The Tazima Earthquake of 1925.

By

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(*With plates I–XVIII.*)

1. Outline sketch.

The earthquake which shook the northern part of the province of Tazima, lying on the Japan Sea, at about 11 h on the morning of May 23rd, 1925, resulted in the destruction of 3400 houses with a death toll of 428 lives. It was indeed a semi-worldshaker, and of such magnitude that the seismic waves generated were perceptible to seismographs half way round the globe. In marked contrast with this, however, the meizoseismal area was quite small, for on following the lower reaches of the Maruyama river (also called Asago river), it embraced an area no larger than 16 km. E-W by 20 km. N-S. The origin was in all likelihood near the cove of Tuiyama situated at the outlet of this river where it discharges into the Japan Sea, so that another meizoseismal area of equal extent must have extended to the northward of this place.

While the meizoseismal area practically comprised the soft, damp ground forming both banks of the Maruyama river, the region surrounding it consisted of hard igneous rocks and old sedimentary rocks. The two last-named being poor shock-absorbers, acted as favourable media for the transmission of seismic waves, a fact which presumably had no small influence in the distribution of the seismic intensity.

The energy of the vibrations upon leaving the meizoseismal region of soft rocks and entering the hard rocks surrounding it, immediately fell off in intensity, and the isolated patches of high intensity scattered here and there, such as we have been accustomed to associate with the general run of earthquakes, were very few in number. Although the seismic intensity abruptly diminished in its progress in the manner just stated, it maintained thenceforward an uniform rate of energy for a considerable distance. (See Pl. I and II.)

Perhaps the most noteworthy feature of this earthquake is the fact that, unlike in most earthquakes, the meizoseismal area was sharply marked off from the other areas, one of the contributing causes being no doubt the differences in their respective geological characters, that surrounding the meizoseismal area being virtually a barrier wall of granite and liparite.

As shown on Pl. I, there were two centres of maximum destructivity in the meizoseismal area, one in the southern part of it in the town of Toyo-oka and the other in the northern part along the shore of the cove of Tuiyama. In the former the comparatively heavy damage suffered, as shown in the tables annexed, was due to two causes—extremely soft nature of the ground composing the region and the faulty construction of the houses, although as a matter of fact the seismic intensity here ought to have been less than at places situated on the mouth of the river. As to the northern part of the meizoseismal area, whereas in the town of Kinosaki the houses were also of bad construction, the effects of maximum destruction were observed in the village of Tai forming a part of Minato-mura despite the fact that this region is of Tertiary formation, all of which would seem to imply proximity to the origin. Or we might regard it as the epicentre, but in the absence of definite information concerning changes in the adjoining sea-bed, the question will have to be left in abeyance. However, a post-seismic survey of the region has been made by the Naval Hydrographers (Report no. 33, Imperial Naval Hydrographic Dept.), thus providing us with much valuable data for reference and study, but what displacements have been observed were in no case so great that we could hardly deny them as due to probable errors, neither were there any tidal waves registered by the tide-guages so that we will not be far out in assigning the origin to the neighbourhood of the coast along the cove of Tuiyama, situated just at the point where the Maruyama river empties into the Japan Sea. In support of this conclusion we might mention the newly formed Tai fault, and also the manner of distribution of the aftershocks about the region as personally experienced by the writer during his four days stay in the district which ended May 31st. As to instrumental determinations of the origin, those based on records furnished by a few observatories located at no great distance from the affected area, indicated in the main a point quite close to Tai as the likely origin.

TABLE I. Casualties.

Prefecture	Town or village	Preseismic		Burnt houses	Collapsed		Semi-collapsed houses	Damaged houses	Total	Killed	Wounded	Remarks
		dwellings	population		houses	%						
Hyôgo	Toyooka	2,178	11,097	1,483	489	25	30	122	2,124	87	293	Conflagration
	Hatidyô	368	1,910		13	4	42	224	279	2	7	
	Nitta	480	2,449		28	6	121	301	450	1	3	
	Mie	408	2,527		15	4	50	225	290		8	
	Taduno	444	2,311		102	23	118	208	428	8	13	
	Gonosyô	677	3,293		56	8	20	421	497	5	9	Hanya hamlet burnt
	Utikawa	305	1,642		61	10	50	79	190	11	13	
	Kinosaki	702	3,410	548	30	50	10	16	604	272	198	Conflagration
	Minato	813	4,434	148	438	72	142	93	821	33	243	Tuiyama hamlet fire
	Takano	648	3,540		31	5	61	199	291		8	
	Nakasudi	498	2,761	1	8	2	40	254	303		4	Severest in Kaya hamlet
	Nakatakano	405	2,531				11	394	405			
	Kasumi	1.055	6,135					53	53			
	Kutisatu	528	3,326		1		5	368	374			
	Kokuhu	701	3,370		3		23	309	335		4	
	Nasa } Sansyo }									2	1	
	Total	8.151	42,750	2,180	1,275		723	3,266	7,444	421	804	
Kyôto	Kumihama	458	1,927		20	4	50		70	7	30	
Total				2,180	1,295		773	3,266	7,514	428	834	

TABLE II. Seismic observations at the different stations.

Station	P or $\overline{P}$ 11h	Dur. prel. tre.	intensity (Mercalli)	Dir. initial phase	Remarks
	m s	s			
Tokusima	9 06	19	5	S	Sharp, pendulum clock stopped.
Kyoto	44	16	5	NW	Aftershocks, pen. clock stopped.
Toyooka	57		11	S26° W	$\overline{P}$.... 11.0 mm. S, 0.5mm. W.
Niihama	10 00		3		
Tu	02	23	4	W	Aftershocks, vert. mot. pron.
Koti	04		3		
Tadotu	04	22	5	ESE	Gentle.
Yagi	05	25	5	NW	Sharp.

TABLE II (*Continued*).

Station	P or $\overline{P}$ 11h	Dur. prel. tre.	intensity (Mercalli)	Dir. initial phase	Remarks
	m s	s			
Okayama	07	71	4	SSE	
Hikone	08		4		Pen. clock stopped.
Sumoto	09	16	5	SSE	
Hamada	12	35	4	NNE	
Hukui	12	17	4	SE	Pen. clock stopped.
Wakayama	14	20	5	S	Gentle.
Takayama	16	31	0	WSW	
Husiki	16	26	3	SW	Gentle.
Gihu	17	22	3	WNW	Pen. clock stopped.
Sisaka-zima	18		3		
Sionomisaki	19	32	3	SSE or NNW	Gentle.
Turuga	20		4		
Kure	21	34	4		
Kanazawa	27	15	3	SW	Gentle.
Matumoto	28	41	0	SE	
Nagano	30	44	3	ENE	Sharp.
Matuyama	31	33	4	NNE	Gentle.
Iida	36		0	W	
Takata	38	47	0	ESE	
Numadu	39	49	1	SW	
Simonoseki	42	45	0	WSW	Sharp.
Kohu	44	46	4	WNW	Gentle.
Tokyo	45	65	1		
Kumagai	46	53	1	ENE	Gentle, aftershock.
Utunomiya	48	62	0		
Niigata	49	62	2	NE	Gentle.
Tukubasan	50		0		
Maebasi	50	56	0	SW	
Yokohama	51	61	1		
Mera	54	62	0	WSW, ENE	
Mito	57	67	0	ESE	
Nagasaki	59	77	0	WSW	Gentle, aftershock.
Hukuoka	11 00	58	0	W	
Saga	00	81	1		
Miyazaki	02		0		

TABLE II (*Continued*).

Station	P or $\overline{P}$ 11h	Dur. prel. tre.	intensity (Mercalli)	Dir. initial phase	Remarks
Tyosi	$11^m\ 05^s$	80^s	0		
Yamakata	05	82	0		
Kagosima	13	92	0		
Midusawa	17	86	0	NE	

We shall now proceed with the results of our investigations made in the affected area.

Toyo-oka town. Coincident with the earthquake fires started from three different places but fortunately they were easily extinguished. However, two hours later, namely, at about 13 h 30 m, fire starting from an overturned house next door to the post-office spread rapidly and consumed two-thirds of the town, including most of the principal buildings. It is generally held that the reason for the fire having assumed such dimensions was due to the fact that the local fire-brigade after having quelled the first fire, had relaxed their vigilance to such an extent that when the second fire-call came they were quite unprepared for immediate response, thus causing loss of much valuable time. Also the streets leading to the scene of the fire were so blocked with prostrated houses and other debris that traffic was greatly impeded, if not prevented altogether. These circumstances interfered somewhat with our own investigations into the damages caused by the earthquake as apart from the fires. On the other hand fortunately, Dr. T. Matuzawa, Assistant Professor of the Imperial University, Tokyo, in charge of a number of students from the Seismological Institute were on the spot so that full investigations concerning the fires, their origin and extent besides meteorological conditions and various other matters were duly taken in hand by them, as can be seen from their reports already published, so that it will not be necessary for me to dwell on them in this paper. (See Pl. XVI) The action of the Meidi Fire Insurance Co. in promptly despatching an official to conduct full investigations regarding the conflagration on the lines initiated by one of our members, Prof. Seiji Nakamura, at the time of the great Kwanto earthquake cannot be too strongly commended. With the permission of the said company we have incorporated into this report as a supplement, their charts for which favour, as well as for the many valuable and interesting photographs loaned us, we take this opportunity of expressing our sincere appreciations. (See Pl. XVII and XVIII.)

We are thus already in possession of much valuable information regarding the damaged condition of the town of Toyo-oka so that I shall here merely confine myself to a bare description of conditions as I found them.

From a general inspection of the devastated district my opinion is that the proportion of houses destroyed as a direct result of the earthquake was from about one-third to one-fifth of the original total (see Pl. VIII–X). On the street facing the railway station and extending for about five blocks east to west, about 90% of the houses were overturned, and in the case of two-storeyed structures most of the lower storeys had collapsed, leaving the upper storey to fall to the ground quite intact (Pl. IX), the direction of fall always being westwards. This section of the city was formerly a lot of paddy fields recently filled in with some five feet of earth, hence newly made ground, which fact was responsible for the heavy damage, but what contributed still more to it was the very defective construction of the houses. In looking over the ravaged areas a noticeable feature was the preponderance of destruction on the streets that ran in an E-W direction, especially so in the newly made ground above mentioned, whereas in the streets which were at right angles to them, the damage suffered was much less notwithstanding the fact that many of them stood on soft ground. This led to the current belief that the earthquake moved in an E-W direction. From my own investigations the direction of the main phase seemed to be from W by N to E by S or from WNW to ESE, so that there would seem to be a modicum of truth in the popular idea, but in settling this question it behoves us to take first of all careful note of the general method of house construction in vogue in this section of the country. Pl. X, Fig. 3, shows a house that was being built at the time of the earthquake and which might be taken as typical of the manner of construction in vogue. In the building of these houses, after the supporting pillars have been placed every meter apart for each of the right and left hand side walls, ties are run through them horizontally also a meter apart, then strengthened by small wedges and the whole then plastered over, but for the sides at right angles to them (one of them, the back, is seen facing us in the photograph) there is no pillar at all between the two end corner posts.

Obviously such a structure will offer considerable resistance to a shock coming in a direction parallel to the protected walls, but they will be positively at its mercy should the motion come from a direction at right angles to them. In the latter case the resistance will probably be no more than one-tenth of that in the former. It follows then that houses so constructed are safe for earthquake motion in one direction only, but dangerous when it comes from a direction perpendicular to it so that they are not earthquake-proof.

Now since the earthquake motion was practically in an E-W direction, houses, which faced the streets running in the same direction, obviously had their protected walls perpendicular, and their unprotected walls parallel, to the direction of the street and consequently with the earthquake motion, with the result that much damage was suffered, whereas houses facing streets that ran in a N-S direction escaped with little or no damage. However, even in the case of houses of the former class, those that had several supporting pillars in the interior partitioning walls in an E-W direction withstood the shock as in the case of the one seen left standing in the foreground of Pl. X, Fig. 2.[1] It should also be noted that with houses facing streets running N-S, although the walls that were parallel to the longer axis of the house suffered no damage, those forming the shorter axis were in several instances put out of plumb.

Kinosaki. This town is a watering place situated along a small valley of Tertiary formation and has six thermal springs in a line with the river course. Of its 700 houses a large number were hotels, mostly three-storeyed with a sprinkling of four-storeyed buildings. While the houses built directly on local rock free of loose surface soil were not so affected, those built lower down on comparatively soft ground following the river course collapsed mostly at the junction of the first and second storeys with the upper storey intact, so that two-storeyed houses became one-storeyed and three-storeyed houses became two-storeyed as shown in Pl. XI, Fig. 3 and 4. Under these conditions fires naturally broke out from a number of places. With the big shock it started from five different sources which soon after increased to eight. Flying sparks and cinders helped to spread the conflagration, and within about four hours the major portion of the town consisting of 548 houses was laid waste with a casualty list of 272 lives. Pl. XI, XII and XVII will

1) Although not shown in the photograph, this particular house had several pillars in the required direction in the partitioning walls in the interior of the house, so that it was saved.

help to convey some idea of the havoc wrought, not even forests escaping the ravages of the all-consuming fires. The proportion of ruined houses as a direct result of the earthquake, however, does not seem to have exceeded 50% of the original total as an examination of Pl. XVII. An idea of the appearance of a house escaped from a fire can be gained by comparing Pl. XI, Fig. 3 which was taken before, with Fig. 1 of Pl. XII taken after, the fire on May 29. Although I took up my headquarters on the second floor of the abandoned Kinosaki Hotel, there were several other buildings temporarily abandoned but which could well have been used as a makeshift.

Momosima is a hamlet situated on the other side of a hill forming the northern boundary of the spa town of Kinosaki, with the greater part of itself built on a filled up swamp. The damage here was unduly heavy with even a case of a house that shifted bodily from its foundation (Pl. X, Fig. 4). Not very far from here a portion of a railway track subsided, causing temporary suspension of traffic, but all railway damages were repaired with amazing alacrity so that by midnight of the eventful day traffic on all the lines were functioning. The loss from damages within the compounds of the two stations of Kinosaki and Toyo-oka, including that of the station buildings, was estimated to reach *Yen* 200,000, the comparatively small damage being largely due to their having been situated on hard ground.

There were rumours to the effect that the hotsprings of Kinosaki had undergone changes, so in order to verify them I made personal examinations of the springs at 17 h on the 29th of May and obtained the following results:—

Dizo-yu	(spring)	49°.0C
Itino-yu	,,	59°.6
Mandara-yu	,,	59°.8
Kôno-yu	,,	48°.6

which being their normal temperatures, no changes have taken place, a most fortunate thing indeed for this town and which will largely determine its future reconstruction possibilities.

Minato-mura. As this group of hamlets was in the epicentral region the damage caused by both earthquake and fire was very great as can be seen from Table III. At Tuiyama, one of the hamlets, the northern part of it comprising more than a half of the entire hamlet was wiped out, leaving intact only a new temple that was in course of erection (see Pl. XVIII). In the central part of this hamlet about a quarter of the total number of houses were either shaken down or else badly damaged, while in the southern section there was an equal proportion of houses damaged, although very slightly. At the hamlet of Seto, also, despite the hard nature of the ground, the damage was very great, particularly so at the Kôsai primary school (Pl. XIII, Fig. 1 and 2), where a beam at the entrance of the building fell and crushed a boy to death. On the left hand side of Fig. 2 in the same photograph is shown the roof of a sheltered playground, which also fell in and crushed five young people to death. The chief causes underlying the heavy damage to the school have been treated by Mr. Taniguchi (report in Japanese), but what arrested my attention when I visited the spot was that a portion of the space covered by the school building was newly made ground where an earth-fissure had formed running right underneath the building. When this fissure opened it naturally tore the building asunder. There were also constructional defects in the building itself with simply aggravated matters. As to the southern wing of the building which was left standing, we found that it was resting on rock without the usual mantle of loose soil, and where we could not detect a single earth-crack. Thanks to the good material employed in this part of the building the only effect of the shock that we could discover was a slight canting of the building towards the north, but as its ability to withstand aftershocks was apparent, our party did not hesitate to spend a night on the upper floor. As to the aftershocks that were felt here by us that night, and also on the following morning, they will be taken up in a later paragraph.

The village office of Minato-mura is shown in Pl. XV, Fig. 4 and is a substantially built ferro-concrete structure, such that it was claimed to be a model of what such offices in Japan should be. Beyond a few insignificant cracks on the walls the building came through the severe ordeal quite unscathed, with the result that in the days immediately following the earthquake it was utilized considerably by various investigation parties and others, but the undignified action of these people in scampering pell-mell out of the building on the occasion of every aftershock, thus augmenting the then nervous tension of the ignorant populace, was very thoughtless to say the least.

Tai. In this hamlet 82 out of a total of 83 dwellings were thrown down, leaving unharmed only a two-storeyed Young Men's Club building. There were left standing, besides, a warehouse and a temple, but all the dwelling houses proper were demolished (see Pl. XV, Fig.

TABLE III. Casualties in Minato-mura.

Hamlet	Population	Dwellings						Killed	Wounded
		total	burnt	collapsed	semi-col.	damaged	col. %		
Kozima	390	83	0	23	52	6	28	1	5
Seto	574	116	1	48	53	14	41	4	33
Tuiyama	1377	250	145	68	37	0	85	19	82
Kei	1129	191	2	92	*70	27	85	6	15
Tai	494	83	0	67	*15	1	99	7	46
Hatakami	317	59	0	10	*24	25	57	0	0
Mihara	153	31	0	1	*20	20	68	0	0
Total	4434	813	148	309	271	93	72	37	182

* Repair incapable.

