THE GREAT EARTHQUAKE OF JAPAN

1891.

BY
JOHN MILNE.
AND
W. K. BURTON.
PLATES BY K. OGAWA.

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IN

JAPAN, 1891.

BY

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PUBLISHED BY LANE, CRAWFORD & CO., YOKOHAMA, JAPAN.

PRINTED AT THE TOKYO TSUKIJI TYPE FOUNDRY,
17, TSUKIJI NICHOME, TOKYO, JAPAN.

PREFACE.

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We have to thank Mr. J. Conder, F.R.I.B.A., Mr. J. E. Beale, Mr. H. J. Snow, and other friends for assistance kindly rendered in various ways, in the putting together of the work.

We think no apology is needed for the manner in which Mr. K. Ogawa has reproduced the photographs. We may mention that they are really permanent, in the sense that they will not fade in any length of time. They are as permanent as the paper that they are printed on. It may be worth mentioning that this very paper is a product of the Earthquake District, being manufactured only in Echizen. Indeed due to this fact, there has been some delay in the printing of the proofs there having been difficulty in getting the paper in Tokyo.

JOHN MILNE.
W. K. BURTON.

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THE GREAT EARTHQUAKE IN JAPAN, 1891.

JAPAN is a land of Earthquakes and Volcanoes. Every year its inhabitants are shaken by at least five hundred shocks, and at intervals—several of which fall within the memory of the living—some part or other of the Empire is visited by a terrible catastrophe.

When nature thus exerts itself cities are rocked like ships upon the ocean, and it is some time before equilibrium is restored. There is a mighty effort, as if a mountain range had escaped the pressure that held it in its crumpled form, and the country is suddenly thrown into the most violent oscillation. Complete relief, however, is not obtained at once, and, for some months, minor yieldings announce themselves with subterranean thunderings and smaller shakings on the surface. In these years one or two thousand shakings are added to the average five hundred.

When we are not shaken by Earthquakes, certain sections of the country are threatened by volcanoes. Only a few years ago a terrible explosion took place on the side of the grass-covered Bandaisan, and in less than ten minutes a tract of country measuring thirteen miles by ten was submerged beneath a sea of earth and boulders at least one hundred feet in depth. Hamlets and farms were buried, and nearly 600 people lost their lives.

In Japan there are at least three lines of weakness through which volcanic forces have forced openings, and around these the ejected material has built up cones. The first of these lines—which is at least 1,000

miles in length—comes from Kamchatka through the Kuril Islands and Yesso down Nippon. Here it is met by a second line about 1,500 miles in length, almost at right angles, which runs through the Bonin Islands to the Ladrones in the Pacific. The third line comes up from the Philippines through Formosa to the centre of Kiushiu, where it terminates in Asosan, a volcano with a ring-formed crater ten miles in diameter.

In middle Japan there are no volcanoes, but severe Earthquakes have been as frequent there as they have been in other portions of the country. The greatest frequency is along the east coast, and these disturbances, which are of daily occurrence, do not come from the volcanoes, nor does their frequency show any relationship to volcanic action as exhibited at craters.

Throughout all history we find speculations as to the cause of these terrible disturbances. Almost every nation, from the Kamchadales to the Patagonians, has its myth explaining the origin of Earthquakes, many of them attributing these movements to the unruly behaviour of some monster or god imprisoned beneath the earth.

In the middle of the eighteenth century, when 60,000 people lost their lives at Lisbon, and when Earthquakes were frequent throughout the world, sermons were preached from the pulpits of every denomination setting forth that these terrible visitations were in direct consequence of man's wickedness. This view is well summed up in a little poem called "The Earthquake," written in 1750, which runs as follows:—

What pow'rful hand with force unknown,
Can these repeated tremblings make?
Or do th' imprison'd vapours groan?
Or do the shores with fabled Tridents shake?
Ah no! the tread of impious feet,
The conscious earth impatient bears;
And shuddering with the guilty weight,
One common grave for her bad race prepares.

*

That Earthquakes are the result of vapors confined in the earth, endeavouring to escape, is a view held by many ancient writers, and even in Shakspeare's Henry IV. we read:—

> Diseaséd nature oftentimes breaks forth
> In strange eruptions; and the teeming earth
> Is with a kind of colic pinch'd and vex'd
> By the imprisoning of unruly wind
> Within her womb; which, for enlargement striving,
> Shakes the old beldam earth, and topples down
> Steeples and moss-grown towers.

