THE SEVERE JAPAN EARTHQUAKE OF THE 15TH OF JANUARY, 1887.*

By S. Sekiya.

[Read February 18th, 1887.]

Soon after the occurrence of the earthquake of the 15th of January last, which caused considerable damage to property in and near Yokohama, the authorities of the Imperial University directed the writer to visit the places which had been affected by the shock, and to make a full report of all the circumstances. The results thus arrived at form the subject of the present paper. Before proceeding with this, however, it seems desirable to give some particulars respecting the principal shocks which have been felt in the Empire since 1879.

The Earthquake of February 22nd, 1880,† is the severest that has been experienced in the Plain of Musashi during the last ten years. The damage done to buildings was very much greater than on the recent occasion. Its origin was in the Bay of Tōkyō, and the boundary of the disturbed area is shown on Plate I.

On the 25th October, 1881, Nemuro in Yezo, was visited by a somewhat destructive shock. Fissures were opened in the ground, and the damage to property was not inconsiderable.

The well-known Atami Spa and its neighbourhood were convulsed on the morning of September 29th, 1882, by a sudden and severe movement, which damaged embankments, destroyed an historical monument, and did sundry other mischiefs.

* This paper was also published in the Journal of the College of Science, Imperial University, Japan, Vol. 1., Part III.

† See *The Earthquake of February 22nd, 1880*, by John Milne, Transactions of the Seismological Society of Japan, Vol. 1, Part II.

The earthquake of October 15th, 1884, also marked on Plate I., originated in the Bay of Tōkyō, and affected the Plain of Musashi. It overturned a considerable number of chimneys, cracked walls, and broke articles in museums and elsewhere. In Tōkyō, the greatest horizontal movement, on soft ground, was 42 mm., or double the amount observed on the 15th of January last. However, the total damage, taking the whole affected area into account, was smaller.

The seismic waves in the disturbance of October 30th, 1885, extended over the whole of Northern Japan and part of Yezo, shaking a land area of 34,738 square miles. But, though of great extent, they fortunately did little harm.

On July 23rd, 1886, quite a destructive earthquake visited Shinano and the neighbouring provinces, overthrowing several houses, and forming fissures in roads and hill-sides. The shock also stopped the flow of a hot spring at Nozawa. The part most severely shaken was a mountainous district some 2,000 feet above the sea, including the famous active volcano of Asama, and many extinct craters. This case was an unusual one, as most of the larger earthquakes in Japan extend along the sea-shore.

Next in the list comes the severe shock of last January.

It thus appears that this empire is visited by a more or less destructive earthquake *almost once a year*, and that the Plain of Musashi is affected in like manner *at intervals of a few years*.

The shock of last January was of most unusual violence. It originated near the coast, about 35 miles south-west of Tōkyō, and the seismic waves propagated nearly 200 miles to the west and north-east along the Pacific seaboard. On the north-west they approached but do not quite reach the shore of the Japan Sea. They shook in all about 32,000 square miles of land area. The limit of the disturbance is indicated on Plate I.

In Tōkyō the disturbance began at $6^h\ 51^m\ 59^s$ P.M., with slight tremors. After thirty seconds from the commencement, the greatest horizontal motion (21 mm.) was recorded. The time taken to complete one to-and-fro motion of the ground was 2.5 seconds. The maximum vertical motion was only 1.8 mm., being, as usual, very small compared with the horizontal movement. The principal motion continued for more than two minutes, during which time no less than *sixty distinct shocks* occurred. The maximum velocity and maximum acceleration, which measure the overthrowing and shattering power of earthquakes, have been calculated from the above numbers, and found to be respectively 26 mm. and 66 mm. per second. These numbers, considering the range of motion, are small; or, in other words, the oscillations of the ground were comparatively gentle and slow, which serves to explain the fact that but little harm was done to property in the Capital. The above measurements were made by Ewing's Horizontal Pendulum and Vertical-motion Seismographs. In Yokohama Hipp's Seismograph registered a horizontal motion of 35 mm.

