the north-eastern coast of Kyûsyû is merely a prolongation of the western coast of Sikoku. The results thus far attained are shown in Fig 3.

Chapter II. Topographical Changes in the Past that Were Accompanied by Earthquakes.

The *Dai-Nippon Disin-siryo*, a catalogue of Japanese earthquakes compiled by Mr. M. Tayama, originally under the supervision of Prof. Sekiya but later under that of Prof. Omori, records ten cases of earthquakes which accompanied conspicuous topographical changes. Among these ten there was only one in which the changes were co-seismic as well as pre-seismic. The writer, however, has brought to light two more such cases, namely the Adigasawa earthquake of 1793 and the Hamada earthquake of 1872; the records relating to them having been unearthed in the courses of record-hunting trips to these localities. Particulars of all these changes, together with those of two recent occurrences, will be found summarised in the table on page 18.

Detailed accounts of these earthquakes with special reference to the topographical changes which they accompanied are given in the following paragraphs.

No. 1. The Tosa earthquake of 684.

This earthquake is said to have taken place shortly before midnight on Nov. 29. The *Nihon-syoki*, the oldest authentic history of Japan extant, speaks of land-slides and river-floods; of the numberless dwellings, shrines and temples destroyed in the various provinces; of the countless number of men and cattle killed and wounded, and of the thermal springs of Iyo that ceased to flow. Mention is also made of a tract of land in Tosa measuring no less

Table I.

No.	Date	Locality[1]	Upheaval		Subsidence		Remarks
			Extent	Max. height	Extent	Max. height	
1	684 XI 29	Tosa			9 km²	?	Sank under the sea
2	1331 VIII 15	Senrigahama, Kii Prov.	3 km	2 or 3 m			
3	1596 IX 4	Ooita, Bungo			10 km²	10 m	Uriu Is. sank under the sea.
4	1703 XII 31	Kwanto	1500 km²	6 m			
5	1707 X 28	Nankaido	SE coast of Tosa	3 m	NW coast of Tosa	3 m	
6	1793 II 8	Adigasawa, Mutu Prov.	12 km	3 m			Preceded by slow upheaval
7	1802 XII 9	S part of Sado	25 km	2 m			Do.
8	1804 VII 10	Kisakata, Ugo Prov.	10 km	2 m			
9	1847 V 8	Nagano	8 km	1.2 m	8 km	1.2 m	
10	1854 VII 9	Iga & Ise			1×0.2 km	1.5 m	
11	1854 XII 24	Nankaido	500 km²	1.3 m	1500 km²	1 m	
12	1872 III 14	Hamada, Iwami Prov.	20 km	2 m	20 km	3 m	Preceded by slow upheaval
13	1896 VIII 31	Rikutyu & Ugo.	60 km	1 m	60 km	1 m	
14	1906 III 17	Kagi, Formosa	25.5 km	1 m	25.5 km	1 m	

1) See Fig. 3.

than 500,000 siro (8.25 sq. km.) which sank under the sea. Judging from local traditions, this submergence would seem to have taken place, either on the coast in Takaoka county situated south-west of the city of Kôti or in the vicinity of the city itself. It is said that on this occasion two villages called Oora and Oda, each with its thousand habitations, were swallowed up by the sea. The region is Cretaceous with a shore line of the *rias* type—a formation it would seem eminently suited for such happenings. It may be remarked here that a similar state of things happened also in the case of the Nankaido earthquake of 1707.

No. 2. The Senrigahama earthquake of 1331.

Senrigahama is the name given to a strip of coast on the western

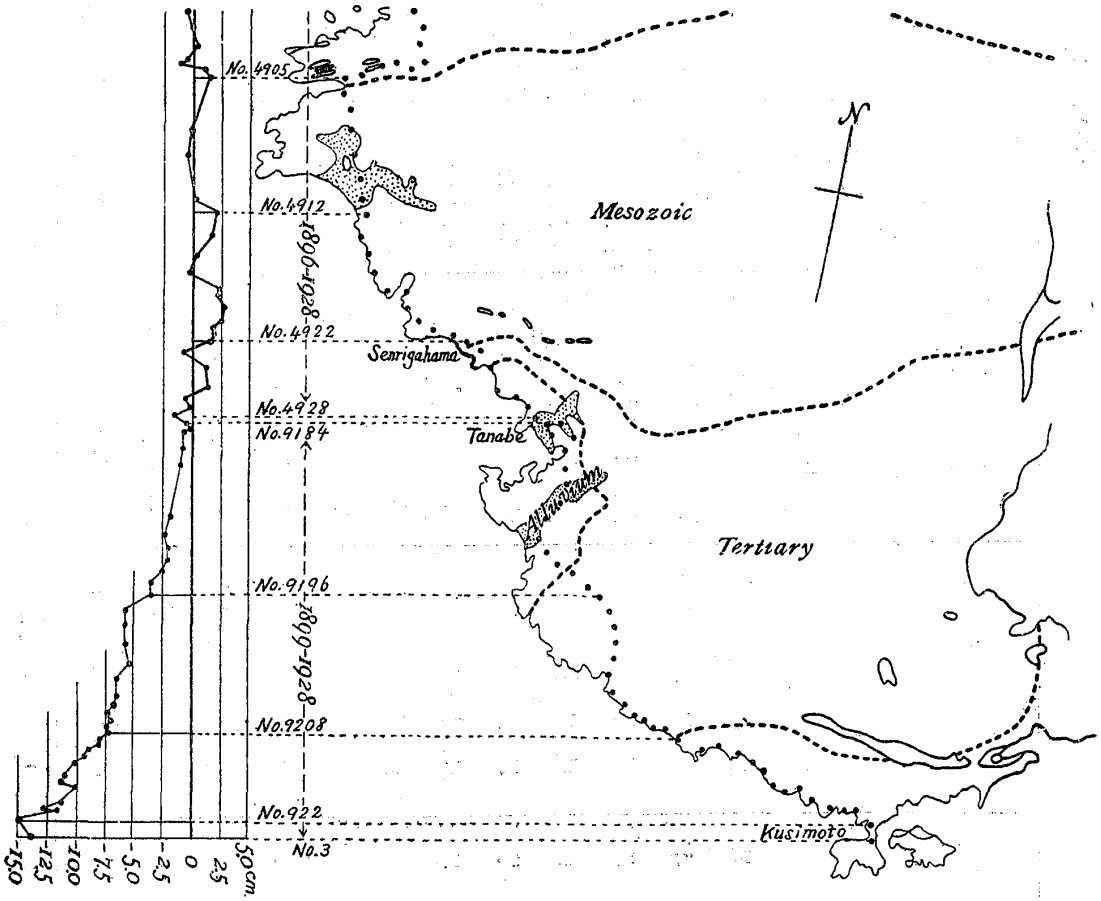

Fig. 4.

side of the Kii Peninsula. Bench-marks Nos. 1920–1923 of the Military Land Survey lie quite close to the shore here, so that the precise levellings of 1896 and 1928 should be helpful in the study of this earthquake.[1)]

The earthquake took place on Aug. 15th. In consequence, the shore of Senrigahama was suddenly elevated, and it was found that for a distance of nearly three km. it had widened considerably when compared with what it was before the earthquake. Since this seashore today has nothing like the imputed width, we think we may safely put the change down to one of the minor phases of that change on a much larger scale which has been and is still going on in this peninsula. The earthquake although destructive was quite local in character, and might well have been the precursor of the non-local destructive earthquake of 1361, which caused such awful havoc in the southern part of Central Japan, especially in the Kii Peninsula, besides bringing in its train *tunamis* on the shores of Kii Channel and Osaka Bay. Furthermore, since the recent chronic tilting of the locality, as revealed by the levellings already referred to, was a sharp backward tilt, and quite independent of the contiguous rock mass, it may be legitimate to assume that the topographical change that came with the earthquake of 1331 consisted of a sharp, independent tilting of the mosaic block which is the northernmost segment of the Tertiary block forming the end of the peninsula.

No. 3. The Bungo earthquake of 1596.

