colony was gathered in the Gaiety Theater, for the production of "The Irresistible Marmaduke," and there was genuine alarm when the brick structure tossed and twisted and the walls complained sorely of the test they were undergoing.

A large number in the audience rose to their feet in apprehension, while those nearest the doors accepted discretion as the better part of valour and hurried out. What might have been a panic was averted by the coolness of those upon the stage, however, and the play itself was interrupted only for a few seconds, the actors and actresses taking up their parts before the shivers in the building had stopped and while the windows were still rattling merrily.

Leave Hotel Lounge

At the Grand Hotel, those in the lounge and lobby immediately decided that the Bund was preferable to anywhere indoors, and there was a general exodus. In the other hotels somewhat similar scenes were enacted.

No damage whatever in Yokohama is reported, however, and the life of the city flowed along, the subject of the temblor being dropped as a street topic fifteen minutes after the buildings ceased swaying.

Water Supply To Be Intermittent For Brief Period.

After a "dry" Sunday Tokyo today found itself confronted by a situation unparalelled in the history of the 300 years since Yedo started taking its water supply from the Tama River. Water was to be had from the taps at intervals during the day but it may be some time before normal service can be restored. Officials of the Water Department state that they are doing their utmost to resume regular service but are unable to predict how long it will take to repair the damage done by last week's severe earthquake which wrecked the intake open conduit of the water system.

Water is being pumped from Yodobashi reservoir to Ushigome, Yotsuya and Komagome wards and the remainder of the city is being served by the gravity system as rapidly as the water can be properly filtered. The contents of the reservoir, the only one unemptied, is not in a condition to be served without filteration.

Temporary Repairs Made.

An official announcement of the completion of temporary repairs on the intake open conduit was issued at 11 o'clock last night. It was explained that the rain had retarded the work and

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that the temporary discontinuation of service was unexpected. On Saturday afternoon the Department had issued a statement stating definitely that there would be no cessation of service. This premature announcement caused considerable inconvenience throughout the city as many households which had stored a supply of water as provision against a possible famine emptied the containers when they received the official assurance that there was nothing to fear.

However, the officials did their best to make amends by rushing the repair work, personally supervising the immense crews of men they set to work.

The communique last night said that water would be served only between the hours of 6 and 8 o'clock this morning and after 4 o'clock this afternoon. But this plan was evidently as water was to be had from the faucets at intervals throughout the day.

Two Princes Affected.

Because of the private reservoir on the Palace Grounds, the Imperial Household did no suffer from the famine. Most of the Imperial Princes have wells at their Palaces but Prince Kan-in and Prince Kuni were in the same predicament as commoners and had to have water transported to their residences.

Chiefs of all the wards in Tokyo met in council yesterday afternoon to discuss relief measures.

Ten navy tankers were dispatched from the Yokosuka Naval Station to bridges along the Sumida river yesterday and discharged cargoes of water to motor trucks and other tank-bearing vehicles. The water was then distributed throughout the city in a manner best calculated to relief distress and provide fire protection.

Water Carts New Job.

Tokyo streets, never ultra-perfect, were filled with whirling dust today as a result of the cessation of the sprinkler service. The sprinkling carts, however, were not idle. They were taken off their prosiac task of supplying thirsty roads and put to the more romantic service of watering parched throats. Throughout the day the sprinklers were used to haul water from wells, private reservoirs and tank-ships to the sections of the city which had no other supply.

Over half the population of Tokyo is dependent on the city waterworks for its water. There are 214,676 faucets in 362,542 houses. Tokyo contains about 600,000 houses. There are 4,589 municipal and 2,432 private fire hydrants. The daily volume of water used on December 8 was about 8,160,000 cubic feet. Nineteen thousand wells supply 100,000 houses.

Locomotives hauling the 43 trains which daily pass through Tokyo were supplied with water today at Osaki station.

Mr. Takahashi, Station Master at Tokyo Station, is supplying the needs of the 300 employees under his control from the reservoir at his official residence.

Bread Supplants Rice.

Bread appeared in many households yesterday for the first time because of the lack of water with which to boil rice.

Fire, which started as a small blaze in a blacksmith shop but got out of control because of the water famine, razed 13 buildings and partially burned three others in Koishikawa ward yesterday afternoon. The flames were extinguished when a small hose was run to the Tenjin-gawa River. Several large buildings, including the Higher Normal School and a paper factory, were threatened.

Five modern fire engines stood idle and helpless last evening while a crowd put out a fire in a second-hand clothes shop by throwing mud on the flaming garments. The fire occured at Ryusenji-machi, Shitaya ward.

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Mayor Baron Goto In Public Message On Water Supply.

Tokyo is to have five hours water service today and there will be a gradual increase in the length of time when the city can be served, according to a message to the public issued by Mayor Baron Goto.

In order that the Navy water tankers might assist in relieving the famine here the battle cruiser Kongo which was due to set sail on a cruise has delayed her departure from the Kure Naval Station. The tankers would, under ordinary circumstances, have been engaged in supplying the warship.

Major Takeda and 30 men of the Military Motor Transport Corps were engaged yesterday in aiding in the distribution of water on lorries and other officials did their part towards preventing distress as a result of the breakdown of the waterworks. Yokohama also took a hand in the relief work and sent further supplies of water here.

Mayor's Message.

In his message Baron Goto says:

"I exceedingly regret that the water supply of the entire city has had to be cut off owing to the destruction of the Tamagawa water source.

"In consequence of the immediate repair work since December 12 the conditions have improved so far that a temporary water channel has been constructed enabling the passage of 8,000,000 cubic "shaku" of water per day.

"Unfortunately, however, it will be necessary to cut off the water supply of the city for a certain number of hours for a few days longer in order to fill the 20 reservoir basins at Yodobashi which have been emptied owing to the damage to the main source. As the Mayor of Tokyo, I must ask the citizens for their pardon for having put them to such a great degree of inconvenience.

Urges Consideration.

"The water will be let through once a day for a certain number of hours starting on December 13, when the supply will be available for 5 hours from 10 a.m. to 3 p.m. The service will be gradually lengthened daily so as to supply the water needs also of those living at the extreme ends of the city.

"I feel obliged to appeal to you citizens, therefore, to exercise every care against the lavish use of water so as to expedite the complete restoration of the waterworks system to its normal state. I should like you all not to try to store large quantities of water during the hours the water is allowed to run for bathing or laundry purposes, so as to enable all the citizens of Tokyo to receive an adequate supply of water as quickly as possible.

Usual Supply Of Water Promised Tokyo Tomorrow.

Normal water supply will be available in Tokyo tomorrow, according to an announcement made by the City authorities this morning. Today the service will be given ten hours.

The water was turned on at 6 o'clock this morning and will continue until 4 o'clock this afternoon, according to early plans, although it is possible that it will be found convenient to serve the public until a later hour.

Inhabitants of the Toyotama District are having their trouble as a result of the breakdown of the Tokyo water intake tunnel. Emergency repair work resulted in the flooding of 200 houses in the District. The Chief of the District lodged a protest with Vice-Mayor Ikeda.

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Fig. 2. Map showing the position (•) of the Epicentre of the Strong Earthquake of Jan. 14, 1923.

A dotted arrow (thin) shows the direction of the movement at the very commencement of the earthquake, while a dotted arrow (thick) indicates that of the 1st displacement of the maximum vibration at the commencement of the principal portion.

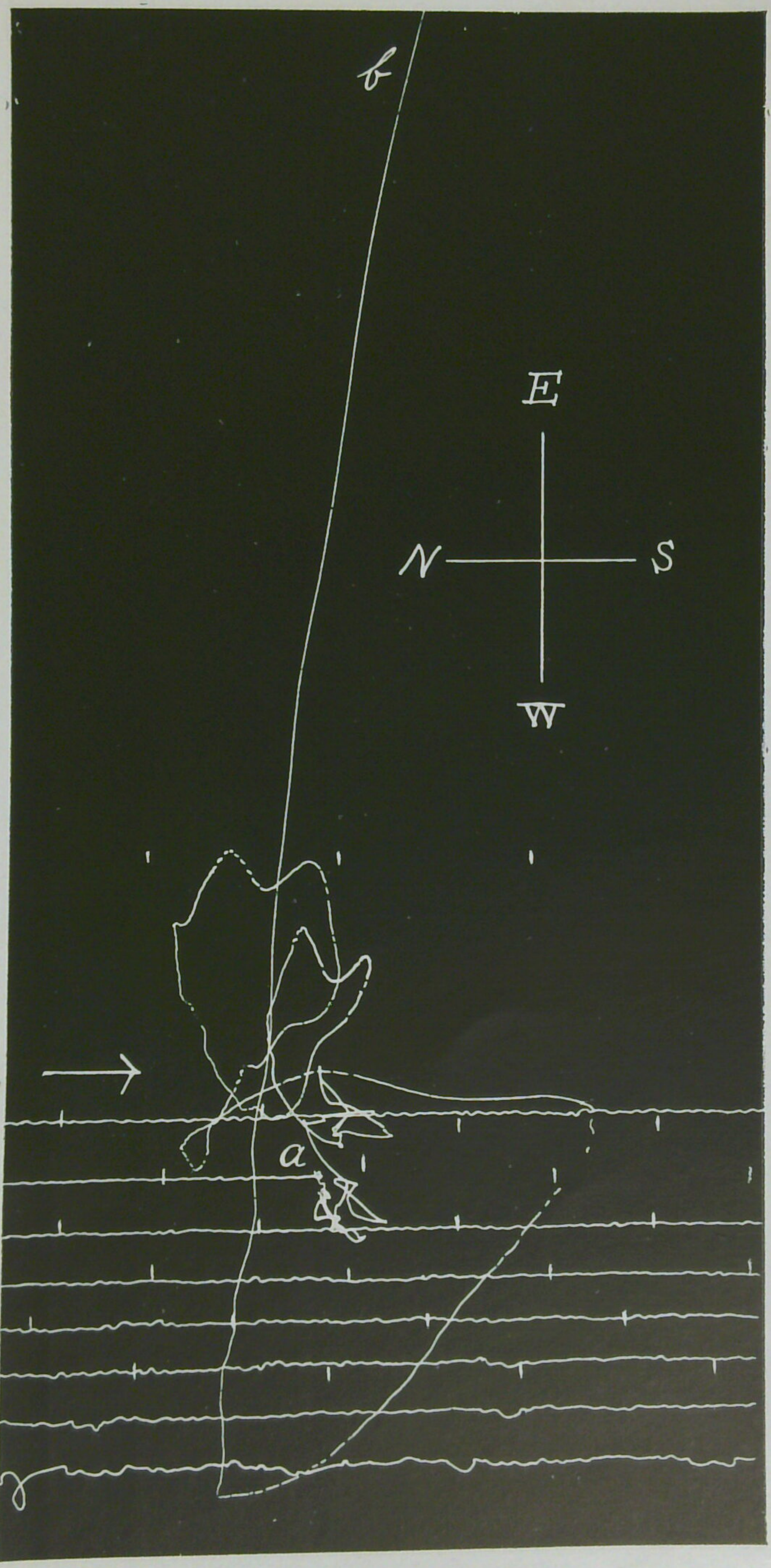
The arcs have been drawn about the different observing places as centres each, with the radius equal to the central distance corresponding to the respective duration of the preliminary tremor.

The *shaded* parts are of Tertiary and other rocky formations, while the *unshaded* (white) parts are alluvial and diluvial plains.

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Tokyo Observation of the Strong Earthquake of Jan. 14, 1923.

Fig. 5. Duplex Pendulum Tromometer Diagram. (Hongo.)



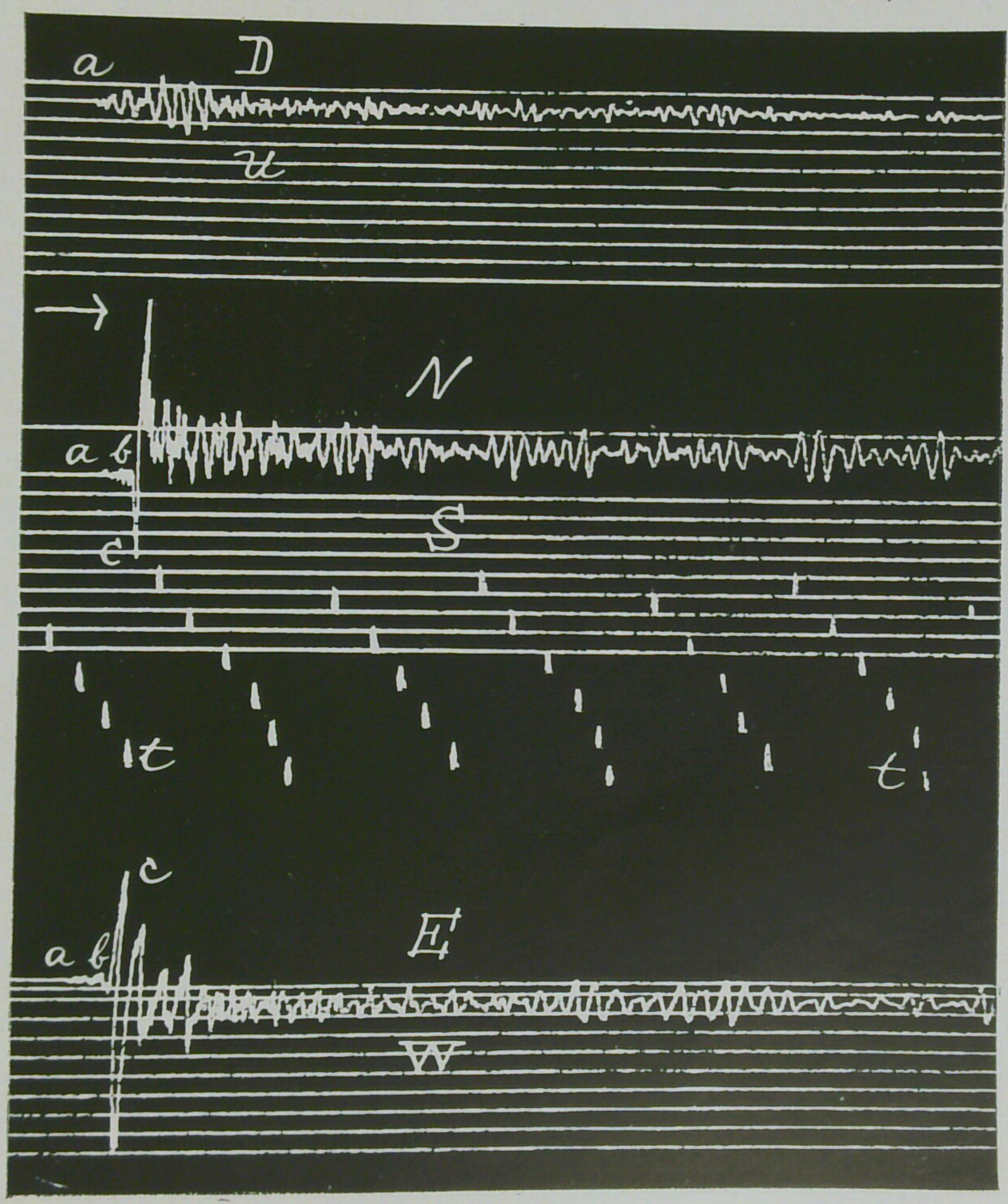
Magnification = 40.
The pointer went out at *b*.

a. . . .Commencement.
The small vertical dots mark successive minute of time.

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Tokyo Observation of the Strong Earthquake of Jan. 14, 1923.

Fig. 7. Strong Motion Seismograph Diagram. (Hongo.)



Magnification = 1.6

a . . . . Commencement.

bc . . . . 1st Displacement of the Max. Vibration at the commencement of the Principal Portion.

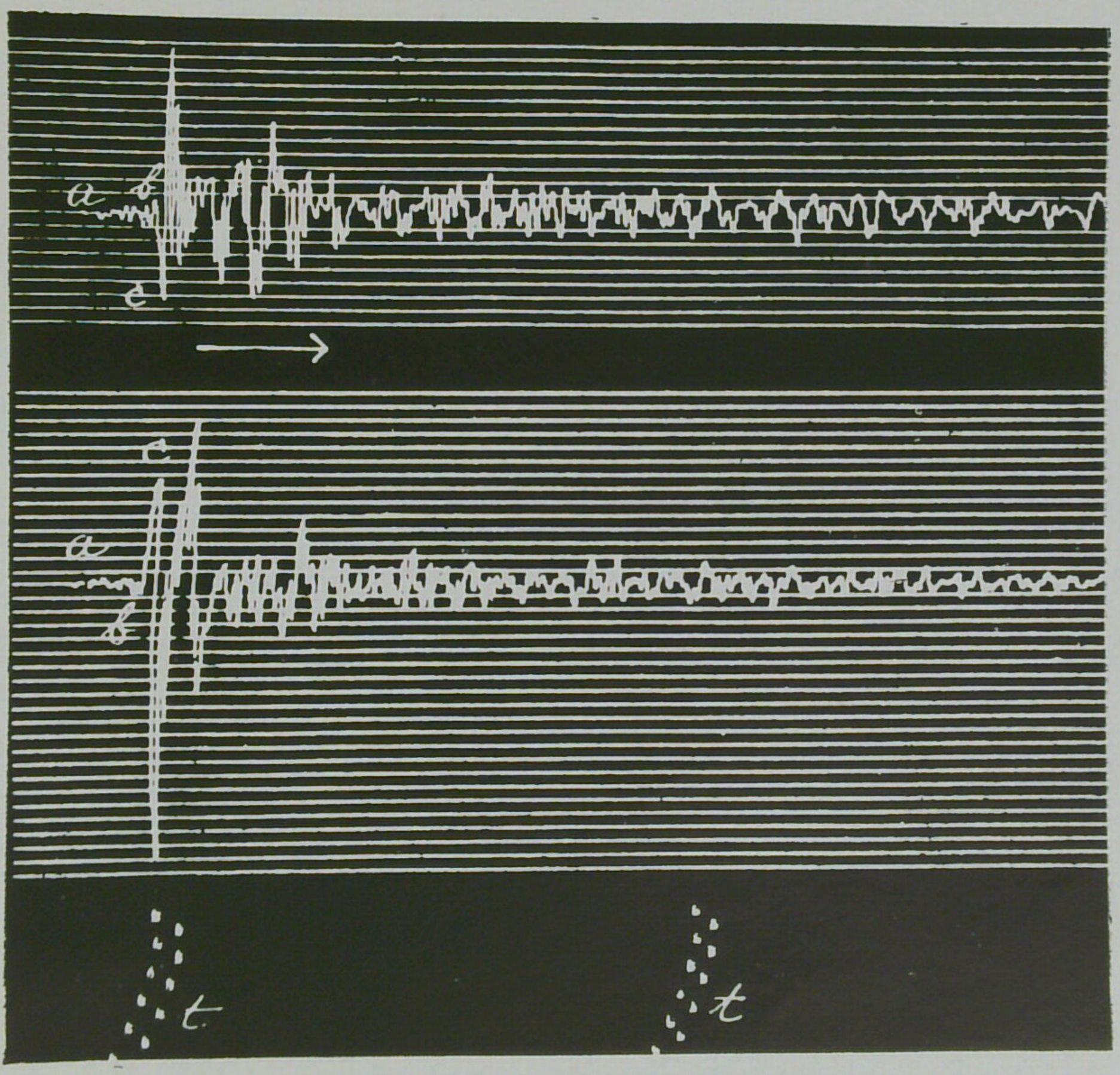
t . . . . Successive Time (Minute) Marks.

ab . . . . Preliminary tremor.

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Tokyo Observation of the Strong Earthquake of Jan. 14, 1923.

Fig. 8. Strong Motion Seismograph Diagram. (Hitotsubashi.)



Magnification = 1.53

a . . . . Commencement.

b. . . . 1st Displacement of the Max. Vibration at the commencement of the Principal Portion.

t . . . . Successive Time (Minute) Marks.