The origin of the shock was in a narrow band of country running from west to east in the province of Sagami, parallel to the coast, at a distance from it of about seven miles. The red shading on Plate I. indicates this band. It emanates from the western or mountainous parts of the province, passes through the southern foot of Ōyama (4,125 feet above the sea-level), and reaches the Bay of Yokohama in a total distance of about thirty miles. I believe the most probable cause of the shock to have been faulting or dislocation of the earth's crust along the band above named. This inference is supported by the fact that the parts of the country through which the western half of the band passes consist of rocks of different geological formations, interwoven in such a way that their junctions present lines of weakness favourable to earth-snaps. The topographical features of the district—high mountains on the north and comparative low plateau and sea-shore, on the south—also lend strength to this conclusion. Unequal distribution of loads on the earth's surface tends to facilitate bending and folding of the rocks.

It is along the above-named axis or band that the effects were most striking. They were mainly confined, however, to a small breadth on either side of it, so that places as little as two or three miles to the north or south experienced a well-marked diminution of seismic enegry. This is not the first instance in the history of severe shocks in which the destructive effects have been practically limited to a small area near the origin.

More especially on the hilly or western portion of the origin, land-slips and cracks were numerous. The cracks mostly took place in banks, hill-sides, or other situations favourable for their formation. The writer counted no fewer than seventy-two in a distance of seven miles, the largest measuring a foot wide and five hundred feet long, and all of them running parallel to the axis of origin, which is also parallel to the general contour of the country. Several wells became turbid. In some of artesian character the water permanently decreased; in others it increased. There is a ferry across the large river Banyū where it is crossed by the axial band; but the water was so agitated by the shock that for some time afterwards the boat could not be used. The water in one of the rivulets on the west became muddy. The shock was severely felt on board of vesssels in Yokohama harbour, the people in many of them rushing on deck under the impression that they had been run into. The effect upon these vessels were doubtless caused partly by motion communicated through the cables, and partly by agitation of the water due to movements of the sea-bottom. The earthquake was preceded by the usual warning roar or rumbling, as of distant cannon, emanating apparently from the western part of the origin-band. In that district, too, the after-shocks on the same night were five in number, while in Tōkyō there was only one. There were four tremors near the origin during the night of the 16th.

Dwelling houses in country-towns and villages are always built of wood. Their frame-work is of timbers from four to seven inches square, crossing one another at right angles. The uprights are placed about three feet apart, and stand on rows of squared stones or boulders, the intervening spaces being filled with bamboo-laths, on which is laid the mud-plaster that forms the walls. Tiles and straw are principally used for the roof-covering. In the district near the origin these wooden houses shook with great violence. Several of them were more or less twisted, cracked, or unroofed. Sliding doors, covered with paper or of wood, which serve as shutters, partitions, and windows in Japanese houses, broke and were shot out of their grooves. The joints between the frames were in some cases badly loosened. Fig. 2 on Plate II shows how one of these joints suffered, together with the paper covering of a sliding door which was rent by the vibrations. Although there are thousands of wrecked houses in the district of origin, on the verge of falling down, and looking as if a strong breeze would be enough to blow them over, buildings of this class nevertheless withstood the violence of the earth movements so far as to escape actual demolition. The writer saw only two small rotten hovels which had been thrown down. This circumstance shows the tenacity of wooden framed structures. Prof. T. Mendenhall, in a report* on the recent catastrophe at Charlestown, says—"As was to be expected, buildings constructed of wood suffered much less than those of brick. The interior of wooden buildings, however, would often exhibit a scene of total destruction, furniture, book-cases, etc., having evidently moved with great violence."

Fire-proof stores, or *Kura*, suffered severely as to their walls. These buildings have wooden frames strongly joined by horizontal and vertical pieces, and closely covered with laths, the whole making up a compact box-like structure. The roof is tiled, and the wall is carefully plastered with a mud which has a slight cementing property, to the thickness of from three to nine inches. This plaster is put on in several layers, each

* The *Monthly Weather Review*, U.S. Signal Service, August, 1886.

layer being added after the preceding one has dried. The whole process is an expensive one. The walls, on account ot their great thickness and the poor tenacity of the mud, are easily cracked or stripped. As many as sixty or seventy per cent. of the *kura* suffered from the recent shock. Fig. 1, Plate II., shows one of them with its walls badly damaged, and shows also the method of framing the timbers. It is evident that these thick-walled structures should be replaced by brick buildings, which are equally fireproof and much stronger.

It may be mentioned, however, that the framework of *kura*, after having been entirely stripped, has withstood the most violent earthquake on record.