1 and 2). Unfortunately, it was the season for rearing the silkworm with the result that the inmates of 36 of the houses were making use of charcoal fires for the purpose, so that immediately after the big shock, fire broke out in three different places, while smoke was seen to be issuing from several others. At the same time pitiful cries for help could be heard coming from several quarters from underneath the fallen beams and other heavy material, but those who were able got together and promptly set to work to put out the fires before attempting any rescue work. After the fires had been put under control attention was concentrated on the extrication of the unfortunates pinned under the fallen buildings, whereupon 58 out of a total of 65 persons were saved.

In the case of most earthquakes, after a preliminary tremor lasting from 7 to 10 seconds comes the big shock, but at Tai the preliminary tremor lasted only a second or two, or three seconds at the most, which helps to confirm the report that these seven who were killed were found to have died in the very act of their occupations, in other words death was instantaneous owing to the suddenness of the principal shock. Now, since the greater the shock the greater is the casualty proportion likely to be, credit for this small casualty list must be given to the wisely directed efforts of the inhabitants in first fighting the fires before undertaking rescue work, for if the fires had been allowed to hold full sway, as was the case at Toyo-oka, Kinosaki and Tuiyama, the death-list would have been far greater, to say nothing of the inevitable heavy losses in property. If on the other hand these good people had reversed the order of things and taken up rescue work first, their success would have been limited, since much time would have occupied the work of rescuing the people imprisoned under fallen roofs, beams and such heavy material, so that hardly before anything could be accomplished the fires would have rapidly advanced and swept everything before them. For the poor unfortunates a little delay in rescue would have been nothing compared with the deadly fire peril. This experience drives home to us in an eloquent manner the importance, in the event of a destructive earthquake, of first fighting the fires before proceeding with the rescue work, as a step towards reducing the casualties to a minimum. To show how well the people of Tai were provided in the matter of fire control, we learnt that there was even a female fire-corps equipped with a gasolene fire-engine. Obviously, it is only with such ideas and equipment on the part of the citizens that earthquake emergencies can be met in a proper and efficient manner.

It was in this region that the so-called Tai fault (Pl. I and XIV) was discovered, and in regard to which I shall make only a few remarks, referring the reader to Professor N. Yamasaki's valuable paper following the present report.

The fault is on the top of a hill, the highest part of which is 231 meters, and lying to the north of the village of Tai. There were formed two fault lines almost parallel to each other and running in a direction SW to NE for a distance of nearly 1500 meters, the distance separating the two being about 400 meters at the widest part. A view of the hill as seen from Tuiyama is reproduced in Pl. XIV, Fig. 4. The spot on the hill where a landslide occurred forms one end of the fault line, and Fig. 1 and 2 show where the western fault line traverses a grove of willow trees, the making of willow wicker baskets being an important industry here. While the vertical dislocation here was only 20 cm. and the horizontal shift (the western side towards the south) not more than 6 cm., there were places where the vertical shift, or throw, was as much as 1 meter. Fig. 3 is a continuation of the same pictures and shows the formation of a trench, the spot in the middle of the picture where a man is seen standing being the central part of the rift.

Some ascribe this dislocation to a mere surface movement but my opinion is that it is deepseated, as will appear in the next paragraph.

The hamlet of Kei suffered almost next to Tai, the loss being 161 houses out of a total of 191 with six persons killed. Here also fires broke out but with the aid of a gasolene fire-engine they were put out after two houses had been burnt down. From reports received later, it seems that very conspicuous earth-fissures were noticed at a place lying southwards of the primary school, and that for several days following the great shock warm water was being ejected from these fissures. The fact that these cracks were in a direction parallel with the Tai fault lends strong support to our conclusion that they were a continuation of the fault.

Kumihama. This is a town in Kyoto prefecture, and as is shown in Pl. XVIII, Fig. 2 destruction was confined almost to the central part of the town, particulary the soft grounds forming the river banks, but considering that it was distant only 8 km. from the epicentre, the damage sustained was small, being only 4% of the total. By the time the seismic energy had reached this place much of it must have been dissipated, but an interesting phenomenon in connection with the earthquake left its record in the sinking under 7 feet of seawater of a paddy field and a mulberry patch that were on either side of the mouth of the Kadurano-gawa, a stream discharging into the northeastern end of Kumihama Bay (see Pl. XV, Fig. 3). The area of these two fields was 25 acres, and while at some places the overlying depth of water was as much as 7 feet, the average depth was about 4 feet. These two spots were however nothing more than a sort of delta formed by deposits of soil and sand which had been accumulating for the last 10 years, and being only loosely held together, the earthquake simply shook them off so that they slid into the sea. Of almost equal interest was the production of a *seiche* in the northern half of the bay, brought about by the slipping of the two fields just described and resulting in waves as high as three to four feet.

Takano. This town is situated at the same distance westwards from the epicentre as Kumihama is situated from it eastwards and with pretty much the same proportion of houses thrown down. What claimed our attention here was the displacement made by the main sanctuary of the Takano shrine the shift being 16 cm. in a direction S 62°E.

Another interesting thing here was the yielding of a girder of the wooden bridge spanning the Takano-gawa river (Pl. XIII, Fig. 3). According to the village office people, one of their officials was just crossing the bridge when the girder gave way, whereupon he instantly ran for his life to the opposite side of the river, upon reaching which he found to his astonishment that the earthquake had already ceased completely—another proof attesting the extraordinary suddenness with which the big shock came and as suddenly went away.

2. Measurements of the earth-movements.

Although in most countries, including our own, observational methods for the rapid motion of distant earthquakes are in a fairly advanced stage of development, those for the fundamental slow motions of the same class of earthquakes, or for near earthquakes for that matter, do not seem to be receiving the attention they deserve at the hands of investigators. Personally, I cannot help deploring the unsatisfactory character of the seismograms of the recent earthquakes as obtained at various stations situated close to the scene of the disaster. The Osaka station possesses an Omori seismograph with which good records were obtained (Pl. V), but owing to instrumental defects the natural free vibrations of the pendulum are found to be mixed up with the preliminary tremors, so that to determine the actual ground movements is extremely difficult. In these circumstances the only course open is to confine our analysis first to such records, the comparative correctness of which we are reasonably certain, and then go on to the actual ground movements which took place at Osaka.

The Tokyo observations. At the Seismological Institute very valuable records were obtained with a horizontal seismograph having a self-vibration period of 33 sec. E-W and 30 sec. N-S and a magnification of 1.5 times. To this we have added the record given by a vertical component seismograph with a self vibration period of 12 sec. and magnification 20 times, the three traces being shown on Pl. III. We had, besides, two instruments with a self vibration period of 10 sec. and magnification 2 which gave fairly good results (Pl. IV), but soon after the commencement of the main phase rather large undulations crept in, thus proving imperfect damping and the necessity for considerable corrections. However, even were we to make the required corrections, it is necessary that we firstly consider the 1.5 times seismogram, the details of which are as follows :—

Magnification=1.5 times; time of commencement=11 h. 10 m. 49 sec.; duration of preliminary tremor=61 sec.; total duration=30 min.

The E-W motion.

Period of P		=10 sec.	Amplitude (a) of P		= 0.2mm. W
do. S		= 3.1 sec.	do.	S	= 0.8mm. E
Period of most intense phase (E)		= 3 sec.	Double amplitude ($2a$)		= 7 mm. E
do.	L	=13 sec.	do.		= 4 mm. E
do.	M	= 8 sec.	do.		=14.8mm. W

The N-S motion.

Period of P		=10 sec.	Amplitude very slight.		N
do. S		= 4 sec.	do.	= 0.8mm.	N
do. most intense phase	(E)	= 3 sec.	Double amplitude	= 3.6mm.	N
do.	L	=14 sec.	Amplitude	=14 mm.	N
do.	M	= 8 sec.	do.	=14 mm.	S

The resultant wave.

Direction of P by tromometer=E upwards.

Period of most intense phase	(E)	= 3 sec.	Double amplitude	= 7.9mm.
do.	M	= 8 sec.	Amplitude	=20.4mm.

The vertical motion (Diagram 3).

P=upward motion.

Period of most intense phase	(E)	= 3 sec.	Double amplitude	= 2.6mm.
do.	M	= 6 sec.	Amplitude	= 3.8mm.

Results from 2-time mag. instrument (Pl. IV).

Period of P			Amplitude of P	
do. S		= 4 sec.	do.	S=0.9mm. E; 0.8mm. N
do. most intense phase	(E)	= 3 sec.	Double amplitude	8mm. E; 3mm. N; (resultant wave 8.8mm.)
do.	M	=12 sec.	do.	23mm. E (resultant wave 31mm.)

In the 2-time mag. record above, the vibration periods of S, E etc., when compared with the free vibration period of the pendulum, is less than one third of that of the latter and by comparing same with the record of the 1.5 times seismograph, we see that it closely approaches the actual ground movement, thus rendering any correction unnecessary, but as the period of the M waves approached very closely the natural vibration of the pendulum, resonance effects were set up. Now assuming the earthquake motion to consist of sinusoidal waves, and introducing a correction for the resonance phenomenon with ratios of amplitudes of consecutive phases, the values of which are 2.17 and 1.97 in the E-W and N-S components respectively, then the amplitudes of the M phase in the E-W and N-S components together with that of their resultant come out as 11, 13 and 17 mm. The results thus obtained are very near those given by the diagram of the 1.5-time seismagraph.

The Osaka observations. (See Pl. V.) These were made by an Omori seismograph (natural size) having a free vibration period of about 4 sec. Details are

Time of commencement=11h. 10m. 4.4 sec.; duration of preliminary tremors=14.8 sec.

P. Towards W 0.7mm.; N 2mm.; downwards 0.5mm. Between *a* and *b* the natural period of the pendulum has twice obscured the traces of the actual ground movement, which fact can be confirmed by comparing the diagram with that of the aftershock of May 26th,

S. On the large natural vibrations, *c*, *f* and *g*, of the pendulum may be seen superposed the main phase movement which has made two complete swings back and forth.

The first wave $\bar{s}cd$—23mm. W; 8mm. S. Next 37mm. E, 3.5mm. N.

The second wave *def*—15.5mm. W; 8.5mm. S. Next 33.4mm. E, 27.5mm. N.

From here onwards the pendulum's own free vibrations cannot be disentangled from the true motions of the earth particle. From the foregoing data we have deduced the follownig elements:—

Direction of the initial tremor=N 20° W.

Double amplitude of the maximum earth-movement (assumed to be *cd*) =37mm. with a period of 1.6 sec. and direction E by N.

Although results of observations of the initial severe shocks are as above, those of the aftershocks made at the various stations were more satisfactory, especially those of Prof. Shida of the Kyoto University made with his new sensitive seismograph of 20,000 times magnification, which in a very brief interval recorded as many as 12,000 aftershocks. There are, besides, observations from the stations of Toyo-oka, Kobe and Osaka which we have tabulated in order to facilitate comparisons, and which will be found as an appendix to this report. I wish now to take this opportunity of sincerely thanking all those who so kindly sent us their observations. Although a note of dissatisfaction was sounded in an earlier paragraph concerning the seismogram that was sent us by the Osaka observatory, I should like to explain that the complaint had reference to the inefficient condition of the instrument and not with the members of the staff there, to whom, in particular, I feel bound to convey my appreciation of the good work done in spite of the handicap of a defective instrument.

When contrasted with the great Kwanto earthquake, the present one showed some distinct peculiarities, the outstanding one being the unusual short duration of the shaking. In the vicinity of the epicentre the duration perceptible without instrumental aid must have been about 20 sec. As for the duration of the preliminary tremor, around Kinosaki it was most likely some seconds, but at Minato-mura it could not have been more than from one to two seconds or at the most three seconds. For the main phase, the one that causes the destruction, it seems to have been a matter of only one or two complete swings back and forth. Actual experiences at the primary schools of Kei and Seto seem to bear out these conclusions. There is also the experience of the village official as already described, who on running for his life from a bridge whose girder gave way, to the opposite bank of the river a distance of 40 meters, found on his arrival there that all motion had completely stopped.

As regards the intensity of the earthquake, observers are practically unanimous in the opinion that in the vicinity of the epicentre it must have been about 40% of the acceleration due to gravity, but as to the period, or the amplitude of the said motion, there is a diversity of opinion. To take one example, there is Dr. Suda's figure, based on the personal experience of Mr. Yamazaki, Director of the Toyo-oka observatory, as well as on records of aftershocks, and from which he deduces 0.2–0.3 sec. as the period of the maximum phase. While I do not in the least question the verity of the said personal experiences, nor that of the observations of the aftershocks, I am sorry that I am compelled to admit difficulty in accepting this particular motion that has been considered by him as being the main motion which was responsible for shaking down buildings, those wooden ones that stood from two to four storeys in height, and as this question is an important one from the standpoint of practical seismology I shall discuss it fully.

Up to now there have not been many earthquakes in which the ground movements at or near the epicentre were measured by instrumental means. For Tokyo, we have had some two or three examples, but in none of them did the main phase, which is the motion that causes the destruction, have a period of less than from about one second. We find this exemplified in the case of the Tokyo earthquake of June 20th, 1894; in the Ryugasaki earthquake of Dec. 8th, 1921 (Pl. VI); in the Uraga Channel earthquake of April 26th, 1922 (Pl. VII), and finally in the great Kwanto earthquake of Sept. 1st, 1923. But even in these we shall find superposed on the main phase waves, small waves (ripples) which we might call "harmonics," but which ought not to be ignored. Turning our attention to the seismogram of the Uraga Channel earthquake selected for elucidation, the main phase shows a double amplitude of 59mm. with a period of 1.4 sec., but in addition to this, there is seen following it for an interval of some 10 seconds, a small wave having a total amplitude of 7 mm. and a period of 0.8 sec. This record was rejected by the late Dr. Omori as being imperfect and unreliable (Seismological Notes, No. 3, Art. 11) although I must confess inability to see anything the matter with it, for on comparing it with the diagram obtained by the Tanakadate strong motion seismograph (loc. cit., Pl. III, Fig 4) its trustworthiness is quite apparent. In our next example, the Ryugasaki earthquake, we find another important thing. This earthquake in its E-W motion registered 34mm. for its double amplitude in one single wave of period 3.6 sec., whereas in the N-S motion during the same interval, two waves are shown, which is to say that whereas for the first and second waves the double amplitudes are 29 mm. and 12 mm. respectively, the periods are for either case one half that of the corresponding E-W motion, namely 1.8 sec. These horizontal motions compounded give a parabolic curve as per diagram in Pl. VI. Possibly, doubts may be entertained as to whether or not this difference of periods in both components is, as in Melde's experiments, due to errors arising from natural vibrations inherent in the instrument, but when contrasted with the period of this motion, not only is the natural period of the seismograph three times that of the earth's vibration of 3.6 sec., but the record from a horizontal pendulum with a free vibration period of 30 sec. (Seism. Notes, No. 2, Fig. 5) is just the same as the register obtained with this instrument of 2-time magnification and period 10 sec., so that it does not seem as if the difference in periods in both components can be accounted for by any instrumental peculiarities. For this earthquake, besides the foregoing, there is recorded for several seconds following it, another small wave of double amplitude of 4 mm. and a period of about 0.8 sec.

In large earthquakes like the preceding the amplitude of the small wave, or ripples, is comparatively small, but as the earthquake diminishes in strength the period of the fundamental wave also diminishes. On the other hand, the small wave that is superposed on it becomes more and more pronounced, so that eventually the fundamental wave is recognised only with difficulty. Under these conditions the period of the main phase of a small earthquake becomes reduced to the order of one second or thereabouts.

As the probable reason for this I venture to submit the following:— In any earthquake the fundamental waves, together with their harmonics, are propagated from the focus, but the period of the former varies with the energy of the original impulse, and also with the extent or size of the block regarded as a vibration-generator. These variations would also seem to determine whether the harmonics shall be monotonic or otherwise. Leaving aside the question of whether or not we are justified in our interpretation of the seismograms, it must be said that the majority of the actual cases that have been studied have led us to the foregoing conclusions, therefore, in the case of the Tazima earthquake we cannot very well take the period of the maximum phase of a small aftershock as the period of the maximum phase of the initial severe shock. As being appropriate to the preceding discussion a table is here added, in which are compared the observational results at Osaka and Tokyo of the initial severe shock of the Tazima earthquake, together with those of the aftershocks of May 26th (see No. 88 in the list of aftershocks appended) and June 23rd., and from which can be seen the magnitudes of these three earthquakes and the periods of their maximum phases.

TABLE IV. Comparative view of the seismic observations at Osaka and Tokyo.

Date	Osaka (distance 125 km.)		Tokyo (distance 460 km.)	
	Double amplitude	Period	Double amplitude	Period
	mm.	sec.	mm.	sec.
May 23	37.0	1.8	10.4	3.0
May 26	6.1	1.2	0.18	1.8
June 23			0.054	1.6

According to this table the period of the main phase as registered at Tokyo is nearly 50% greater than that of the corresponding phases registered at Osaka, the explanation of which would seem to be that in the transmission of the earth vibrations those of quick period were quickly absorbed by the intervening medium, thus rendering its traces on the diagram almost illegible. Furthermore, in the Osaka diagram of the initial big shock, attention is drawn to the small waves with a period of 0.8 sec. which are distinctly seen following the S-N motion *cd*, E-W motion ff' and the vertical motion *c*. Perhaps these small oscillations are characteristic of the Osaka region, but seeing that waves of such a period can be noticed quite prominently even in the preliminary tremor, I am still inclined to regard them as nothing more than waves propagated from the seismic focus.