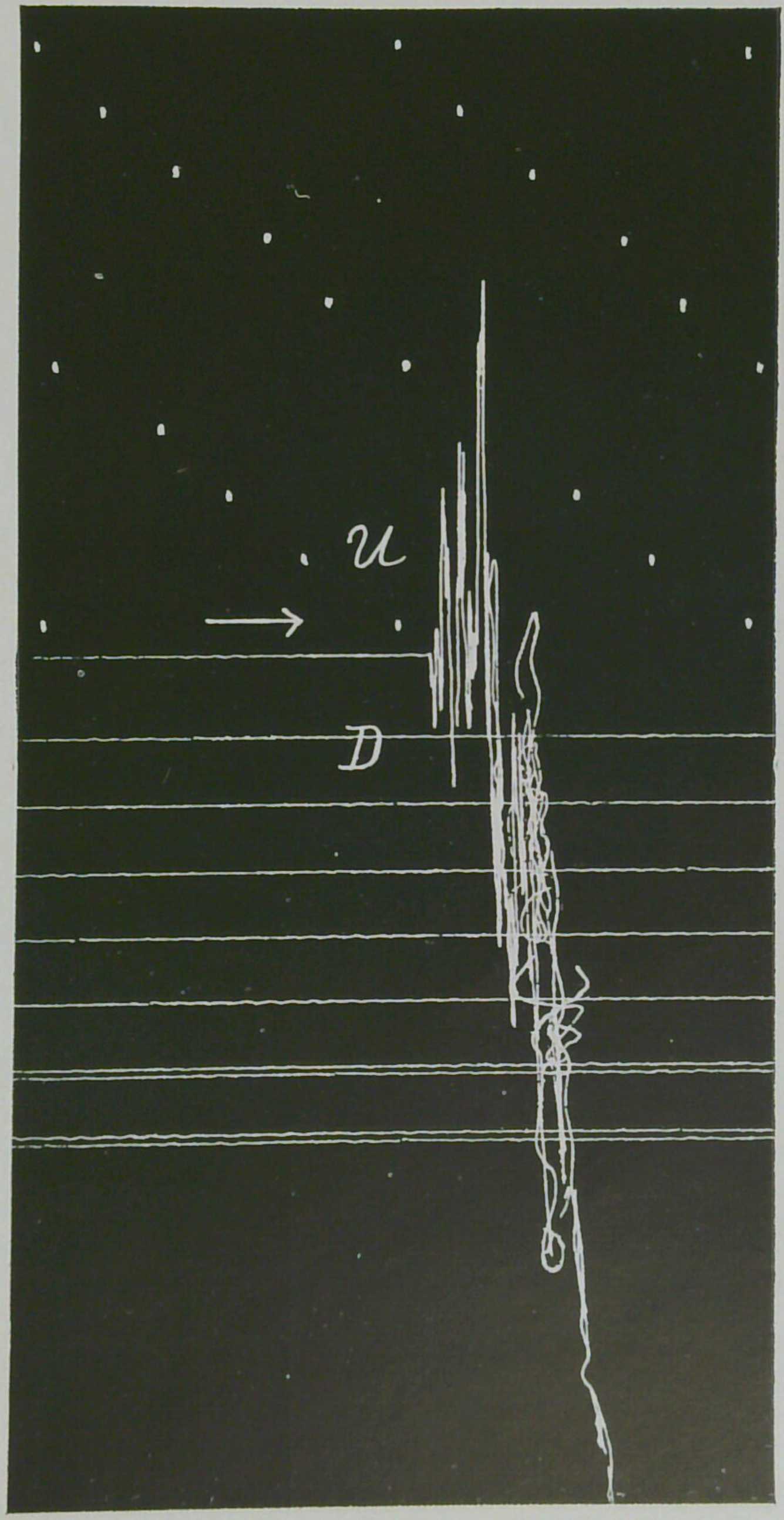
ab. . . . Preliminary Tremor.

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Tokyo Observation of the Strong Earthquake of Jan. 14, 1923.

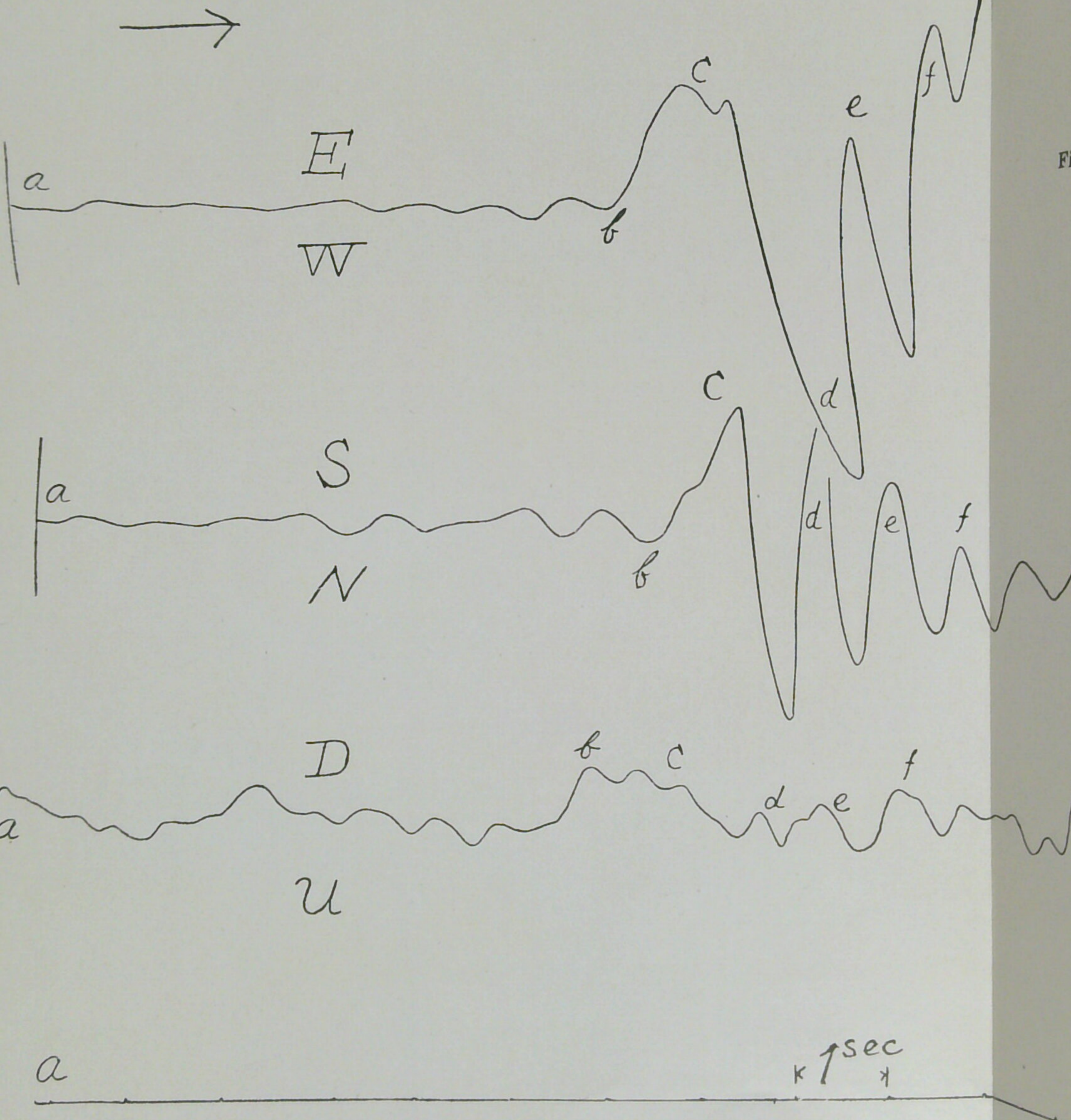
Fig. 9. Vertical Motion Tromometer Diagram. (Hongo.)

Magnification = 36.7



Pointer went out.

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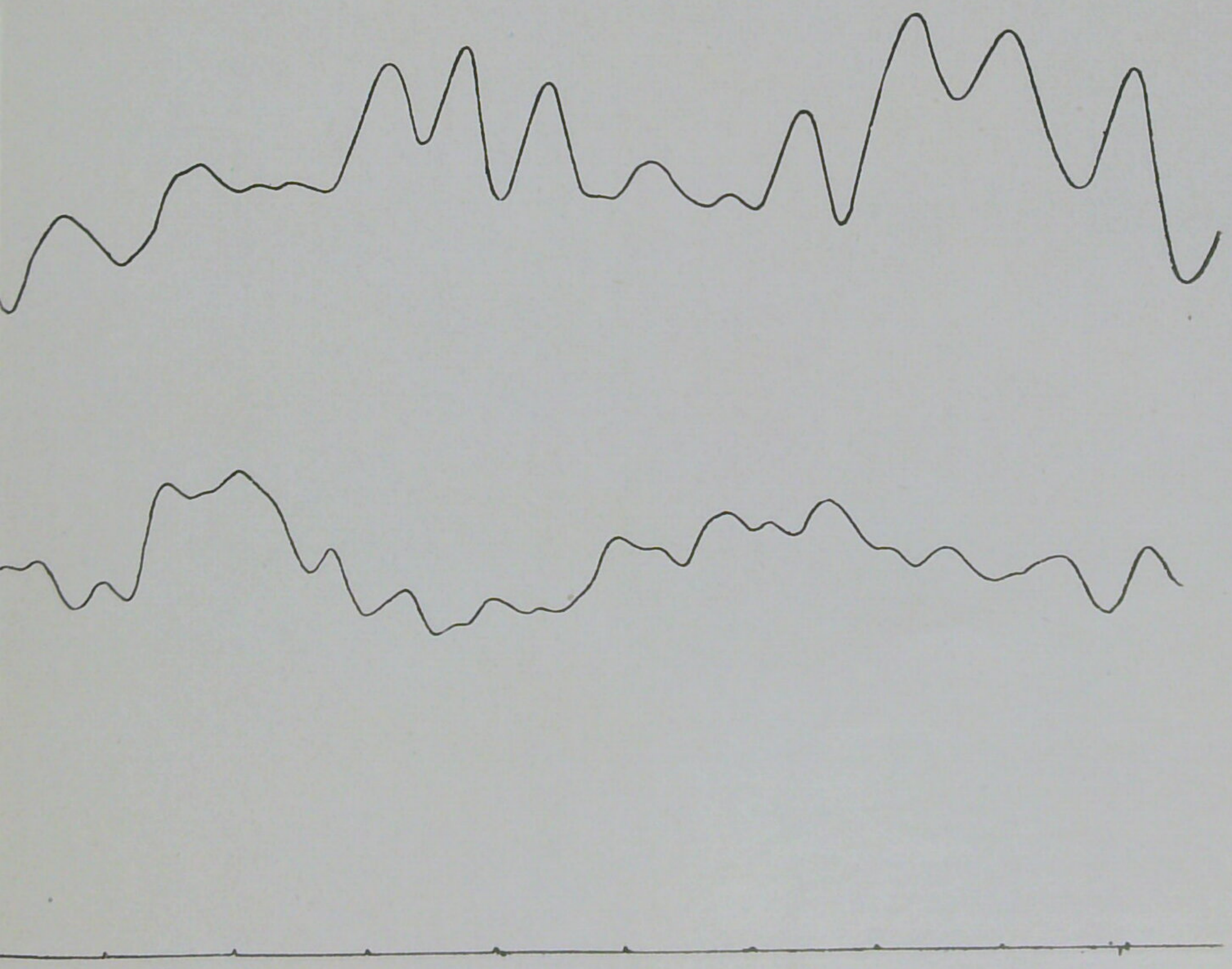
Tokyo Observation of the Strong Earthquake of Jan. 14, 1923.

Fig. 3. Ordinary Gray-Milne Type Seismograph Diagram. (Hitotsubashi.)

Magnification : 3.5 (Horizontal Compt.); 7.0 (Vert. Compt.).

a....Start. *b*....Commencement of Principal Portion.

a, *b*, *c*, *d*, *e*, *f*....Corresponding movements in the three components.



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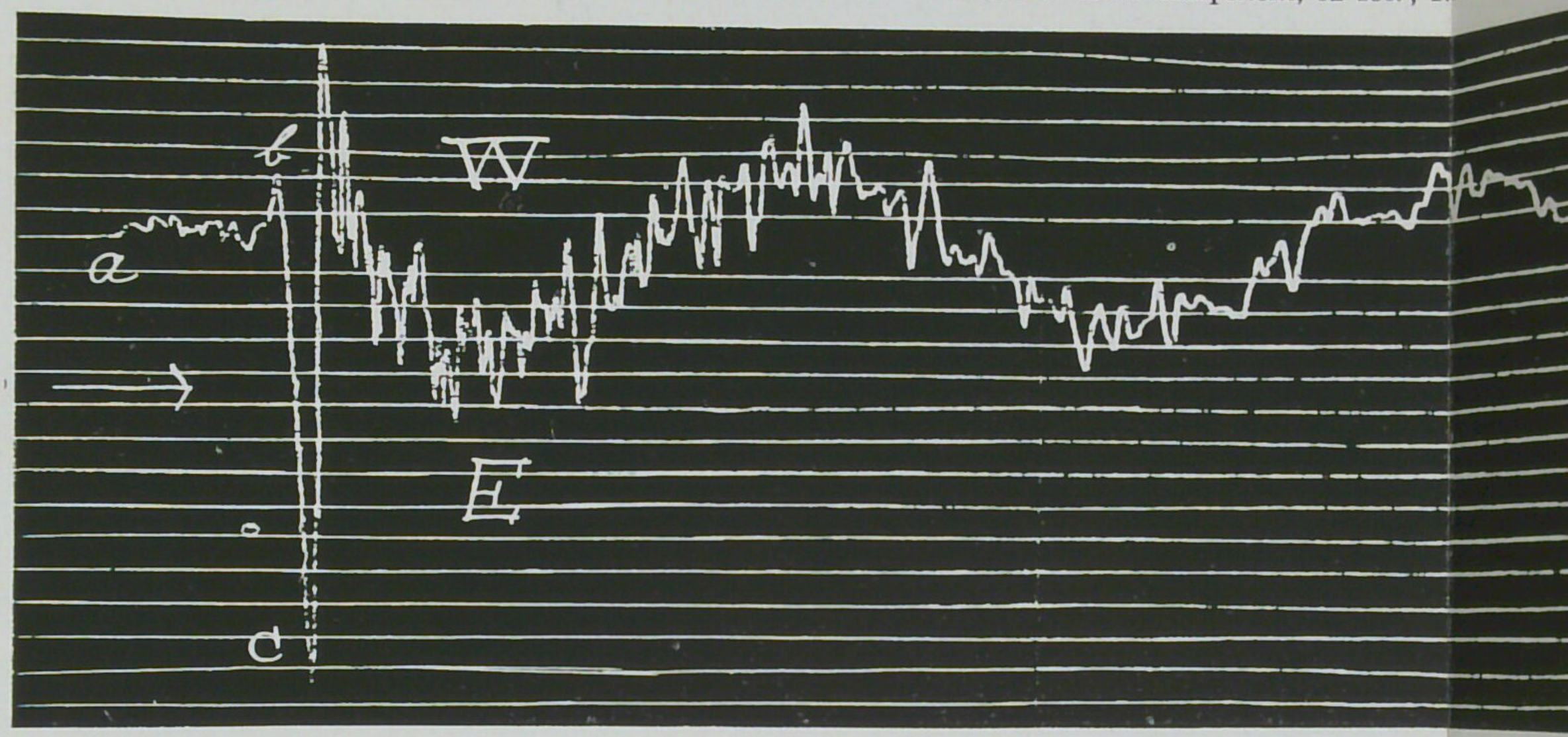
Tokyo Observation of the Strong Earthquake of Jan. 14, 1

Fig. 6. Horizontal Pendulum Strong Motion Seismograph Diagra

a ....Commencement. *ab*....Prelimin

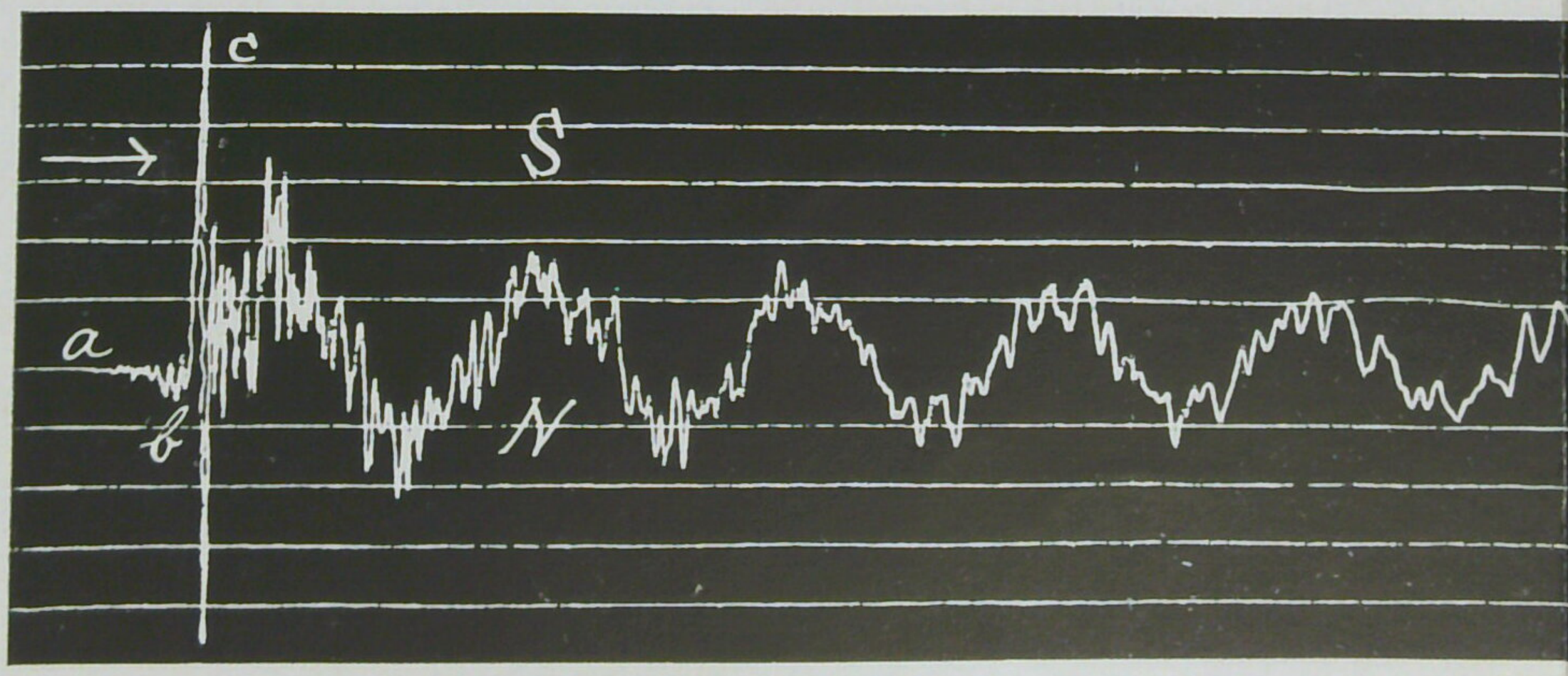
bc....1st Displacement of the Maximum Vibration at the commencement of t