In Yokohama houses are built of different types and with a variety of materials, so that they afford a fair field for the comparison of seismic effects. It is very fortunate that, judging from the effects wrought by the recent earthquake on both land and buildings, the seismic intensity in this town was less than one-third of that in the western or hilly parts of the origin-band. But for this, the results would have been highly disastrous.

The houses which suffered most were the composite structures of wood and stone. They are built of wooden frames encased with stone blocks, each of the latter measuring 2 ft. 9 in. long, 9 in. wide, and 6 in. thick, and being clamped to the wooden planks inside by three iron-nails. Plate III. shows one of these houses that was affected by the recent shocks, together with the details of the stone attachments. The nail, called *kasugai,* is 5 in. long and $\frac{7}{10}$ in. square, and bent at right angles at its two ends. The stone is soft and brittle, being volcanic rock of the worst quality. In time the iron-nails get rusty, and the stones are so acted on by rain and frost as to be easily cracked, or detached from the wooden frames, even by moderate shakings. These buildings, erroneously called European houses, already exist in abundance, and unfortunately increase each year in number. They are generally constructed with bad materials and on faulty principles; the object of the builders being to attain fair protection from fire, along with the appearance of a stone building, at the least practicable cost.

Two brick structures received serious damage (Plate II. Fig. 3), cracks having been formed, as usual, at the corners of the buildings and over the windows. The seismic vibrations, however, left no traces on the Town Hall, the Custom House, Prefectural Office, and other well-built structures of brick or stone.

In Yokohama wooden houses sustained no damage worth mentioning. Joints were more or less loosened and tiles occasionally fell down from the roofs. The tiles that are fastened to the framework of wooden houses, to form walls, were in some case detached in large quantities. There are decidedly many improvements which might be made in the present wooden buildings, both of Japanese and so-called European styles, especially in the arrangements of joints, the scientific distribution of materials, etc. If these and other defects were properly remedied, such dwellings might be made pretty safe as against earthquakes. In sites little liable to danger from fire, one may find, in this country, wooden houses built three and even four centuries ago. Wood, no doubt, will continue for a long time to be the chief building material in this country.

In Japan, however, fire is a more constant and even more dread enemy than earthquakes, while terrible conflagrations are often brought about by destructive shocks. Hence, brick and stone should, and probably will in time come to be largely employed for building, especially in towns. The question, then, is to select certain types of brick or stone houses which are best calculated to resist earthquake shocks. Sheet and bar iron houses, as used in Australia, would make very efficient earthquake-proof buildings, although they are not free from several objections.

After the terrible catestrophe of 1883 in the island of Ischia, the Italian Government appointed a Commission* to consider the reconstruction of the buildings in that island. The Commission, after investigating the different modes of constructions most suitable for earthquake countries, submitted models of houses in wood and in combinations of wood and masonry, which were adopted. The Commission recommended that buildings should be chiefly constructed with an iron or wooden framework, carefully joined together by diagonal ties, horizontally and vertically, the spaces between the framework being filled in with masonry of a light character. Not more than two stories above ground were to be allowed, etc., etc.

In Italy brick houses are joined by iron tie-rods; and similar devices are now, to a certain extent, used in this country. Concerning the erection of brick or stone houses in Japan, much valuable information is to be obtained from the Italians, who, like ourselves have lived for centuries amidst terrible shakings, and who, no doubt, have gained much experience in the constructive arts suitable to the conditions of our existence here.

A prominent feature in the effects of the recent earthquake was the overthrowing of brick chimneys in Yokohama, especially on the Bluff. Soon after the shock, circulars were sent round to the principal residents, asking for information as to the effects of the shock on the buildings occupied by them. More than fifty answers were received, and the facts embodied in them have been of great value in preparing this paper. The writer takes this opportunity of expressing his warmest thanks for the kind assistance thus rendered to him. From these answers, from the Police Reports, and from actual observation, fifty-three chimneys appear to have been destroyed. In one instance a heavily-coped chimney fell in a large mass through the roof, and severing a strong beam of 1 foot by 8 inches on the second story, penetrated to the ground floor.

* Proceedings of the Institution of Civil Engineers, Vol. LXXXIII, season 1885-86—Part i.