As motions causing the destruction of fairly tall buildings in the epifocal area we might mention firstly the wave of period 1.8 sec., although, I presume that the small wave of period 0.8 sec., together with the one of 0.2-0.3 sec. that was felt by Director Yamazaki, did really exist and that they showed their effects as well. Needless to say, we cannot very well consider the period alone independent of the amplitude, but taking for granted that the acceleration as deduced from the period and amplitude is an invariable quantity, it may not be unprofitable to see what will result as a change in the period. Assuming the seismic intensity to have been 40% of that of gravity, then the amplitudes for periods of 0.2 or 0.3 sec. work out to 4 mm. or 9 mm. Such a small but quick motion might overturn cylindrical objects of small height, or cause small cracks in walls. It might also be felt as a fairly strong shock by the unaided senses. But their effect on objects having larger natural periods of oscillation of their own would probably be very much less. For this reason I have an apprehension that an error has been made in the conclusion that the main phase responsible for the destruction was the wave of period ranging from 0.2 to 0.3 sec. as personally felt by Director Yamazaki.

In the first earthquake there were no cases observed of large displacements made by simple-shaped objects. The most conspicuous one did not show a greater shift than 5 or 6 inches. (Pl. X, Fig. 4.) This would seem to suggest that there was no motion sufficient in either strength or amplitude to cause large displacements, nor a repetition of shocks that were violent but of smaller amplitude. On the other hand, while the magnitude of the shocks was on the whole on a small scale, so long as any objects were displaced we should be able to recognize the effects of the horizontal motion where it overcame the frictional forces during the instantaneous interval.

It would seem that in and around Momosima the seismic intensity was something like 40% of gravity, so that were the acceleration of the vertical motion to operate against gravity at the instant, we could readily imagine objects displaced instantly or by a succession of rapid motions. However, the amplitude of a motion with period 0.2 sec. and an acceleration 40% of g is not likely to be much over 4 mm., hence, as already mentioned, not only is it difficult to suppose that such a small horizontal movement can be responsible for the overturning of tall wooden buildings, but it does not even seem sufficient to explain the phenomenon of small displacements. Since, moreover, the vertical motion of such quick-period waves in working against gravity is very liable to produce displacement, then at places like Takano situated close to the origin, it was probably responsible for the small displacements cited, notwithstanding the fact that the intensity of the horizontal motion was no more than about 20% of gravity.

In concluding our remarks on the nature of this earthquake motion, attention is called to the phenomenon of stationary waves exhibited by the mud stratas of the lower part of the Maruyama river, and also on both of its banks. These were gravity waves due to the earthquake motion having acted similarly to water that is confined in a vessel. The area affected by this earthquake being longer in the N-S than in the E-W direction, and as the direction of the main phase was likewise in a nearly E-W direction, there was a nodal line along the middle part of the river basin parallel to the banks, while along both banks stationary waves with loops could be observed. As a consequence of this we should expect to see phenomena resembling inundation at the river shores, and this is what has precisely happened, it being traceable in the paddy fields either as surface undulations or as earth cracks ejecting mud and sand in such a manner as to confound at times the investigators who were in the neighbourhood trying to discover faults.

3. The seismic origin.

As stated in an early paragraph, the distribution of the earthquake intensities points to either the cove of Tuiyama or its vicinity as the origin. Taking this place as the centre, a reduction of the results of observations of four near stations brings us practically to the same conclusion, but, unfortunately, the fact that these observations do not include one from a station situated in the north, somewhat discounts their value. The question then arises as to whether or not we ought to take for the epicentre a locality some kilometers north of Tuiyama, which in any case is not likely to exceed 10 km., and to obtain which accurately, we have available the distances computed from the durations of the preliminary tremors from seismograms of the above four stations. An alternative method is to determine it from the directions of the preliminary tremors, but the objections to both of these methods is that seismic waves are not transmitted in anything like an orderly or regular manner. In the unavoidable circumstances the writer, in his quest for the seismic origin, had to rely on his own personal observations of the aftershocks during his four days sojourn in the shaken districts, and which will be found arranged in Table V below.

Tables V. Aftershocks felt by unaided senses.

Date	Aftershock no. in Appendix	Duration prel. tre.	Azimuth earthq. sound	Intensity	Place of observation
d h m 27 16 35	181	sec. 3	NNE	weak	Momosima
28 21 38	—	—	E by S	slight	Seto Prim. school
29 00 16	208	—	E by S	do.	do.
29 07 39	214	1	E	strong	do.
29 12 30	218	—	S 60° E	slight	Kanzui
29 17 49	222	—	N 60° E	do.	Kinosaki
30 06 07	—	3	NE	do.	do.

As nothing more than a compass and a stopwatch was used in the above observation, the scientific value of the results are obviously open to question, but in anticipation of contingencies like the present, the writer has been using this seemingly rough and ready method for some time, always comparing them afterwards with the instrumental results, until by dint of practise a stage of proficiency has been reached, whereby, as in the case of the preliminary tremors, the errors are invariably within 10% of the true results. As for the earth sounds or rumblings, since the apparent direction of the origin as indicated by these sounds do not always accord with the actual origin owing to topographical irregularities, only those that were heard on plains or level ground have been considered. Out of the seven listed above, the one heard at the Kôsai Primary School in the early morning of the 29th had especially to do with the shock that violently shook the already partly demolished school-house. This shock was strong enough to alarm some of the members of our party who passed the night on the upper floor of the partly ruined school-house. The writer was however able to experience it outside of the building on level ground. Since the severe aftershock of the 26th, this one, in the opinion of many, was the strongest felt, and that in all its features, from the earth-sound down to the main-phase, it was a faithful repetition of the initial violent shock.

At Tai and Kei the duration of the preliminary tremor was only a matter of one or two seconds, or three seconds at the most, whereas at Kinosaki and Takano it was barely three seconds. The reason why, as in the above list, the preliminary tremors could not be noticed was that either they were too weak to be sensible, or that they did not exist. The accuracy of observations made on the third night may be questioned on the score of physical strain and fatigue on the part of the observer through lack of sleep, but it is well to explain that in investigation tours like the present, the writer generally manages to do with little or no sleep for days, keeping strict vigil with compass, watch, candles and matches so as not to allow the slightest phenomenon to escape unobserved, with the result that such observations are likely to be more accurate than those made in the day time.

By collating the foregoing aftershocks with the observations made at Toyo-oka, we get the origin as being near the eastern shore of Tuiyama cove, or rather about where the Tai fault made its appearance. However, the focus from whence originates the aftershocks is not always the starting point of the initial severe shock, but if the latter were really situated a little distance off the cove of Tuiyama, then it would be legitimate to expect aftershocks in that vicinity, so that during the four days of our sojourn aftershocks should have visited that region. Again, as has already been stated, there are observers who hold that the aftershocks of the 29th behaved similarly to the initial severe shock, which goes to strengthen the writer's conviction that the latter had its origin in the Tertiary block forming the right hand shore of Tuiyama cove, in which case the intimate relation between the origin and the Tai fault becomes obvious. It would then also accord with the sound directions of the initial severe shock found for various places, namely, NE for Toyo-oka; NW for Kumihama and Mihara; W for Tai and Kei and E for Takano and Kasumi.

The foregoing data for the estimation of the seismic focus naturally apply to that of the focal depth as well. Personally, the writer is in favour of taking the depth as being under 25 km., say, about 10 km., which would then be in accord with the intensity distribution. On the latter assumption the focal distance from Takano or from Kumihama will be equal to the focal distance from Tai or from Kei increased by 30%, in which case the notable disparity in the seismic intensities referred to previously become explainable. If, on the other hand, we take the depth as, say, 40 km., then the distances from the places just mentioned to the seismic origin will practically be the same, but we shall then find ourselves in a dilemma since this would argue practical uniformity of geological structure for all the places mentioned, in which event the disparity in the seismic intensity distribution would remain unexplained.

In the present discussion when the focal depth is considered in connection with the duration of the preliminary tremor as basis of computation, then the term seismic origin means the point of propagation of the seismic motion, but when it is considered from the standpoint of intensity distribution, then it refers to the centre of the area where the seismic force is being generated. When the seismic force is very great we must consider the two as separate and distinct, but if the shock is slight and is more or less of a local character there is no harm in treating them as the same. Dr. K. Wadati, who investigated the depths of the seismic focus and the layer of discontinuity from the transmission curves of the $\overline{P}$ and P phases of the present earthquake, estimated the focal depth at 33 km.[1] The discrepancy of the data on focal depth thus worked out may be due to the difference of foci dealt with. We might also add that while with earthquakes of inland origin, as distinguished from those of submarine origin, the focal depths in the majority of cases seem to be in the order of 40 to 50 km., their depths for destructive earthquakes come out comparatively shallow.

Let us now try to imagine how the seismic force acted. Taking first its projection on the zone of activity as a strip along the eastern shore of Tuiyama cove, one end of which is in alignment with the right bank of the lower Maruyama river in a SSW direction and extending to the east of Kinosaki, although it is difficult to form an opinion as to the distance it extended in the other direction. In the absence, then, of any traces of changes in the sea-bed or evidences of tidal waves, (the seiche of Kumihama Bay having no bearing on this subject), the writer hesitates to prolong the principal portion of this area northwards, and would merely place it at a distance some 2 km. from the eastern shore of Tuiyama cove and then extend this a little towards NNE and SSW. This then is the projection on the earth's surface of the block being acted upon by the forces generating the earthquake, although, for reasons previously stated, we take the actual centre of the zone at about 10 km. below the surface. Now suppose that this has been cut by a vertical plane running E-W and that we are looking at one of the cut surfaces from the south. The zone in question will then appear again in front as a narrow strip. This strip is a slant, sloping downwards from east to west, and it is convenient to regard the force as acting along the western side of this strip and in a downward direction from E to W. On this assumption not only the various phenomena connected with the seismic origin, but the distribution of the direction of the preliminary

1) K. Wadati: Geophysical Magazine, Vol. I, No. 3.

tremors observed at the various stations (Pl. II) will find themselves accordant.

Again, let a line A be drawn through the seismic origin and draw lines B and C, one on each side of A and 200 km. distant from it respectively. Then in the region between A and B the initial phase is directed towards the origin, but in the region A and C, it is directed away from the origin. The explanation of this seems to be that in the case of the initial phase for the region between B and C the seismic waves have been transmitted through the *sial*, whereas for that outside of B and C, the waves have passed through the *sima*. As to the force that acted on the eastern block of the fault, it would appear to be sufficient if we regard it as the result of rebound of the block through release, at the moment of the earthquake, of the long-continued stress which had been acting there, in all probability from the northwest, against the main island of Japan.

4. Causal relationships.

The San-in seismic zone A discussion by the writer on this seismic zone will be found under the title " The Hamada Earthquake of 1872 " in the Report of the Committee No. 77, wherein was also described the characteristics of earthquakes that have originated in this zone, together with their subsequent behaviour, and from which it will be seen that the present earthquake originated in the eastern part of this zone, and that as has already been observed, the seismic activity seems to be shifting in a north-easterly direction. It is also to be noted, as is fully dealt with in a subsequent article in this report by Dr. Yamasaki, that with unmistakable signs of the focal zone having undergone conspicuous changes in the past, the occurrence of the present earthquake is not a matter for surprise. In this connection we might add that some of our party were made the targets of uncomplimentary remarks on the assurance of the Kinosaki districts from future destructive earthquakes alleged to have been made by the late Dr. Omori, but it is well to explain that it is highly probable that the assurance was due to some misinterpretations of certain data covering the seismic history of the region.

Premonitory signs. In respect to this earthquake there seems not to have been wanting certain secondary causes deserving notice, one of which was the coincidence of the time of occurrence of the earthquake with the period of the new moon. Of greater significance, however, was the manifestations, prior to the earthquake, of signs pointing to certain agencies at work in bringing about the final catastrophe. The observations of the Toyo-oka station of the Kobe Marine Observatory, although very valuable in other respects, failed to reveal any evidences of foreshocks or earth-tiltings, but it would be illogical to deny even minute tiltings from the negative evidence. The reservoir of the Toyo-oka water-works, which, by the way, was maintained by the private efforts of a public-spirited citizen, was in a locality situated southwards of the Genbudo railway station. We learn that from about the day before the earthquake the water volume appeared to observers as having suddenly diminished.

After the earthquake prospects seemed favourable for a careful re-survey by the Land Survey Department of the levelling route passing through the affected districts, but it failed to materialize, although even if it did, it is a cause for regret that the route extending from the direction of Miyadu, passing through Kumihama and Toyo-oka and then proceeding southwards through mountains, links only distant Tottori without approaching at all the meizoseismal area. In addition to this drawback there is the unfortunate fact that benchmarks at several important points have lost their original identity, not only through the action of the elements but also through the perversity of ignorant people.

We are pleased to be able to say that nearly two years after the above was written, that is on March 7th, 1927, a survey was started as a result of the severe Tango earthquake which followed the Tazima earthquake, and what was most fortunate, the survey took in the latter district as well. The results of this survey have enabled us to deduce changes in the land-level which took place in the regions forming the subject of this paper, and from which it seems that in Toyo-oka and vicinity there was a depression of some 30 cm. in the level districts and about 10 cm. in the hilly sections. From this it is quite natural to conceive of considerable changes having occurred in and around the neighbour-hood of lower Maruyama river, which was only to be expected as a result of the mechanism of earthquake generation referred to in previous paragraph. (See Pl. I.)

Relation with the Outer Seismic Zone. (The two seismic zones lying parallel to the trend of the island arc, one on the western or Japan Sea side, and the other on the eastern, or Pacific Ocean side, are called respectively the Inner and Outer Seismic Zones.) During the periods preceding and following the great Kwanto earthquake of 1923, activities were displayed by the outer seismic zone and continued for some time, so that the severe Tazima earthquake which took place in this period may safely be considered as having had some causal relationship with the great Kwanto visitation. As parallel cases we may take the earthquake which originated at sea off Kusiro and Nemuro (Hokkaido) on the 22nd of March, 1894, with the one that occurred at Sakata (Ugo Province) on the 22nd of October of the same year. In 1896, on the 15th of June, came the great submarine earthquake of the N.E. Japan which was accompanied by that great tidal-wave, whereupon on the 31st of August of the same year, the provinces of Ugo and Rikutyû in northern Japan were visited by a great earthquake. Dr. Suyehiro has called attention to a similar sympathetic relationship in the case of the present earthquake, and indeed it is not impossible to trace connections between the inner and outer seismic zones of Japan. For example, after the great earthquake and tidal-wave had visited the provinces of Hyûga and Osumi in the year 1662, that is fourteen years later, in the year 1676, there was an earthquake in Tuwano in the province of Iwami. Four years after the great earthquake and tidal-wave in the Nankaido, namely in 1711, there was an earthquake at the boundaries of the three provinces of Mimasaka, Inaba and Hôki. On the 23rd of December, 1854, a severe earthquake originated off the Tokaido and the following day another big one originated off the Nankaido with tidal-wave, and within a period of from three to four years after this, four severe shocks struck Tuwano and Hamada in the province of Iwami, throwing down walls and stone fences, with finally the very violent earthquake of Hamada of 1872. Seeing, therefore, that the present violent earthquake occurred one year and eight months after the great Kwanto earthquake of 1923, we cannot very well refuse to acknowledge the relationship here as were found for the foregoing examples.

APPENDIX

Observations of Aftershocks at the Different Stations.

($\overline{P}$: Toyo-oka 11 h 9 m 57 s, Kôbe 11 h 10 m 2 s, Osaka 11 h 10 m 4 s)

No.	Toyo-oka		Kobe		Osaka	
	Date	Intensity*	Time	Dur. prel. tr.	Time	Dur. prel. tr.
	May d h m		h m	sec.	h m	sec.
1	23 11 10.0	VI				
2	11 10.2	,,				
3	11 10.2	,,				
			11 19.9			
			11 21.2			
			11 21.7			
			11 24.6			
4	11 37.3	V	11 37.7	11.4	11 38.7	13
			11 38.7			
5	11 46.5	,,				
6	11 47.6	,,	11 59.8			
7	12 01.3	,,	12 02.7	13.8	12 02.8	14
8	12 07.5	IV	12 08.9	13.3		
9	12 22.9	,,	12 23.3	13.3		
10	12 31.7	,,	12 32.2	12.4		
			12 35.3			
			12 40.7	13.6	12 40.9	12
11	12 55.4	,,				
			13 15.4			
12	13 52.5	,,	13 52.9	13.7	13 53.0	19
13	14 00.2	,,	14 00.9	13.0	14 01.0	15
14	14 02.0	,,	14 03.5			
15	14 47.3	,,	14 47.7	13.4	14 47.3	14
16	15 43.3	,,				
17	16 25.7	,,	16 26.4	13.6	16 26.5	12
			16 30.9			
18	17 08.4	III	17 09.4			
			17 09.5	12.3		

* I=slight, II=rather weak, III=weak, IV=rather strong, V=strong, VI=violent.