Natural Oscillation Period: E.W. Component, 32 sec.; N.S. Compon



Magnification = 4.8

Time Sc



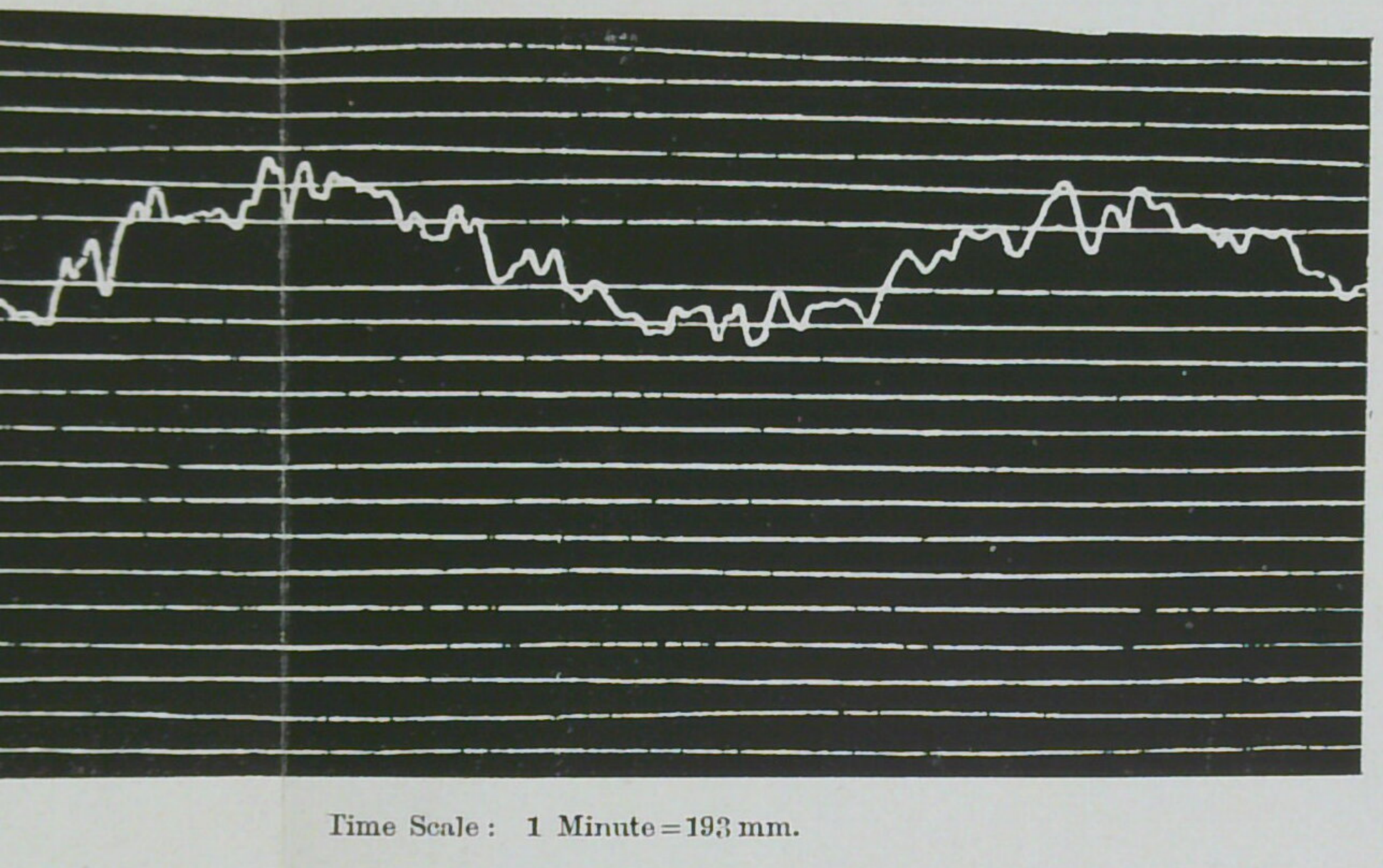
Magnification = 4.0

Time Sc

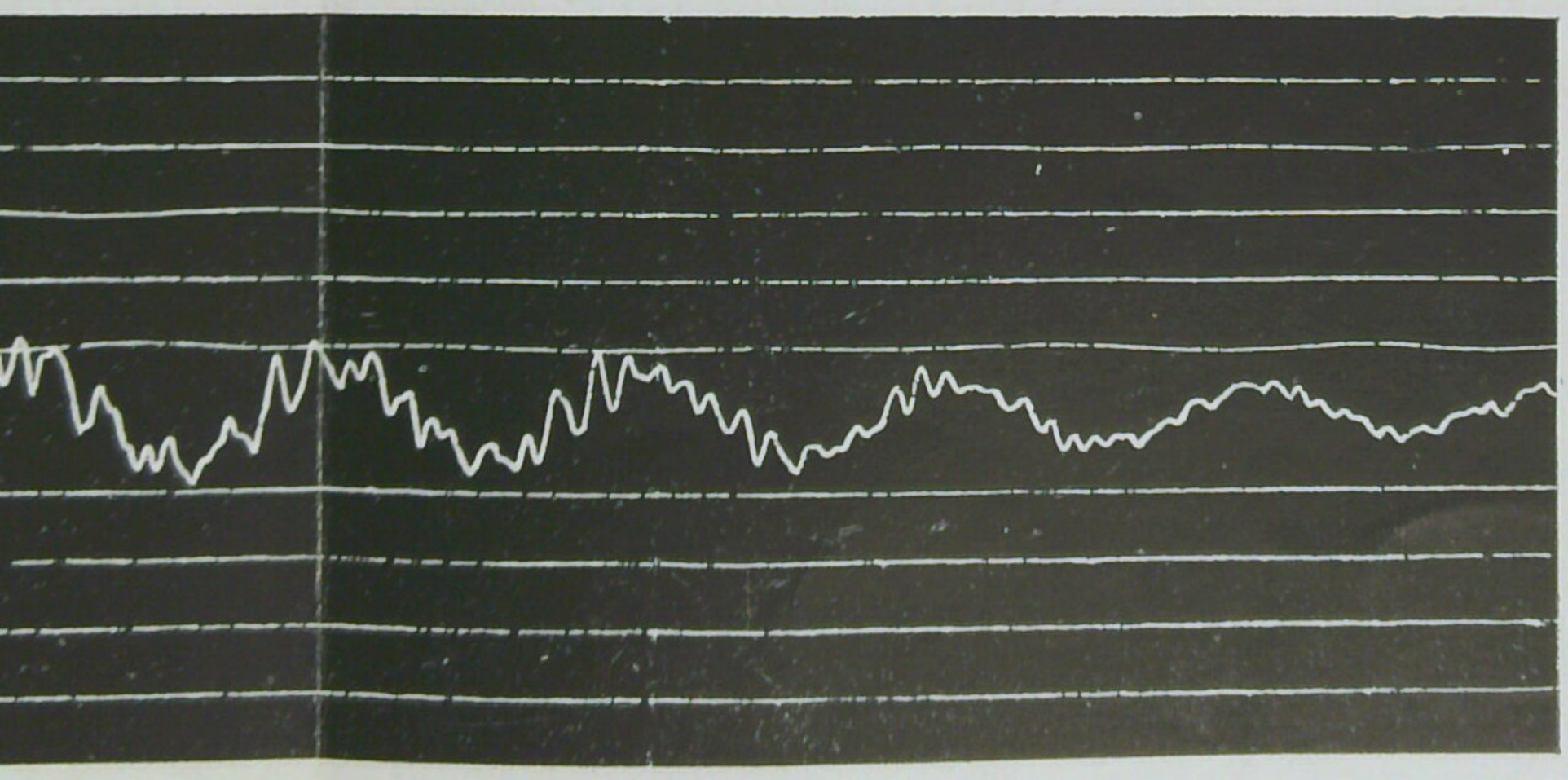
rong Earthquake of Jan. 14, 1923.

tion Seismograph Diagrams. (Hongo.)

ab....Preliminary Tremor.
on at the commencement of the Principal Portion.
ponent, 32 sec.; N.S. Component 26.2 sec.

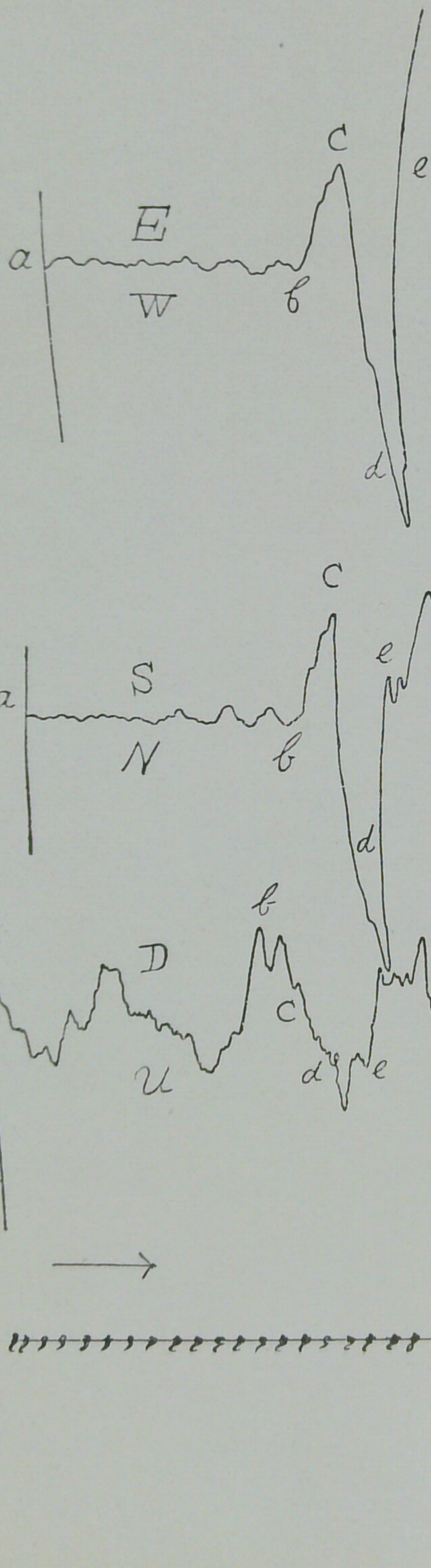


Time Scale: 1 Minute = 193 mm.



Time Scale: 1 Minute = 92 mm.

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Tokyo Observation of the Strong E

Fig. 4. Ordinary Gray-Milne Type Se

Magnification : 3.5 (Horizontal Compt.) ;

Natural Oscillation Period : Hor. Compt.,

a....Start. *b*....Commencem

a, *b*, *c*, *d*, *e*, *f*....Corresponding Mov

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Tokyo Observation of the Strong Earthquake of Jan. 14, 1923.

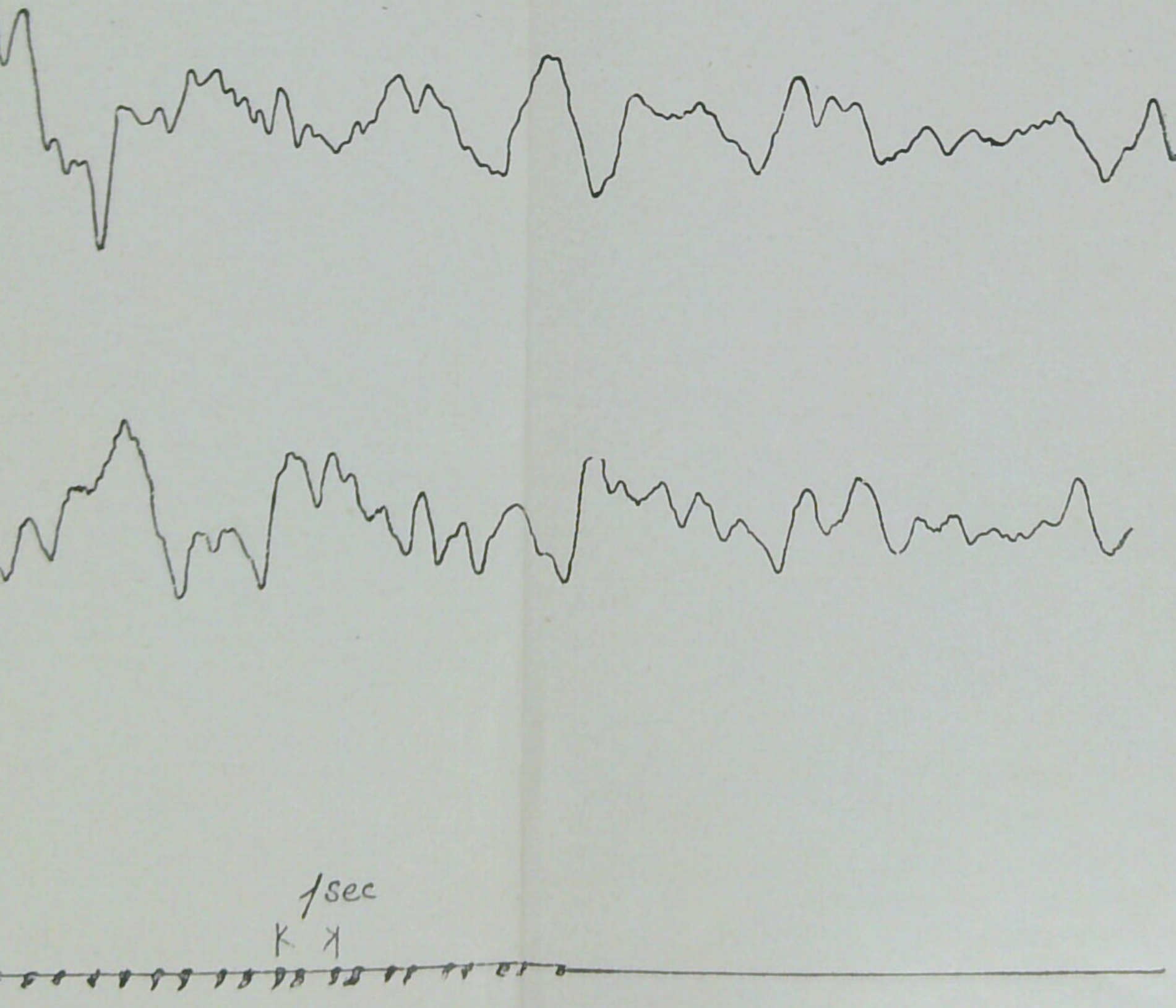
Fig. 4. Ordinary Gray-Milne Type Seismograph Diagram. (Hongo.)

Magnification: 3.5 (Horizontal Compt.); 21.0 (Vert. Compt.).

Natural Oscillation Period: Hor. Compt., 3.5 sec.; Vert. Compt. 4.0 sec.

a....Start. *b*....Commencement of Principal Portion.

a, *b*, *c*, *d*, *e*, *f*....Corresponding Movements in the three components.



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IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE

震災豫防調査會　觀測錄

大正十二年三月　第五號

SEISMOLOGICAL NOTES

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TOKYO

March 1923

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Note on the Nature of Destructive Earthquake Vibration.

By **F. OMORI,**

Member of the Imperial Earthquake Investigation Committee.

Introduction. In the present note the author tries to explain the nature of the maximum vibration in a destructive earthquake, a problem which was often handled in an erroneous way, but which has received a clear definition in the observation of the recent strong earthquakes of Formosa, of the Kwanto provinces, and of Shimabara (Kyushu).

Variation with distance of the character of earthquake motion. Firstly, in a typical distant earthquake register furnished by tromometers sensitive to the slow oscillations, the maximum amplitude motion (m_3, fig. 1) has an average period of about 20 seconds and occurs generally in what I call the 3rd phase of the principal portion. The 2nd preliminary tremor (t), due to the transverse wave, is generally well defined, but insignificant in comparison to the subsequent maximum motion phase. Secondly, with a large earthquake of comparatively near origin, for instance, the

Diagrammatic Representation of Earthquake Motion.

Fig. 1.

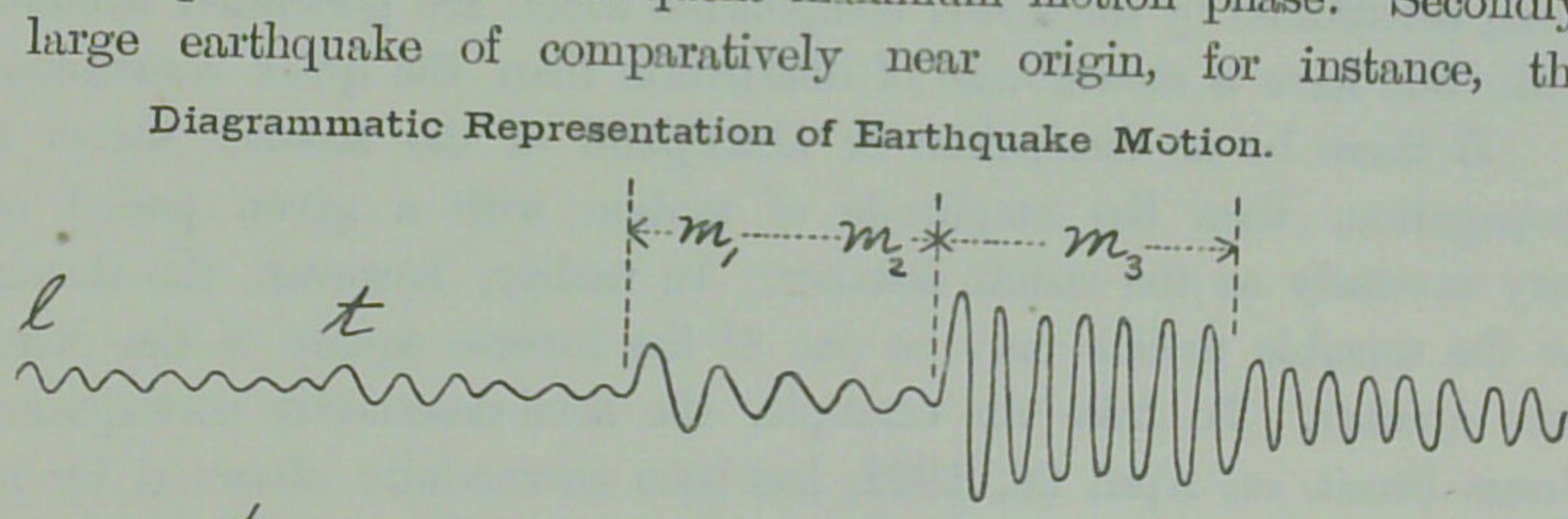


Fig. 2.

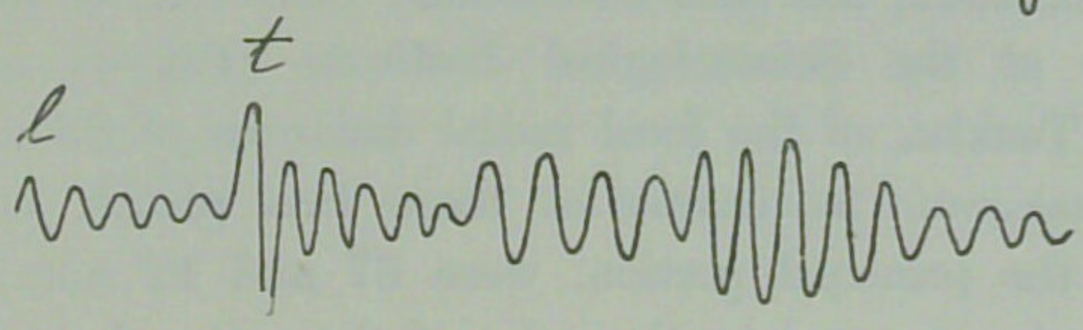
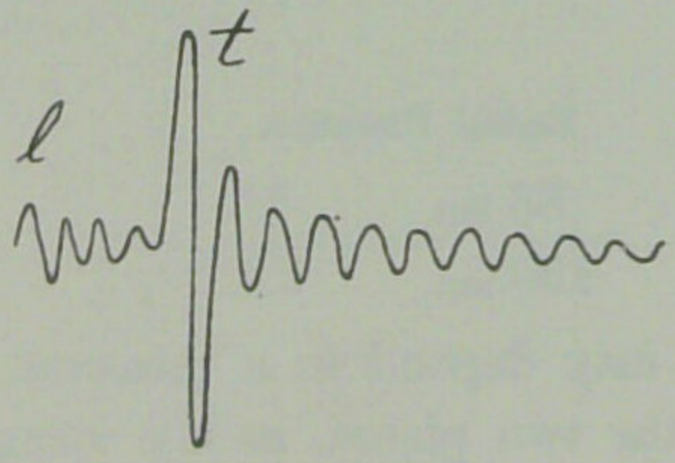


Fig. 3.



l ..... Longitudial motion.

t ..... Transverse motion.

m_1 = 1st Phase, Principal Portion.

m_2 = 2nd „ „ „

m_3 = 3rd „ „ „

Figs. 1 and 2.
Tromometer Register.

Fig. 3.
Strong Motion Seismograph Register.

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Formosa earthquake on Sept. 2, 1922, observed in Tokyo, the 2nd preliminary tremor (t, fig. 2) becomes quite prominent and forms an active, if not the maximum, phase of the whole motion, which, however, is entirely unfelt and comprises slow period oscillations. Thirdly, in the destructive earthquake motion of very near origin recorded on a strong-motion seismograph, the transverse wave (t, fig. 3) becomes actually the maximum vibration responsible for the seismic damage, whose period is generally not much different from 1.5 second. Now the complete earthquake motion is composed of several sets of waves with different transit velocities and of different lengths of period. From the comparison of the first and second cases, it may be supposed that the transverse wave (t) following the first preliminary tremor decreases with the radial distance more quickly than the maximum phase m_3 (fig. 1). This is probably a consequence of the more rapid energy dissipation in the wave propagation of the quicker movements, the predominating periods in the (t) and (m_3) phases being about 8 and 20 seconds respectively. Similar reasoning applies of course to the *sensible* quick vibrations of period of 2 seconds and under. The destructive maximum vibration (t, fig. 3) will rapidly diminish with the radial distance and finally disappear, being substituted by the slower components which are generated simultaneously with, but have a slower rate of dissipation than, the quick constituents.

If there be no dissipation or absorption of the seismic waves in their propagation, then the amplitude of motion with a given period ought to vary inversely as the radial distance. In reality, however, the decrease rate for the sensible motion may be one of the inverse square of the distance, or even quicker. To take an example, the semi-destructive earthquake of the Uraga Strait, on April 26, 1922, has been successfully observed by means of the proper seismographs at the Seismological Institute (Tokyo) and the Seismological Station of Tsukba, of the focal radial distances of 83 and 150 km. respectively. The maximum movements at these two places, occurring at the commencement of the principal portion, were 67 and 12 mm., in the ratio of 5.6 : 1, which is almost equal to the cube of the ratio of their radial distances, as follows :—

	Max. Motion.		Radial Distance.	
$\frac{\text{Tokyo}}{\text{Tsukba}}$	$\frac{67\text{ mm.}}{12\text{ mm.}}$	$= \frac{5.6}{1}$;	$\frac{83\text{ km.}}{150\text{ km.}}$	$= \frac{1}{1.9}$.

This quick rate of the amplitude decrease may depend in a measure on the difference in the nature of the terrain at the two places, as the formation of Tsukba is granitic, while that of Hongo is diluvial and loamy. (Seismologi-

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cal Notes, No. 3.). The general decrease rate my probably be taken to be one of the inverse square of the distance.

Nature of the destructive maximum motion. I first summarize the result of the four cases of successful strong-motion seismograph observations,(1) three made at the Seismological Institute (Tokyo) and one at the Nagasaki meteorological observatory, there existing no other instance of the similar measurements in Japan and elsewhere. In each case, the observing place was not much distant from the seismic focus, the radial distance varying between 49 and 83 km., with the corresponding duration of the preliminary tremor between 6.6 and 11.2 sec. The character of the earthquake motion was quite simple, the well-defined preliminary tremor being abruptly succeeded by the maximum vibration, followed by smaller movements, as is diagrammatically illustrated in fig. 4.