About one-half of the chimneys thrown down during the shock were cut in two at their junction with the roof; while some dislodged the tiling and did sundry other damage to the buildings at their points of contact. Evidently the chimneys and the houses moved with unequal range and with different vibrational periods. Professor Milne has more than once recommended that chimneys should be built thick and squat, without heavy ornamental mouldings or copings; and be, if possible, disconnected from the roofs. Those houses in which his suggestions had been adopted suffered no damage on the 15th of January.

Generally, the relations of the seismic effects to the geological, topographical, and other features of the various localities were found to corroborate previous experience. That the seismic vibrations in hard ground are very much less than in soft soil was well illustrated on the recent occasion. At the University, where the ground is hard and firm, the seismograph recorded only 8 mm. horizontal motion, as compared with 21 mm. registered by a similar instrument placed on soft soil a mile distant. Totsuka is a small town, with a long single street running along the foot of a hill; one side of the street, however, is built on made-up ground. Most serious damage was done on that side, while the opposite houses suffered very much less, though not more than twenty feet distant. Houses built on cliffs and hill-brows received more damage than those situated at the base or on the flat summits of the same hill. To observe the effects of marginal vibration, the writer recently placed one seismograph at the steep edge of a loamy hill 38 feet in height, and another similar instrument at its foot. The motions, thus far measured, at those two levels are found to be in the ratio of 2 to 1. A third instrument will shortly be set up on the flat summit of the same hill. Observations of a similar nature, on different rocks and at various heights, will form the subject of a further paper. It is probably owing to marginal vibration that houses on the Bluff of Yokohama are always heavy sufferers from earthquakes.

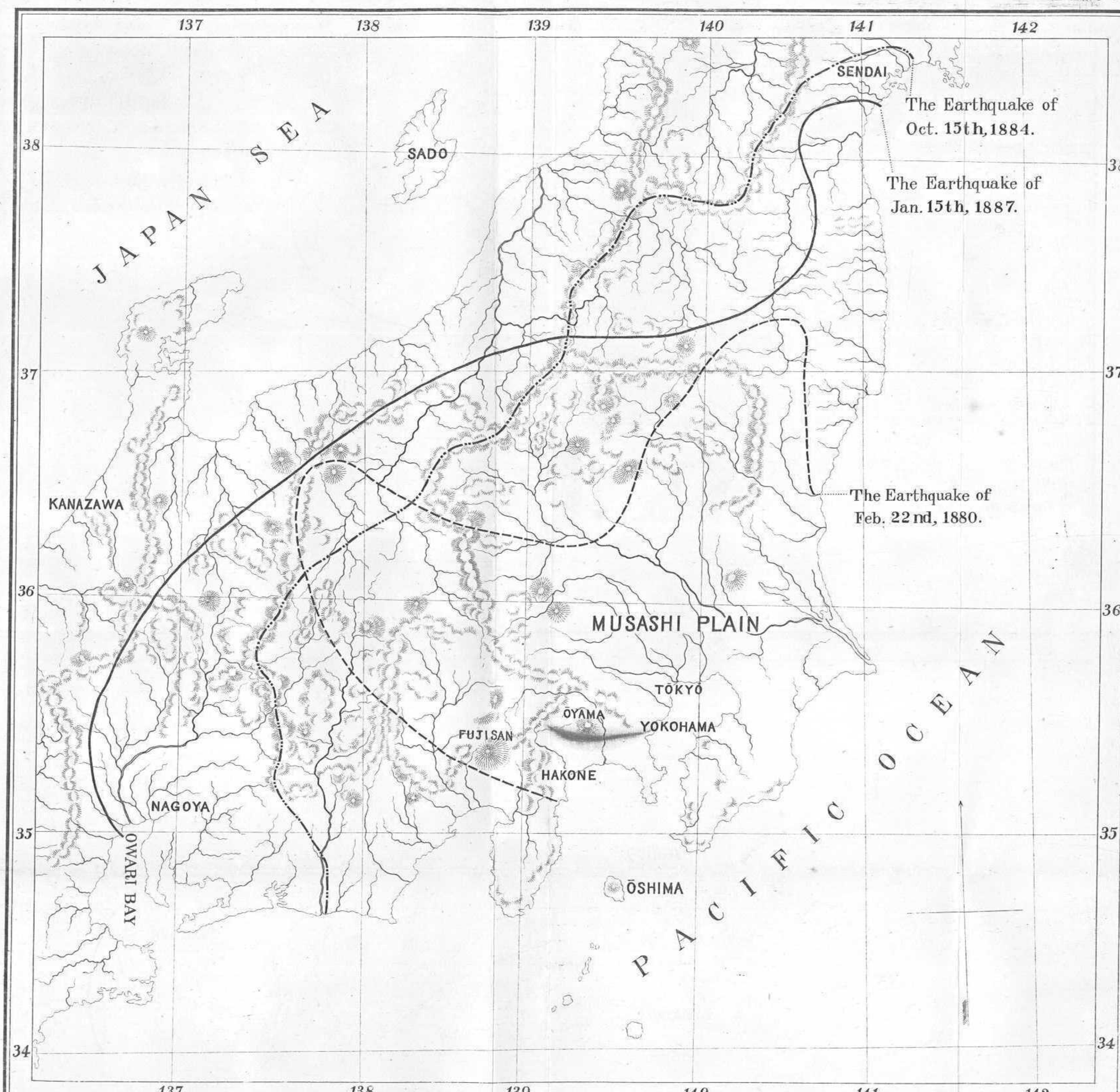
The extensive and rapidly increasing use of kerosene lamps in Japan constitues a grave danger in severe shocks. The lamps now in common use are of very brittle materials, contain the most combustible of oils, and are usually poised on ill-balanced stands. In the great earthquake of 1855, at a time when kerosene was unknown in this country, fire broke out in Yedo at more than thirty points, setting a very large part of the city in a blaze. In the event of another such shock, the mischief which would be produced from this cause alone is awful to contemplete. Great credit will be due to any one who can invent a convenient earthquake safety-lamp, which, it is to be observed, will also continue a valuable safeguard in ordinary daily life. It is true, so-called safety-lamps are sold in Tōkyō, but they are very ineffective and miserable affairs. The use of metallic oil-holders would doubtless greatly lessen the danger.