This earthquake was felt on the fourth of September after a month of more or less continued seismic activity. It came about 7 hours before the celebrated Husimi earthquake which became

1) A. Imamura: Jap. Jour. Astr. & Geop., Vol. VII, No. 1.

famous in connexion with an incident in the life of the great historical personage Taiko-Hideyosi. In former times there was an island called Uriu-zima situated a short distance off the site of the present city of Ooita, and which had an area of 2.3 km. N-S by 4 km. E-W with a population of as much as 5,000. This island is

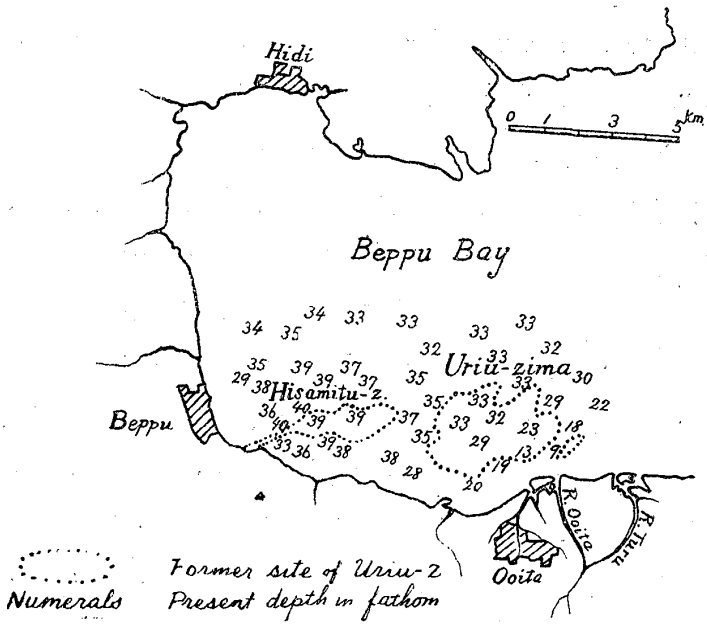

Fig. 5.

now no more above water, lying as it does some 30–40 fathoms below the surface of the sea. Contrary to what is the experience with most big earthquakes, the destruction was not instantaneous; that is to say, it did not come as a single blow so to speak. In the afternoon of the eventful day a shock was felt that was severe enough to open fissures in the ground and cause damage to buildings. Then quiet reigned for a while, but at 5 p.m. was distinctly heard that ominous, dull roar so characteristic of approaching *tunami*. Panic-stricken, the people fled for safety; some to high ground and others to the shore opposite, but 708 persons were unfortunately caught in the on-rushing flood. On the following morning to everyone's amazement, Uriu-zima (island) was found

to have subsided to a considerable extent and that three-quarters of its area had been drowned. Needless to say, later subsidences must have added their quota to the reduction of the island to its present plight of submergence under 30 odd fathoms of water, but the denuding action of sea waves and other agencies must also have had their share in the work.

We might add that about a year later, on Sept. 10, 1597, the region was visited by another severe shock when the small promontory of Hisamitu-zima, situated between the above mentioned island and the city of Beppu, vanished under the sea.

No. 4. The Kwanto earthquake of 1703.

This non-local, destructive earthquake, having characteristics much in common with its 1923 namesake, took place about two in the morning of Dec. 31st. In the severity with which it shook the Kwanto region as well as in the extent of area shaken, it nearly equalled that of the 1923 earthquake; but in the topographical changes on land which the earthquake accompanied and in the magnitude of the tidal waves, those of the 1703 earthquake were much greater. In Yedo (now Tokyo) and in Odawara fires started from a number of centres and added to the horrors. The total killed was 5,233 while the houses thrown down numbered 20,062.

That the *tunami* was bigger in the case of the present earthquake will be apparent from the following records. In Kamakura and neighbourhood the wave came as far as the second gate of the Hatiman Shrine, that is into the grounds of the Kômyôzi Temple, and swept away most of the houses in the villages of Kotubo and Katase, while in Itô 163 persons were drowned. On the Pacific side of the Bo-So Peninsula the wave was so high that on the coast of Kuzyûkurihama it rushed as far inland as 2.4 km. from the beach. The shores of Tokyo Bay were also flooded, and in the

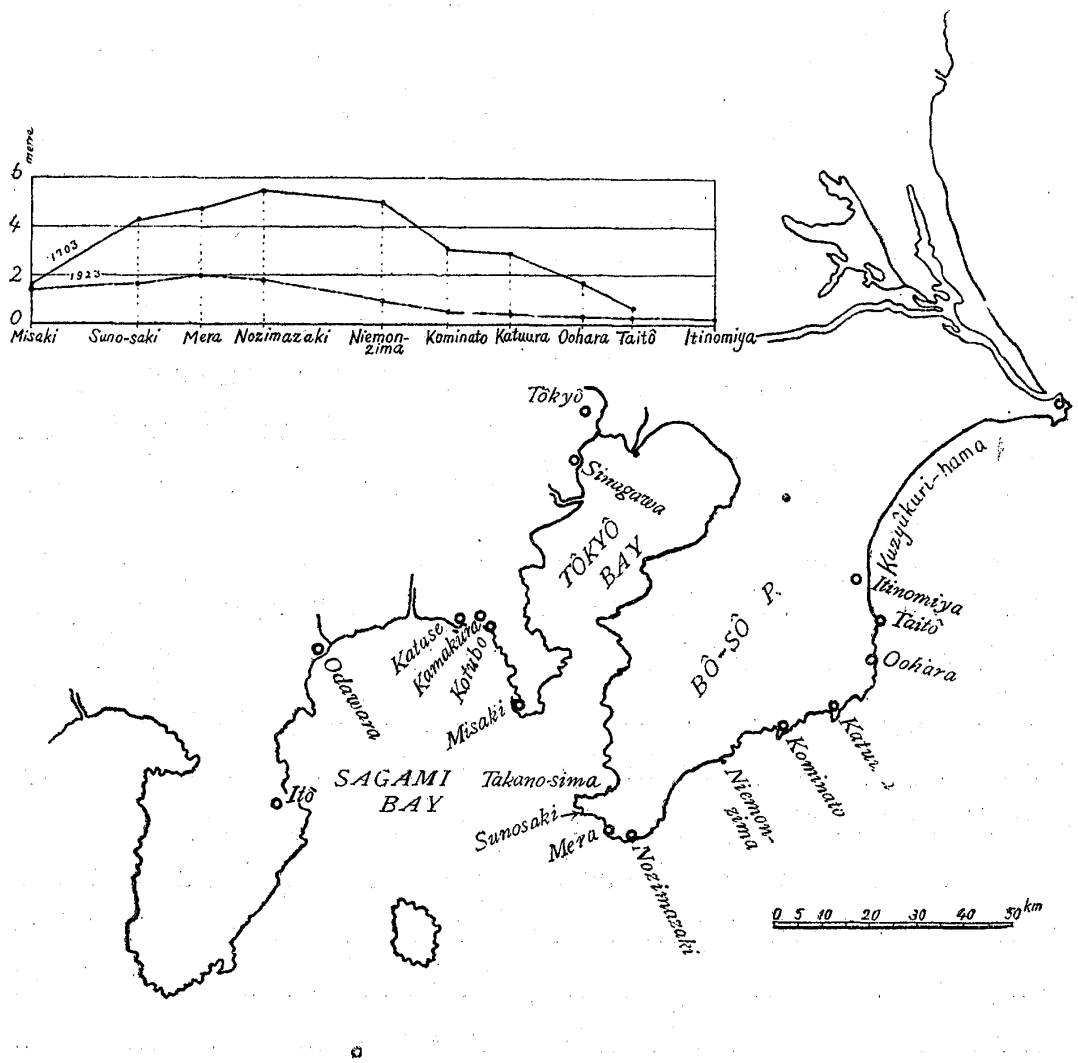

Fig. 6. Map showing the topographical change accompanied by the Kwanto earthquake of 1703.

city itself the wave came as far as the south of Sinagawa. These facts would seem to suggest that the changes wrought in the sea-floor were on a larger scale than was the case with the 1923 earthquake.

The changes that took place on land were no less remarkable. We give below a comparative table of the upheavals associated with each of these two earthquakes for various points on the southern coasts of the Miura and the Bo-So Peninsulas.

Table II.

	Misaki	Takasima	Sunosaki	Mera	Nozima-z.	Niemonzima.	Kominato	Katuura	Oohara	Taito	Itinomiya
1703	1.6[m]	2.5	4.2	4.7	5.5	5.0	3.0	2.9	1.7	0.7	?
1923	1.4	1.6	1.6	2.0	1.8	0.9	0.5	0.4	0.3	0.3	0.2

Of these data, those for the 1923 earthquake were deduced from precise levellings and geodetic triangulations, while those for the 1703 earthquake were estimated by the writer after careful consideration of the pre-seismic mean sea-level as indicated on the faces of Tertiary cliffs by perforations of the boring shells, *Lithophaga nasuta.*[1] It might be added in passing that an ancient map of Mera and environs dating back to 1653 and records of the upheaval of Nozima, formerly an islet but now a peninsula, have shown themselves to be in fairly good agreement with our data for these two places as given in the above table.