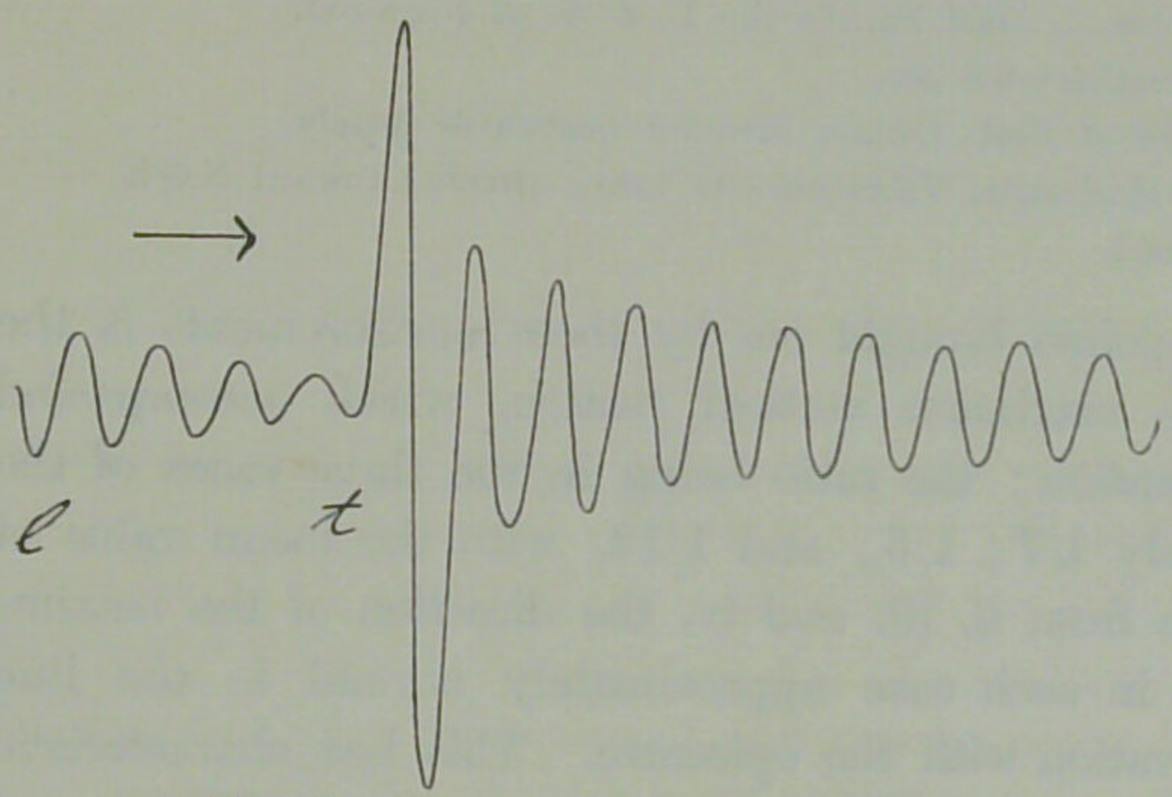


Fig. 4. Strong Earthquake Motion.
l.....Preliminary Tremor.
t.....Principal Portion.

[Seismological Institute Observation.(2)]

(i). Tokyo Earthquake of June 20, 1894, at 2. 04 P. M.

Max. Horizontal 2a=71 mm., directed toward S. 71° W. Complete Period=1.8 sec.
Max. Vertical 2a=10 mm.
Resultant Motion=73 mm.; Max. Acceleration=444 mm/sec.^{2}

(ii). South Hitachi Earthquake of Dec. 8, 1921, at 9. 31. 41 P. M.

Position of Seismic Epicentre.... .. 58 km. to the N. E. of Tokyo.
Duration of Preliminary Tremor=8.8 sec.
1st Horizontal Displacement in the Prel. Tremor directed toward S. 65° W., accompanied by an upward displacement.
Max. Horizontal Vibration=36 mm., directed toward S. 39° E. and N 35° E.; Complete Period=1.7 sec.; Max. Acceleration=246 mm/sec.^{2}
Max. Vertical Motion=7.0mm.

(iii). Uraga Strait Earthquake of April 26, 1922, at 10. 11. 41 A. M.

Position of Seismic Epicentre .. 68 km. to the S. slightly E. of Tokyo.

---

(1) 2a denotes the double amplitude, or range of motion.

(2) The complete seismographic diagrams of these three strong earthquakes are given respectively in the Publications of the Imp. Earthq. Inv. Comm., No. 4, (1900), and in Nos. 2 and 3 of the Seismological Notes, (1922 and 1923).

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Duration of Preliminary Tremor = 11.1 sec.
1st Horizontal Displacement of Prel. Tremor directed toward the South slightly East, accompanied by a downward motion.
Max. Horizontal Motion = 67 mm., directed toward N. 78° W.;
Complete Period = 2.0 sec.; Max. Acceleration = 330 mm/sec.²
Max. Vertical Motion = 5.5 mm.

[Nagasaki Met. Observatory Observation.]

(iv). Shimabara Peninsula Earthquake of Dec. 8, 1922, at 1.52 A. M.
Position of Seismic Epicentre,....34.6 km. to the E. 6° S. of Nagasaki.
Duration of Preliminary Tremor = 6.6 sec.
1st Horizontal Displacement of Prel. Tremor directed westwards nearly.
1st Displacement of Max. Horizontal Vibration = 41 mm., directed toward N.6°E.
(No vertical motion register.)

One of the important points brought out by these measurements is the comparative smallness of the maximum vertical motion, which accompanied the maximum horizontal vibration; the ratio being in the three cases of the Tokyo observation respectively 1/7; 1/5; and 1/12, with the mean value of 1/8. Again, as will be seen from ii, iii, and iv, the direction of the maximum horizontal vibration was in each case approximately normal to the line connecting the place of observation with the epicentre. This last characteristic has also clearly been brought into light by the Tokyo observations of the recent Formosa earthquakes*.

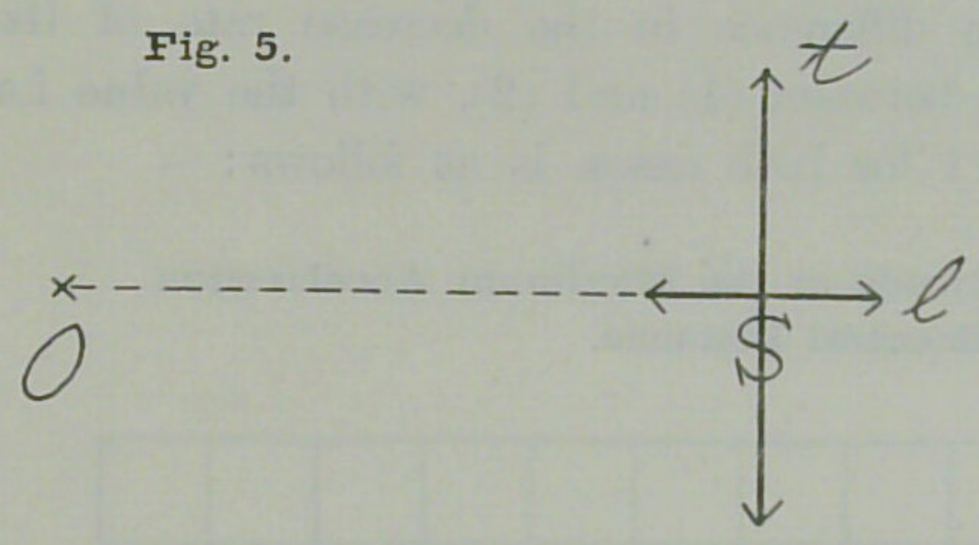
As is well known, the longitudinal wave has greater propagation velocity than the transverse. Thus, let 0 (fig. 5) be the seismic focus, then any point S will be shaken first by the longitudinal and later by the transverse vibration; the time difference of arrival of these two sets of waves being the duration of the preliminary tremor. Now, at the epicentre C (fig. 6), the longitudinal wave becomes entirely vertical and the transverse entirely horizontal. Hence, in the main, at the epicentre the preliminary tremor ought to be vertical and the principal portion horizontal. In other words, even at the epicentre itself the vertical motion would be smaller than the horizontal, in the ratio of the amplitude of the preliminary tremor to that of the maximum vibration, and the buildings strong against the horizontal shock may consequently be regarded as earthquake-proof. Naturally, seismic damage, composed chiefly of the overturning, cracking, fracturing, and sliding of the architectural and civil engineering structures, must be heaviest in the epicentral area, and not, as formerly supposed, at the region whose epicentral distance is equal to the focal depth. In the great Mino-Owari (Central Japan) earthquake of Oct. 28,

* See the next Article.

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1891, there was in the Neo-Valley, a wooden-frame temple-gate which was displaced 1 metre off the foundation stones, and several stone lanterns (*ishidoro*) whose pedestal plates were scattered about, with the maximum displacement amount of 107 cm. (See for the illustrations the Publications of the Imp. Earthq. Inv. Comm., No. 12, 1902.) These extraordinary signs of the great violence of the earthquake motion have been found only in the epicentral region. The predominance of the transverse wave may not be the fact if an earthquake be caused by a surface or underground action of the nature of an explosion. The smallness, however, of the preliminary tremor vibrations in usual cases seems to indicate the extreme rarity of such an occurrence.

Fig. 5.



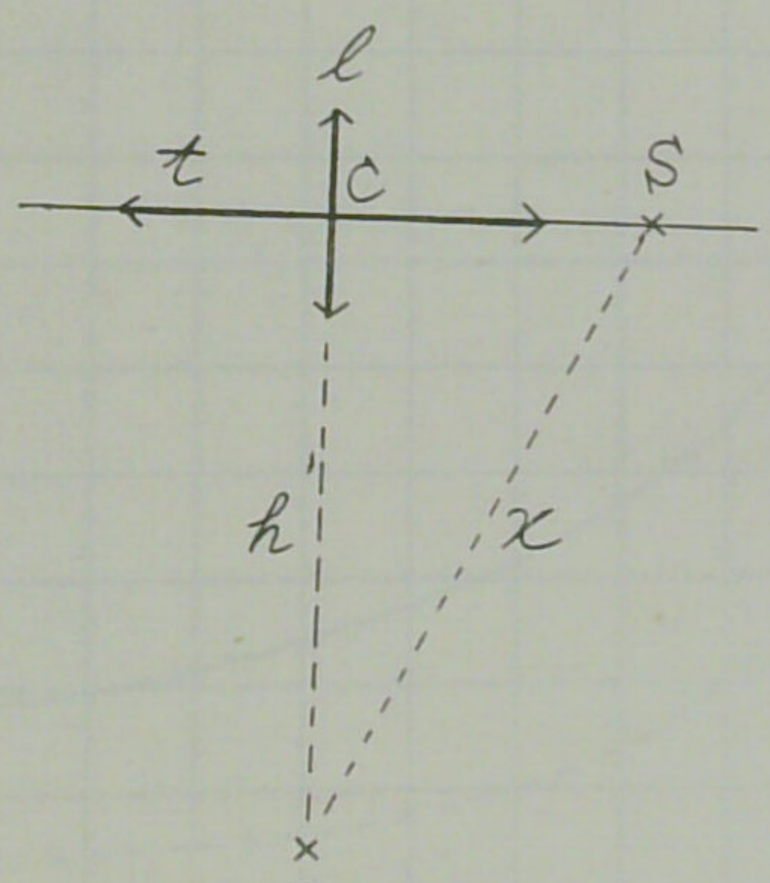


Fig. 6.

CS.....Surface.
O.....Focus.
C.....Epicentre.
S.....Observing Place.

The transverse motion at any observing place *S* (fig. 6), with the necessary condition of being normal to the radius *OS*, may be, (1), normal to the plane *OCS*; (2), may be in the plane *OCS*; or, finally, (3), may be intermediate to these two positions. According to the supposition (2), the transverse motion at *S* would have no horizontal component normal to the epicentral radius *CS*, which could be recognized as such in the horizontal-motion seismogram. Without assuming in any way the impossibility of the supposition (3), the comparatively small amount of the vertical component accompanying the maximum horizontal vibration, which is approximately transverse to the epicentral radial distance, indicates that the supposition (1) is nearly correct in most cases. For a given vibration period, the amplitude a and the maximum acceleration A of the maximum transverse motion then varies inversely as the focal radial distance x, provided there be no dissipation of seismic energy :—

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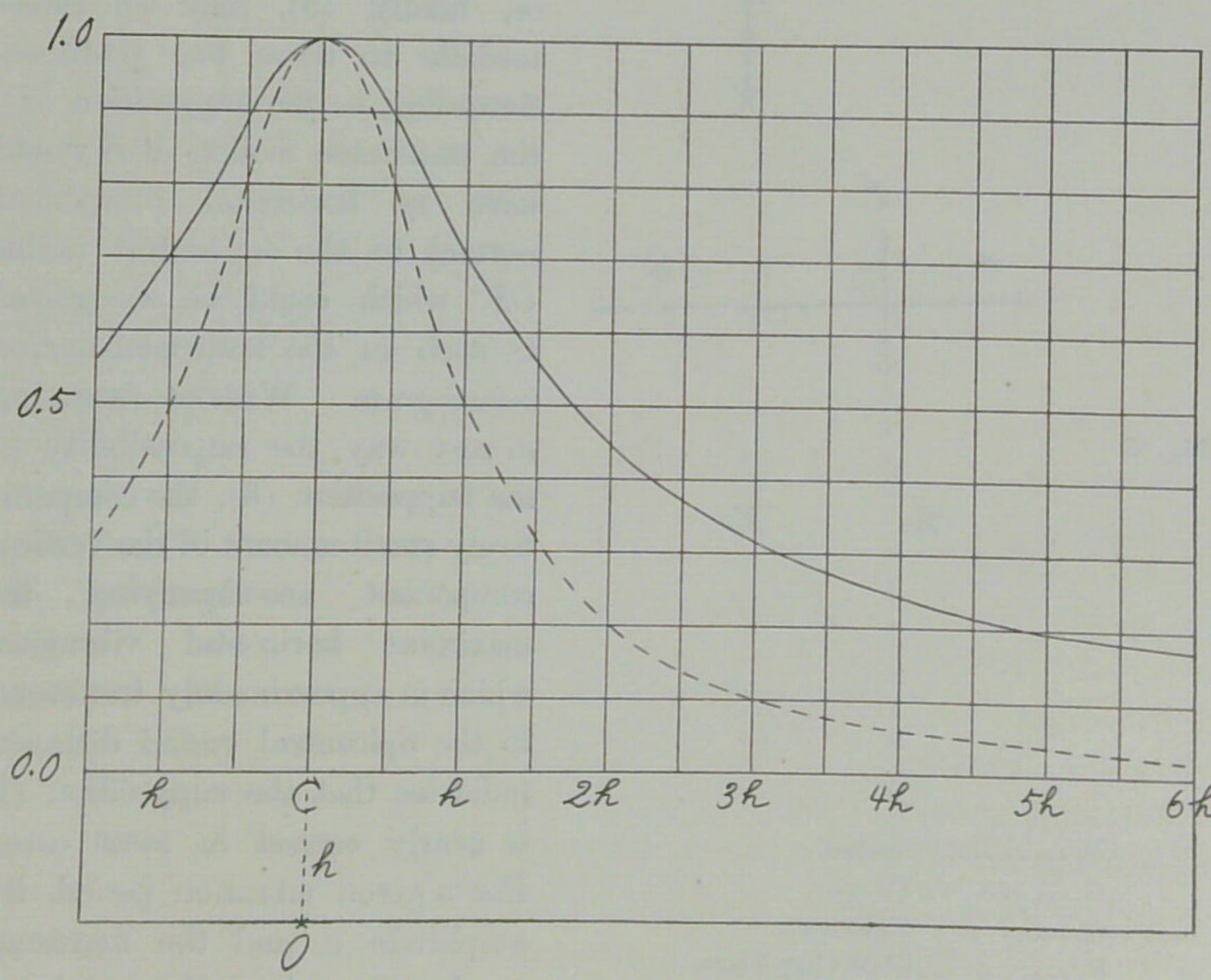
$$2a=\frac{p}{\sqrt{h^2+r^2}}\,;\quad A=\frac{q}{\sqrt{h^2+r^2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

in which p and q are constants, h the focal depth and r the epicentral radial distance of an observing place S (fig. 6). If the focal depth be very nearly zero, the relation between $2a$ or A and the epicentral distance becomes one of rectangular hyperbola. Under the more probable supposition of the variation wiih the inverse square of the distance, we have:—

$$2a=\frac{p'}{h^2+r^2}\,;\quad A=\frac{q'}{h^2+r^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where p' and q' are constants. The difference in the decrease rate of the acceleration, or intensity of motion, between (1) and (2), with the value for the epicentre ($r=0$) assumed to be 1 for both cases, is as follows:—

Fig. 7. Variation of the Amplitude or the Maximum Acceleration with the Epicentral Distance.



Full Curve is drawn according to Equation (1)
Dotted Curve „ „ „ (2)

r=Epicentlal distance. 0=Seismic focus. h=Focal depth.

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Maximum Acceleration $= A$	$r=0$	$r=h$	$r=2h$	$r=3h$	$r=4h$	$r=5h$
(1) $\frac{q}{\sqrt{h^2+r^2}}$	1	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{5}}$	$\frac{1}{\sqrt{10}}$	$\frac{1}{\sqrt{17}}$	$\frac{1}{\sqrt{26}}$
(2) $\frac{q'}{h^2+r^2}$	1	$\frac{1}{2}$	$\frac{1}{5}$	$\frac{1}{10}$	$\frac{1}{17}$	$\frac{1}{26}$

Direction of the destructive maximum motion. In the case of an earthquake caused by the formation of a geological fault stretching for a considerable distance, the directions of the destructive maximum vibration on both sides of the epifocal zone seem to be nearly parallel to it, or symmetrical to it with a certain amount of convergence or divergence. In the epicentral area of a destructive earthquake with a localized focus, the

Fig. 8.

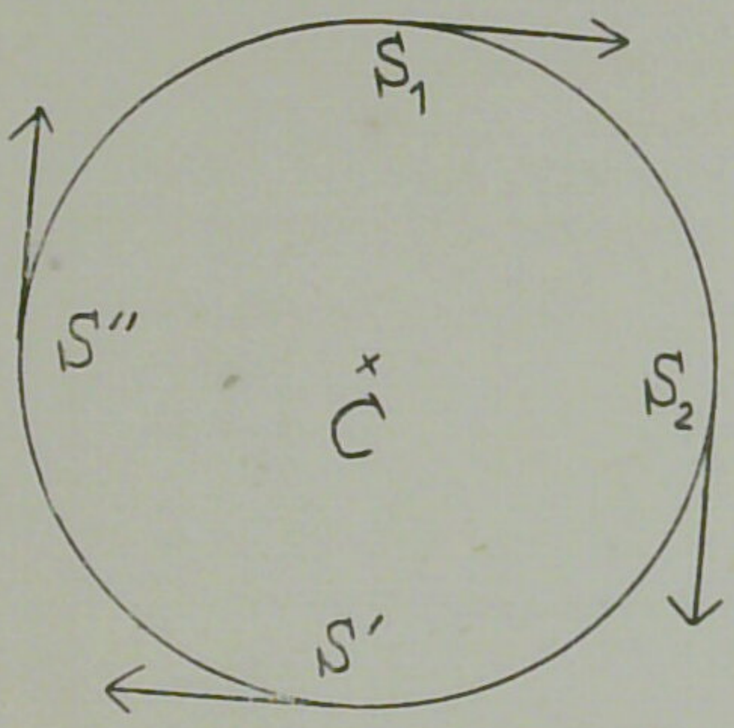


Fig. 9.

Diagrams illustrating the direction of the destructive earthquake motion in the neighbourhood of the epicentre *C*.

S_1, S_2....S', S''....Different observing places in the epicentral area.

direction of the maximam horizontal motion assumed to be identical with that of the overturning and sliding of the different structures, may be as is diagrammatically illustrated by arrows in fig. 8, where C is the epicentre and S_1 S_2 S' S''....different places of observation in the vicinity affected simultaneously by the transverse seismic wave. The direction of the maximum horizontal displacement at a number of places, S_1 S_2,....situated on one side of the epicentre would be reverse to that at the places S', S'',....on the opposite side, as shown in fig. 9. Such has been observed to be the case more or less accurately in the epicentral area of the destructive Shimabara (Hizen) earthquake on Dec. 8, 1922, at 1. 52 A. M.

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Note on the Destructive Formosa Earthquakes of 1922.

By **F. OMORI,**

Member of the Imperial Earthquake Investigation Committee.

With Plates I and II.

Introduction. The earthquke on Sept. 2, 1922, which originated off the north-eastern coast of Formosa, was of the same order of magnitude as the Karenko (花蓮港) earthquake on June 5, 1920, also of sub-oceanic orgin. In point of the seismic damage it was the severest which shook the island since the Nanto (南投, Central Formosa) earthquakes in 1916 and 1917. Another strong earthquake took place from a closely neighbouring centre on the 15th of the same month. It is the chief object of the present note to describe the duplex pendulum tromometer diagrams of these two earthquakes, and one of their after-shocks which occurred on Dec. 2 of the same year. The frequent occurrences of the after-shocks caused much panic among the inhabitants of the northern Formosa, and I was telegraphically asked from the Formosa Government-General on the 18th of September about my opinion with regard to the future course of the seismic activity. To this I have answered telegraphically that the seismic activity off the north-east coast of the island, continued from 1910, was probably brought to a rest, and that Taihoku and the vicinity was, for the present, in an epoch safe from the visitation of destructive shocks.

Position of the seismic centres. According to the tromometer observations at the Seismological Institute in Tokyo ($\varphi = 35° 42' 35''$ N.; $\lambda = 139° 45' 58''$ E.), the preliminary tremor of the strong shock on Sept. 2, 1922, whose time of occurrence was 4. 20. 28 A. M. (Japan Standard Time), lasted $3^m\ 40^s$ and the direction of the vibrations at the commencement was S. 58° W. and N. 58° E.; the very first horizontal movement being in the latter direction, accompanied by an upward displacement. Calculating from these elements of motion, the position of the seismic centre is found to be as follows: 2070 km. to the S. 58° W. of Tokyo; $\varphi = 24° 32' 47''$ N.; $\lambda = 122° 25' 15''$ E. (Fig. 2.) The tromometer observations at the Formosan meteorological stations were as follows:—

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Earthquake on Sept. 2, 1922.