The vapour to which we now look as being a possible cause of Earthquakes is that of water. By capillary action, water soaks downwards to heated regions, and the resulting steam, we know to be the motive power at our volcanoes. The earth's crust not being sufficiently strong to withstand the increasing subterranean pressure, whole mountains have been dissipated as dust and boulders, and although a great portion of the force of the explosion has been spent in the creation of air waves, earthquakes of considerable magnitude have been produced. Similarly we can conceive of subterranean explosions as the producers of Earthquakes.

Certainly the fact that many Earthquakes occur in volcanic countries and near the ocean where we therefore have both heat and moisture, supports such a view.

A cause which would produce Earthquakes in non-volcanic countries like Switzerland, and even in volcanic countries like Japan, is the general process of mountain formation, by which—as we know from actual measurements—the superficial layers of the earth's crust have, in some cases, been crumpled up to the third of their original length.

Evidence of recent elevation on a coast line, as for example in this country, may mean that this process is yet in operation. On account of the heterogeniety of the materials constituting the earth's crust, we cannot suppose the action to be uniform, and now and then the strata, refusing to be farther bent, collapse with a crash,

and possibly a slip, and it is these huge internal sudden jars, which are succeeded by smaller jars until equilibrium is restored, that shake the earth.

Equally well, as has already been hinted, we may conceive Earthquakes to be the result of the bow-like springing back of huge subterranean folds, and they might then indicate short stoppages or even retrogression in the general process of mountain crumpling.

Some Earthquakes which have broken submarine cables, have been accompanied by enormous submarine subsidences or landslips, and Mr. W. G. Forster, of Zante, regards these sudden changes in the bottom of the ocean as being the cause rather than the effect of many Earthquakes.

In whatever way Earthquakes may be produced—whether at the critical point when steam pressure is balanced by rock resistance, or when the elasticity of rock masses equals the compressing forces—it is clear that there are many influences which may disturb the balance amongst the opposing forces.

Among these last straws which are placed upon the camel's back, which may act like the pull of a trigger to a gun, we may mention the influence of barometric pressure. Although Earthquakes do not appear to be connected with local barometrical fluctuations, it seems quite possible, as pointed out by Dr. C. G. Knott, that they may be connected with seasonal fluctuations; for example, Earthquakes are more numerous in Japan during the winter months, when the barometric gradient across this country is steeper than it is in summer. Again, Earthquakes are slightly more frequent when the moon is in perigee, or when its attractive influence is at its maximum.

Many believe that Earthquakes are in some way related to a peculiar state of the atmosphere; but supposing this to be a fact, meteorological observations have thus far failed to reveal the nature of such conditions.

Although electrometers have not hitherto shown us with certainty that at the time of Earthquakes there are changes in atmospheric electricity, yet we can imagine that, just as a stick of sealing-wax when electrified by friction will lift a piece of paper, so a measurable stress may be placed upon the surface of the earth or ocean by an

electrified atmosphere above it, and a discharge of this electricity might result in disturbing the equilibrium of any delicately balanced system of strains beneath. Observations on atmospheric electricity are only made at a few important observatories, and what effect atmospheric electricity may have, either upon earth stresses or human organization, is unknown. The only effect produced by Earthquakes at magnetical observatories appears to be purely mechanical.

Without entering into further details, to sum the matter up, it appears that there is a complexity of causes which may enter into the production of earthquakes, the proper investigation of which may possibly lead to fortelling the advent of these terrible phenomena.

A subject which has commanded attention has been the study of Earthquake motion. By means of a variety of seismographs, all of which are due to the ingenuity of workers in Japan, each vibration from the beginning to the end of a disturbance, which often lasts several minutes, can be absolutely measured. The preliminary tremors, to which human beings are hardly sensible, may on account of their rapidity, possibly be the origin of certain sound phenomena, and explain why, just before a shock, pheasants scream, horses become restive, and several of the lower animals give us a few seconds warning of more decided movements.

By observations at the bottom of a pit we have discovered that the motion there is less than it is upon the surface, and hence the advantage of giving a house deep foundations and an open area.

By studying the effects of Earthquakes upon buildings, rules have been formulated for those who have to construct in Earthquake shaken regions, and after the experiences of the last terrible disturbance it is to be hoped that these rules will receive greater attention.

The great disturbance which we illustrate, occurred about the centre of Japan, in the prefectures of Aichi and Gifu.

The severely shaken district, in many portions of which the destruction of buildings and engineering works was complete, extends over 4,200 square miles. The area in which brick buildings were affected reaches as far

as Tokyo to the east, and Kobe to the west, or over an extent of country of 4,400 square miles. The disturbance was, however, felt from Sendai in the north to Nagasaki in the south, or over an area of 92,000 square miles, and had Japan been surrounded by land instead of water, the land area shaken would have been about 400,000 square miles. Delicate instruments may possibly have been affected at the antipodes. Effects were noticed in Shanghai.