It will thus be seen that the topographical changes, both terrestrial and submarine, connected with the earthquake of 1703, occurred on a larger scale than those connected with the earthquake of 1923. We shall also find that the upheavals undergone by the various points on the Bo-So Peninsula, from the westernmost one up to that on the extreme south of the peninsula, namely, Misaki, Sunosaki, Nozima-zaki and Niemon-zima, indicate that the direction of the tilt was in the main NW-SE. This coupled with the fact that the uplift at Mera, Nozima-zaki and Niemon-zima, all of which lie on a line trending SW-NE, i.e. perpendicular to the direction mentioned in the preceding lines, are almost equal in amount, lead us to the conclusion that the tilting of the

1) A. Imamura: Jap. Jour. Astr. & Geop., Vol. V, No. 3.

Kwanto block associated with the 1703 earthquake was *onward* hence similar to that which occurred in 1923, although the neutral axis seems to have been shifted slightly towards the southeast.

No. 5. The Nankaido earthquake of 1707.

This earthquake, which occurred on the 28th of October at about one in the afternoon, was of the non-local, destructive type. It originated off the coast of Nankaido and was the most violent ever recorded in this country. Houses were shaken down in 26 provinces; the distant outlying ones being Suruga, Kai, Sinano, Mino and Oomi in the east and north; Harima in the north-west; and the eastern provinces of Kyûsyû in the west. The disasterous effects of the terrible *tunami* were felt as far as Idu in the east to Kyûsyû in the west. The wave reached its maximum at Tanesaki near Kôti where it attained the enormous height of 70 feet. After passing through the Bungo Channel it washed the coasts of Suo and Nagato in the Inland Sea, while another wave sweeping through the Kii Channel entered Osaka Bay and charged into the city of Osaka. Here the piled up waters tore thousands of boats from their moorings in the harbour; some being wrecked while others were carried further up the river, destroying every bridge that stood in the way. The dead numbered 4,900 and the number of houses either destroyed or washed away totalled 29,000.

As regards topographical changes, we have a few records covering Kii and Tosa. Judging from the subsidences that occurred at Tanabe and Singu, both in Kii Province, it would appear that an acute, onward tilting took place in the southernmost Tertiary block of the peninsula in much the same way that we have seen in connexion with the earthquake of 1854.

The changes in Tosa consisted of an upheaval on the eastern, and a subsidence on the western, side of the river Monobe, which

in all probability, occurred in two different ways, namely, (i) block-tilting on the eastern side with its strike trending NE-SW lifting the SE side of the block, and (ii) block-tilting on the western side with its strike trending W-E and dipping northwards. (See Fig. 8.)

The evidences of the tiltings of the different blocks are as follows:—

For block A—Muroto and Turo were elevated as much as 7–8 feet. The eastern coast from Muroto as far as None, which are Tertiary in formation, escaped the effects of the *tunami*, whereas the section of the coast lying to the north of None suffered much damage.

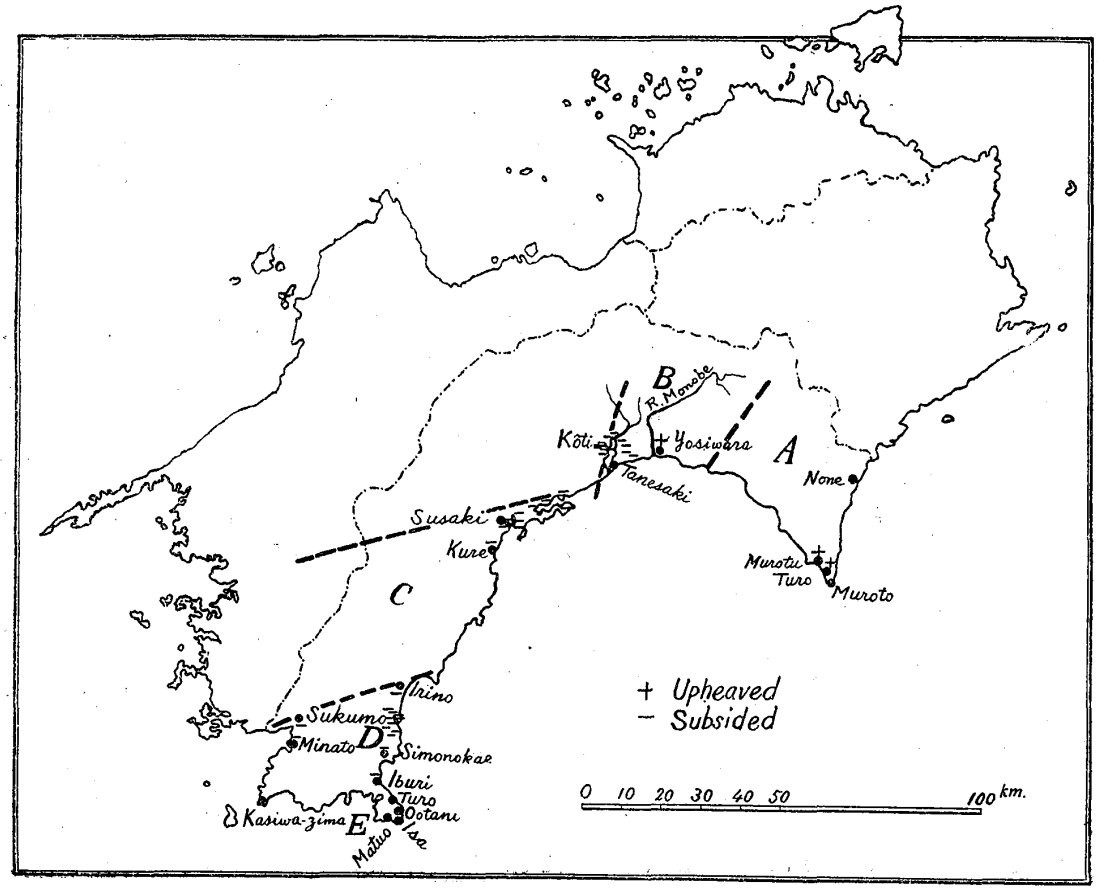

Fig. 7.

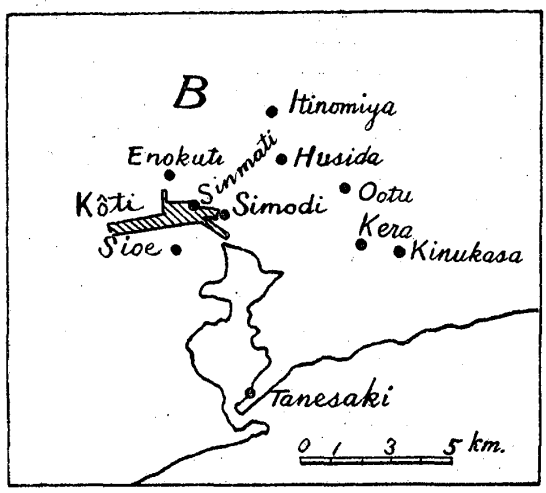

Fig. 8.

For block B—The towns and villages in and around the city of Kôti, such as Sinmati, Simodi, Sioe, Enokuti, Itinomiya, Husida, Ootu, Kera and Kinugasa, subsided sufficiently to be under more or less sea-water since the day of the catastrophe, whereas Yosiwara was uplifted nearly 7 feet.

For block C—Sinkings of nearly two metres were recorded at Inohama, Hukusima, Ryû, Urauti, Okuura, Tutizaki, Oonogô, Ikeuti and Kure; all of which are situated at or near the northern end of the block.

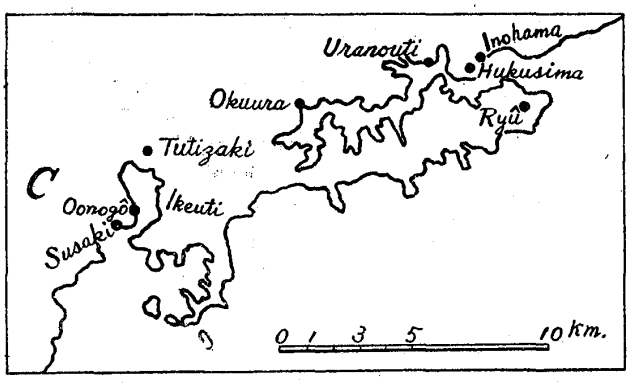

Fig. 9.

For block D—Subsidences were reported from Irino, Nabesima, Takesima, Isawa, Kotuga, Yamadi, Sanesaki, Hukaki, Masaki, Tukurabuti and Simonokae, situated on the eastern side of the northern boundary of the present block; as also from Sukumo and Minato, on the opposite side of the same boundary.