No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	d	h	m		h	m	sec.	h	m	sec.
19	23	17	19.3	II	17	20.1				
					17	32.1				
					17	38.2				
					18	05.2				
20		18	27.1	,,	18	28.7	13.3			
					18	39.0	13.3	18	39.0	19
					18	46.9				
21		18	57.0	,,						
22		22	26.2	,,	22	26.4	12.4			
23		22	27.1	,,	22	27.4				
24	24	1	50.0	,,	1	50.4				
					2	16.0				
25		8	10.7	I	6	05.9				
26		9	33.8							
27		9	39.5							
28		9	53.0							
29		9	54.0							
30		9	55.5							
31		9	55.8		9	56.0				
32		9	56.1	I	9	56.4	13.0			
33		10	55.9							
34		11	09.5	I						
35		11	19.4	,,						
36		12	35.4							
37		12	56.7							
38		15	46.8							
39		16	46.9	I	16	47.1				
40		16	50.3	,,	16	50.8				
41		17	56.8							
42		17	59.9							
43		19	51.7	I						
44		19	55.3	III	19	55.6	13.9	19	55.7	14
45		20	00.6							
46		20	01.0							

	d	h	m		h	m	sec.	h	m	sec.
47	24	20	03.9							
48		20	32.4							
49		21	04.1							
50		21	23.4							
51		21	54.3	III	21	54.5	12.2	21	54.5	16
52		22	23.5							
53		22	27.4							
54		23	11.7							
55	25	0	21.8							
56		0	41.2							
57		0	47.2							
58		0	49.3							
59		1	20.5							
60		3	38.2							
61		7	00.7							
62		7	16.8							
63		7	20.4							
64		7	32.5	I	7	32.7				
65		7	51.3							
66		9	26.9							
67		9	33.9							
68		10	07.9	I						
69		10	34.2							
70		11	01.7	II						
71		11	13.7	I						
72		14	57.3	,,						
73		15	52.1							
74		17	04.-							
75		20	34.-	I						
76		21	10.-							
77		21	14.-							
78		22	24.5		22	25.0				
79		22	27.8							
80		23	18.3	II	23	18.6	12.0	23	18.6	19
81		23	19.2							
82		23	41.0	II	23	41.4	14.0	23	41.4	19
83		23	41.2		23	42.6				
84		23	44.2	I	23	44.7				

No.	Toyo-oka Date	Toyo-oka Intensity	Kobe Time	Kobe Dur. prel. tr.	Osaka Time	Osaka Dur. prel. tr.
	d h m		h m	sec.	h m	sec.
85	25 23 46.9					
86	23 55.2					
87	26 0 03.9					
88	1 22.3	IV	1 22.6	13.0	1 22.7	18
89	1 26.2	II				
90	1 28.8					
91	1 31.5	I				
92	1 36.9	,,				
93	1 41.9					
94	1 44.4					
95	1 46.3					
96	1 46.6					
97	1 50.9					
98	2 00·9					
99	2 06.9					
100	2 11.6					
101	2 33.9					
102	2 34.9					
103	2 35.6					
104	2 36.7					
105	2 55.5					
106	2 59.5					
107	3 08.9					
108	3 10.2		3 10.8		3 10.7	14
			3 11.3			
109	3 16.0					
110	3 31.9		3 32.2		3 32.2	19
111	3 39.7					
112	3 52.1					
113	4 06.2					
114	4 11.7					
115	4 24.6					
116	4 43.6					
117	4 47.6					

	d	h	m		h	m	sec.	h	m	sec.
118	26	4	48.1							
119		5	17.7							
120		5	39.2		5	39.2				
121		5	43.5							
122		5	49.3							
123		6	20.5							
124		6	38.9							
125		6	42.3							
126		6	52.8							
127		8	12.6							
128		8	33.5							
129		8	42.4	III	8	42.7		8	42.7	15
130		11	28.7	I						
131		14	09.7							
132		14	25.6							
133		14	48.7	III	14	49.0	13.0			
134		14	54.0							
135		15	57.1	II	15	57.5	14.3	15	57.6	14
136		17	22.3							
137		19	29.0		19	29.3	13.3			
133		19	50.5							
139		20	02.4							
140		20	14.2							
141		20	22.7							
142		20	43.0							
143		21	25.1	II						
144		21	36.1	I	21	36.7				
145		21	47.2	,,	21	47.4	15.2	21	47.5	17
146		21	49.7	,,						
147		22	33.4		22	33.7	13.6			
148		22	41.3							
149		23	09.5							
150		23	09.6	I						
151		23	47.7							
152	27	0	30.8							
153		0	32.4							
154		1	10.6							
155		1	21.0							

No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	d	h	m		h	m	sec.	h	m	sec.
156	27	1	28.5							
157		1	40.6		1	40.8	15.0	1	40.9	15
158		1	43.2							
159		1	44.5							
160		1	44.9		1	44.8	11.4			
161		2	01.5							
162		3	01.7							
163		4	59.1							
164		5	12.1							
165		5	17.2							
166		6	52.6							
167		8	16.8							
168		8	41.5							
169		8	42.2							
170		8	47.4	I						
171		8	47.8							
172		10	11.8							
173		10	13.1							
174		11	35.9							
175		12	05.6							
176		12	50.2							
177		13	33.2							
178		13	41.1	I	14	39.0				
179		16	11.0		16	11.3				
180		16	11.3	III	16	11.6		16	11.7	16
181		16	35.0	,,	16	35.5	12.6			
182		16	52.2							
183		17	54.5							
184		18	08.8							
185		18	33.9	I						
186		22	39.4							
187		23	35.7							
188	28	1	33.6	I	1	38.9	13.0			
189		3	49.1							

	d	h	m		h	m	sec.	h	m	sec.
190	28	4	36.6							
191		7	36.1							
192		9	24.4	I						
193		9	45.7	,,						
194		12	44.6							
195		13	08.7							
196		13	10.3							
197		14	10.9							
198		15	02.6							
199		15	30.0							
200		15	46.1	I	15	46.3	13.4			
201		17	37.0							
202		18	55.6	II						
203		19	08.0	I						
204		21	42.9							
205		21	43.5	I						
206		22	40.3	,,						
207		23	38.0							
208	29	0	16.0	I						
209		2	51.2		2	54.8				
210		4	21.6							
211		4	31.1							
212		4	32.3							
213		5	33.8							
214		7	40.0	IV	7	40.3	13.0	7	40.3	15
215		7	40.9							
216		8	24.0	II	8	24.4				
					10	54.2				
217		11	08.8							
218		12	29.9	I	12	30.3				
219		14	24.4	,,						
220		17	47.8	,,						
221		17	48.0	,,	17	48.0				
222		17	48.1	II	17	48.3		17	4.83	22
223		17	49.2							
224		22	18.3							
225	30	6	47.1	I						
226		11	00.9							

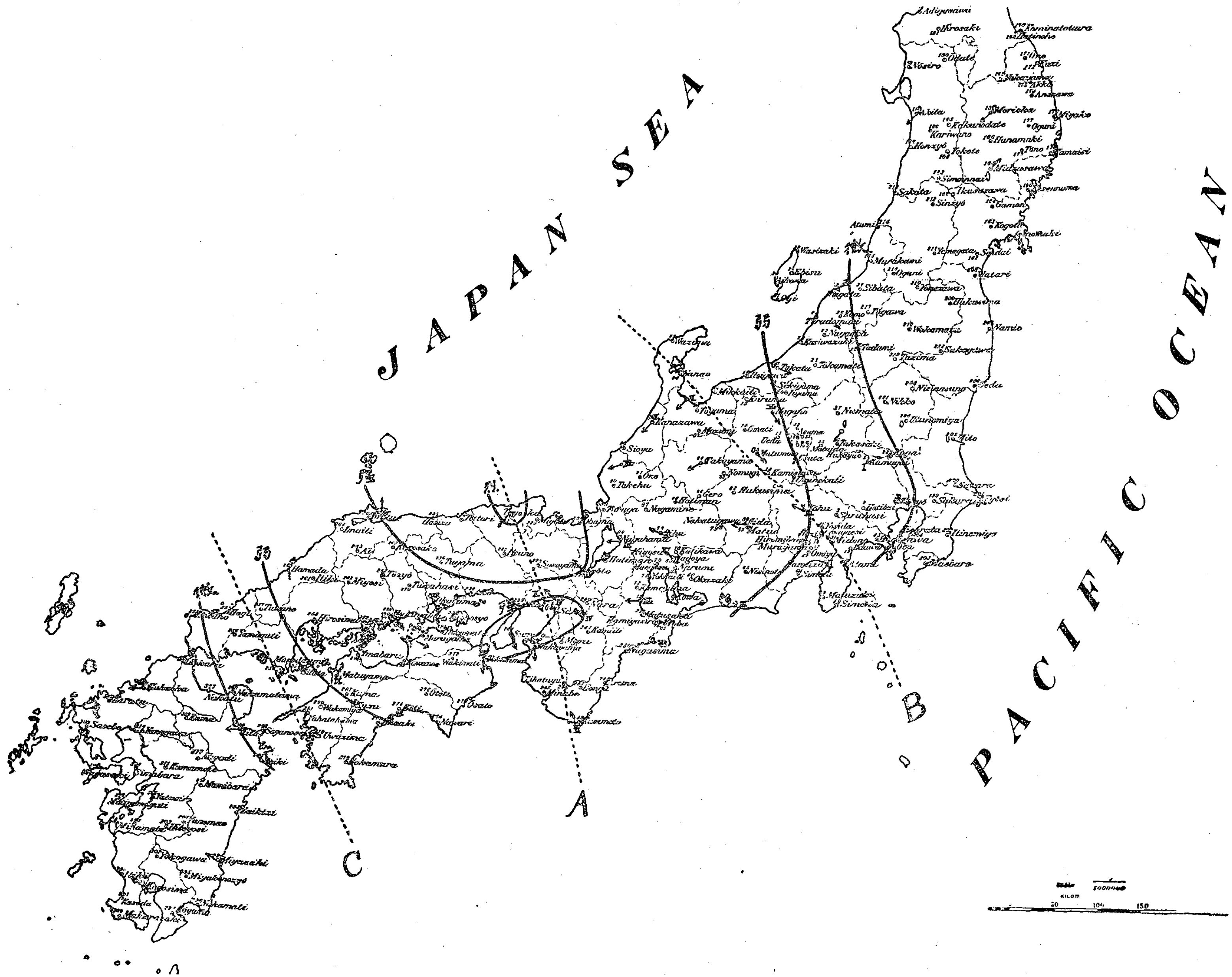
No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. pral. tr.
	d	h	m		h	m	sec.	h	m	sec.
227	30	14	00.7							
228		17	04.3							
229		18	12.7	I						
230	31	0	43.0							
231		7	42.3							
232		10	34.9	I						
233		14	19.3	II	14	19.9				
234		19	33.5	I						
235		20	47.0	I						
236		22	47.2	,,						
	June									
237	1	2	08.6							
238		4	07.8	I						
239		5	28.4	,,						
240		8	49.8	,,	8	50.8				
241		11	41.7							
242		11	45.1							
243		12	12.7							
244		12	27.5							
245		15	28.8							
246		15	44.0							
247		16	37.0							
248		17	55.1	I						
249		23	16.0							
250	2	6	32.6							
251		7	45.4	I						
252		9	02.2	,,						
253		10	37.1							
254		11	31.4	I						
255		12	31.7	,,						
256		12	42.2							
257		12	58.1	I						
258		22	23.4							
259		23	29.9	II	23	30.4				

	d	h	m		h	m	sec.	h	m	sec.
260	3	0	25.0							
261		1	31.7							
262		1	32.3							
263		5	43.1							
264		9	57.9							
265		10	59.5							
266		17	41.1	III	17	40.4		17	40.7	36
267		17	41.9	I						
268		17	42.1	,,						
269		23	06.2							
270		23	55.0							
271	4	10	57.1							
272		14	26.0	I	14	26.4				
273		14	58.4	,,						
274		15	48.7	,,						
275		16	38.4							
276		17	09.2	I						
277	5	1	17.0							
278		10	23.2							
279		16	57.9	I						
280	6	2	47.7							
281		12	29.5							
282		12	44.9							
283		12	45.5							
284	7	4	22.9							
285		13	49.9							
286		14	32.8							
287		22	39.0							
288	8	6	51.0							
289		13	27.8							
290		13	36.3	I						
291		15	35.1							
292		17	28.7							
293		17	33.1							
294		20	38.3	I						
295		23	57.0							
296	9	0	22.9							
297		7	05.3							

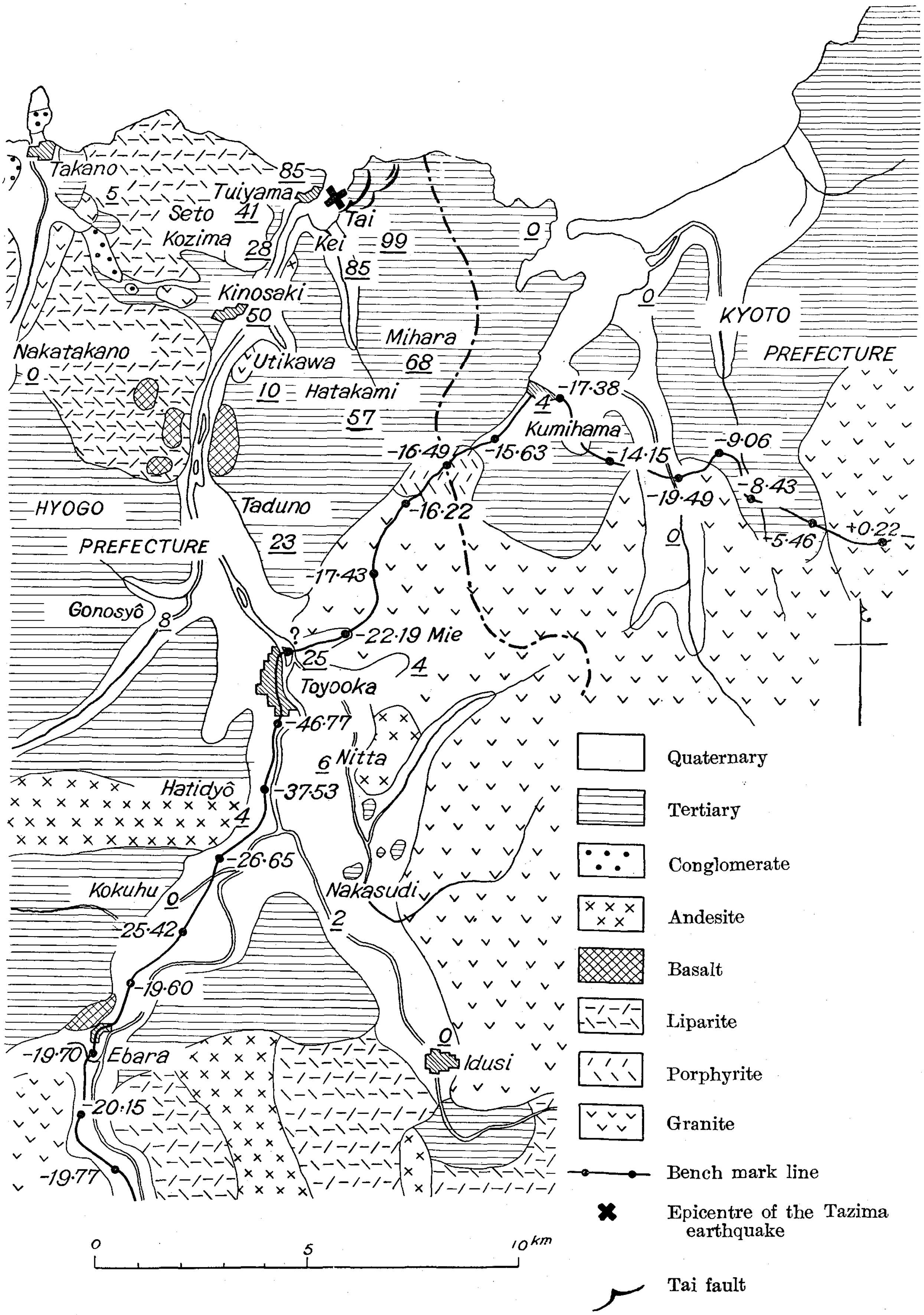
No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	d	h	m		h	m	sec.	h	m	esc.
298	9	7	42.1							
299		7	51.9							
300		15	20.5							
301		17	36.7							
302		22	44.8							
303		22	50.9							
304	10	7	02.2							
305		7	58.6							
306		8	13.7							
307		14	18.4							
308		17	34.4							
309		17	50.8							
310		22	58.6		22	58.8				
311		23	58.7							
312	11	5	17.1							
313		10	00.5							
314		10	00.5	I						
315		10	00.6							
316		10	11.0	I						
317	12	0	11.1							
318		3	48.0							
319		7	46.7							
320		7	46.7							
321		7	53.0							
322		8	14.3							
323		11	44.2							
324		11	44.3							
325		11	44.3							
326		15	57.9							
327		15	57.9							
328	13	6	48.9							
329		15	25.8							
330		7	34.6							
331		7	42.1							