Meteorological Observatory.	Latitude $=\varphi$ (N.)	Longitude $=\lambda$ (E.)	Time of Occurrence.	Intensity.	Duration of preliminary Tremor.	Focal Distance.
			h m s			
Taihoku.	25° 02′	121° 31′	4 16 21	Strong.	12.2 sec.	92 km.
Taichu.	24 09	120 41	4 16 10	Moderate.	12.5	93
Tainan.	23 00	120 13	4 16 06	Slight.	18.0	169
Karenko.	23 58	121 36	4 16 32	Moderate.	11.0	84
Taito.	22 45	121 09	4 16 43	Slight.	27.7	239
Koshun.	22 00	120 45	4 15 23	Slight.	28.6	246
Ishigaki-jima.	24 20	124 10	4 16 15	Moderate.	21.0	191

The position ($\varphi=24°\ 30'$ N., $\lambda=122°\ 15'$ E.) of the seismic centre, deduced from these observations by Mr. H. Kondo, Director of the Taihoku meteorological observatory, is identical with the result already described, being situated about 55 km. off the N. E. coast of the island, to the east slightly north of the town of Tainanoo (大南澳). The position of the epicentre is 106 km. distant both from Taihoku and Karenko.

The Formosa and Ishigaki-jima observations of the 2nd strong earthquake were as follows:

Earthquake on Sept. 15, 1922.

Meteorological Observatory.	Time of Occurrence.	Intensity.	Duration of Preliminary Tremor.	Focal Distance.
	h m s			
Taihoku.	4 31 48	Strong.	12.5 sec.	94 km.
Taichu.	4 31 48	Moderate.	17.9	168
Tainan.	4 31 46	Slight.	27.0	234
Karenko.	4 31 42	Moderate.	13.5	101
Taito.	4 31 24	Slight.	--	—
Koshun.	4 31 40	„	24 4	215
Hokoto.	4 32 10	„	8.5	66
Ishigaki-jima.	4 31 00	Moderate.	24.0	211

Casuality. The total amount of the casuality due to the two destructive earthquakes and the subsequent strong shocks was 17 killed and 34 wounded, while the number of the dwelling houses totally and partially destroyed were respectively 30 and 763. (See Table I.)

Duplex pendulum registers. The three Formosa earthquakes on Sept. 2 and 15, and on Dec. 2, 1922 have been successfully registered on the duplex pendulum tromometer with a magnification ratio of 20 set up in the earthquake-proof observatory of the Seismological Institute. The charac-

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teristics of these three earthquakes are diagrammatically illustrated in fig. 1. The actual registers are reproduced in plates I and II.

Table. I. Destructive Earthquakes in Formosa, 1922.

(Times are given in the Standard Japan Time, or that of 135° E. Longitude.)

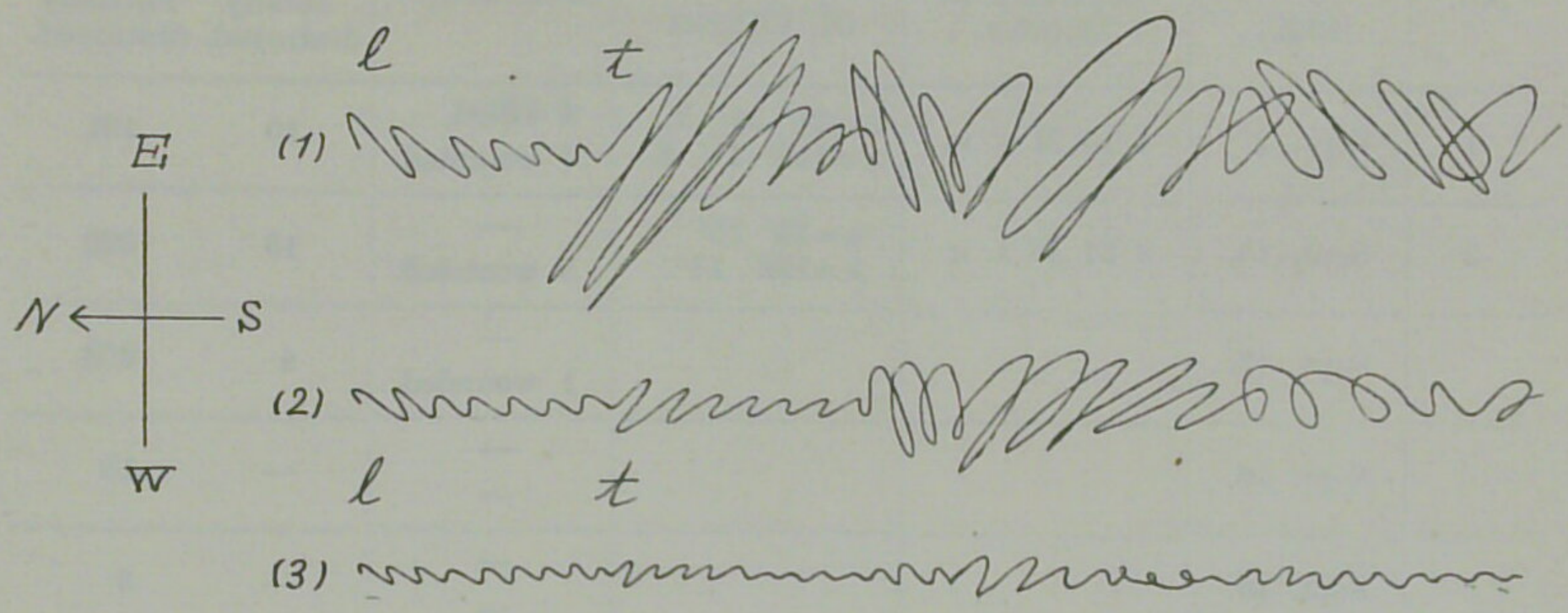
No.	Date. (1922)	Time of Occurrence in Taihoku.	Position of Origin	Casuality.	Dwelling Houses.	
					Totally destroyed.	Partially destroyed.
1	Sept. 2.	4 16 21 A. M.	$\varphi=24°\ 33'\ N.$ $\lambda=122°\ 25'\ E.$	4 killed. 7 wounded.	10	131
2	Sept. 15.	4 31 48 A. M.	$\varphi=24°\ 35'$ $\lambda=122°\ 13'$	— 5 wounded.	13	320
	Sept. 17.			— 1 wounded.	4	203
	Sept. 18.			— —	—	15
	Sept. 19.			— —	—	3
	Sept. 2–19.	(Statistics relating to the aboriginal districts.)		6 killed. 16 wounded.	3	35
3	Oct. 15.	8 47 05 A. M.	$\varphi=24°\ 36'$ $\lambda=122°\ 18'$	6 killed. 2 wounded.	—	11
4	Dec. 2.	0 47 00 P. M.		1 killed. 2 wounded.	—	33
5	Dec. 13.	11 04 02 P. M.		— 1 wounded.	—	12
Sum	—	—	—	17 killed. 34 wounded.	30	763

The duplex pendulum tromometer record of the earthquake on Sept. 1, 1922, reproduced in Pls. I and II, began with the vibrations in the direction of N. 58° E. and S. 58° W., with the maximum $2a=0.8$ mm. $3^m\ 34^s$ after the commencement there took place a well defined group of large movements in the S. 55° E.–N. 55° W. direction with the maximum range of $2a=4.15$ mm. $2^m\ 50^s$ further on there set in vibrations in the E. N. E. -- W. S. W. direction ($2a=2.4$ mm.), followed about 1 minute after by those in S. S. E. – N. N. W. direction ($2a=3.8$ mm.). At about $6^m\ 30^s$ after the commencement of the principal portion, there began again vibrations in a N. E. – S. W. direction ($2a=3.9$ mm.), followed 1 minute later by those in a S. E. – N. W. directions ($2a=3.1$ mm.). Then, at about $9^m\ 50^s$ after the commencement, again there

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set in well defined vibrations in the N. E. – S. W. direction ($2a=3.5$ mm.). The subsequent portion, with alternations of the group movement in the transverse and longitudinal directions, was much smaller. So far, what may be regarded as the principal portion lasted together about 11 min.

Fig. 1. Diagrammatic Illustrations of the Formosa Earthquake Horizontal Component observed in Tokyo.



l ... Longitudial Motion. t ... Transverse Motion.
(1) ... for the earthquake on Sept. 2, 1922.
(2) ... „ „ Sept. 15, 1922.
(1) ... „ „ Dec. 2, 1922.

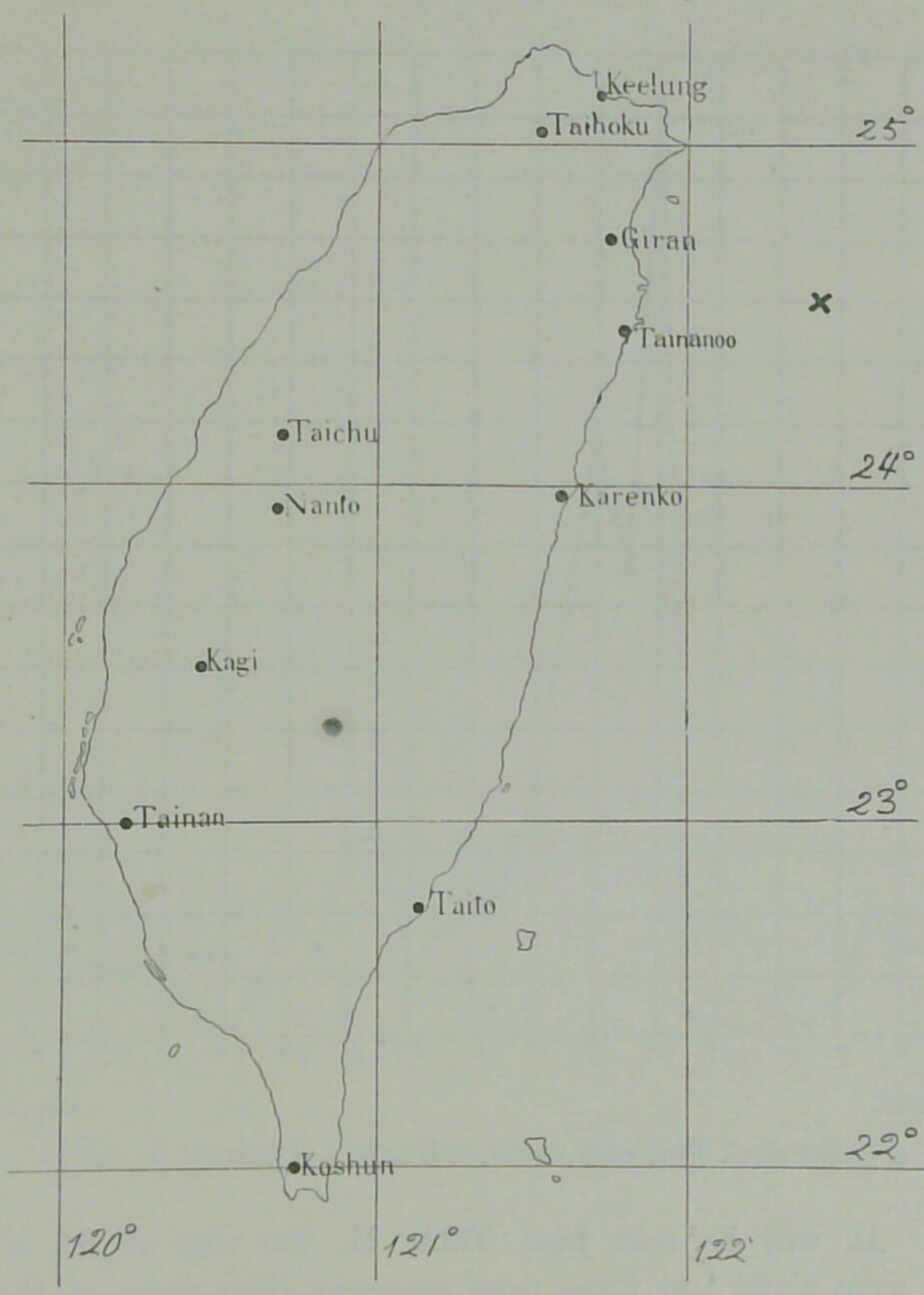
The record of the 2nd earthquake, that on Sept. 15 reproduced in fig. 5, began with small movements ($2a=0.08$ mm.) in the general N. E. – S. W. direction. About $3^m\,45^s$ after the commencement there began larger, but not very prominent, movements in a S. E. – N. W. direction. $3^m\,32^s$ further on there took place larger oscillations ($2a=4.5$ mm.) in the direction of S. E. – N. W., followed about 1 minute later by others ($2a=4.0$ mm.) in an E. 55° S. – N. 55° W. direction. Then, about $7^m\,45^s$ after the commencement of the large motion phase, there took place well defined vibrations ($2a=4.1$ mm.) in the E. 80° S. – W. 80° N. direction, followed for the next $4^m\,30^s$, by movements ($2a=1.5$ mm.) chiefly in the N. E. – S. W. direction. So far the large motion phase lasted together $8\frac{1}{3}$ minutes. The subsequent motion was much smaller. In the diagram of the smaller Formosa earthquake on Dec. 2, 1922, at 0.47 P. M., the maximum motion phase, consisting of vibrations of $2a=0.6$ mm. chiefly in the E. E. S. – W. W. N. direction, occurred about 11 minutes after the commencement. (Fig. 6.)

Propagation along the major arc. The Tokyo tromometer registers of the earthquake on Sept. 2, 1922, indicate the major-arc propagation composed of the vibrations (W_2) of period of about 20 sec., at 7.32.57 A. M.,

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namely, 3 h 12 m 31 s after the commencement, becoming still slower in period from 7.49.37 A. M. The W_2 waves correspond to the 3rd phase in the principal portion of the minor-arc propagation, which arrived in Tokyo 10 m 05 s after the commencement of the earthquake. The time difference between these arrivals of the major-arc and the minor-arc propagations was

Fig. 2. Map of Formosa indicating the Position of the Epicentre of the Strong Earthquake on Sept. 2, 1922.



(×) Seismic Origin.

(•) Meteorological Observatory.

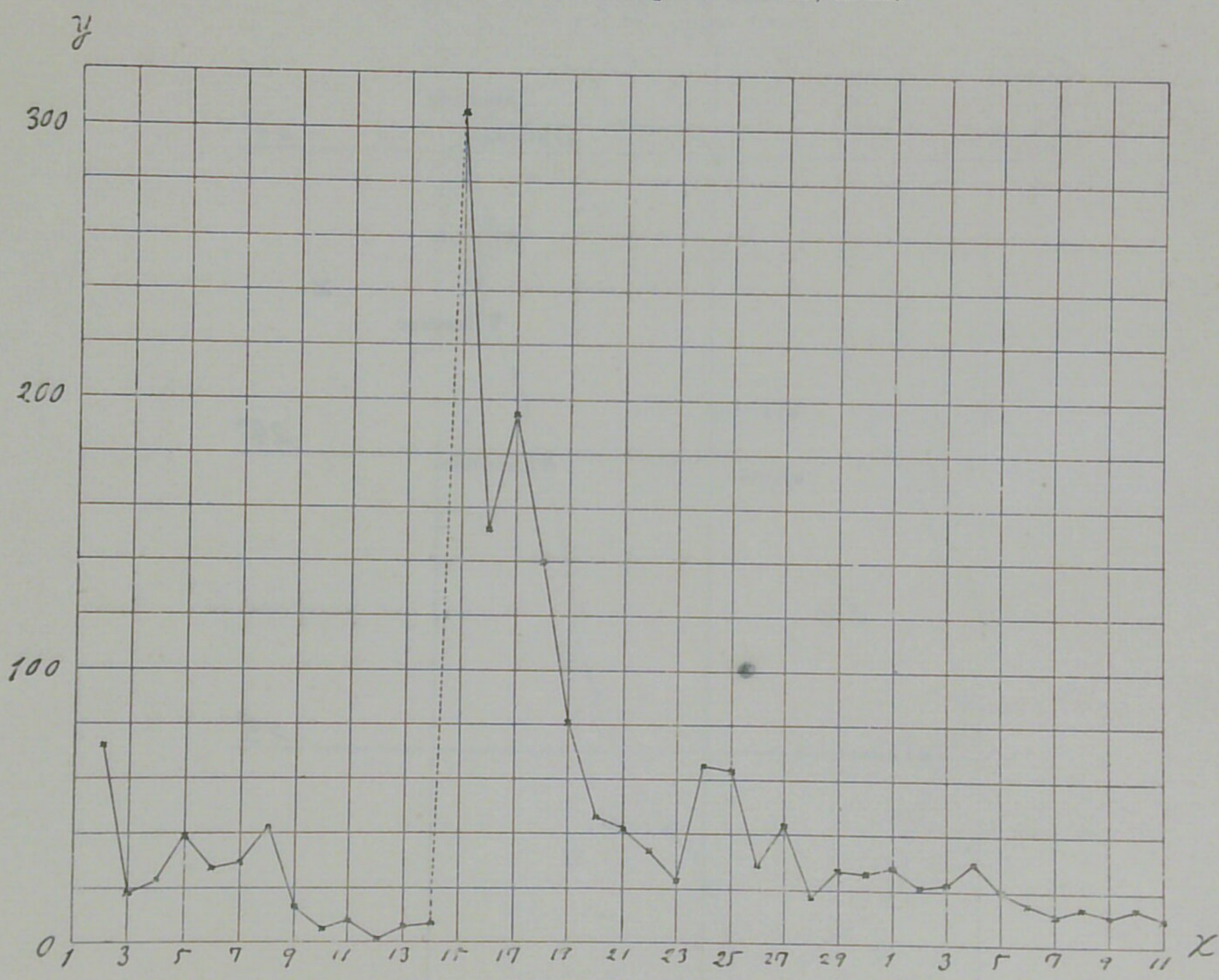
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3 h 02 m 26 s, corresponding to the distance difference of $40000-2\times2070=35860$ km., with the average transit speed of 3.3 km./sec., as follows:—

$$(37930 \text{ km.}-2070 \text{ km.})\div 3^h02^m26^s=3.3 \text{ km./sec.}$$

After-shocks. According to the Tokyo observations the strong earthquake on the 15th of September was much smaller than that on the 2nd of the same month. The radial distance of Taihoku was about 90 km. in

Fig. 3. Daily Frequency Variation at Taihoku of the After-shocks of the Two Earthquakes of Sept. 2 and 15, 1922.



y = After-shock Frequency corresponding to x (expressed in days).

both cases. As will be seen from Table II, the after shocks of the 2nd earthquake were about four times more numerous than those of the 1st, in *disproportion* to the relative magnitudes of the two disturbances. Now each after-shock may be regarded as removing a residual weak point existing at,

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Table. II. Daily Number of the Unfelt and Sensible After-shocks of the Strong Earthquakes on Sept. 2 and 15, 1922 and on June 5,1910.

(Tromometrically observed at Taihoku.*)

The figure enclosed within brackets indicates the number of sensible shocks, the rest being insensible.

Mouth. / Day.	1922				1923		1910
	IX	X	XI	XII	I	II	VI
1	—	28 (1)	3	3	3	0	—
2	72 (5)	21	7	13 (1)	0	5	—
3	18	22 (1)	8 (1)	4	4 (1)	2	—
4	23 (2)	30	6	10	1	4 (1)	—
5	39 (2)	20	10	8	3	1	51 (5)
6	27 (1)	15 (1)	5	3	5	3	50 (1)
7	29 (3)	11	5	3 (1)	0	3	28 (1)
8	42 (3)	14 (1)	2	6	9	1	29
9	13	11 (1)	10	2 (1)	3	4	13 (1)
10	5	14	5	4 (1)	3	3	9
11	8	10 (3)	3	8 (2)	3	1	5
12	1	9	10	4	1	0	2
13	6 (1)	18 (1)	7	7 (2)	2	13	4
14	7	28 (3)	3	7	5	2	3
15	306 (11)	92 (9)	4	4	4	1	1
16	152 (5)	25	1	4 (1)	2	1	2
17	195 (17)	26 (1)	4	3 (1)	2	3	4
18	140 (4)	14 (1)	2	3	5	2	1
19	81 (3)	12	7 (1)	5	1	0	2
20	46 (1)	7	5	1	7	2	3
21	42 (2)	12	2	2	4	0	2
22	34 (2)	11	5	3	5	2	3
23	23 (1)	7	3	3	3	1	1
24	65 (2)	7	3	1	5	2	0
25	63 (2)	3	6	1	4	2	0
26	29 (2)	3	3	5	1	5	0
27	43 (1)	8 (2)	8 (1)	1	4	0	2
28	17	15	5 (1)	5	1 (1)	12 (1)	0
29	27 (1)	10	2	1	3	—	0
30	26 (2)	3	3	0	3 (1)	—	0
31	—	7 (1)	—	1	4	—	—
Sum.	1579 (73)	513 (26)	147 (4)	125 (10)	100 (3)	75 (2)	215 (8)

* Communicated by Mr. H. Kondo, Director of the Taihoku meteorological observatory.