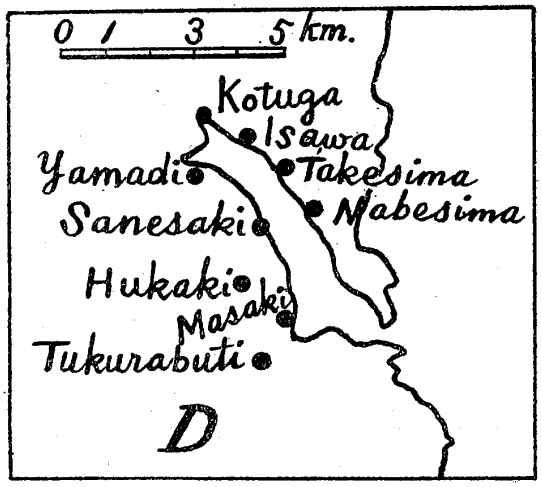

Fig. 10.

For block E—The only subsidence recorded was at Iburi. The fact that the *tunami* was quite harmless at Turo, Isa, Ootani and Matuo, all of them on the opposite side of the block, strongly suggests that the latter side underwent no subsidence.

No. 6. The Adigasawa earthquake of 1793.[1]

At about 1 p. m. on Feb. 8, this earthquake having its epicentre at Ootose, violently shook the western half of the province of Mutu, causing a loss of 12 lives and the collapse of 164 houses. The rather light casualty despite the severity of the shock was owing to no other cause than that the region was sparsely populated. There was a *tunami* but the damage was trifling.

The topographical changes on the other hand were most remarkable. A strip of the coast extending for some 12 km. with Ootose as its approximate centre, was lifted as much as 3 metres at the highest point. But what is still more remarkable was the pre-seismic change of the last stage that was experienced at Adigasawa, a town lying some 12 km. to the east of Ootose. It is said that on the morning of that fateful day some people standing

1) For details see A. Imamura: Rep. (in Japanese) Imp. Earthq. Inv. Comm. No. 95.

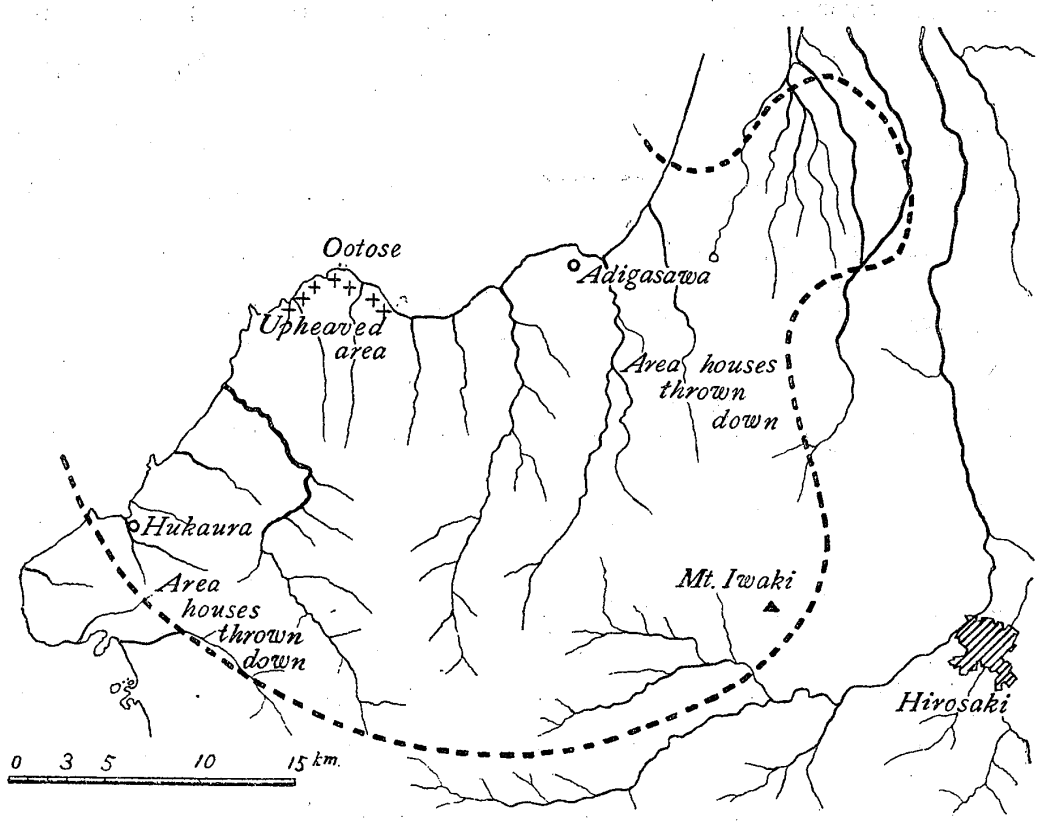

Fig. 11. Map showing the disturbed area in the Adigasawa earthquake of 1793.

on the seashore noticed an extraordinary ebbing of the tide which was mistaken for the warning of an approaching tunami, whereas it was nothing more than an upheaving process actually going on before their eyes. Horror stricken they fled into the hills and for some hours anxiously awaited there the dreaded tunami. To their consternation, however, what eventually did come was not the much dreaded wave but a tremendous earthquake. Owing to landslides and to falling boulders and other rock debris, they promptly forsook their place of refuge and made for the

beach again, whereupon they were at last overtaken by the object of their first apprehension—the tunami.

It might be added that the district is Tertiary in formation, overlain here and there with new eruptives.

No. 7. The Sado earthquake of 1802.

This earthquake which took place on the 9th of Dec. at two in the afternoon, shook with great violence the southern part of Sado Island and caused the destruction of 1,150 houses through collapse or fire and a loss of 19 lives. The little seaport town of Ogi received the brunt of the shock, and here most of the buildings were shaken down, when eventually 328, out of the total number 453, caught fire.

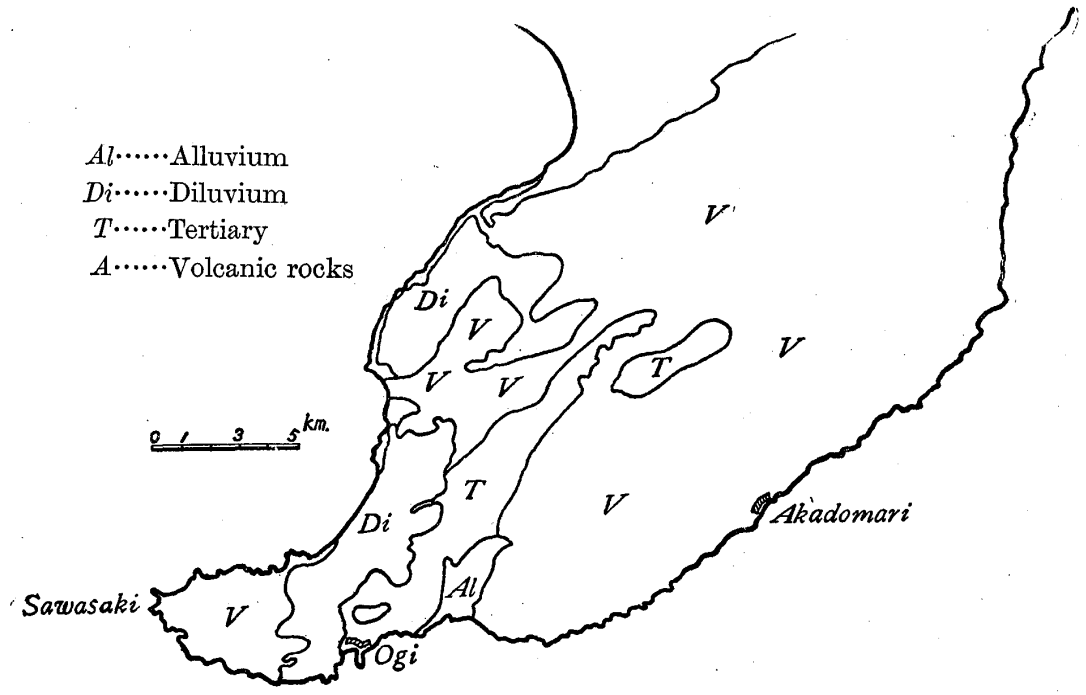

Fig. 12. Map showing the seismic area of the Sado earthquake.