During his inquiry the writer was shown sixteen lamps that had been broken in the recent earthquake. In one instance the kerosene caught fire, and it was with great difficulty that the residents extinguished it by the aid of wet mats.

NOTE.—Since writing the above paper, the writer has observed in *Iron* of February 25th, 1887, an account of Mr. Phillips' Shaftesbury Petroleum Lamp, which apparently fulfils all the requirements of an earthquake safety-lamp. "The invention consists of a sliding rod passing through the body of the lamp, one end being attached to an extinguishing cap, whilst the other, which rests on the table, is weighted. Directly the lamp is put out of the perpendicular, the rod, by means of very simple gearing, slides through the tube and brings the cap over the wick, instantly extinguishing the flame. It is real protection to life and property, for if knocked over or dropped, it goes out instantly." It is stated in that journal that the lamp stood all the tests well. One complete set can be purchased at the low price of two shillings and nine pence (nearly 90 *sen*) at No. 1, Holburn Viaduct, London.

Discussion.

Professor Milne, after testifying to the practical value of his colleague's contribution, raised irreverent smiles on the faces of his audience by the naive remark that Seismology was "rather a favourite subject of his." In a short address he re-affirmed the precepts laid down in the paper as to the all-importance of skill and solidity in our buildings. He warned us against top-heaviness of every kind, whether as regards high-pitched roofs, heavy balconies, or projecting chimnies, accounting for the apparent contradiction afforded by the safety of Japanese temples, with their ponderous roofs and relatively slight supports, by explaining that these owe their stability to the elastic and many-jointed arrangements of their substructure. He reminded us once more of the value of seismic surveys, showing that from a kingdom down to a compound it is possible to map out the areas of greatest safety. As here, in this island of Japan, the west coast is wholly free from shocks, in marked contrast to the coast we live on, so may be found all about us sites only a few chains apart in which the seismic conditions are wholly different. And he went on to show that, having thus pitched upon protected sites, and having also determined the prevailing direction from which shocks proceed, other forms of earthquake-armour are still within our reach, in the shape of isolated foundations, free supports in certain cases, and, generally a judicious planting of our buildings, so that their diagonals, or at least their longer sides, shall be parallel to the direction of the horizontal motion produced by earthquakes. As ill-luck has it, Japan's capital and this her chief seaport of Yokohama lie in a very hot-bed of seismic activity. We must therefore make the best of the evils of our position—gradually of course, as in the nature of things is only possible, but none the less determinedly.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JAPAN SEA
SADO
SENDAI
The Earthquake of
Oct. 15th, 1884.
The Earthquake of
Jan. 15th, 1887.
The Earthquake of
Feb. 22nd, 1880.
KANAZAWA
MUSASHI PLAIN
TŌKYŌ
ŌYAMA
YOKOHAMA
FUJISAN
HAKONE
NAGOYA
OWARI BAY
ŌSHIMA
PACIFIC OCEAN

Plate II.