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or in the neighbourhood of, the seismic focus, and the non-occurrence or a scarcity of the after-shocks is to be taken as a sign of the existence of some abnormal condition preventing the disturbed portion of the earth's crust about the seismic focus getting back into the equilibrium state. For the sake of comparison, in Table II is also given the daily number of the after-shocks observed at Taihoku of the strong earthquake off the coast of Karenko on June 5, 1920, at 1.22 P. M., which caused a causality of 25 wounded and killed. The numbers of the after-shocks which occurred at Toihoku during the 13 days following these three strong earthquakes were as following:—

(i) Earthquake of June 5, 1920: 201 after-shocks
(ii) ,, Sept. 2, 1922: 290 ,,
(iii) ,, Sept. 15, ,, : 1219 ,,

From these figures it may be inferred that the first two strong earthquakes followed by comparatively small numbers of after-shocks, did not bring to an end the seismic disturbances of recent years in this part of the seismic zone lying off the eastern coast of Formosa. The great abundance of the after-shocks subsequent to the smaller earthquake (iii) probably marks the end of the epoch of seismic activity in question. The northern part of the island of Formosa may probably be assumed to be the locality where the activity of some strength is to be displayed next.

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IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE

震災豫防調査會　觀測錄

大正十三年七月　第六號

SEISMOLOGICAL NOTES

No. 6

PAGE

A. IMAMURA. Preliminary Note on the Great Earthquake of S. E. Japan on Sept. 1, 1923. 1

TOKYO

July 1924

International Seismological Centre

Preliminary Note on the Great Earthquake of S. E. Japan on Sept. 1, 1923.

By **A. Imamura.**

Member of the Imperial Earthquake Investigation Committee.

With Plates I-VII.

Introduction.

1. The great earthquake which devastated S. E. Japan on Sept. 1, 1923, was by no means the most severe that has visited this country, but perhaps if we search recorded history for seismic disasters of appalling magnitude, not one can be found to equal it in the number of lives lost and the amount of property destroyed through its agency. To give precise scientific information concerning it is a matter of absolute necessity; the writer most qualified for this would have been late Prof. Omori but unfortunately he was just previously attending the Pan-Pacific Scientific Conference in Australia, and his death occurred soon after his return. During his absence, he left the duties of the Director of the Seismological Institute, as well as of the President and the Secretary of the Imp. Earthquake Investigation Committee, in my care; and I think I may say that I did my best in re-organizing the Committee—its office was burnt up with its important papers—in order to carry out the most accurate official investigation. Thus I was obliged to take up the work concerning this information, bnt I doubt if I can do it satisfactorily.

2. As I have stated above, the disaster was extraordinarily heavy in comparison with the magnitude of the shock. More than 95% of the loss of property was due to the fire caused by the first quake. It is my utmost regret that we as seismologists could take no measures of precaution in mitigating such disaster; but I ask your indulgence while I tell you of the facts. Our colleagues, especially Prof. Omori, often gave advice to the citizens of Tokyo to improve the construction of the water-pipes which had often been proved to become inefficient even in the case of a moderate

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shock. In addition, I announced in 1905 through the Journal "Taiyo" my opinion that there was a possibility that Tokyo might be visited by a destructive earthquake in the near future, to be followed by a general conflagration should the system and equipments of fire protection remain unimproved, when we might experience a loss of lives to the extent of 100,000 or more. I discussed this view in full detail, but peopele refused to believe me. There was even an eminent scientist who ridiculed my opinion once at that time and again in 1915, as nothing other than a rumour which might cause a general panic.

3. Contrary to Prof. Omori, I have been very lucky. I was just in our institute at the moment of that great shock, could appreciate fully the earth-movement, and after half an hour was able to give to more than a score of journalists, some brief information about the exact time of the earthquake occurrence, position of the epicentre, characters of the earth-movements and the possible effects on land and sea in the disturbed area, which now I find to have been not so much mistaken. Soon after the first shock, fire broke out at two places in the university, and within one and a half hours, our institute was enveloped in the raging smoke and heat; the shingles now exposed to the open air, as the tiles had fallen down as the result of the shock, began to smoke and eventually took fire three times. I can not tell you how desperately I fought against the fire without water or any help from outside, commanding at the same time the rest of the men to carry away the more important things into safe places. It was 10 o'clock at night before I found our institute and observatory quite safe.

4. Most seismographs in the institute were wrecked, and only one component of a seismograph with the index magnification of two times kept going throughout. The instruments, however, were soon adjusted or repaired, and 5 min. after the beginning of the quake the following seismographs were running :—

1. A complete set of seismograph with the index magnification of two times.
2. A complete set of seismograph registering the earth movements in actual size.
3. E. W. components seismograph with the magnification index of 1.5 times.
4. N. S. component seismograph similar to No. 3.

Besides these, two more instruments with automatically starting record-receiver were available. A few instruments with higher magnification index were running after a day or two.

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5. The Imp. Earthquake Investigation Comm. appointed the different subcommittee to investigate the last earthquake each from the stand point of pure seismology, geology, meteorology, architecture, civil engineering, hydrography, geodesy, mechanics, chemistry, etc. I expect their complete reports will appear within a few months; here I am giving a short note only as a preliminary of the report in my share.

Observations of the earth-movements.

6. Actual feeling at Hongo. I was just sitting in the Seismological Institute. At first, the movement was rather slow and feeble, so that I did not take it to be the forerunner of so big a shock. As usual, I began to estimate the duration of the preliminary tremors, and determined, if possible, to ascertain the direction of the principal movements. Soon the vibration became large, and after three or four seconds from the commencement I felt the shock very strong indeed. Seven or eight second passed, and the house was shaking to an extraordinary extent, but I considered these movements not yet to be the principal portion. When I calculated the 12th second from the start, there arrived a very big vibration which I took it at once as the beginning of the principal portion. Now the motion, instead of becoming less and less as usual, went on to increase its intensity very quickly and after 4 or 5 seconds I felt it to have reached its strongest. During this epoch the tiles were showering down from the roof making a loud noise and I wondered whether the building could stand or not. I realized the directions of the principal movements distinctly and found them to have been about N.W. or S.E. During the following 10 seconds the motion, though still violent became somewhat less severe, and its character was gradually changing into slower but bigger vibrations. For the next few minutes we felt the undulation like that which we experience on a boat in windy weather, having now and then been threatened by severe after-shocks. After 5 minutes from the beginning I stood up and went over to see the instruments.

7. Instrumental observations. All the instruments provided with magnification index higher than 5 times did not register even the preliminary tremors completely, but they gave important data as to the direction of the initial phase. Two seismographs writing the earth-movements, one in two-time magnification and the other in natural size, registered the preliminary tremors completely, but their writing index went out within 6 seconds from the beginning of the principal portion, except the E. W. component of the

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former which kept all through. Consequently it will be most convenient to trace the earth-movements according to this instrtument, and if necessary, to supplement it with the data given by the rest of the instruments.

8. Seismograph with two-time magnification. Instrumental constants: In each horizontal component, the distance between the point of support of the horizontal pendulum and the heavy bob (2100 gr. in weight)=200 mm.; the pointer prolongation=200 mm.; the proper pendulum period=10 sec. Correction of orientation=13° counterclockwise. In vertical component, the distance between the point of support and the heavy bob (230 gr. in weight)=100 mm.; the length of the spiral spring when free=80 mm.; the same when elongated by the weight=300 mm.; the horizontal length of the writing index=100 mm., and its vertical length=200 mm.; the proper pendulum period=5 sec. The rate of motion of the record-receiver=4 cm. per min. Each instrument has oil damper.

9. Time of Commencement: 11h. 58m. 44s. This is the mean value of the times given by all available instruments in the institute. Time is kept by the three chronometers; namely, Nordin No. 1479, Frodsham No. 3548, and Russel No. 7102, each being compared with the time signal given by the Tokyo Astronomical Observatory every Monday and Thursday.

10. Initital phase. It made a displacement of 1.0 mm. eastwards, 1.1 mm. northwards and 0.3 mm. upwards in 2.3 sec. This gives N 42° E upwards as the apparent direction of the initial phase, and N29° E upwards as its corrected value.

As the direction of the initial phase is very important in determining the origin, I should enumerate the data given by other sensitive instruments. Thus the horizontal pendulum seismograph of the vibration period of 35 sec. and with the magnification index of 15 times registered the initial movement as much as 0.56 mm. eastwards and 1.27 mm. northwards, giving N 24° E as the resultant direction. The observation by the following two pairs of seismograph is regarded to be more important:—

I. Omori's instruments with the magnification indices of 15 times in the E. W. component(1) and 20 times in the N. S. component(2) showed the initial displacement of 0.12 mm. towards the east and 0.24 mm. towards the north in 1.2 sec., giving the resultant direction of N 27° E.

II. Omori's tromometers with the magnification indices of 120 times in both components(3) showed the initial displacement of 0.098 mm. towards the east and 0.24 mm. towards the north in 1.2 sec., giving the resultant direction of N 22° E.

(1-4) For the instrumental constants, reference is to be made to Prof. Omori's Seismological Notes, No. 2, section 10, (ii), (v) and (viii).

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The initial phase registered by the above instruments may be a harmonic of that given by the 2-time magnification seismograph; the displacement corresponding to the latter was registered by the more sensitive instruments too, but the indices went out before the elongation was reached.

Thus taking the means of all these observations we obtain N 26° E as the direction of the initial movements at our institute.

Lastly I add the observation by vertical component seismograph of the magnification index of 20 times.(4) This instrument showed the initial displacement of 0.5 mm. upwards during the first 2.3 sec.

11. Duration of the preliminary tremors. We can without much hesitation put the beginning of the principal portion, that is, the rigid wave propagated from the origin, at *a* in the seismogram, where the earth-movements became suddenly big. This gives 12.4 sec. as the duration of the preliminary tremors, showing some coincidence with my own actual estimation. The datum given by another instrument registering the earth-movements in natural size in 13.1 sec., but it is less accurate.

12. The principal portion. The N.S. component is more conspicuous than the other components. It indicates three distinct waves *abc*, *cde* and *efg* each with a period of 1.35 sec. Just at the end of these vibration, the writing index went out of the record-receiver. Fig. 2 shows the resultant horizontal earth-movement corresponding to these three waves, the E. W. component being also taken into account. The displacement *fg* is equal to 8.86 cm., from which the intensity of the earth vibration comes out to have been about 1/10 of the acceleration of gravity. This must be regarded as the max. intensity of the earthquake motion at the site of the Tokyo Imp. University. During this epoch the vertical component did not exceed more than 1 cm.

After that time, the earthquake motion was only registered by the E. W. component. From its diagram as well as that given by an after-shock which took place at 5 h. 22 m. (G. M. T.) on the same day and originated very near to the first destructive shock (see fig. 8), it seems that later the motion became much greater but slower, and possibly there existed an enormously large vibration with a range as great as 20 cm. and a period between 2.5 and 4 sec. During the first two minutes, the motion was most conspicuous, and the following 8 min. the next.

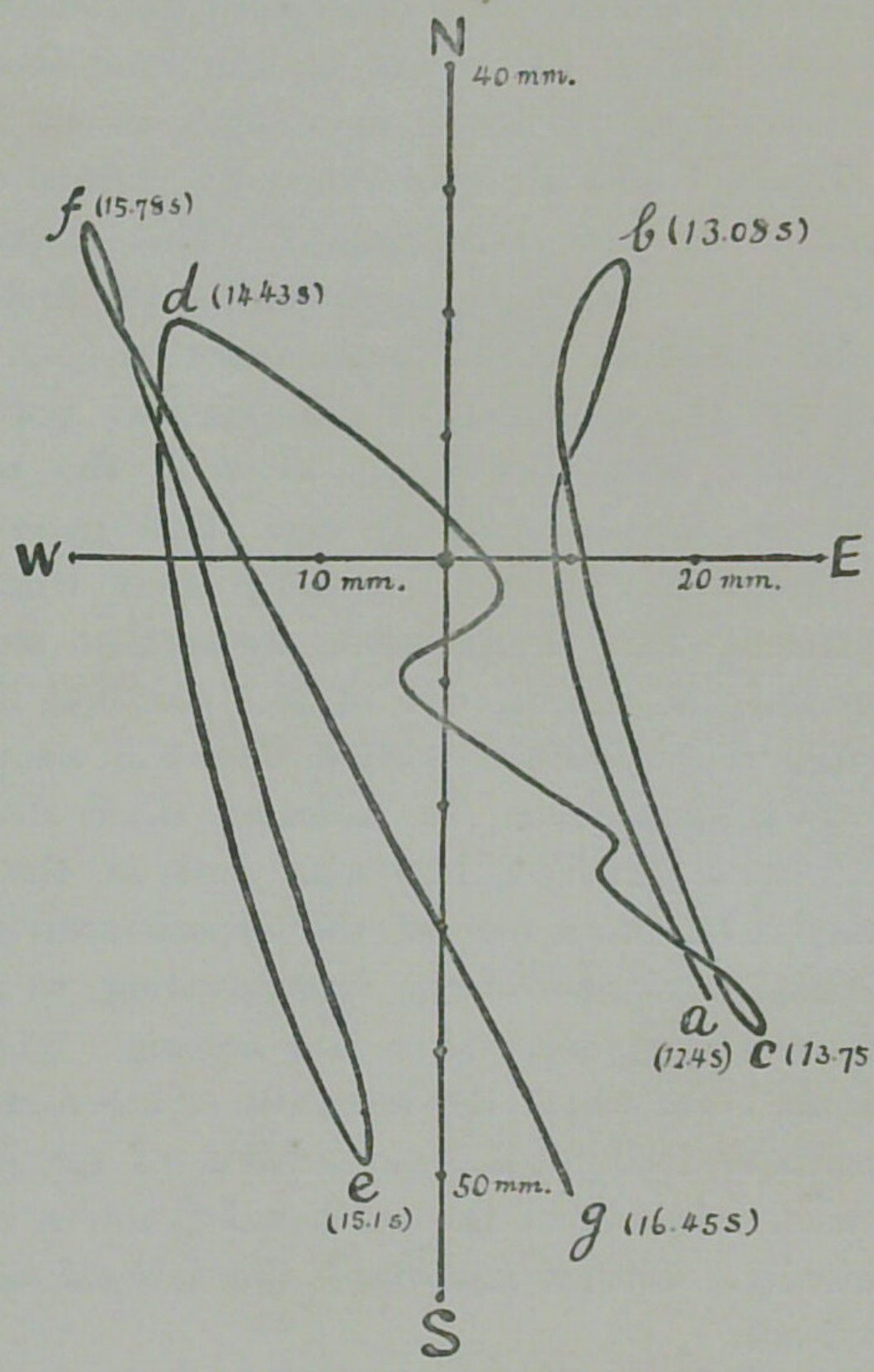
13. The end portion. Before the earthquake motion was yet finished, there took place many after-shocks, some of which attained to the category of semi-destructive nature. Consequently the end portion of the first shock was often masked by those after-shocks, and therefore it is impossible to

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estimate the exact time of the final phase. Prior to the earthquake of 5h. 22m., very minute slow undulations are recognizable; this may perhaps correspond to the latter part of the end portion, so that I assume 2 h. 20 m. as the durations of the total earthquake motion.

14. The origin. From the data given above, I put the origin, that is the place where earthquake action began, at a point 92 km. distant in the direction of S26°W from Hongo, Tokyo. Combining the initial horizontal displacement (=1.5 mm.) with one-half of the vertical component (=0.25 mm.), we get 10° and 15 km. as the rough estimation of the dip and depth of the origin respectively. The coordinates of the epicentre turn out as follows:—

Fig 2. The resultant horizontal movement at the commencement of the destructive earthquake on Sept. 1, 1923.



$$\lambda = 139° 21'.8\ \text{E}, \qquad \phi = 34° 58'.6\ \text{N}.$$

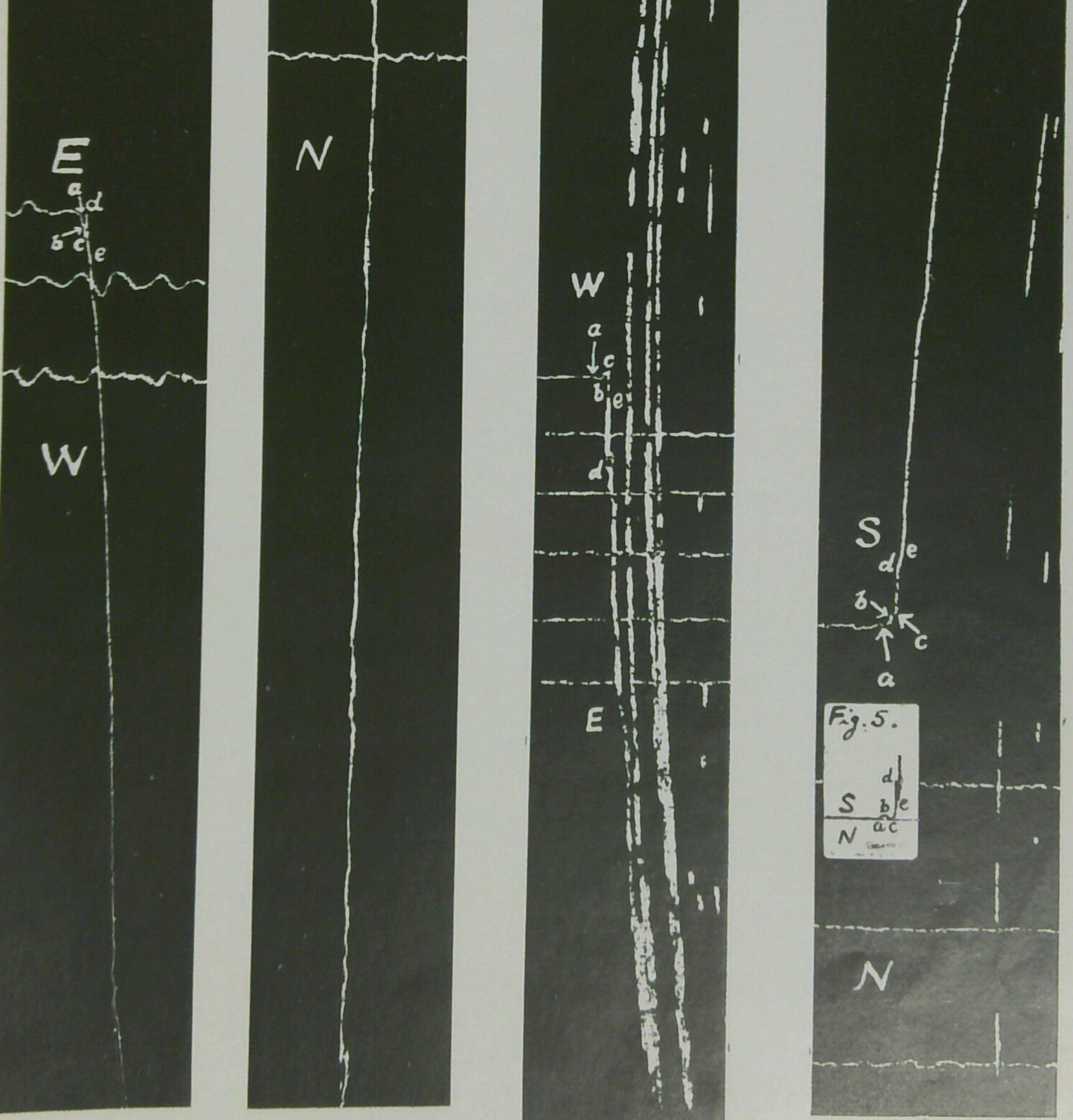
It must, however, be added that there are a few investigators who put the origin in the western part of the Province of Sagami.