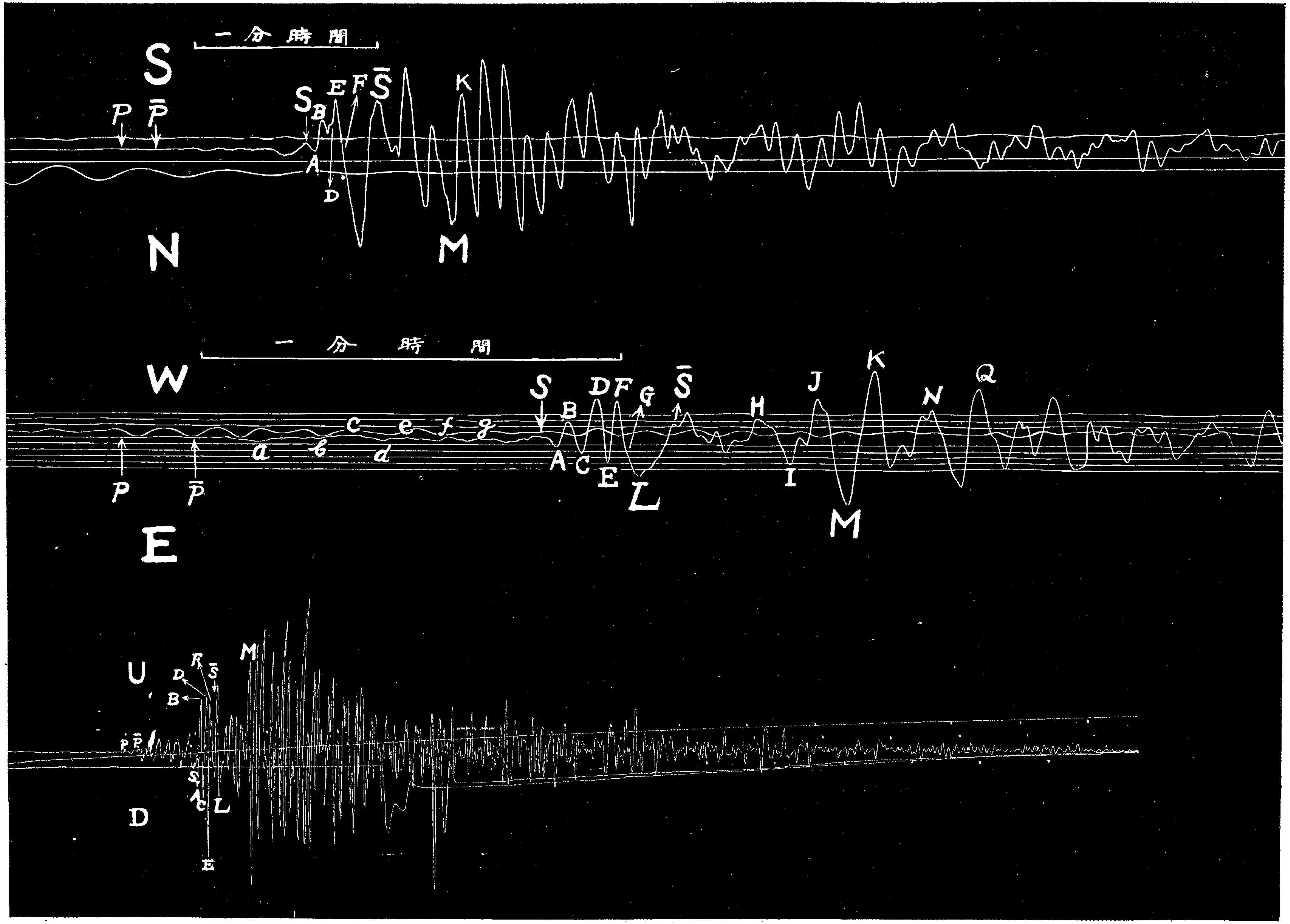
	d	h	m		h	m	sec.	h	m	sec.
332	13	7	50.5							
333		14	49.0							
334		15	12.8							
335		15	13.1							
336	14	0	20.6							
337		9	33.1	I	9	33.4		9	33.5	16
338		9	59.6	II						
339		11	16.9							
340		22	26.1							
341		22	26.2							
342	15	0	01.5							
343		2	10.9							
					10	01.0				
344		11	10.0							
345		11	13.7							
346		11	13.7							
347		15	30.5							
348		18	48.1							
349	16	5	31.9							
350		7	29.9							
351		7	35.7							
352		10	13.5							
353		10	58.2							
354		15	53.1							
355		18	00.3							
356	17	4	32.9							
357		8	37.0							
358		8	43.3							

Isoseismals and directions of the initial phase.



Map showing the seismic area of the Tazima earthquake of 1925. (Numerals underlined denote percentage of houses collapsed. Numerals by the B. M. route denote the height change in cm.)



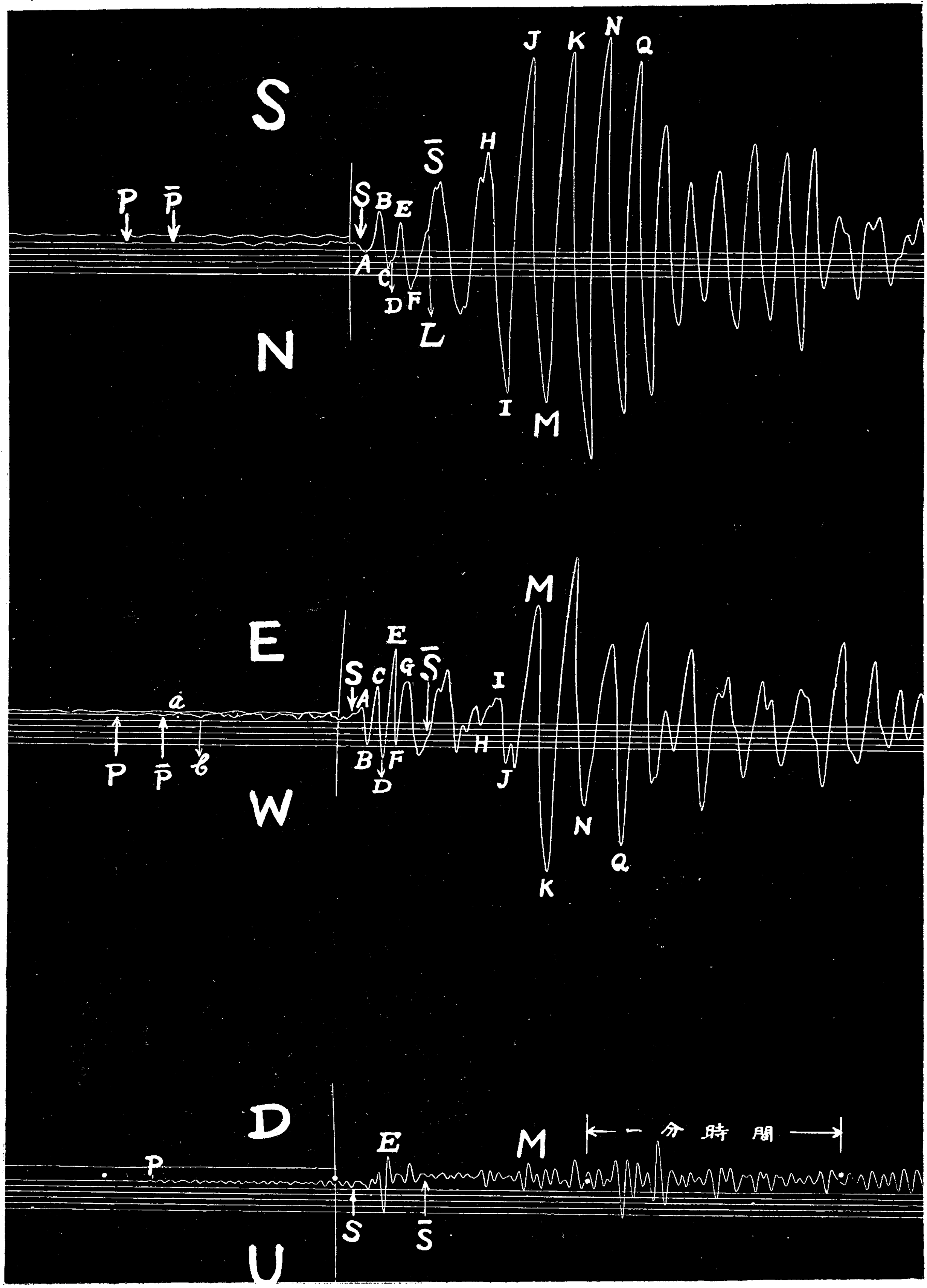


Tokyo observation of the great Tazima earthquake.

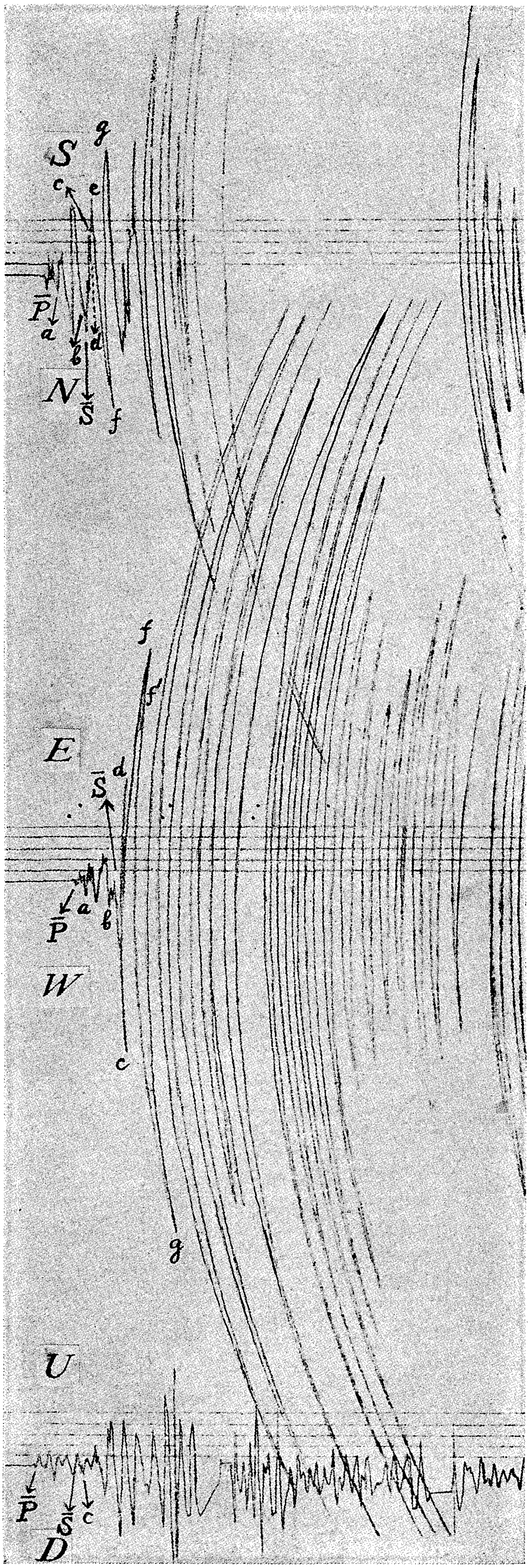
Index magnification: EW=1.5, NS=1.5, Vert.=10.

Tokyo observation of the great Tazima earthquake.

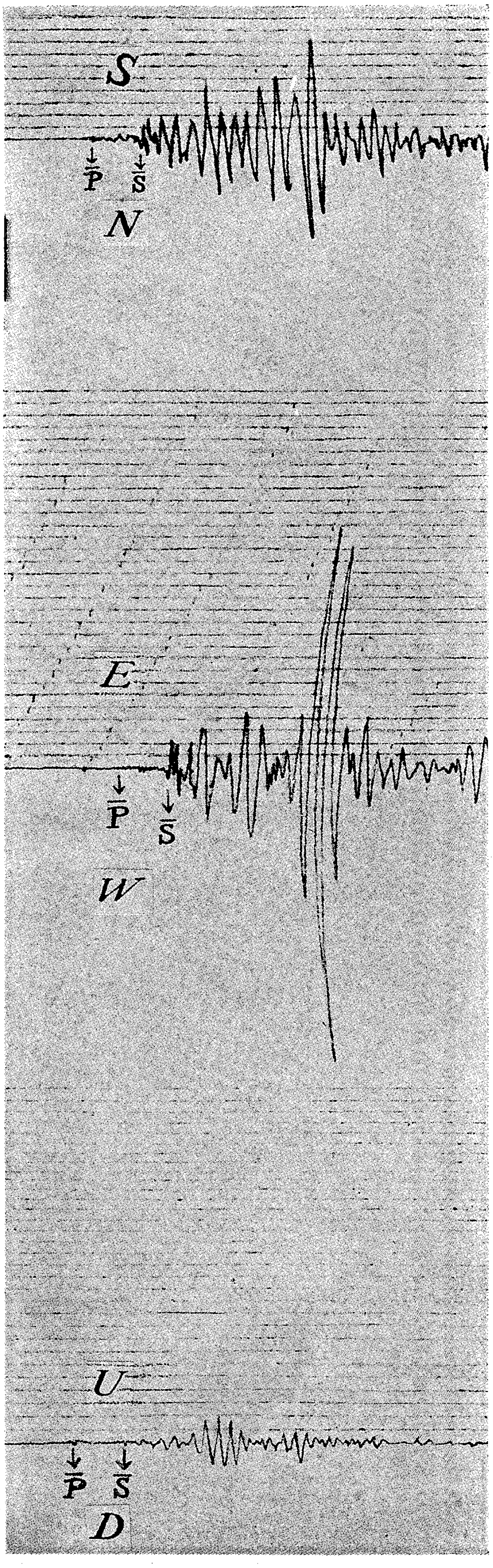
Index magnification = 2, time-scale = 4 cm./min.



Osaka observation of the Tazima earthquakes. No index magnification.



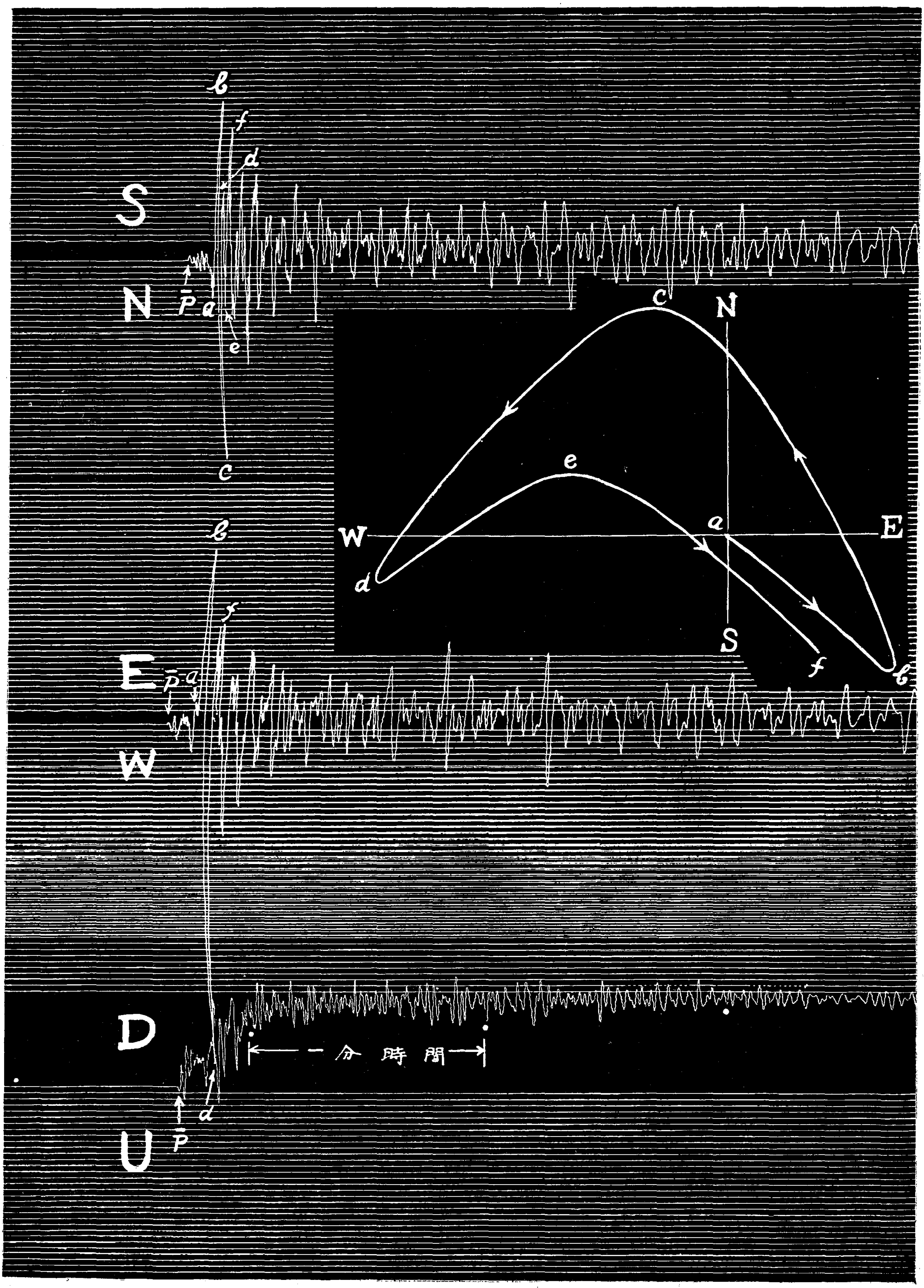
Earthquake of May 23.