Fig.1

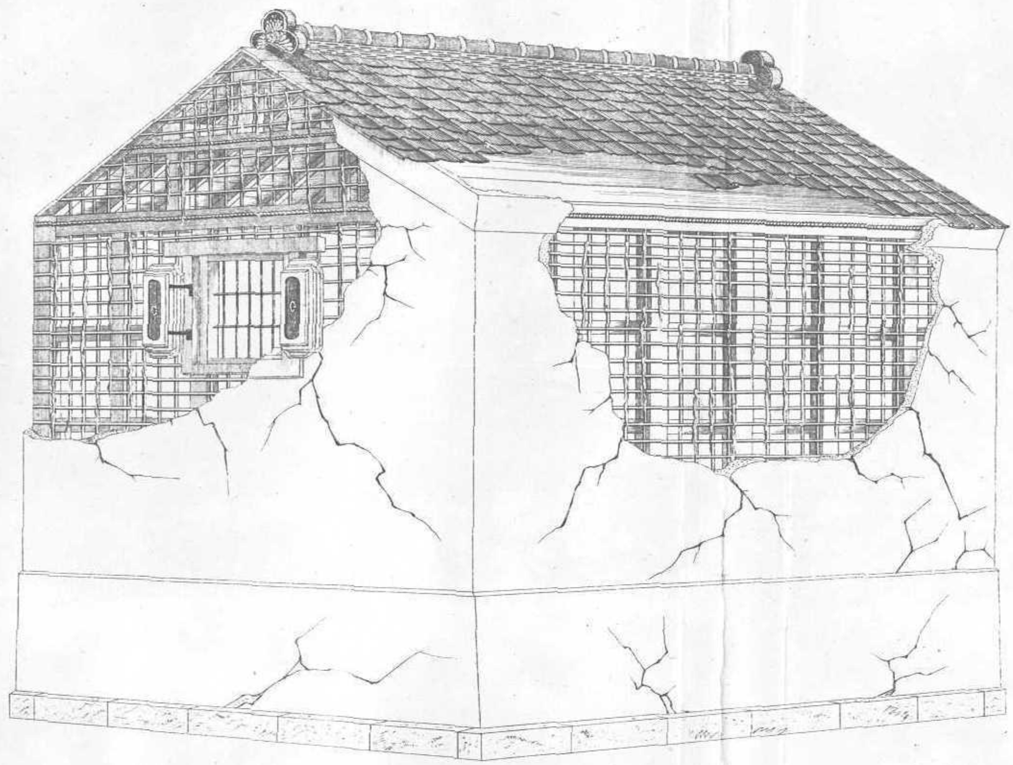

Fig.2

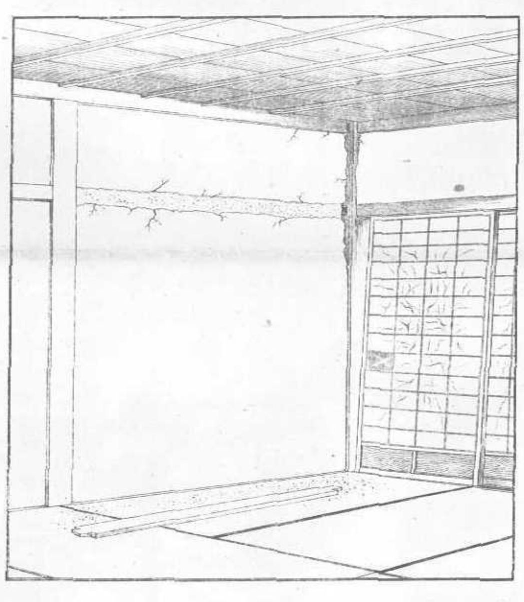

Fig.3