At about 10 in the morning of the same day the place was visited by a somewhat milder shock. By this time an extraordinary ebbing of the tide was taking place until some parts of the harbour had become actually dry. The inhabitants however misinterpreted the phenomenon for the harbinger of a tidal wave, just as they did at the time of the Adigasawa earthquake as described in the preceding paragraphs. An accurate measurement of this upheaval is wanting, but we shall not be far wrong in assuming it to have been about a metre. The permanent uplift at Ogi however was as much as 2 metres. The coast was raised from Sawasaki in the east to as far as Akadomari in the east—a distance of nearly 25 km. The character of the formation here is also Tertiary, pierced at places by new eruptive rocks.

No. 8. The Kisakata earthquake of 1804.[1]

This earthquake which took place at midnight on July 10 originated in the west of Mt. Tyôkai, with Kisakata as its epicentre. New eruptive rocks prevail in this district, but the basal layer is Tertiary. As Mt. Tyôkai, which had begun its latest eruption 4 years ago, was still active, the shock was considered by many as having been caused by the eruption, but it will be seen that the shock betrayed not the slightest characteristic of a volcanic earthquake. The meizoseismic area comprised a somewhat narrow zone measuring 70 km. by 15 km. Kisakata was violently shaken and out of 523 dwellings, 423 collapsed and 65 persons were killed. The number of houses destroyed for the whole of the disturbed area totalled 5,500 while the loss in lives was 330.

This earthquake is notorious for having deprived Japan of a very picturesque scenery afforded by the Kisa-kata lagoon (kata

1) Loc. cit.

means lagoon). The lagoon had a circular area of about 2 km. radius and was filled to an average depth of 2 metres with clear sea water. The charm of the lagoon was greatly enhanced by 99 pine-clad islets that were dotted all over the placid waters. But the topography was changed overnight as the result of an upheaval of which the earthquake was an accompaniment, and with the sudden disappearance of the pretty lake there arose an aggregation of unsightly lands and muddy pools. Kisakata had arisen at least two metres, while at Konoura, some 6 km. away, the amount arisen was about 1.3 metres. It must be remarked that not all the changes were elevations: at localities not far removed there were subsidences as well. Thus at Kotaki about 4 km. to the southeast of Kisakata, an area of a few sq. km. was depressed about a metre in consequence of which the course of a stream was completely altered.

No. 9. The Zenkôzi (now Nagano) earthquake of 1847.

This earthquake, at about 9.30 on the evening of May 8, originated near Zenkôzi and laid waste the northern part of Sinano and the western part of Etigo; throwing down as many as 30,000 houses besides an additional 13,000 which were partially levelled. It came in the midst of a religious service at the Zenkôzi Temple so that thousands of devout worshippers were among the victims, besides some 8,500 others that met the same fate.

Fires promptly broke out in the towns of Zenkôzi, Iiyama, Inariyama, Sinmati, etc., and practically completed the destruction. In Zenkôzi out of a total of 2,236 dwellings only 142 were left unscathed by fire or earthquake.

The most characteristic phenomenon in connexion with this earthquake, however, was the extraordinary large number of

landslides that took place and the consequences which they brought about. It is said that the number altogether did not fall short of 43,000, hence small wonder that many villages were buried under falling debris. The largest of these occurred between Komatubara and Sinmati (see Fig. 13) and completely blocked the course of the River Saikawa, with the result that in the course of a week or two there came into existence a temporary lake measuring 28 km. by 4 km. at its widest part. This new lake however was not destined to remain for long, for at the end of 19 days the blocking dam gave way and let loose the enormous quantity of water, giving rise to a terrible inundation which carried destruction before it, sweeping everything off both banks of the lower river course. Some 4,800 houses and 28 persons were thus swept away.

The topographical changes, with which we are most concerned in connexion with our studies, duly appeared in the form of a conspicuous fault line. It was in the meizoseismal area with a trend SW-NE and extended for about 8 km. At a point near Nagano the NW side of the fault had arisen as much as 2.4 metres relatively to the opposite side.

No. 10. The Iga-Ise Earthquake of 1854.[1]

This disasterous earthquake, which took place on July 9 at about two in the morning, laid waste not only a great part of the northern section of the province of Iga where it originated, but also the NE part of Ise and the N corner of Yamato as well; the casualties being some 5,000 houses destroyed and 1,352 persons killed.

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1) For details see A. Imamura: Rep. (in Japanese) Imp. Earthq. Inv. Comm. No. 77

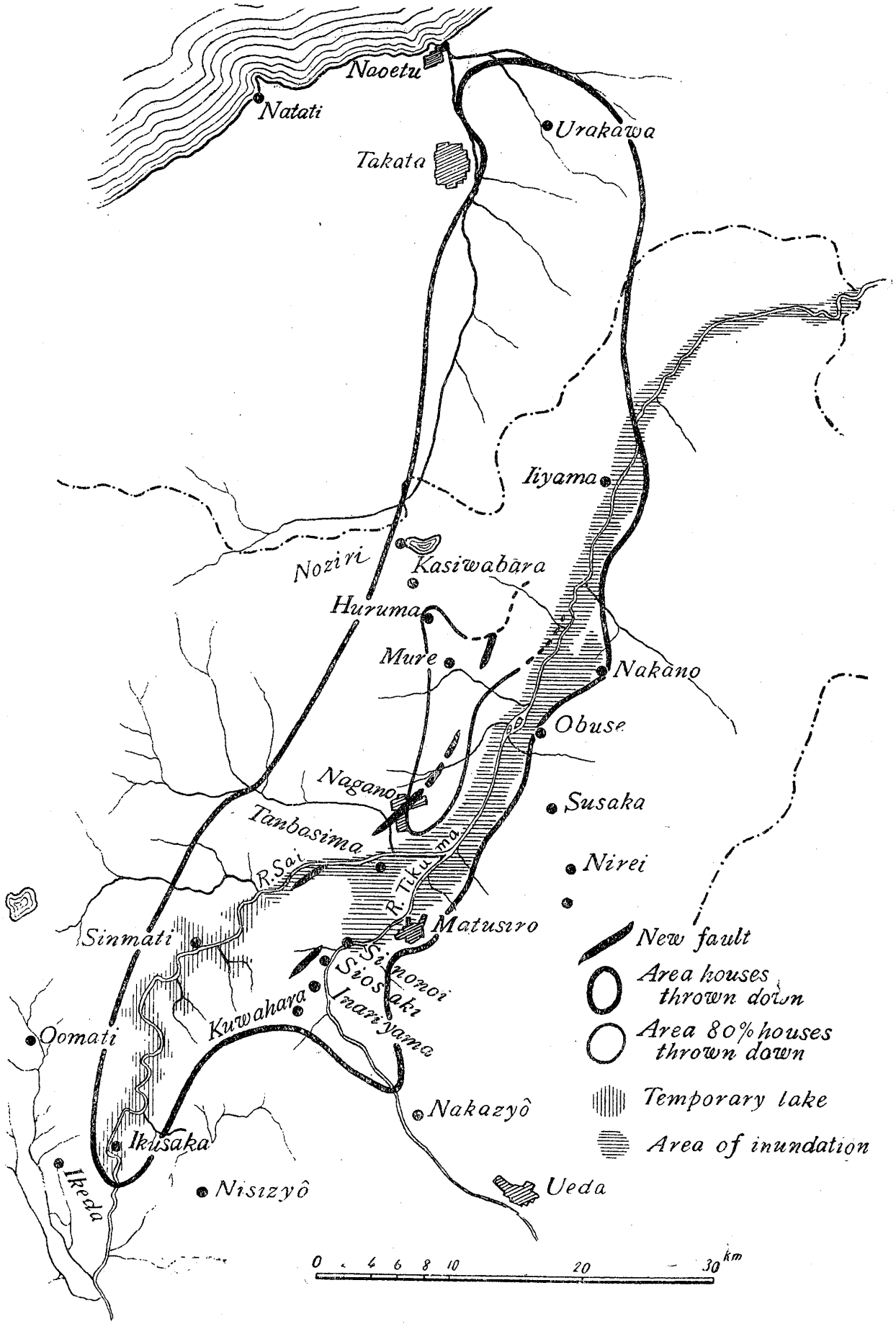

Fig. 13. Map showing the disturbed area in the Zenkôzi earthquake of 1847.

The coming of this earthquake was heralded by many foreshocks, the earliest of which was felt 3 days before in the town of Ueno as scarcely more than subterranean rumblings. At noon of the 7th a strong shock was felt, followed by one still stronger two hours later. After that a succession of slight shocks followed, although most of them were mere rumblings. Twenty-seven of them were counted before evening. On the 8th things seemed to have quieted down somewhat, although in addition to a number of slight shocks, a moderate one was felt near two in the afternoon, succeeded by two or three more slight shocks until at 2 a.m. of the following morning came the final destructive shock.