Earthquake of May 26.

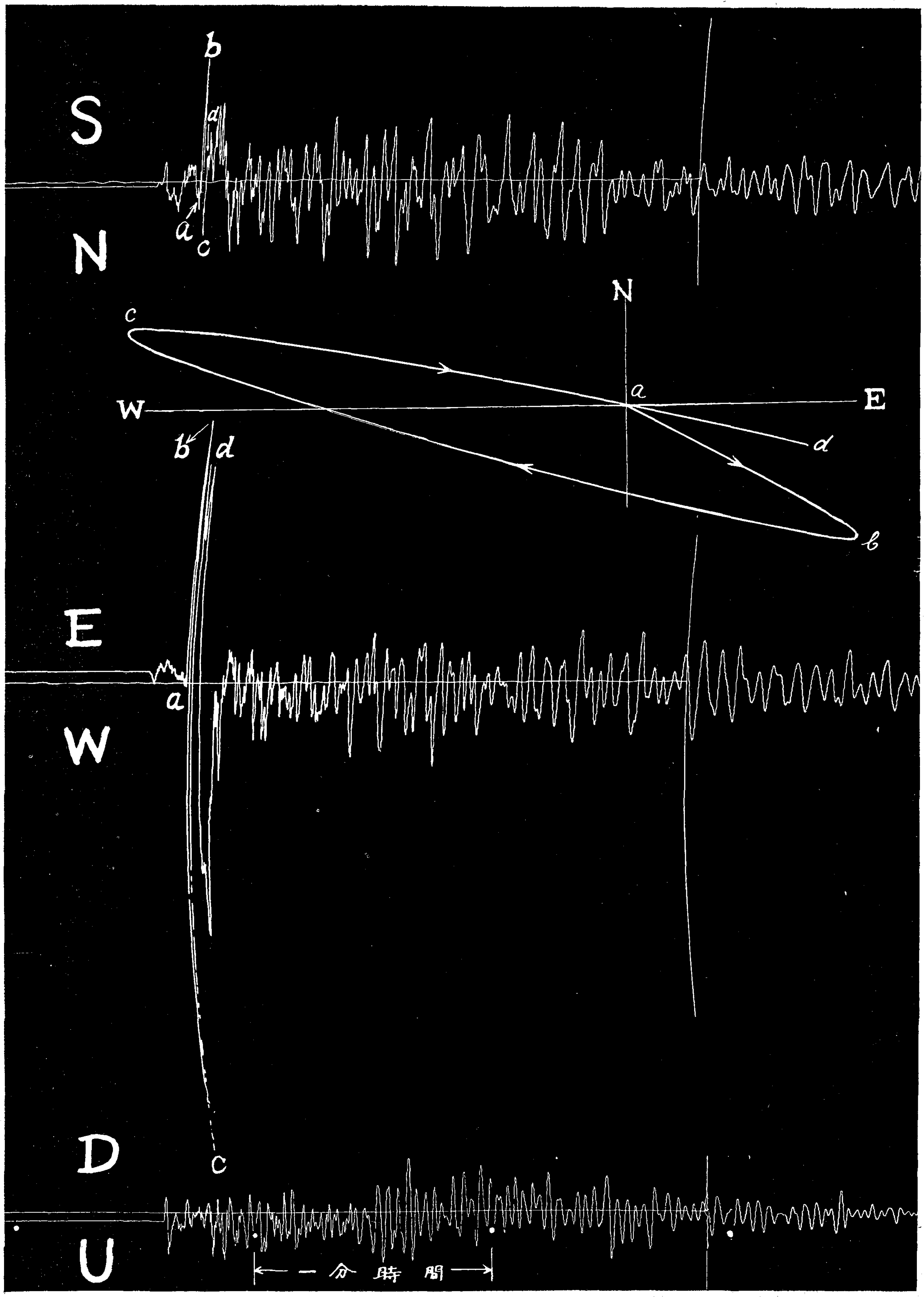
Tokyo observation of the Ryugasaki earthquake of Dec. 8, 1921.

Index magnification = 2, time scale = 4.0 cm./min.



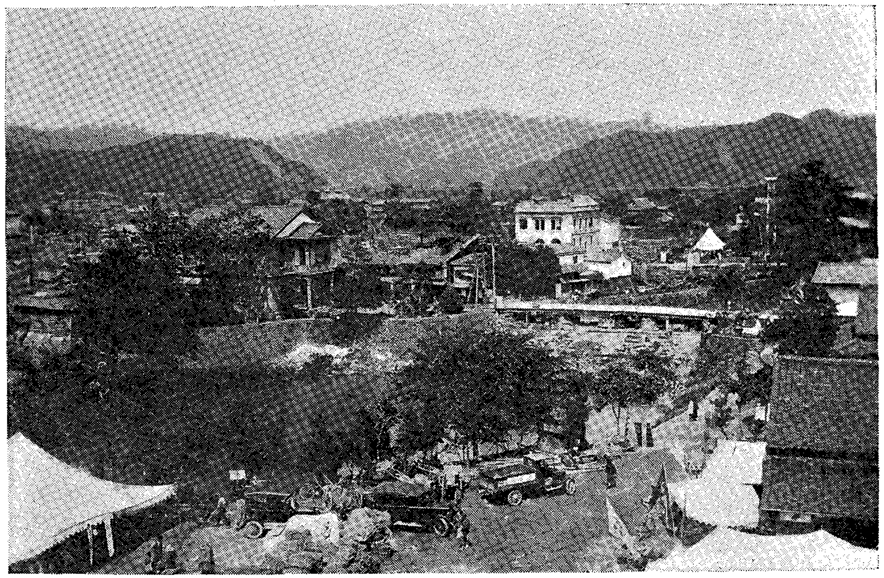
Tokyo observation of the Uraga Channel earthquake of April 26, 1922.

Index magnification = 2, time scale = 4.0 cm./min.

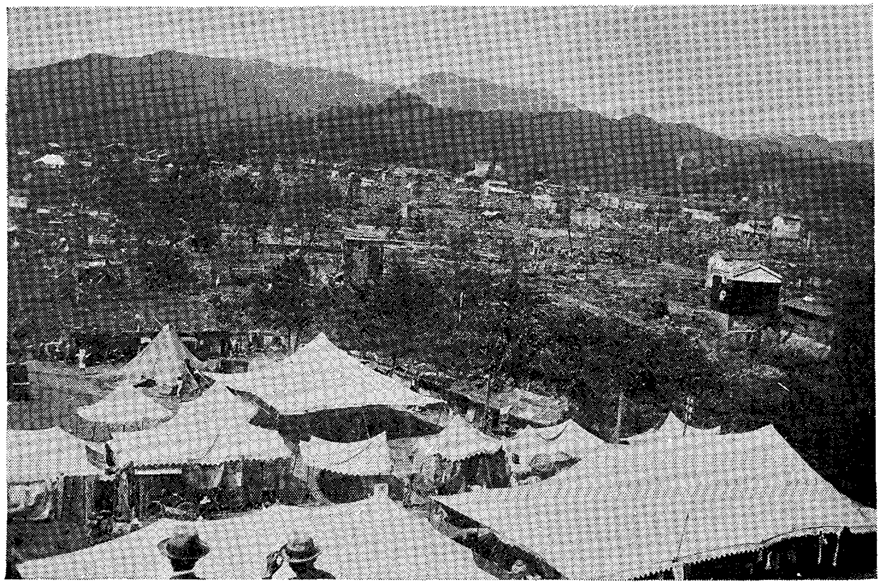


The town of Toyo-oka from the roof of the Toyo-oka primary school.

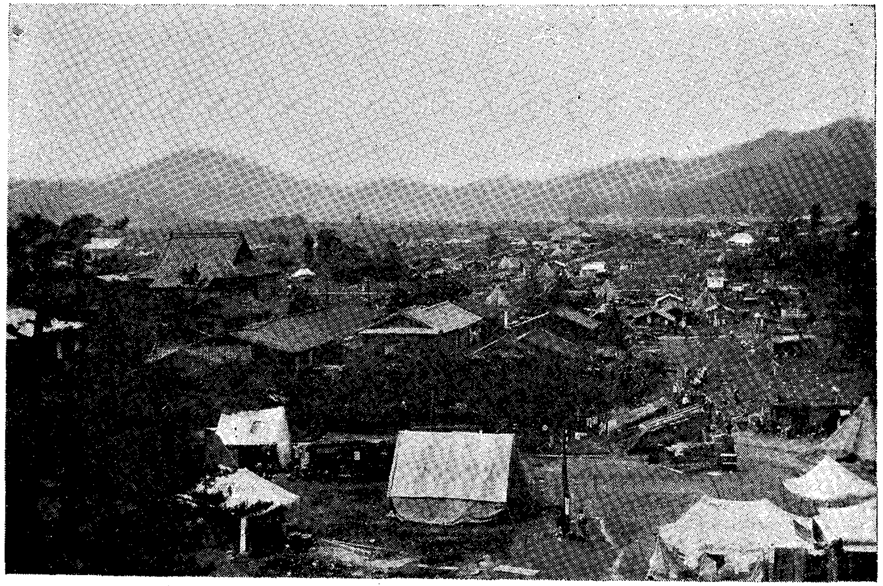
1



2

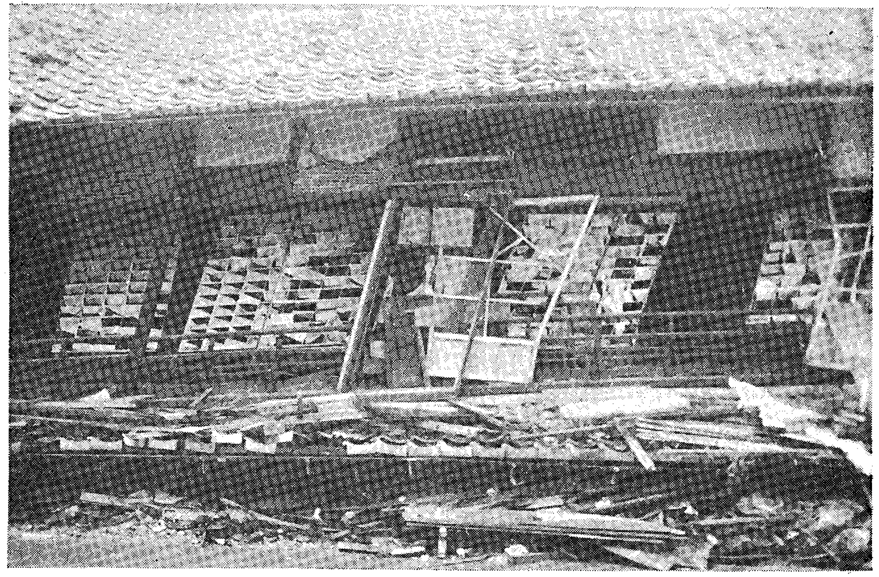


3

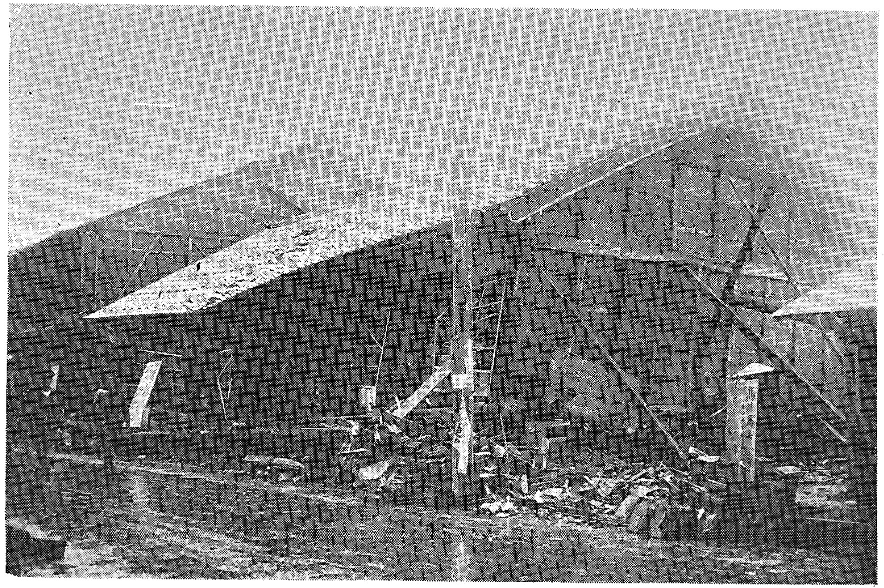


4

1. Vicinity of the Toyo-oka town office.

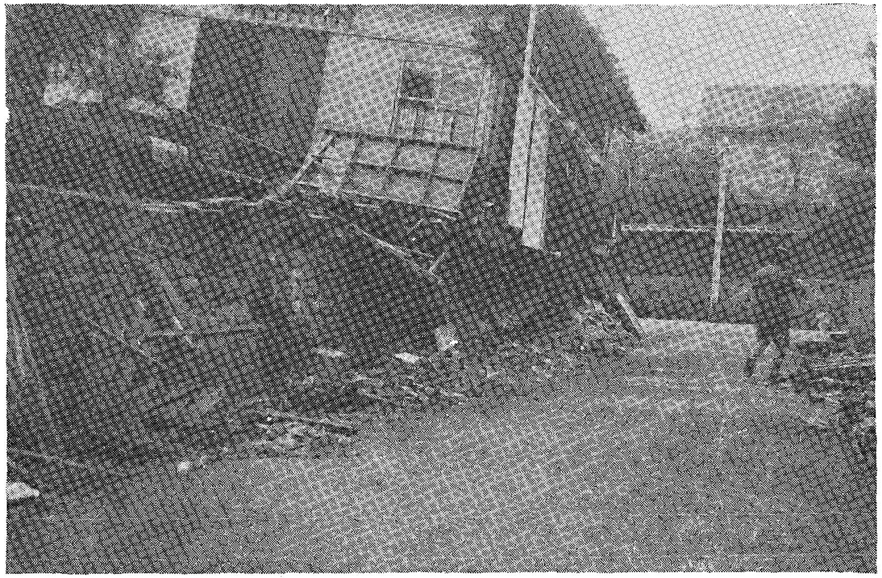


2. Street facing Toyo-oka railway station. Collapse of first story with the second story resting on the ground.



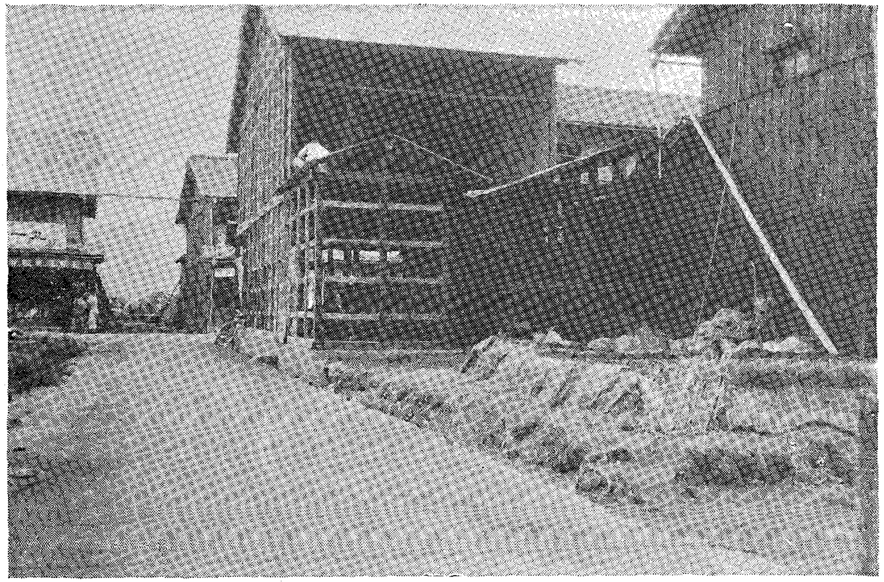
3. Same as No. 2.

4. Toyo-oka Agricultural Bank building. The interior has been burnt out.

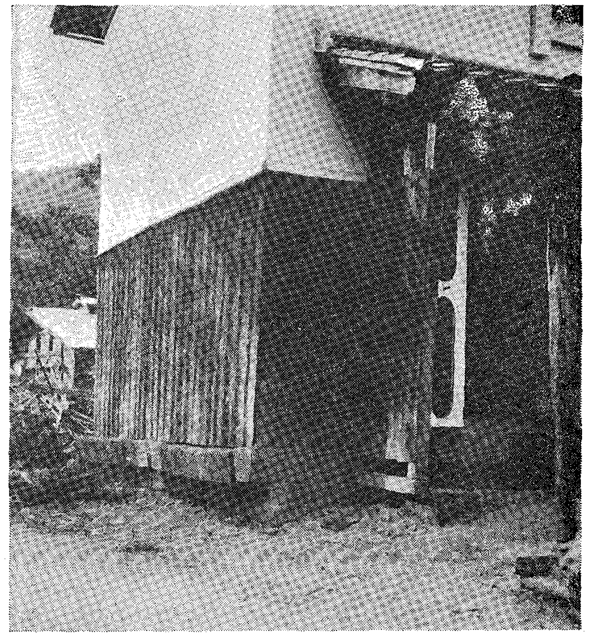


1. A back street in Toyo-oka. Collapse of first story. The second story has taken its place.

2. Toyo-oka. A 2-storied house quite intact because it had many supporting pillars in the walls parallel to the direction of the main earthquake motion.