15. Observations in the different meteorological stations. The annexed table shows the result of observations at the different meteorological stations. The time of commencement of the earthquake motion is to be regarded as generally correct within a few seconds though there may be certain exceptions. As to the direction of the initial phase, I have examined the seismograms myself, and, when there was any ambiguity, studied them by the copies photographically magnified. The following are the two extraordinary examples of such studies:—

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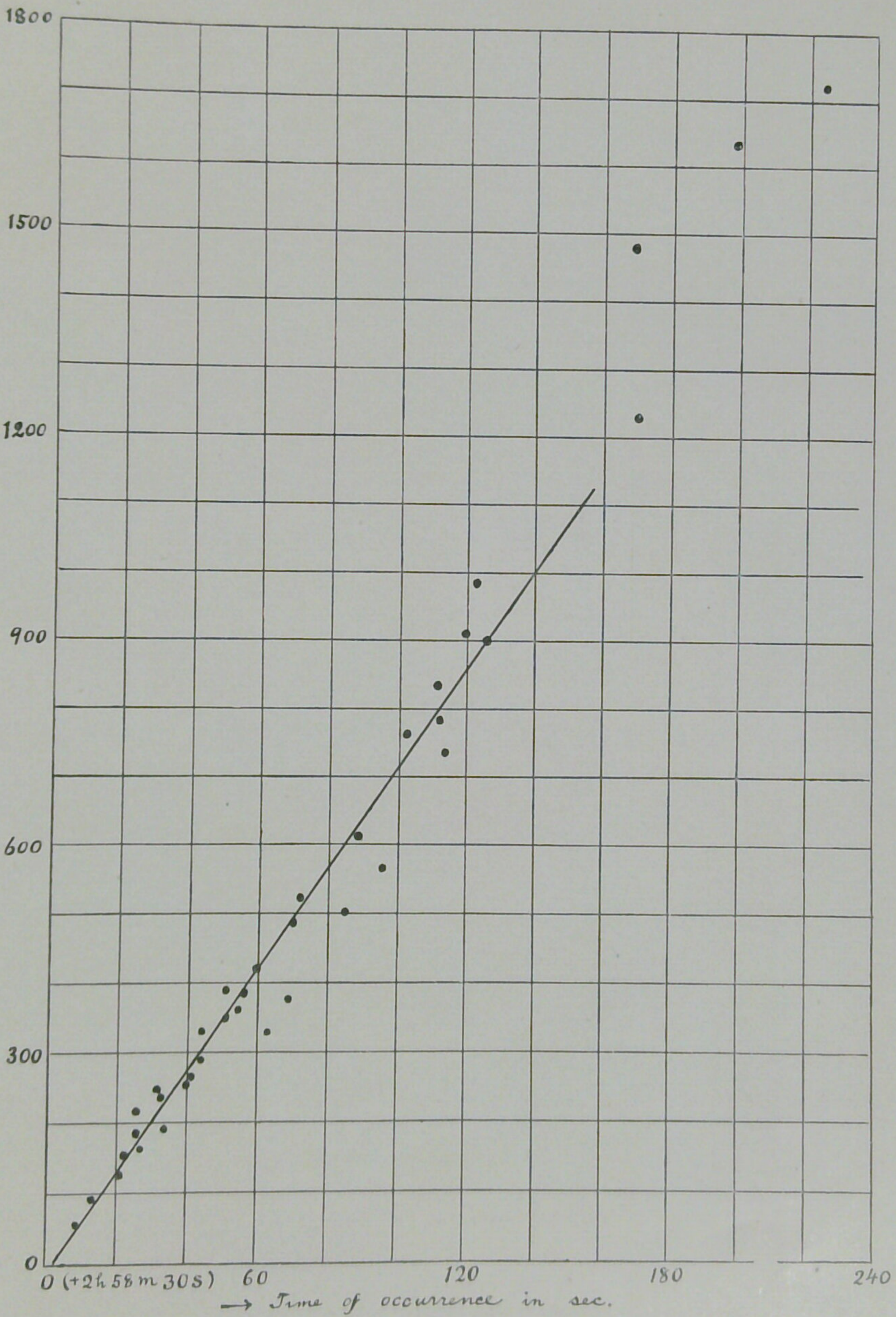
Fig. 3. Mera Observation.
Magnification = 100.
Speed of the record-receiver
= 93 mm : 1 min.

Fig. 4 Numadu Observation.
Magnification = 100.
Speed of the record-receiver
= 92 mm : 1 min.



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Fig. 6. Graph showing the relation between the time of occurrence and the focal distance.



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Mera seismogram. In comparing both components (see fig. 3), sudden displacements starting from d towards the west in one component and towards the north in the other seem to correspond to one another, then the displacements cd and bc in one component have each their correspondence in the other, while the displacement ab in the E. W. component is represented in the N. S. component by no movement. Thus the direction of the initial phase in Mera should be regarded as due west. (There is another assumption, namely, that the displacement ab in the E. W. component and bc in the N. S. component correspond to one another. This would give N24°W as the direction of the initial phase.)

Numazu seismogram. Here the seismogram (see fig. 4.) shows that the N. S. component pendulum was in an unstable condition; the writing index was making displacement towards the south by itself. At the arrival of the earthquake motion, that index seems to have begun its own southward displacement registering earth-movements on its way but never showing the northward displacement. I am of the opinion that the seismogram in this component, if the instrument had been correct, would have been as shown in the annexed diagram (fig. 5). So I have been obliged to estimate the direction of the initial and the second waves in comparing $\frac{ab+bc}{2}$ and $\frac{cd+de}{2}$, which give S47°E and S68°E as the respective results.

16. The data implied in the table furnish a good example as to the relation between the time of earthquake commencement and the focal distance (see fig. 6). The time curve thus obtained is practically a straight line given by the equation $y=7.5x-16$, where y represents the focal distance in km. and x the time in sec. It gives 2h 58m 32s as the time of commencement at the origin, and 7.5 km./sec. as the transit velocity of the elactic wave in the vicinity of origin.

The direction of the initial phase is very important firstly in the determination of the seismic origin, and secondly in conjecturing the character of the seismic action. For the former, the observations at Mera, Numadu, Kohu and Tokyo are most important, especially the last in consequence of its having given the most accurate result and now I find that the coordinates of the origin already given do not require any correction. For the character of the seismic action, it is to be remarked that within a radius of 170 km. there exist four different sectors; namely, the first including Numadu, Mera and Tyosi, the second including Tokyo, the third including Kumagai and

Table I. Observations at the different meteorological stations.

Station.	Focal Distance.	Time of Occurrence.	Direction of Initial Movement	Station.	Focal Distance.	Time of Occurrence.	Direction of Initial Movement
		11h m s				m s	
Mera	43	— —	W	Sionomisaki	377	— —	S56°W
Numadu	49	58 39	S56°E S68°E	Kobe	386	59 26	——
Tokyo	92	44	N26°E	Sendai	390	21	N18° E
Kohu	107	—	N73°W	Wakayama	395	—	S 56°W
Kumagai	130	51	S23° W	Isinomaki	420	30	——
Tukuba	155	53	——	Midusawa	489	40	N
Hamamatu	155	—	S60° W	Okayama	500	55?	——
Maebasi	160	—	E 3°E	Tadotu	522	42	——
Tyosi	162	57	S83° W	Akita	529	—	N18°W
Mito	187	56	S17° W N38°E	Hamada	565	60 06	——
Matumoto	189	59 04?	N42°W	Matuyama	619	59 58	——
Nagano	216	58 56	N26°W	Oita	740	60 24?	——
Nagoya	228	—	S84° W	Hakodate	761	13	——
Takayama	232	59 03	S67°E	Simonoseki	781	22	——
Gihu	244	02	W	Hukuoka	839	22	——
Takata	257	10	N 5°W	Kagosima	903	36	——
Tu	264	11?	S73° W	Nagasaki	910	30	——
Hikone	287	14?	S83° W	Titizima	917	—	——
Kanazawa	303	—	N45°W	Kusiro	987	33	——
Kyoto	330	33?	——	Zinsen	1175	—	N14°W
Niigata	331	14	N 6°W	Odomari	1223	61 20	——
Kanayama	350	—	N18°E	Naha	1480	19	——
Yagi	350	21	S77° W	Tairen	1633	49	——
Osaka	360	24	——	Shanghai	1719	62 15	——
Yamaka a	275	39?	——	Taihoku	2037	61 49	N15°W

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Maebasi, and the fourth including Kohu. Of these, the first and third sectors showed the *pull* towards the origin, while the second and the fourth showed the *push* from it. It is also to be remarked that in all the other stations except Titizima the earth movements began by the *push*. Consequently the seismic action might have been applied in such a manner that the compression along a deep stratum was directed towards the north and the west, while the counter action took place in the upper side along the sectors which showed the *pull*.

The effects on land and sea.

17. Statistics of the casualties and the distribution of seismic intensity. Table II shows the number of casualties in the different prefectures. Table III shows the number of casualties in the most disturbed cities, towns and villages, those in which the ratio of the number of destroyed houses against the total number of the existed houses was each less than 1% being omitted. The distribution in space of the percentage of destroyed houses serves to indicate roughly the distribution of seismic intensity. These data are useful in determining the isoseismal lines. (See fig. 7.)

18. In order to obtain some concrete data as to the seismic intensity, I visited the most disturbed area and studied the effects of shocks on buildings, bridges, short and tall columns, etc., with special attention as to the direction of the principal earth movements. I will give a few examples in the next paragraphs.

19. In Kodu a very simple flat wooden house of the ground area of 4m.×4m. was displaced as much as 91 cm. towards N 25° E. In Odawara, a single-storied wooden house of the ground area of 8m.×5m. was displaced as much as 35 cm. towards N 13° E: a similar one of 10m.×10m. as much as 130 cm. towards N 10° E; and another of 7m.×7m. as much as 75 cm. towards N 10° E. In this town, houses as a rule were collapsed towards the south and mostly took fire; only a narrow area escaped the flames and some houses therein made displacements as I have just described. These enormous displacements seem to have been done in some cases by a single stroke and in other cases by many-fold strokes. Such phenomena can be explained by assuming a strong horizontal vibration accompanied by big vertical one (up and down motions accompanied by north and south ones respectively), as, for example, horizontal acceleration $=\frac{1}{2}g$ and vertical acceleration $=\frac{1}{4}g$.

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Table II. Number of casualtis in the different prefectures due to the earthquake of Sept. 1, 1923.

Prefecture.	Perished.	Wounded.	Missed.	Houses				
				Completely collapsed	Half collapsed.	Burnt up.	Washed away.	Total (except half collapsed).
Kanagawa. (incldiug Yokohama & Yokosuka)	29065	56269	4002	62387	52863	68569	136	131592
(Yokohama)	23440	42053	383	11615	7992	58981		70496
(Yokosuka.)	540	982	125	8300	2500	3500		11800
Tokyo. (including Tokyo City)	68215	42135	39304	20179	34632	377907		398086
(Tokyo City)	59065	15671	1055	3886	4230	366262		370148
Tiba.	1335	3426	7	31186	14919	617	71	31904
Saitama.	316	497	95	9268	7577			9268
Yamanasi.	20	116		1763	4994			1763
Siduoka.	375	1243	68	2298	10219	5	661	2964
Ibaraki.	5	40		517	681			517
Nagano.				45	176			45
Totigi.		3		16	2			16
Gumma.		4		107	170			107
Total.	99331	103733	43476	128266	126233	447128	868	576262

Table III, a. Number of collapsed houses in the different localities most severely damaged.

Locality.	Existed houses.	Collapsed houses.	%
Kanagawa Pref.			
1 Yokosuka	16245	8300	51.1
2 Hinosita	630	151	23.9
3 Ookagawa	599	383	64.0
4 Byobuura	479	103	21.5
5 Kanazawa	914	328	35.9
6 Muturanosyo	745	171	22.9
7 Kamakura	2498	2102	84.4
8 Kosigoetu	735	415	56.5
9 Kawaguti	739	285	38.5
10 Muraoka	220	78	35.4
11 Hukazawa	300	157	52.3
12 Tamanawa	290	43	14.8
13 Kosaka	685	450	65.7
14 Tokuta	836	437	52.2
15 Kawakami	450	160	29.1
16 Nagano	177	46	26.0
17 Nakagawa	623	128	20.5
18 Seya	581	51	8.8
19 Nakawada	745	338	45 3
20 Taisyô	450	140	31.1
21 Toyoda	350	58	16.6
22 Hongô	488	112	23 0
23 Taura	3616	368	10 2
24 Uraga	3427	1710	49.8
25 Kurihama	757	162	21.4
26 Kitasitaura	655	127	19.4
27 Dusi	1948	812	41.7
28 Hayama	1426	472	33.1
29 Nisiura	939	147	15.7
30 Takeyama	431	45	10.4
31 Misaki	1910	227	11.9
32 Minamisitaura	1083	120	11.1
33 Hatuse	612	105	17.2
34 Nagai	880	81	9.2
35 Hudisawa	3076	2413	78.5
36 Tigasaki	3223	1815	56.3
37 Koide	588	400	68.0
38 Samukawa	850	567	66.7
39 Gosyomi	677	400	59.1
40 Arima	628	600	95.5
41 Ebina	882	470	53.3
42 Ayase	924	600	65.0
43 Sibuya	766	136	17.8
44 Mutuai	660	223	33.8
45 Mizo	682	35	5.1
46 Zama	924	54	5.8
47 Yamato	674	57	8.5
48 Oono (K.)	815	42	5.1
49 Ooiso	1649	222	13.5
50 Hiratuka	2883	1387	48.2
51 Suma	1387	454	32.8
52 Oono (N.)	1034	758	73 2
53 Asahi	449	339	75.5
54 Tutisawa	488	370	75.8
55 Kokuhu	697	362	52.0
56 Aduma	1225	529	43.2
57 Isehara	742	322	43.4
58 Takaboya	625	189	30.2
59 Hibita	554	228	41 2
60 Kaname	485	198	40.8
61 Okazaki	292	263	90.2
62 Kaneda	201	84	41.7
63 Toyoda	257	105	40.8
64 Kizima	270	112	41.5
65 Oota	396	270	68 2
66 Naruse	472	195	41.3
67 Hatano	2013	544	27.0
68 Higasihatano	720	148	20.3
69 Matuda	728	180	24 7
70 Nakai	807	255	31.6
71 Kamihatano	329	76	23.1
72 Yadorigi	313	45	14.4
73 Kaminaka	200	60	30.0
74 Yamada	151	82	54 3
75 Soga	480	430	89.5
76 Kaneta	317	120	37.8
77 Yosidasima	238	16	6.7
78 Sakurai	259	180	71 2
79 Okamoto	670	190	33.4
80 Minamiasigara	618	43	6 9
81 Hukazawa	449	86	19.2
82 Sakata	319	45	14.1
83 Kawa	1215	280	23.0
84 Kitaasigara	315	33	10.5
85 Kyôwa	124	12	9.7
86 Atugi	962	505	52.5
87 Nanmori	665	187	28.1
88 Tamagawa	430	52	12.1
89 Konyu	615	77	12.5
90 Tumata	146	35	24.0
91 Sanda	170	9	5.3
92 Hodogaya	4264	1514	26.2

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Table III, b.

Locality.	Existed houses.	Collapsed houses.	%	Locality.	Existed houses.	Collapsed houses.	%	Locality.	Existed houses.	Collapsed houses.	%
93 Sirogô	952	166	17.5	124 Kataura	752	76	10.9	154 Yokoyama	565	32	5.8
94 Ootuna	765	91	11 9	125 Manaduru	1258	263	20.9	155 Inagi	664	47	7.1
95 Asahi	633	64	10 1	126 Yosihama	604	307	50.8	156 Turukawa	834	46	5 5
96 Turumi	3450	227	6.6	127 Doi	625	172	27 5	157 Minami	698	57	8.2
97 Sioda	3457	1020	29 6	128 Tuda	874	79	9.0	158 Matida	1026	132	13.1
98 Tazima	2397	950	39.6	129 Nitta	553	32	5.8	159 Tadao	926	73	7.9
99 Daisi	1695	535	31 6	130 Nakagawa	552	54	9.8	160 Sakai	783	52	6.6
100 Kawasaki	5015	1250	24 9	131 Niihara	760	57	7.5	Tiba Pref.			
101 Miyuki	1617	93	5 8	132 Yokohama	93840	11615	12 4	161 Tigusa	595	32	5.4
102 Hiyosi	590	64	10 8	Tokyo Pref.				162 Tôkai	471	120	25.5
103 Nakahara	770	102	13 3	133 Oomori	4089	1000	24 4	163 Unakami	488	36	7.4
104 Takatu	930	47	5 0	134 Haneda	2562	500	19.5	164 Yôrô	586	50	8.5
105 Tatibana	379	32	8.4	135 Rokugô	836	55	6 6	165 Toda	559	204	36.5
106 Aone	201	14	6 9	136 Magome	430	104	24.2	166 Meidi	770	165	21.2
107 Odawara	4835	890	18.4	137 Suginami	1053	60	5 7	167 Nakagô	535	95	17.8
108 Asigara	2005	1361	67 9	138 Iogi	730	55	7.5	168 Nekata	522	27	5.2
109 Toyokawa	255	209	82 0	139 Minamisendyu	13932	2128	15 3	169 Kohitu	1046	53	5.2
110 Kamibunaka	339	170	50 2	140 Iwabuti	3542	212	5.9	170 Nakagawa	400	105	26 2
111 Simohunaka	272	203	74.6	141 Ozi	9272	4000	43,2	171 Tomioka	547	48	8 8
112 Simosoga	324	317	97 8	142 Mikawasima	6260	1500	23.9	172 Yaehara	441	60	13.6
113 Tazima	141	107	75 9	143 Ogu	1654	605	36.6	173 Susai	520	74	14.2
114 Simonaka	482	388	79 9	144 Sendyu	7506	600	7.9	174 Nakamura	441	79	17.9
115 Maeba	432	100	23 2	145 Umezima	620	35	5.7	175 Koito	505	36	7.1
116 Kôdu	705	279	39.6	146 Ayase	472	14	9 3	176 Sadamoto	425	121	28.5
117 Sakawa	1079	736	68 2	147 Hanabata	681	58	8 5	177 Iino	437	173	39 5
118 Ookubo	583	126	21 6	148 Ioki	235	19	8.1	178 Aohori	635	90	14.2
119 Yumoto	545	61	11 2	149 Kamoido	9922	1000	10.1	179 Huttu	811	96	11.8
120 Onsen	374	80	21.4	150 Oosima	5892	600	10.2	180 Yosino	480	54	11.2
121 Miyagino	328	59	18.0	151 Aduma	6730	400	5.9	181 Oonuki	487	149	30.5
122 Sengokuhara	132	25	18.9	152 Terasima	5559	500	9.0	182 Sanuki	725	123	17.0
123 Hakone	197	40	20.3	153 Sunamati	2847	280	9.8	183 Minato	741	144	19 4

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Table III, c.

Locality.	Existed houses.	Collapsed houses.	%
184 Tenzinyama	504	32	6.6
185 Takeoka	612	46	7.5
186 Kanaya	482	63	13.1
187 Hôdyô	1553	1502	96.7
188 Tateyama	1678	1456	86.7
189 Nisizaki	787	107	13.6
190 Kanbe	555	197	35.5
191 Nagao	658	71	14.0
192 Toyohusa	720	314	43.5
193 Tateno	500	478	95.5
194 Kokonoe	466	372	79.5
195 Inamiya	327	209	63.9
196 Nago	900	870	96.7
197 Hunakata	1071	625	61.6
198 Yatuka	341	71	20.8
199 Tomiura	1035	690	66.8
200 Iwai	840	325	38.7
201 Katiyama	923	179	19.4
202 Hoda	1129	264	23.4
203 Takita	461	99	21.4
204 Kôhu	374	300	80.2
205 Tikura	1278	503	40.2
206 Titose	723	538	74.2
207 Takeda	540	427	79.0
208 Toyoda	540	381	70.6
209 Maru	758	165	21.8
210 Kitamihara	414	27	6.5
211 Minamimihara	486	328	67.5
212 Emi	524	90	17.2
213 Tahara	465	45	9.5
Saitama Pref.			
214 Miyamoto	450	73	16.2
215 Muturi	659	229	34.8
216 Omagi	450	38	8.4
217 Warabi	1125	77	6.8
218 Toda	799	129	19.9
219 Siba	580	132	23.3
220 Sôka	1053	126	12.0
221 Kamino	669	69	10.3
222 Noda	435	24	5.5
223 Totuka	349	55	14.3
224 Angyô	528	104	19.7
225 Sinden	418	149	35.7
226 Kawaguti	3272	488	14.9
227 Yokozone	929	61	6.6
228 Nanpata	546	28	5.1
229 Muneoka	394	29	7.4
230 Ikusa	313	48	13.0
231 Idemaru	390	33	8.5
232 Kyôwa	345	28	8.1
233 Haramiti	515	39	7.6
234 Genwa	404	36	8.9
235 Iwatuki	1407	58	5.4
236 Toyoharu	410	78	19.0
237 Kasukabe	1180	209	17.7
238 Kawadôri	429	107	23.5
239 Takesato	510	157	30.7
240 Sakurai	403	68	16.7
241 Masibayasi	631	36	5.7
242 Oohukuro	475	44	9.3
243 Ogisima	410	33	8.0
244 Niiwa	485	84	16.9
245 Dewa	444	151	34.0
246 Oosagami	514	61	12.8
247 Satto	1018	276	27.5
248 Yasiro	521	47	9.0
249 Tamiya	451	53	11.7
250 Sugito	632	46	7.3
251 Teigô	329	28	8.5
252 Kômatu	562	93	16.3
253 Toyono	388	29	7.5
Yamanasi Pref.			
254 Huzimi	439	70	15.9
255 Kamisone	188	24	12.7
256 Siraikawara	96	6	6.3
257 Kazikazawa	973	68	7.0
258 Asumi	839	76	9.1
259 Osino	393	27	6.4
260 Nakano	285	65	22.8
Siduoka Pref.			
261 Ito	2282	219	9.6
262 Usami	592	33	5.6
263 Aziro	550	114	20.8
264 Taga	450	71	15.8
265 Atami	1381	155	11.2
266 Inno	254	14	5.5
267 Gotemba	1496	302	20.2
268 Takane	425	108	25.4
269 Kitagô	708	316	44.6
270 Oyama	2767	446	16.1
271 Asigara	2591	237	9.2

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20. The railway bridge at Isibasi had two rows each of seven girders laid in the direction of S 15° W, the eastern row being not yet connected with rails; each of the disconnected girders except one at the centre let fall its northern end and hung at the other end like a ladder. Some piers were fractured near their bases, each upper part making a twist counterclockwise about an axis near the western edge of the pier.

The sererest damage, however, to railway bridges was suffered by that at the River Banyu. Here all the brick piers were broken near the water mark and overturned longitudinally towards the lower stream, or speaking more precisely, towards S 28° E in average. The locality extending from here to Hudisawa showd an intensity as much as $\frac{1}{3}$ of g or more, with the direction of motion roughly parallel to that in Tokyo.