The topographical change consisted of a relative subsidence in the epicentral area on the right bank of the river Tuge lying due north of the town of Ueno. For about 1 km. along the river course a strip some 200 m. wide had sunk down, and at the northern boundary of this sunken area was a dislocation with a trend WSW-ENE, while on its southern side there was a relative sinking of about 1.5 m. maximum. The result of this was that the water of river Tuge began to accumulate in the newly formed depression so that in the course of a few weeks a lake had been formed, and it was only after the river bed at a point lower down in its course had been cut down that the river assumed its normal flowage.

No. 11. The Nankaido earthquake of 1854.

This earthquake, which occurred on Dec. 24 at about 5 in the evening, that is 33 hours after a similar earthquake had originated off the coast of Tokaido, belonged to the non-local, destructive class and resembled in many ways the great earthquake of 1707 although its destructivity was not so great. The most violently

shaken regions were the two provinces of Tosa and Awa and the southwestern part of Kii, the air-line distance from west to east of this area being 300 km. It also shook the northern part of Idumo levelling some 150 houses, but we have reasons for believing that this was owing to another large independent earthquake which was set in motion there by the earthquake under discussion.

As usual fires broke out in the towns of Kôti, Tokusima and Tanabe where 2,491, 1,000 and 383 houses were burnt down respectively. In addition to these, fires occurred also in Nakamura, Sukumo, Teiura, Yasuura, Hatanaka, Simoda, Simonokae and Urato.

The *tunami* travelled as far as the Bo-So Peninsula in the east and the eastern coast of Kyûsyû in the west. Its effects were most disasterous on the western coast of Kii and the western portion of the Tosa coast; the wave having swept away as many as 9,000 houses in the former and 3,200 in the latter. The scourging received by Osaka from the earthquake wave of 1707 was almost duplicated, the loss to small craft and bridges being considerable, while as many as 392 persons were drowned in the rivers. Waves also swept through the Bungo Channel and washed the shores of Mitugahama in Iyo Province.

The full casualty list reads:—10,000 houses levelled, 6,000 reduced to ashes, 15,000 washed away and 3,000 people killed.

As to the topographical alterations, there is abundant reason for assuming that those which took place in Tosa more or less resembled those associated with the earthquake of 1707, especially was this the case with the subsidences that took place in Kôti and environs, although they were on a somewhat smaller scale. In Kasiwazima, situated on the northern boundary of block E (see Fig. 7), there was a depression of at least one foot.

As regards changes in the Kii Peninsula, they have been fully discussed by the writer elsewhere.[1] Briefly, it consisted of an acute, onward tilting in a meridional direction, raising the southern end of the southernmost Tertiary block as much as 1.3 metres and causing the so-called *median line* in the north to dip as much as 1 metre.

No. 12. The Hamada earthquake of 1872.[2]

This earthquake, which took place at about 5.20 p.m. on March 14, originated in the central coast of Iwami with Hamada in its epicentral area. The area of maximum disturbance, however, embraced in addition the north-eastern part of Iwami and the north-western part of Idumo, all of which would suggest that the earthquake had its origin in a comparatively narrow zone running near the coast and parallel to it. Some 5,000 houses were shaken down with a loss of 552 lives.

The topographical changes which the earthquake accompanied were indeed remarkable. Briefly stated, the upheaval was on the south-eastern side of a line drawn through Hamada in a north-westerly direction, while the subsidence was on the opposite side of this imaginary line. Taken southwards in order from the north-east corner, the records of upheaval are:—Kawanami an appreciable amount; U-sima more than 2 feet; Kusiro 2–6 ft.; from Matusima as far as Kanasubu 4–5 ft.; Tatamiura 3–4 ft.; a hill in the south of Hamada 1–2 ft.; and the coast SW of the same town 5 ft.

The records of subsidence on the other hand give:—Gosyoyu in Kokubu village 1.5 ft.; Matubara an average of 4 ft.; a hill in the

1) A. Imamura: Jap. Jour. Astr. & Geop., Vol. VII, No. 1.

2) For details see A. Imamura: Rep. (in Japanese) Imp. Earthq .Inv. Comm., No. 77.

north of Hamada 1–2 ft.; at Siroyama (hill) 12 ft.; the western coast of Hamada 1–2 ft.; Setogasima (island) 3 ft.; Nagahama (about 4 km. SW of Hamada) 3 ft.; and at Ooasa (about 5 km. SW of Nagahama) 3 ft. along the coast for a distance of 1 km.

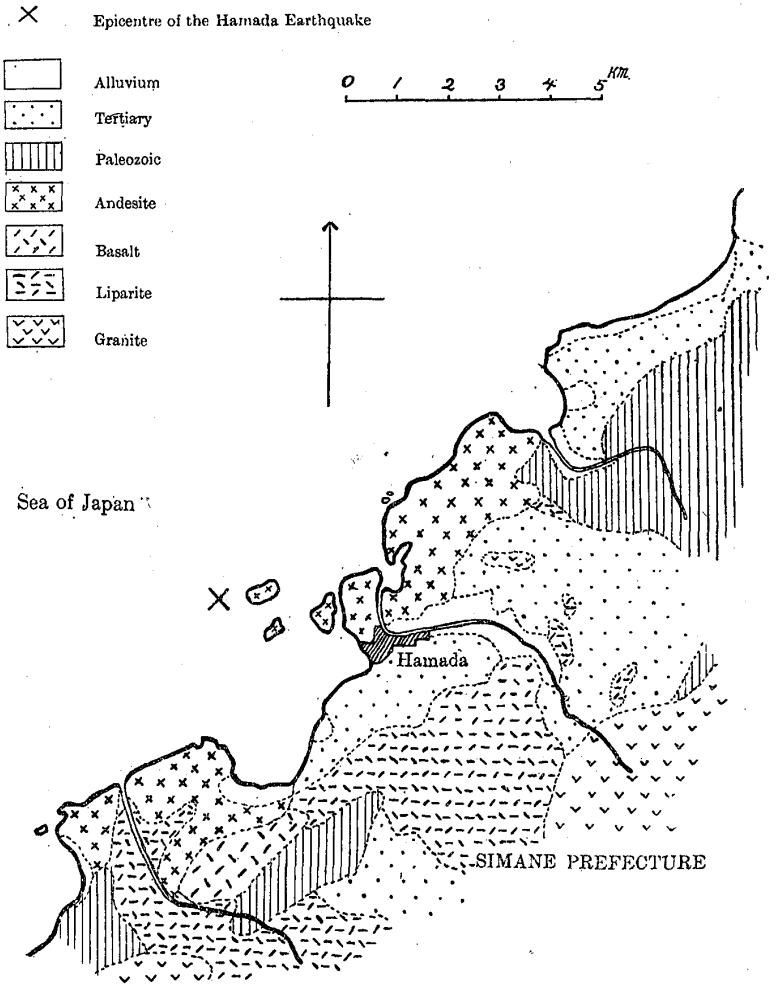

Fig. 14. Geological map of the Hamada district.

The coast line along which these changes occurred is about 20 km. long. We would add that the raised places were generally of Tertiary formation while those that had sunk down were mostly of pre-Tertiary age. The dominant feature of these topographical changes was that the greater the distance of a locality from the

line separating the uplifts from the depressions, the more pronounced was the elevation or depression as the case might be. Thus the change of level at a place in a line drawn at right angles