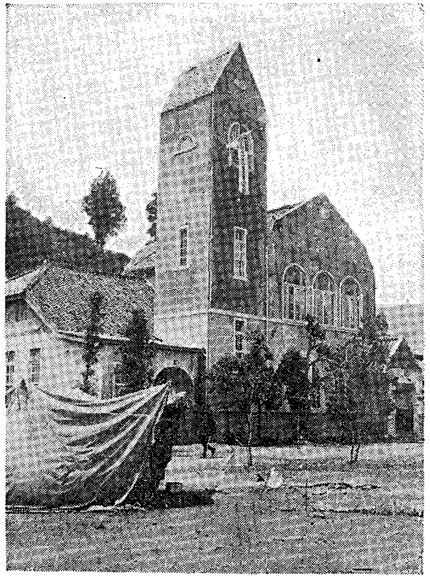


3. House construction typical of Toyo-oka.

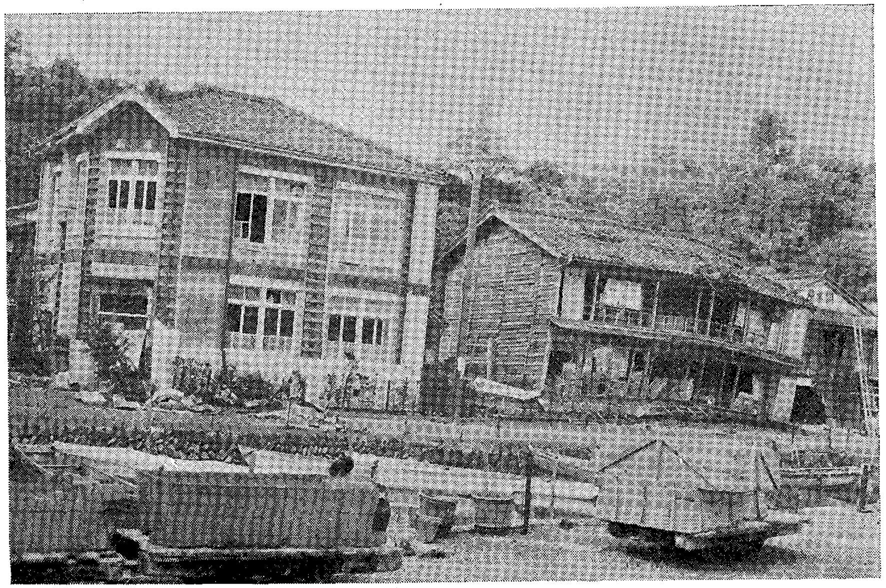


4. Momosima village near Kinosaki town. This mud and plaster warehouse has shifted bodily from its foundation.

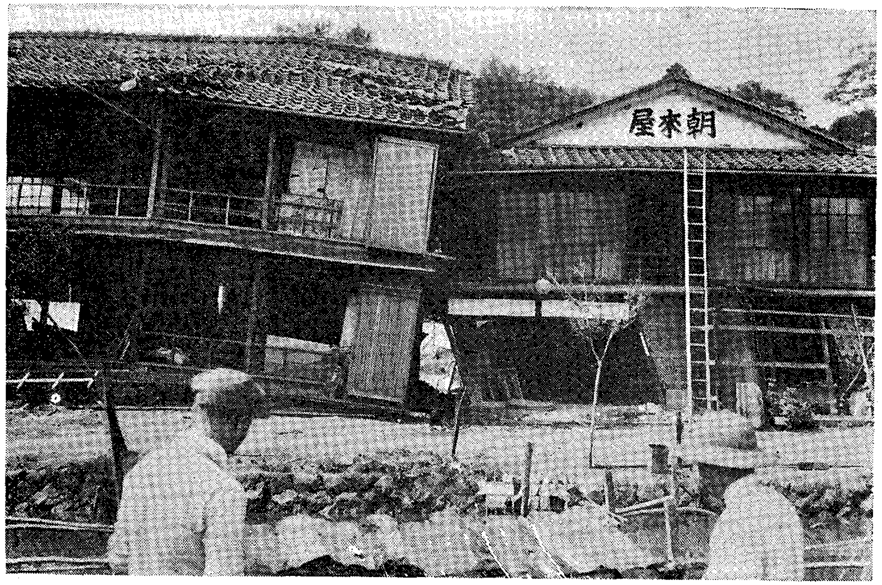
1. Bird's-eye view of Kinosaki after the earthquake.



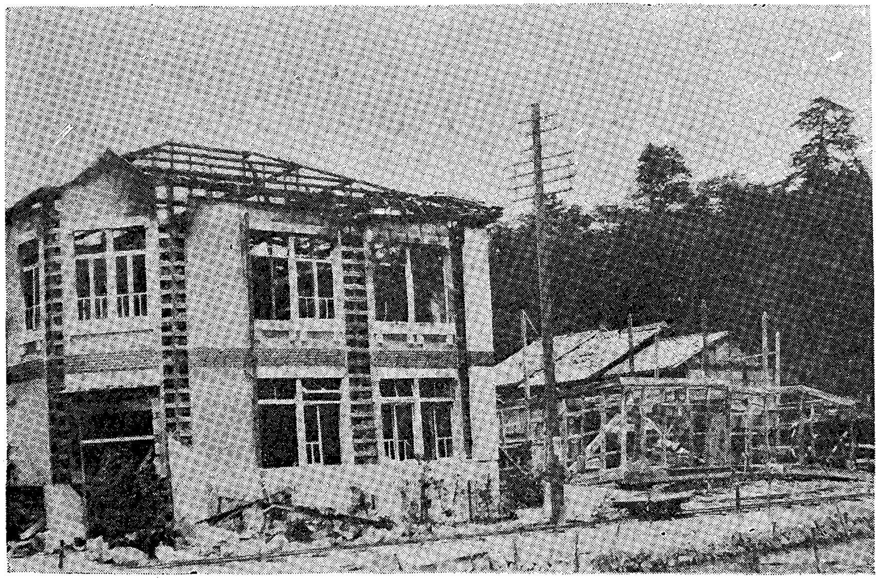
2. Wooden building of foreign style. Kinosaki. (After Taniguchi.)



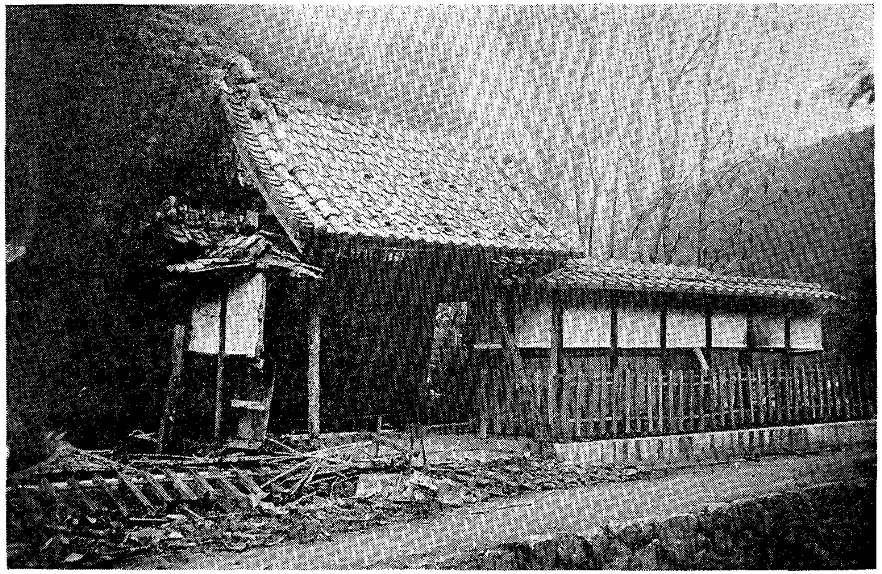
3. Foreign-styled wooden house; collapse of first story of three storied house in the right. (After Taniguchi.)



4. Collapse of first story with the second story resting on the ground (left). (After Taniguchi.)

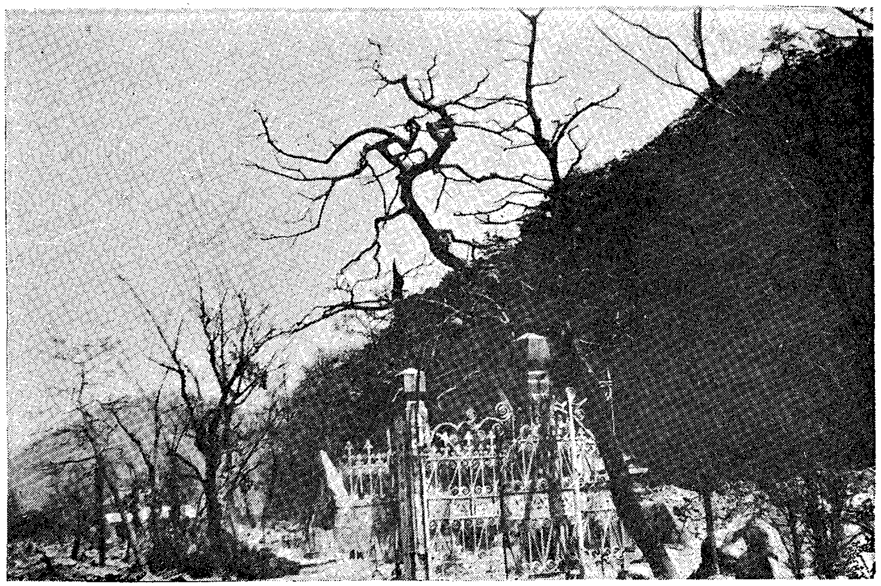


1. A dentist's house, Kinosaki. Burnt on May 29, 1925.

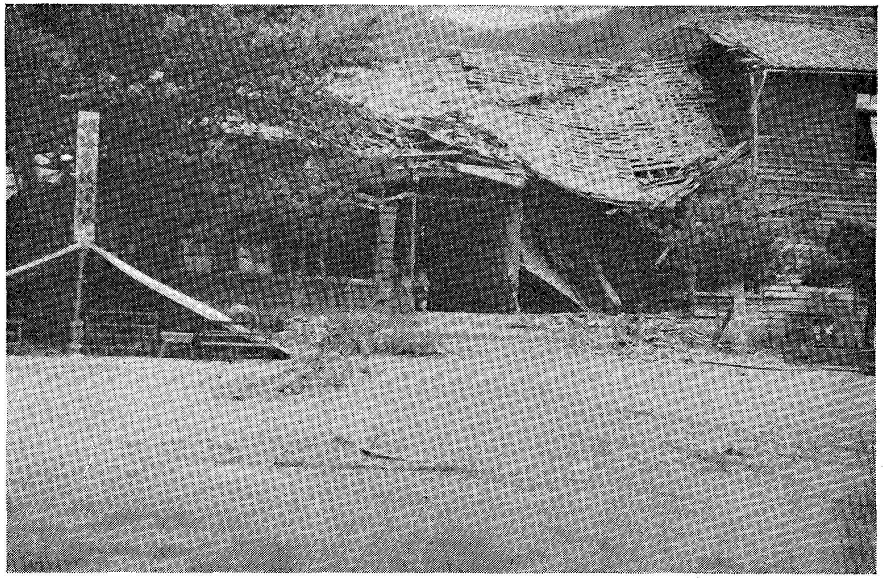


2. A Villa Gunkakuso, Kinosaki.

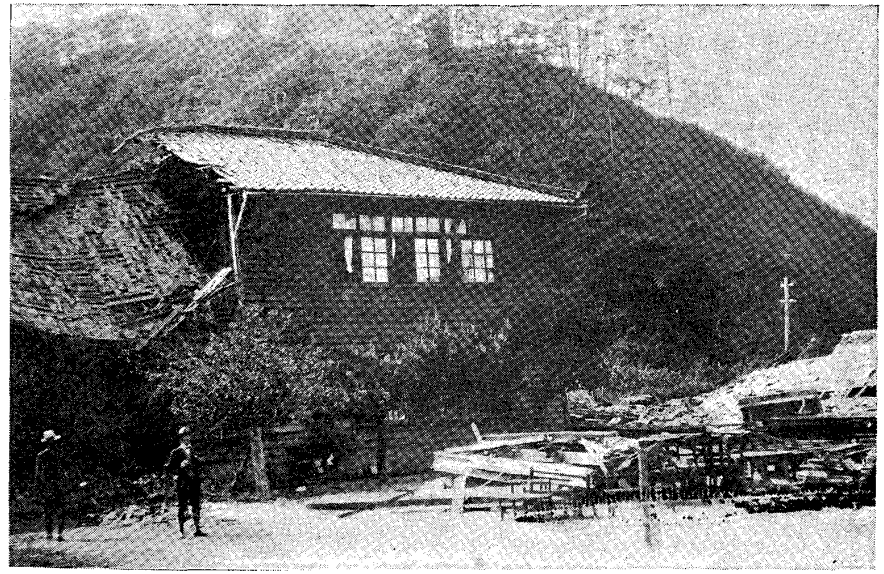
3. Vicinity of Electric-light Co., Kinosaki.



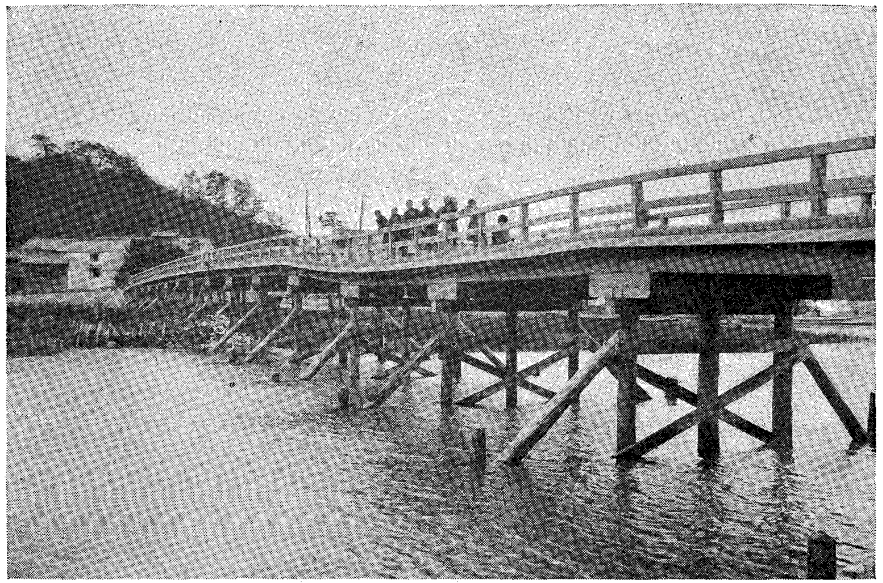
4. A villa Mikiya, Kinosaki.



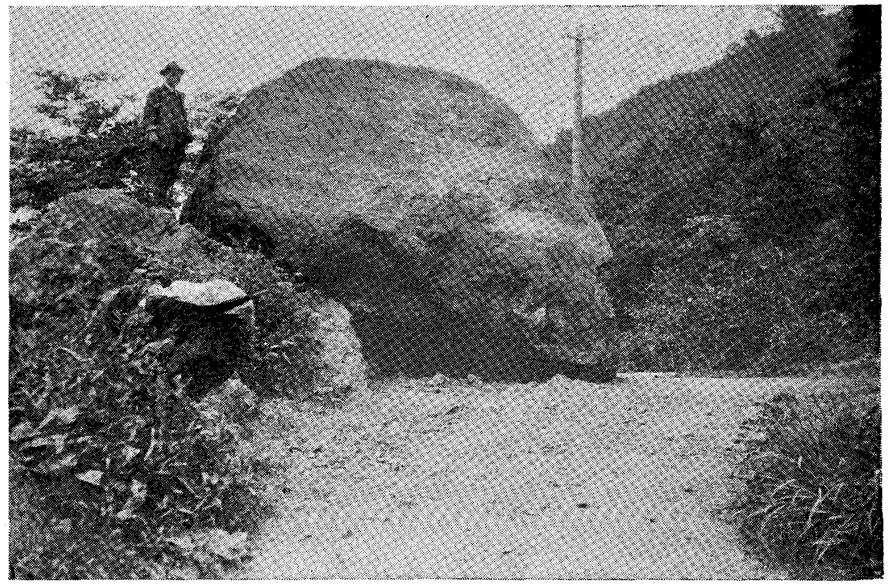
1. Kôsai Primary School.