21. In Kamakura, the seismic intensity varied in the different places according to the geological structure of the situation, having been maximum in the sandy district near the coast with a possible intensity as much as $\frac{2}{5}$ of g, and minimum in the district of tertiary formation. The Daibutu, a famous big bronze monument of the sitting Buddha, sank as much as 45 cm. in the side of S 15° E and was displaced as much as 30 cm. towards the depressed side. Here the temple gate showed a counterclockwise rotation of 10 and a displacement of 20 cm, towards N 5° W, while that at Komyozi was displaced as much as 50 cm. towards N 35° W. Afterwards I installed two seismographs, one at the ground of Kanagawa Normal School—representative of the tertiary formation—, and the other at the villa of Prince Simadu —representative of the sandy district— in order to compare their difference of seismic intensity. I have observed a surprising result that the latter place is shaken in cases of near earthquakes as much as 5 or 6 times more than the former, notwithstanding that the mutual distance is only 2.3 km.

22. In Bo-so Peninsula, the sandy district around Hodyo showed the max. intensity which is almost equal to that in the district of the same geological nature at Kamakura. Here the phenomena of displacement were observable in a few simple houses, but their amount did not exceed 30 cm. The direction of the principal earth-movements seems to have been SE-NW for the most parts in the peninsula.

23. The ground of the City of Tokyo shows equally the variety of the seismic intensity. Previously I have drawn a map showing the distribution of intensity in Tokyo, taking into account the results experienced in the cases of the destructive earthquake in 1855 and the semi-destructive one

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in 1894, the geological structure, the history of its formation as residential land, and the seismographic study of the four different places in or near the city. Soon after the last catastrophe I took up this problem again, and began to study the phenomena not only by means of the seismic effect on buildings in the city including the burnt area, but also by means of seismometric comparison of the aftershocks at 32 stations in the city. This implies very troublesome work, meanwhile I mention only a few interesting results; namely, firstly, the intensity distribution differs according to the nature of the shock, especially according to the vibration period of the earthquake waves; secondly, the soil of alluvial formation, especially the made-ground, is shaken fully three times as intensely as the ground of diluvial formation at Hongo; and thirdly, this difference of intensity is due not only to the difference of amplitudes of the earth-movement but also to the difference of the vibration periods which are generaly shorter in the alluvial soil of the lower town than in the harder diluvial ground.

24. Similar difference was observed in the City of Yokohama. In the lower parts of the town, like Isezakityo, the seismic intensity is likely to have attained to $\frac{2}{5}$ of g, while the same was only $\frac{1}{6}$ to $\frac{1}{4}$ of g in the diluvial ground on the hill. The severe damage to the softer ground may also be due to its irregular subsidence.

25. Lastly, it must be remarked that the fact that the seismic intensity was moderate (say $\frac{1}{10}$ of g) in the area covered by tertiary formation or solid volcanic rock in the peninsulas of Bo-so, Miura and Idu notwithstanding their having been very near the origin, is to be well understood from the nature of the rocks against the seismic waves as it has been shown in the result of observation at two different seismic stations in Kamakura.

26. Change of landscape and sea-bottom. Thousands of conspicuous land slides took place in Miura and Idu Peninsulas, the southern part of Bo-so Peninsula and the mountainous district of south-western Sagami, the most fearful having been the mud-flow which buried the whole village of Nebukawa in the N. E. part of the Province of Idu. The most remarkable phenomena, however, of this kind is the upheaval of the land which showed itself along the coast of the disturbed area. The recent bench-mark survey undertaken by the Survey Department of the Imp. Military Staff has furnished us with the following results :—

1. In the City of Tokyo, subsidence less than 5 cm. has taken place

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to the west of the River Sumida, and that measuring 38, 28 or 35 cm. to the east of it.

2. In Bo-So Peninsula, upheaval has taken place generally; namely, 8 cm. at Hunabasi, 11 cm. near Tiba, 15 cm, near Yawata, 32 cm. near Kisaradu, 69 cm. near Huttu, 91 cm. near Sanuki, 121 cm. near Takeoka, 134 cm. near Katiyama, 157 cm. near Hodyo, 182 cm. near Kokonoe, 99 cm. at Kamogawa, and 51 cm. at Kominato.

3. In the south of Tokyo, upheaval has begun near Kawasaki and has been continued as follows: 10 cm. near Yokohama, 75 cm. near Hudisawa, 85-90 cm. in Kamakura, and 139 cm. at the tidegauge station of Aburatubo in Misaki.

4. From Hudisawa to the west and then to the south-west along the coast, upheaval has taken place as follows; 105 cm. in Tigasaki, 182 cm. at Oiso, 201 cm. near Umesawa, 188 cm. at Kodu, 121 cm. near Odawara, 72 cm. near Manaduru, 10 cm. near Atami, 14 cm. near Aziro, and 5 cm. in Ito.

The above data were obtained under the assumption that the standard bench mark at the ground of the Military Staff did not undergo any change, but it is likely that it suffered a depression of about 50 mm., if the level shown at the tide-gauge station of Aburatubo be taken as the standard.

27. In comparison to such upheaval of land, quite startling is the change of the sea-bottom in Sagami Bay, which was discovered by elaborate work of the Imp. Naval Hydrography. The result is shown in fig. 7, in which only the elevation and depression exceeding 30 m are represented, those less than that amount being omitted. It is estimated that the area and volume of depression have amounted to 700 sq. km. and 50 cu. km. respectively, and those of elevation to 240 sq. km. and 20 cu. km. in all. This result was obtained after surveys had been carried out at 83286 points distributed in the area between Tyosi in the east and Suruga Bay in the west, and between Tokyo Bay in the north and Miyake Is. in the south, and comparisons made with the results of the former surveys carried on mostly during the year 1912, corrections due to the tides of the different periods and meteorological disturbance being of course taken into account. This result, however, seems to require further examination.

28. Lastly, I should add a few words about fault lines. Possibly a remarkable fault might have taken place in the bottom of the heart of Sagami Bay, but so far it has not been discovered. Two minor faults of a secondary nature have been found, one near Nagasawa in Miura Peninsula running towards N 60° W, and the other near Nago in Bo-so Peninsula

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running towards E. by S. Each fault extends for a distance of about 2 km. and has the maximum vertical dislocation of only a metre. (Prof. Yamasaki is said to have discovered another fault near Yokohama).

29. Tunami, or tidal waves. Tunami in its strict scientific meaning were observed not only in the Pacific coast of Japan but also far beyond it. Disasters caused by them, however, were only experienced at a few sea-side places bordering Sagami Bay, as follows:—

Atami (height 12 m.), Ito (height 8 m.), Aziro (height 8 m.) and Ainohama (height 9 m.). In these places, the flood washed away some houses and vessels and caught people and cattle. The northern coast of Osima, the southern coast of Miura Peninsula, and the coast between Kamakura and Enosima were also visited by waves of the heights of about 8 m., 6 m. and 4. m. respectively, but without much resultant loss. According to the observation of Tateyama Meteorological Station, the wave ebbed a few minutes after the shock had been experienced as low as about 7 m. below the former level, and after 5 min. it flooded as high as 2 m. above the former mark; during the next 15 min. it ebbed again as low as 3 m., and 15 min. later it had flooded again as high as 1 m.; after this the waves become less and less, but were observable until 2 o'clock in the afternoon. Here it must be remarked that the new level soon after the first shock must be lower by 1.6 m. than the former one.

30. The height of tunami is not so big in an open sea; it only increases itself when it approaches gradually into shallow water and enters into a v-shaped port. According to Dr. Ikeda, the height of the tunami at Atami was only 1.5 m. at its two promontories, and 3 m. midway between the northern promontory and the corner of the port, while it attained to the enormous height of 12 m. at the corner. Similar observations were made by him as to the tunami at Aziro and Ainohama.

31. One more interesting investigation by Dr. Ikeda was on the direction of wave propagation. In Atami, the tunami come in from ENE and was principally reflected towards the opposite direction except its southern part which was reflected towards ESE. In Aziro it was propagated from NE and was reflected eastwards. In Ainohama it came in from W. and its northern part was reflected towards the opposite direction, while its southern part was reflected towards S. or SW. Comparing these modes of wave propagation with the map of submarine change, it will be found that wherever the tunami came from, there lies unmistakably an area of conspicuous elevation in the sea-bottom near by. Thus the present tunami seems to have been mostly caused by the elevation or its gradient of the sea-bottom,

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those enormous depressions playing only a small part in producing tunami which rose in flood above the original sea-level.

32. Some inhabitants of Osima observed in its western coast two tunami propagated soon after the first shock one from the north and the other from the south, which met one another in front. This can readily be understood in comparing the fact with the above-stated map which shows elevation in the north and depression in the south across the strait between Idu and Osima.

The cause and the seismic zone.

33. So far I have described the seismic phenomena which may probably help us in imagining the real cause of the earthquake in question. The enormous depression and elevation of the sea-bottom in the heart of the Sagami Bay indicates that this area was the seat of the extraordinary commotion which took place thereabout at a certain depth. Possibly a fault line, as I have stated before, might have been produced along or across the boundary of the areas of depression and elevation, containing the seismic focus in it. I have already given my view as to the way of the application of stress, but I hope more reasonable explanation in this subject may be given by other more eminent experts.

34. I am now going on to consider the seismic zone in which the last great shock was seated. The focal areas of the three destructive earthquakes which took place on Sept. 1, 1923, on Dec. 31, 1703, and on Sept. 2, 1923, form one continuous belt in themselves, and this belt is very likely to be a part of the great seismic zone running along the Pacific coast of Japan. It is acknowledged that Japan Island received during certain geological epochs a horizontal stress from the south-east along the line in which the Huzi volcanic chain now lies, so that the seismic zone crossing this line might naturally undergo a strain towards the north.

The secondary cause and the presages.

35. The secondary causes and the presages accompanied by the last shock can be enumerated as follows; namely, the lowering of the water level in well, abnormal eruption of geysers, the crossing of a low barometric pressure along Hokurokudo towards Kinkuasan in N. E. Japan and consequently the development of a secondary low pressure in the northern part of the seismic area, etc.

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36. It must also be remarked that there were some evidences showing the existence of the fundamental cause before the occurrence of catastrophe. One is the recent active state of the dependent seismic zone, and the other is the gradual upheaval of the seismic area.

Of the first, let us enumerate many big earthquakes which took place in the same zone during the last few years. They are shown in the following table:

Table IV. Recent big earthquakes in the Pacific Seismic Zone.

No.	Date.	Origin.	Remark.
1	1918. Sept. 8.	Off Uruppu Is.	Accompanied by tunami.
2	1919, May 3.	Off the coast of N. E. Japan.	
3	1921, June. 2.	Off the S. coast of Etoroku Is.	
4	1921, June. 22.	Off the S. coast of Hokkaido.	
5	1921, Oct. 12.	Off the S. coast of Kunaziri Is.	
6	1923, Feb. 2.	Off the coast of Kamtchatka.	Accompanied by tunami.
7	1923, March. 22.	Ditto.	Ditto.
8	1923, Aril. 14.	Off the S. coast of Kunaziri Is.	
9	1923, April. 27.	Off the coast of Hidaka.	
10	1923, April. 27.	Off the coast of N. E. Japan.	
11	1923, June 2.	Off the coast of Hitati,	

The last mentioned quake is noteworthy. It was accompanied by a dozen of fore-shocks, was so big that the double amplitude of the earth-movement at Hongo was as large as 6.6 cm., and originated on the same seismic zone in the distance of 250 km. from the seat of the last destructive shock on Sept. 1.

No remarkable fore-shock seems to have accompanied the last catastrophe. Only a few shocks were registered in August at Hongo as follows: two unfelt on the 7th, one unfelt on the 17th, and one slight on the 24th. All these originated in or near Sagami Bay.

37. The gradual upheaval of the land was very definitely shown by the tide gauge register at Aburatubo in Misaki. Here the annual mean sea-level was gradually lowering itself during the years 1920-1922, while those at Ayukawa, Wazima and Kusimoto were moving in the opposite sense and parallel to one another. This means that the land of Aburatubo was elevated as much as the difference of the levels indicated by the stations of two categories; and that is equal to 15 cm. Further, the monthly means

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in the last year show the same tendency, indicating at Aburatubo an upheaval of about 10 cm. during the two months before the catastrophe. This amount, however, requires some correction due to meteorological causes.

After-shocks.

38. Hitherto the after-shocks which have been studied by different investigators have related, as far as I am aware, to those in which the fundamental shock was simple, such that its after-shocks originated within definite limits and in a narrow space. It is, however, quite different in the present case. Not only the seismic focal area was very wide, but another destructive earthquake belonging to the same seismic zone took place on the next day and both mingled their after-shocks together. Consequently I have divided the area of the origin into the following three different localities :—

A. The area including the Bay and the Province of Sagami as the main part.

B. Bo-so peninsula and the vicinity of its S. E. coast.

C. The drainage district of the River Tone.

Such classification is based upon the following reasons :—

1. The destructive shocks on Sept. 1 and that on Sept. 2 at 2h 47m were of almost equal size but quite different in their origins.

2. Distributions of the after-shocks were geographically quite distinct in the two systems of Bo-so and Sagami.

3. Distributions of the principal after-shocks in time were quite distinct in the two systems.

4. Earthquake originated in the drainage area of the River Tone is not to be treated as pure after-shock in the strict sense, though I am treating it so in the wider sense only for the sake of convenience.

5. Geographical distribution of the earthquakes which have originated in the vicinity of Tokyo during the years 1914-1922 is quite similar to that of the present after-shocks.(1) This coincidence may perhaps be due to the geological construction of the stage.

39. Tables V and VI have been constructed according to the above view. I am of the opinion that the frequency curve of after-shocks should be treated as to represent the energy fluctuation, but I had scarcely any time for such study. Mean while it is reserved for another opportunity.

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(1) Refer to Prof. Omori's Seismological notes, No. 2.

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Table V. Tokyo Observations of the destructive earthquake in S. E. Japan and its principal after-shocks.

No.	Date	Time of occurrence. (G. M. T.)	Duration.			Strongest movement.		Epicentre.	
			Prel. tremors	Principal portion.	Total.	Range.	Period.	Longitude. (E)	Latitude. (N)
1	Sept. 1	2h 58m 44s	12.4	10	140	88.6	1.35	139 21.8	34 58.6
2	1	3 01 49	9?	<5	(?)	60?	2.0	139 28 (?)	35 10 (?)
3	1	3 17 47	12.0	1.5	>5	4.8	2.4	139 02 (?)	35 02 (?)
4	1	3 24 00	7.2	1.2	7	48.0	1.2	139 19.0	35 25.0
5	1	3 30 20	6.5	0.2	1	8.5	0.5	140 00	35 50.0
6	1	3 36 48	7.4	0.5	2	7.5	2.0	140 05	35 54.0
7	1	3 40 20	9.1	3	>8	39.4	2.0	139 31.7	35 03.8
8	1	3 48 03	13.3	3	>20	57.6	2.0	139 26.4	35 09.7
9	1	4 58 32	12.8	2.5	30	6.1	1.7	140 20.2	40 00.5
10	1	5 22 49	12.9	3	60	21.2	1.5	139 32.1	35 07.5
11	1	7 38 21	12.0	3	15	59.3	4.0	139 00.0	35 20.0
12	2	2 46 55	16.2	4	100	69.7	2.3	140 20.0	30 40.0
13	2	5 10 21	6.4	1	20	9.1	1.2	140 00.0	35 32.7
14	2	9 27 04	11.3	3	>20	57.6	2.6	140 32.0	35 27.6
15	2	9 49 02	12.0	3	20	9.1	2.3	140 37.5	35 23.8
16	2	13 09 29	17.0	2.5	30	45.5	4.6	139 42.2	35 07.0
17	2	14 16 46	12.3	2.2	20	9.1	1.5	139 27.5	35 14.1
18	26	8 24 03	16.0	3	80	26.0	2.3	139 28.3	34 40.7
19	Oct. 3	15 54 29	11.1	1.3	30	10.2	0.8	139 04.6	35 18.6
20	5	13 05 46	9.3	3	30	3.7	0.8	139 07.3	35 24.6
21	Nov. 4	20 45 51	7.0	1	20	15.0	0.5	139 20.0	35 31.8
22	23	2 33 52	8.8	2	10	7.8	0.8	139 29.4	35 15.4
	1924.								
23	Jan. 14	20 50 24	10.2	4	60	59.0	1.8	139 16.6	35 26.2

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Table VI. Number of after-shocks registered at Hongo, Tokyo, during the month of September, 1923.

Locality. / Intensity* / Date. †	A			B			C			Uncertain			Total.
	I	II	III	I	II	III	I	II	III	I	II	III	
1	2	2	9	—	—	—	—	—	2	146	52	—	213
2	1	—	2	1	9	3	—	—	—	149	12	—	177
3	3	—	—	7	—	—	2	—	—	93	—	—	105
4	1	—	—	3	—	—	1	—	—	81	—	—	86
5	2	—	—	3	—	—	1	—	—	72	—	—	78
6	3	—	—	3	—	—	1	1	—	57	—	—	65
7	2	1	—	3	—	—	—	—	—	55	—	—	61
8	1	—	—	5	2	—	1	—	—	76	—	—	85
9	—	—	—	6	1	—	—	—	—	57	—	—	64
10	—	—	—	—	1	—	—	—	—	38	—	—	39
11	1	—	—	4	—	—	—	—	—	40	—	—	45
12	3	—	—	—	—	—	—	—	—	20	—	—	23
13	—	—	—	2	—	—	—	—	—	24	—	—	26
14	1	—	—	1	—	—	2	1	—	19	—	—	24
15	—	1	—	—	—	—	2	1	—	14	—	—	18
16	—	—	—	1	—	—	1	—	—	9	—	—	11
17	2	—	—	1	1	—	—	—	—	11	—	—	15
18	—	—	—	—	—	—	1	—	—	7	—	—	8
19	2	—	—	—	—	—	—	—	—	16	—	—	18
20	2	—	—	2	—	—	—	—	—	7	—	—	11
21	2	—	—	3	—	—	2	—	—	23	—	—	28
22	—	—	—	2	—	—	—	—	—	9	—	—	11
23	—	—	—	—	—	—	—	—	—	4	—	—	4
24	—	—	—	—	—	—	—	—	—	3	—	—	3
25	—	—	—	—	—	—	—	—	—	3	—	—	3
26	—	—	1	2	—	—	—	2	—	7	—	—	12
27	1	—	—	2	—	—	—	—	—	7	—	—	10
28	—	—	—	3	—	—	—	—	—	2	—	—	5
29	2	—	—	—	—	—	1	—	—	4	—	—	7
30	1	—	—	—	—	—	—	—	—	—	—	—	1
Total	30	4	12	54	14	3	15	5	5	1053	64	0	1256

* I.... slight, II....moderate, III....strong. † Japanese time.



Fig. 8. Tokyo Observation of the Earthquake of Sept. 1, 1923: 5 h 22 m 49 s.

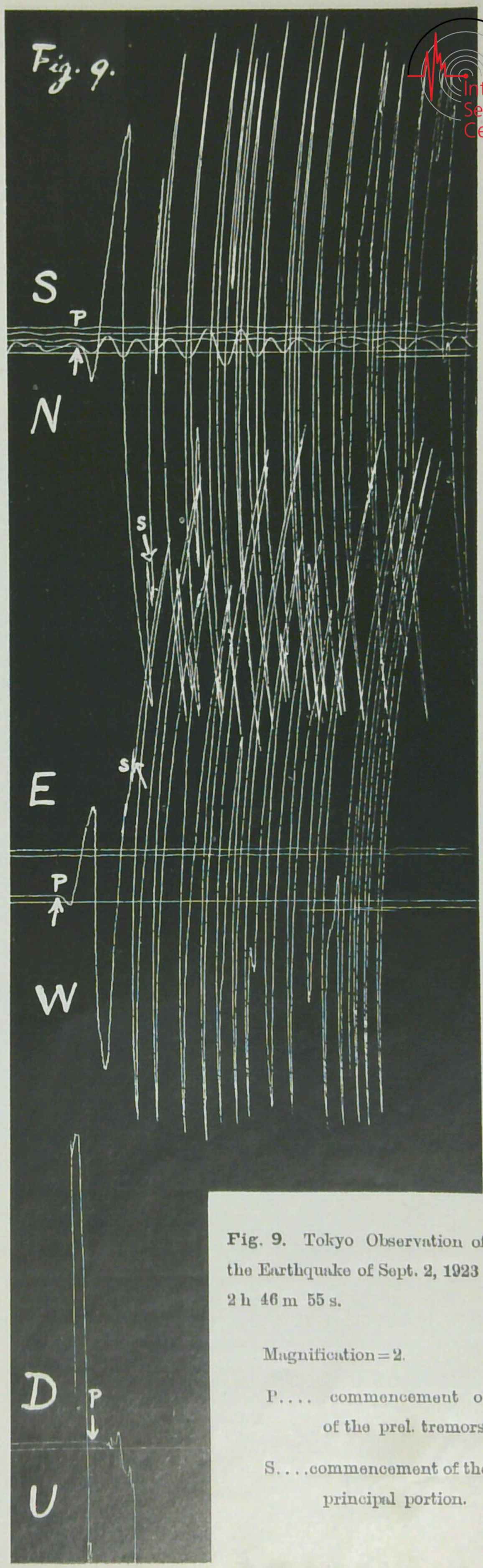


Fig. 9. Tokyo Observation of the Earthquake of Sept. 2, 1923 : 2 h 46 m 55 s.

Magnification = 2.

P.... commencement of of the prel. tremors.

S....commencement of the principal portion.

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