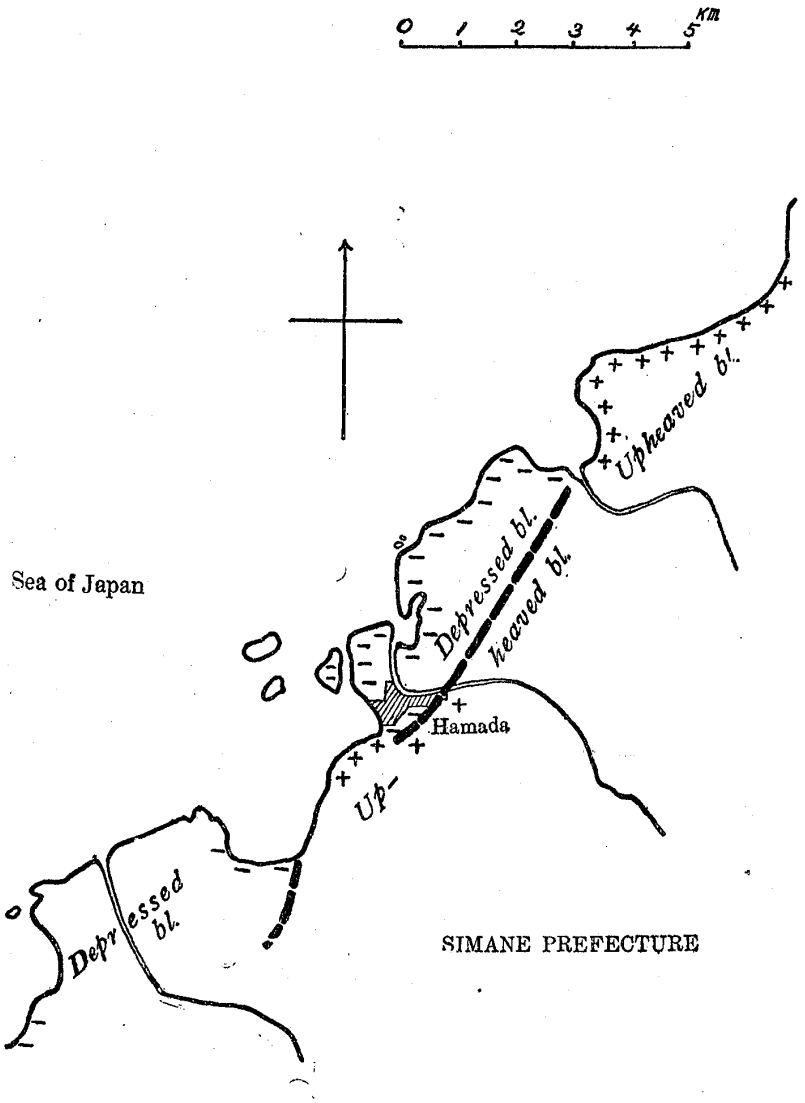

Fig. 15 Map showing the topographical changes accompanied by the Hamada earthquake.

to the boundary line just mentioned would appear as diagrammatically shown in the accompanying figure, a character so often exhibited in connexion with the appearance of a fault line.

Two more interesting phenomena were observed in connexion with this earthquake, namely, fore-shocks and pre-seismic topographic changes. The former were first noticed at the epicentral area as subterranean rumblings some 4 or 5 days prior to the day of the big shock. On the 14th, the day of the final outburst, a moderate shock was felt at 11 a.m. followed by earthquake sounds. At 4 p.m. came a strong shock followed an hour later by one less energetic, and after a lapse of 10 min. came the destructive shock.

As generally happens, a sudden retreat of the sea pointed to a pre-seismic upheaval that was under way, and which this earthquake soon followed. About 150 metres off the shore of Hamada-ura is the islet of Turu-sima, to the foot of which it is said the water withdrew and left a dry connexion with the mainland. Fishermen were soon busy gathering live fish that were left stranded on the newly formed land and collecting earshells from the foot of the islet. Hardly ten or twenty minutes had passed when one of the men, an old seasoned fisherman, shouted excitedly to his comrades urging them to make at once for the hills to escape the tunami, which experience had taught him to expect from phenomena such as he had just witnessed. Before long a tremendous shock was felt, and ten minutes after it the earthquake wave came rolling on, which in this instance was not at all destructive. We are told that similar phenomena repeated themselves also at Nagahama and Kokubo, situated about 10 km. from Hamada, as well as at Isotake and Yusato some 40 km. distant from the same town.

No. 13. The Riku-U earthquake of 1896.[1]

This earthquake occurred on Aug. 31 at 5.06 p.m. in that district whose central axis forms a part of the boundary of the provinces of Rikutyû and Ugo. The earthquake was unique in more respects than one. It took place in a strong gale, when the anemometer of the Akita Meteorological Station was recording a velocity as high as 20 m/s, thus furnishing an exception to the statement made by the late Prof. Omori that destructive earthquakes take place in fair weather. Another remarkable thing was that in spite of the high wind there was no outbreak of fire, with the result that the ratio of deaths to the number of houses thrown down was very small; the respective figures being 206 and 6,000. This extraordinary small ratio is to be explained, however, by the occurrence of remarkable fore-shocks which served as timely warnings to the inhabitants of the approaching big shock, so that they were able to extinguish all fires and betake themselves outdoors.

The fore-shocks began on the 23rd with a slight one at 4.25 a.m. and another one at 1.33 p.m. The first strong shock, however, was felt at 3.57 p.m. of the same day in the northern part of the above-mentioned district with the village of Obonai as its centre. Altogether, the following shocks were experienced:—

On the 23rd—Five weak shocks between 4–6 p.m. and ten moderate ones between 6–11 p.m.
do. 24th—Five slight shocks between 0–5 a.m. and one at 9.16 a.m.
„ 25th—A weak shock at 5.13 a.m. and at 1.32 p.m.
„ 26th—Two or three slight shocks.
„ 27th— do.

1) See N. Yamasaki: Rep. Imp. Earthq. Inv. Comm., No. 11 and A. Imamura, do. 79.

On the 28th—A weak shock at 6.27 p.m.

do. 31st—Weak shocks at 8.33, 8.52, 9.58, and at 10.13 a.m. A slight shock at 3.07 and at 3.18 p.m. A strong shock at 4.42 p.m. followed by a weak shock at 5.50 p.m. The final destructive shock at 5.06 p.m.

The morning of the eventful day was unusually active. Then there was a short lull which was broken by a strong shock that came at 4.42 in the afternoon. Thenceforth it appeared to the

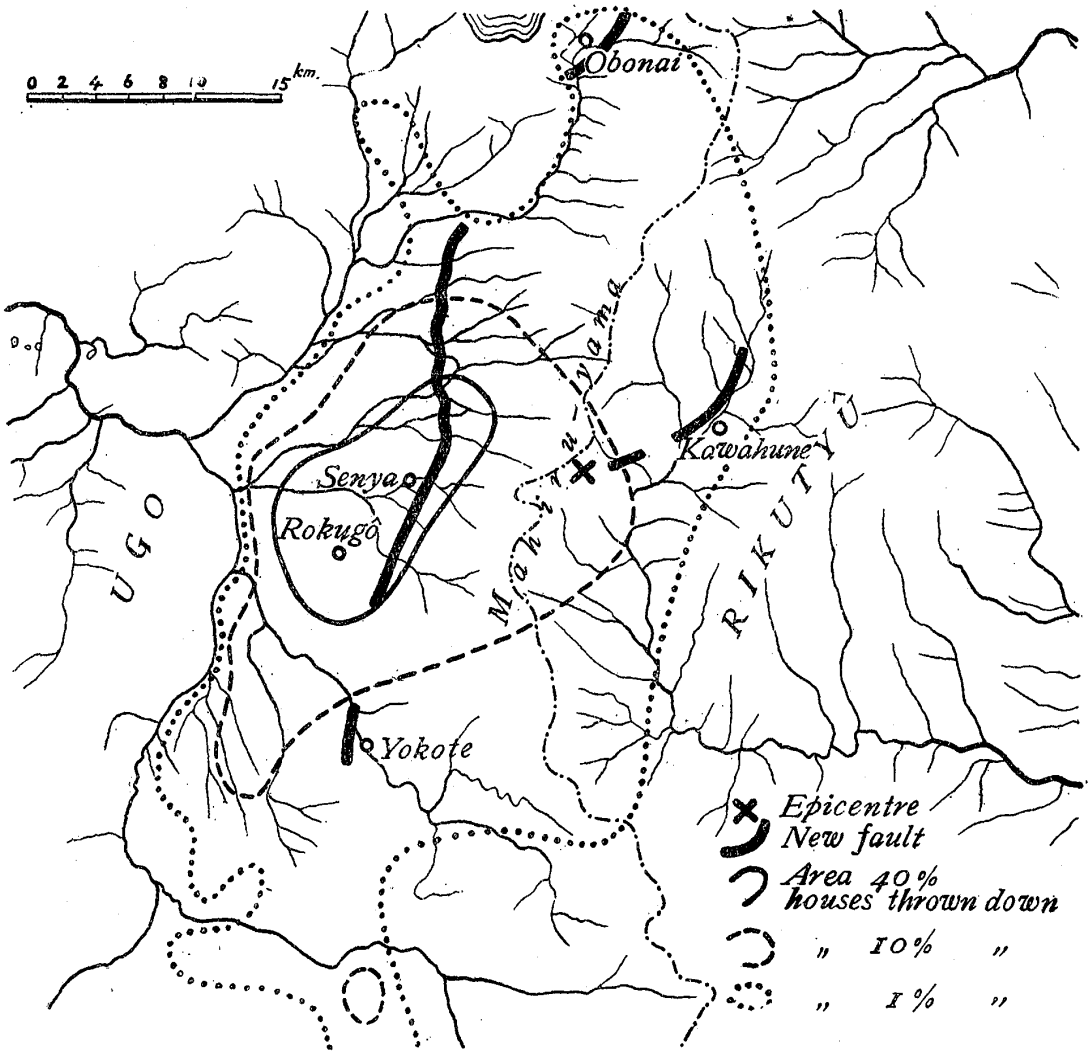

Fig. 16. Map showing the seismic area of the Riku-U earthquake of 1896.

anxious people as if the earth had been trembling incessantly for almost an hour when the climax was reached with the arrival of the tremendous shock that caused such wide-spread damage.