2. Ditto.

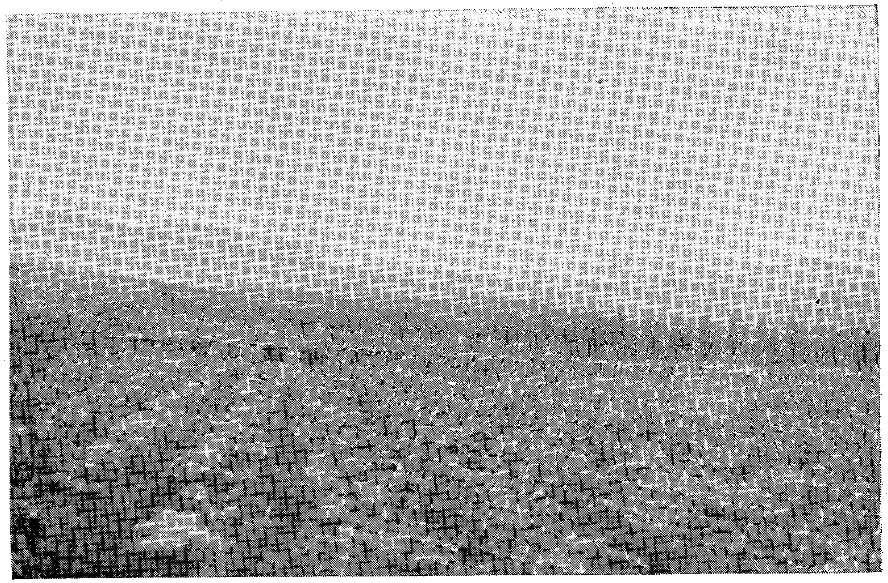


3. Takano bridge. A girder has given way.



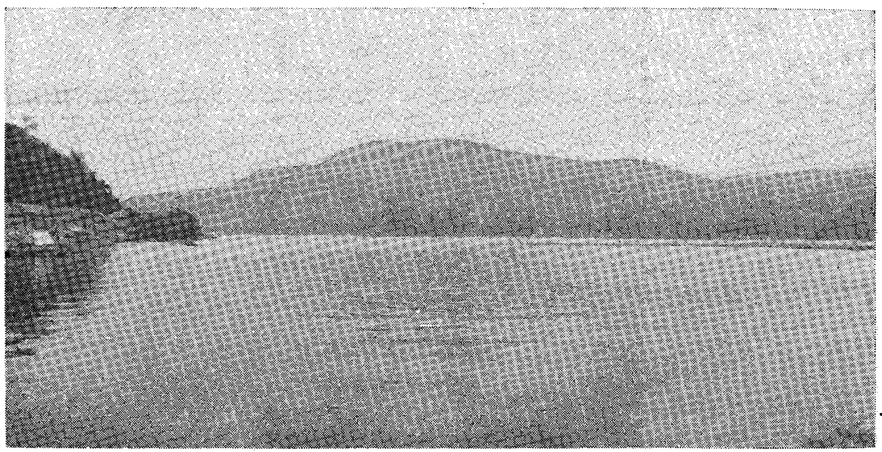
4. Road between Kinosaki and Minato-mura where a big boulder has tumbled down from the hill slope.

1. A fault traversing a field of young willow shoots.

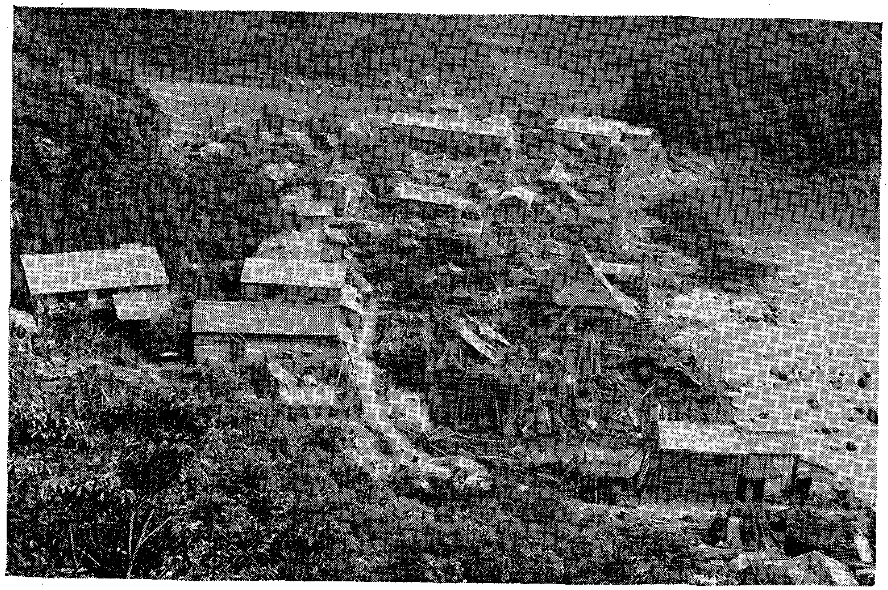


2. Ditto.

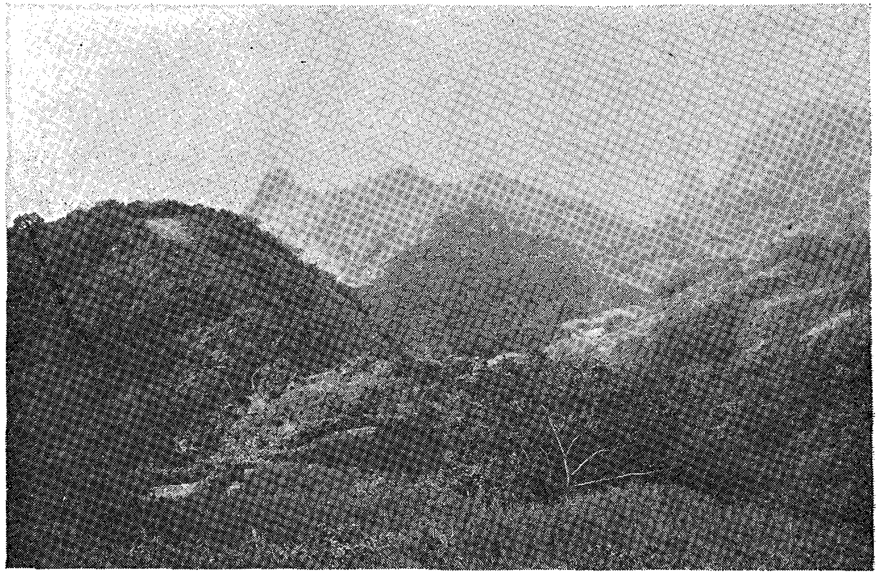
3. A trench.



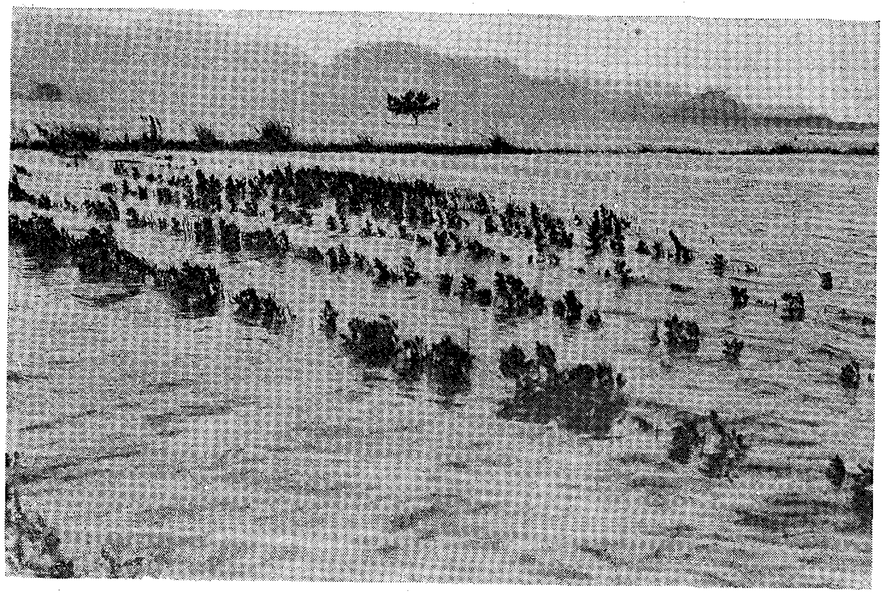
4. A portion of Tai hamlet and the hill on which the fault originated.
(From Seto hamlet looking east.)



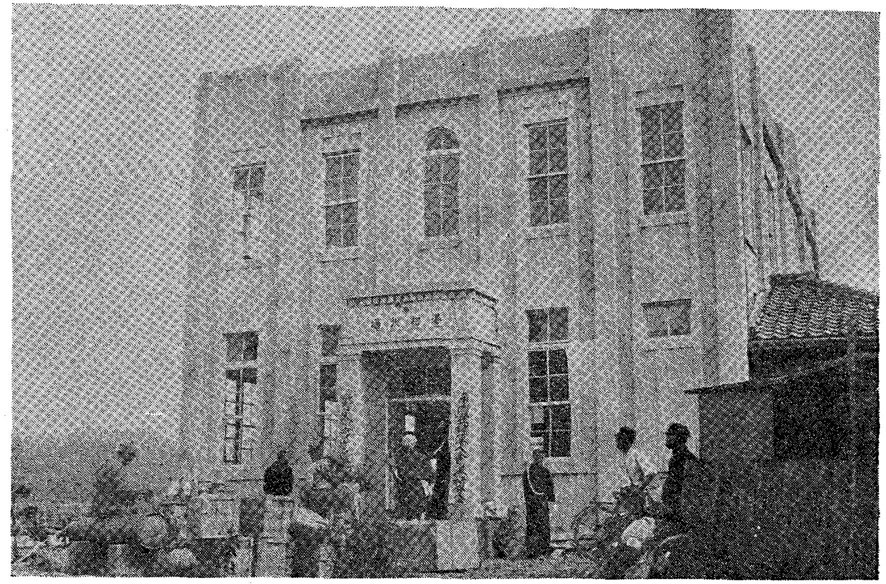
1. Hamlet of Tai. (After Taniguchi.)



2. View of Tai Hill in the epicentral district. (After Taniguchi.)

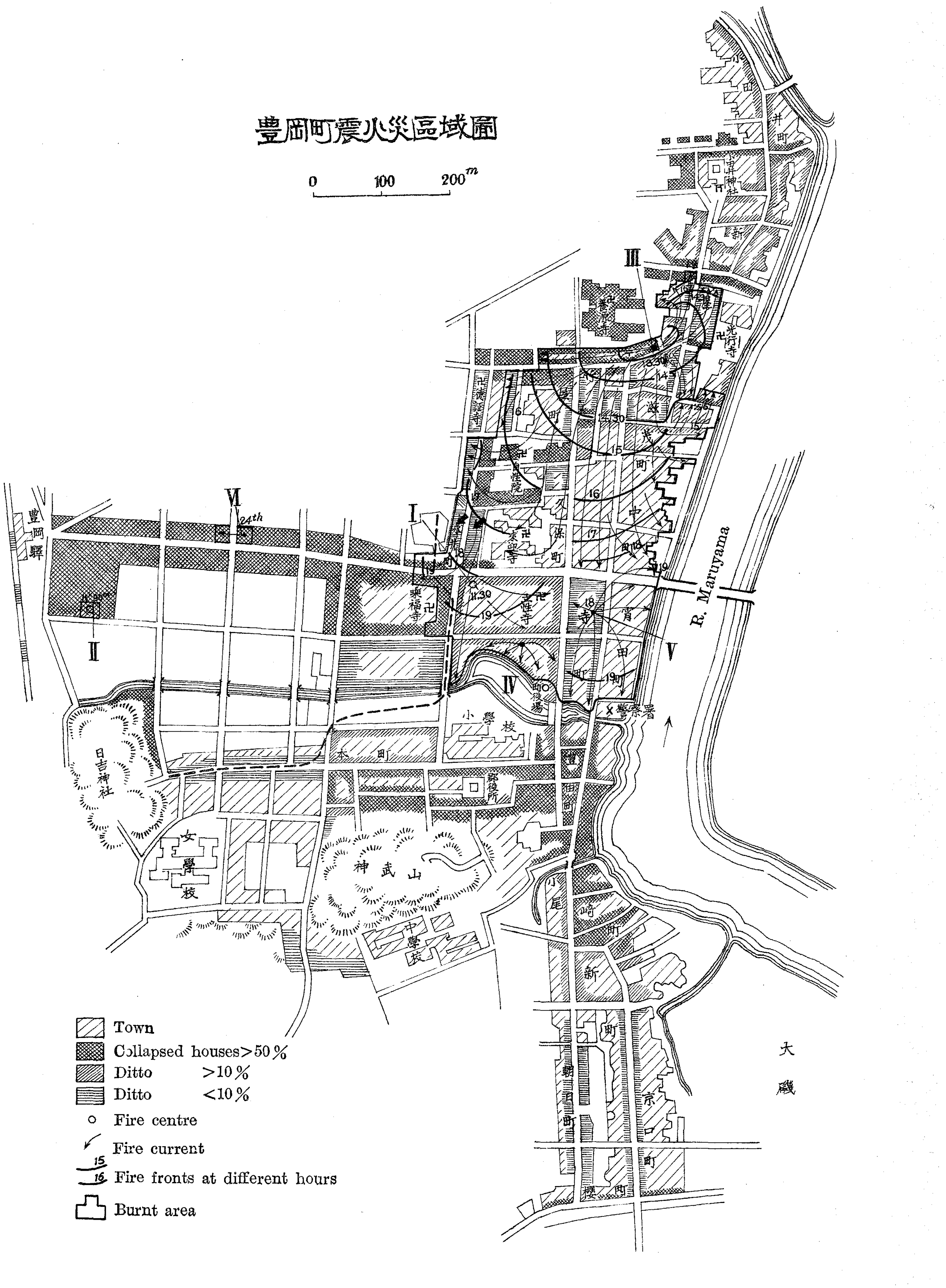


3. Near Kadurano on Kumihama Bay. This mulberry field subsided and is now in 7 feet of water. (After Taniguchi.)

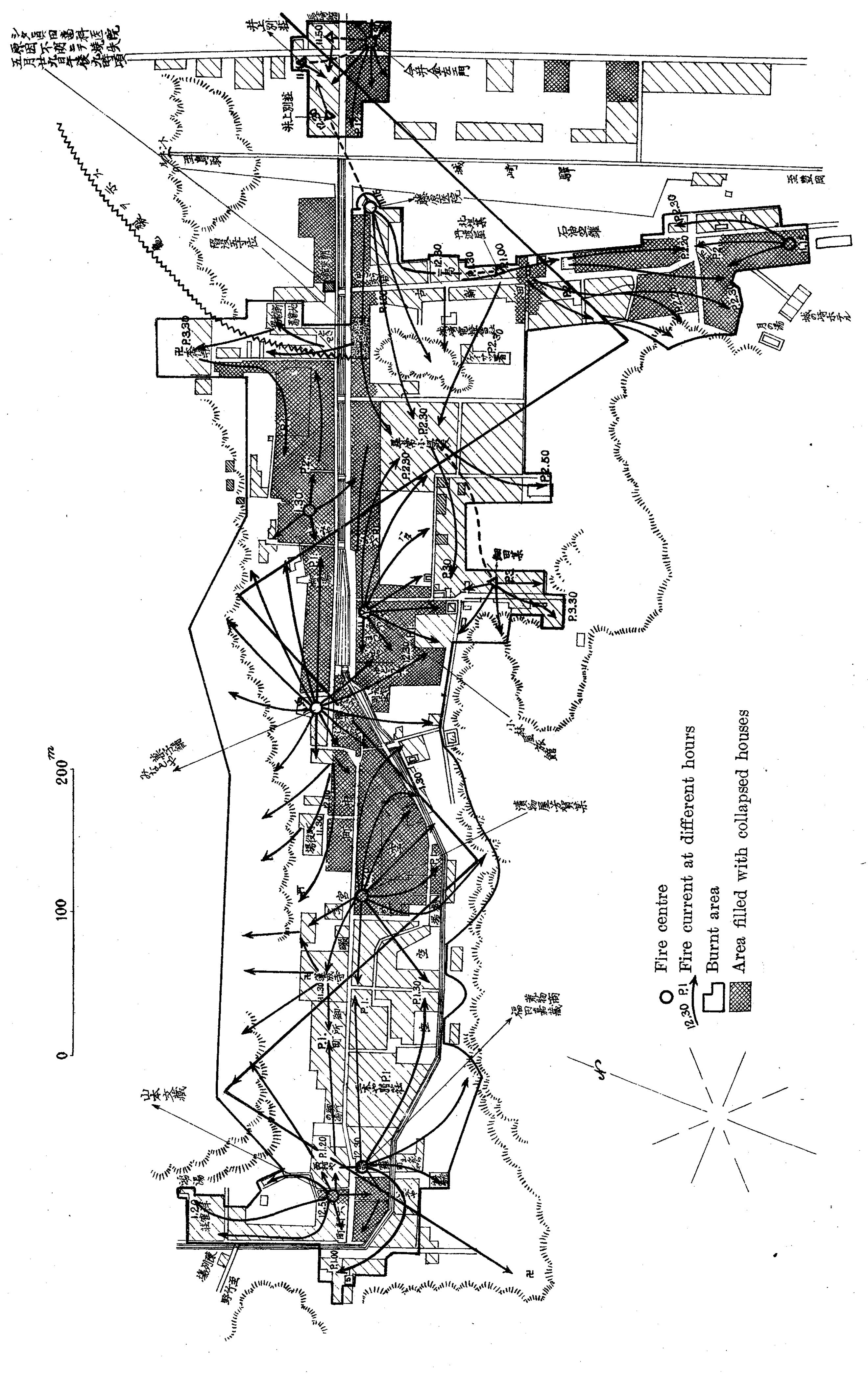


4. A ferro-concrete building in Seto, Minato-mura. Intact. (After Taniguchi.)

Map showing the effects of the earthquake and fire at Toyo-oka. (After Dr. T. Matuzawa, etc.)



Map showing the effects of the earthquake and fire
at Kinosaki. (After Meidi Fire Insurance Co.)



Map showing the effects of the earthquake and fire in Minato-mura (upper) and Kumihama (lower).