A remarkable topographical change was the appearance of two faults named the Senya and Kawahune faults by Prof. N. Yamasaki, who was the first to investigate them. The former could be traced from Obonai in the north to Yokote in the south, with a track trending N-by-E to S-by-W along the boundary of a Tertiary hill called Mahiruyama and a flat Diluvium ground skirting the former. It extended for about 60 km. with a maximum vertical dislocation of nearly 2.5 m. near Senya, upheaving the Tertiary side relatively to the western side. The Kawahune fault was somewhat similarly placed along the eastern boundary of the same hill; extending for some 10 km. with a maximum vertical dislocation of nearly 2 m., and raising the western Tertiary side relatively to the opposite side. Neither of the faults showed any traces of horizontal shifting.

Prof. Yamasaki believed that the Kawahune fault ran almost parallel to the other fault, but the writer after careful examination on the spot in 1910, came to the conclusion that the southern part of the Kawahune fault had its trend nearly at right angles to the other fault.

The mechanism involved in the case of this earthquake would seem to have consisted of an uplift of the wedge-shaped Tertiary block relatively to the contiguous block—a character that was also exhibited in the case of the Mino-Owari earthquake of 1891.

No. 14. The Formosa earthquake of 1906.[1]

The earthquake of Mar. 17, 1906, was the worst that shook

1) For details see F. Omori: Bul. Imp. Earthq. Inv. Comm., Vol. I, No. 2.

Formosa in recent years, being even more destructive than the well-known shock of June 8, 1862. The casualties were

Number of dwellings totally destroyed.	7,284
„ „ „ partially „	30,021
„ „ persons killed.	1,266
„ „ „ wounded.	2,476

The heavy fatalities were due in large measure to the poor quality of the native houses. They were built of sun-dried, mud bricks measuring $22 \times 33 \times 9.5$ cm, loosely cemented with a mortar of mud, and at best mixed with a small quantity of lime. Obviously, houses constructed of such weak material had not the slightest chance of withstanding a vigorous shock, and this coupled with the heavy roofs, made matters worse so that with the

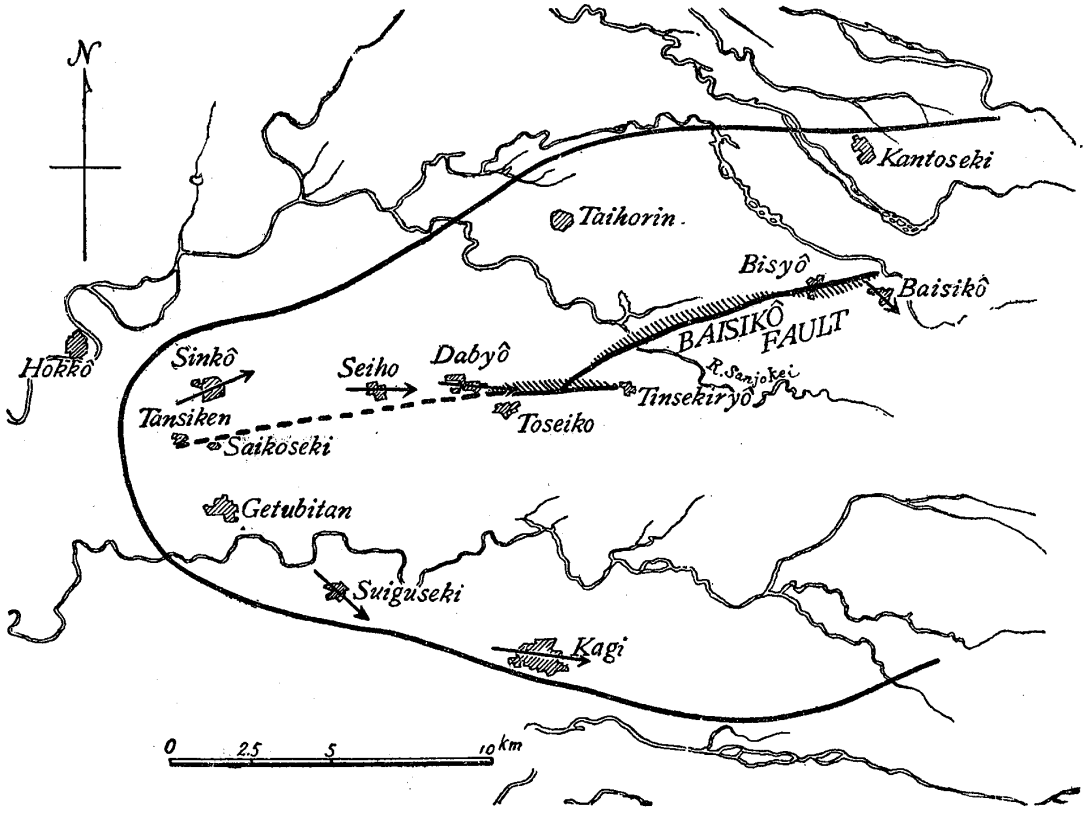

Fig. 17. Map showing the seismic area of the Formosa earthquake of 1906 (The shaded part is the depressed side, the arrow the direction of max. earth-movement.)

first violent shock they were mostly shattered to pieces, leaving little time for the inmates to escape.

The meizoseismic area, which is of Tertiary formation partly overlain by Diluvium, was about 50 km. in length, extending from the vicinity of the town of Baisikô on the east to the city of Sinkô on the west, and about 30 km. in width from the vicinity of the city of Kagi on the south to that of the village of Tarimu on the north. From the limited extent of the area of severe motion, it may be inferred at once that the earthquake centre was not situated deep below the surface, as was in fact indicated by the formation of faults.

The main fault line is most conspicuous at its eastern end, where it crosses the road leading from the town of Taihorin to Baisiko, at a distance of about one km. from the latter town. The fault here runs in a direction N75°E-S75°W, the south side being depressed 6 feet and sheared relatively 6 feet westwards. The small village of Bisyô, under which the fault passed, was completely destroyed. The western continuation of the fault crosses the spur of a Tertiary hill, appearing again to the south of the village of Kaigenkô, at about a km. from Bisyô. The fault then takes a mean direction of N75°E-S75°W and crosses the River Sanzyo-kei, eventually joining the branch fault of Tinsekiryô. This second fault starts from about half a km. to the west of Tinsekiryô, from the top of a gently sloping hill of hard clay, where it shows itself for the first time as a remarkable deep crack two feet wide and 11 feet deep. This fault is nearly in the E-W direction and its western continuation runs through paddy fields to the north of the village of Toseikô, finally reaching the city of Dabyô, beyond whence the disturbance of the ground ceases to be visible. The length of the main fault is about 11 km. while that

of the branch fault is a little over 4 km., the entire length between the Dabyô and Baisikô extremities being 13.5 km.

As stated above, at the eastern extremity of the main fault the south side was depressed and sheared westwards. This condition, however, was reversed in the remainder of the fault, the depression now being invariably on the north side with the shearing eastwards. The maximum amount of the eastward shear was 8 feet and occurred at the village of Kaigenkô, while the northward depression of 4 feet occurred at the last-named place, and also at, as well as near, the place where the fault crosses the Sanzyo-kei River. Along the Tinsekiryô fault the depression was always on the north side, and the shear, the maximum amount of which was 5 feet, was eastwards. In this case, the vertical dislocation was slight and hardly amounted to a foot; too often the only indication being a gradual depression which caused the waters in the paddy fields to collect on one side of the line of disturbance, leaving the other side dry.

To the west of Dabyô there was no surface manifestation of tectonic disturbance; but it is highly probable that there exists an underground continuation of the fault for about 12 km. in the direction W-by-S, as far as the vicinity of the city of Sinkô. Along the zone about this imaginary fault, which is marked in Fig. 17 by a dotted line, large quantities of sand and mud were ejected. Especially, in the vicinity of the villages of Tansiken and Saikoseki, the ejected sand reached a thickness of more than two feet and covered wide areas sometimes half a km. or more in width. The total length of the fault between Baisikô on the east and Tansiken on the west is 25.5 km.