To conceive of the forces required to set so much matter in motion seems almost impossible. We certainly should imagine it to have been an effort exerted over a large area, rather than the result of an explosion at any small volcanic centrum. Strange to say, in the Nagoya-Gifu district, there are neither volcanoes nor volcanic rocks. The Nagoya-Gifu plain is a bed of alluvium lying in a basin of palæozoic hills, and it was in these hills that the disturbance had its origin. On the northern side of the hills, and towards the east and west, intercalated amongst these ancient rocks, there are some bosses of granite, which by their disintegration have assisted in filling up river beds, and tended to raise them above the level of the surrounding country.

If we were asked whether the Gifu-Nagoya plain was a place where Earthquakes were frequent, we must reply in the affirmative. In Japan there are some seven hundred stations where Earthquakes are observed, and from several of them situated on the Gifu plain we find that, in the six years from 1885 to 1890 the number of shocks recorded in that district were respectively, 9, 4, 10, 12, 15, and 36; whilst in the corresponding years in Tokyo, where accurate records are taken with seismographs, the numbers were 51, 55, 80, 101, 115, and 93.

In 1888, in one locality near to the centre of the late disturbance, 19 shocks were observed and a point of weakness indicated. Almost every year in some part or other of the Empire, such places suddenly present themselves, and with the present lesson before us it is well that these local *foci* of seismic activity should be studied.

Violent disturbances took place in the northern part of Gifu in 1826, 1827, and in 1859. Many ordinary dwellings, store-houses, and even mountains suffered; people and animals were killed, rivers were stopped up and floods occasioned. The shocks lasted for several days. In 1880 there were shocks, and sounds came from the north-west.

Notwithstanding these facts, the district generally offers a remarkable example of a decrease in seismic activity. During the last 1,000 years the records of the Kioto, Osaka, and Mino Earthquakes present to us the history of a terrible series of catastrophes. Although the accounts of great disasters become rarer the farther we go back in history, there is no doubt that the occurrence of great Earthquakes in these districts has gradually been separated by longer and longer intervals.

Standing on one of the hills which form the margin of the devastated area, a vast plain, covered with rice fields, dotted with clumps of trees and hamlets, and streaked with the silvery bands of the four great rivers which cross it, stretches as far as the eye can reach. From the western side of this plain—which supports a population of perhaps 800 to the square mile—one sees towards the south the islets and promontories of Owari Bay, before one the turrets of the castles rising through the blue smoke of Nagoya and Ogaki, beyond which come the gently sloping uplands forming foothills to dark green mountains.

The Nagoya-Gifu plain is one of Japan's great gardens, but it has been devastated. A disturbance occurred in the Mino mountains and at once an area, greater than that of the Empire of Japan, became a sea of waves, the movements being magnified on the surface of the soft alluvial plains. In Tokyo, more than two hundred miles from the centre of the disaster, the ground moved in long easy undulations, producing in some persons dizziness and nausea, the movement being not unlike what we might expect upon a raft rising and falling on an ocean swell. Near to its origin the waves were short and rapid, cities were overturned, the ground was fissured, small mud volcanoes were created, and the strongest of engineering structures were ruined. About ten thousand people lost their lives, fifteen thousand were wounded, and 100,000 houses were levelled with the plain, whilst almost every building in the meizoseismal area was shattered.

From the effects that have been produced upon huge engineering structures we must conclude that the earth movements in Mino at the time of the great Earthquake were at least equal to any movements recorded in the annals of seismology.

A question which naturally arises is, whether anything can be done to mitigate the destructive effects of these

disturbances. The answer is decidedly in the affirmative. From experience generally, and as a result deducible from experiment, we know that buildings on certain sites have less motion to contend against than others that may only be at a short distance. The Earthquake at Lisbon in 1755, at Port Royal in 1692, at San Francisco in 1868, at Tokyo in 1854, and even the last disturbance, have shown that buildings on soft ground,—which is generally the plains,—suffer more than those on the hard ground which may be the hills. River banks, the edges of scarps or cliffs, where the forward swing of the free face is naturally large, have always proved to be dangerous sites for buildings. Again, experiments and observation have shown us that the movements at the bottom of a pit, or even in a shallow railway cutting, are less than those upon the natural surface: hence buildings rising from a pit, or buildings with an area or basement are not so severely shaken as those upon the surface. Again, when building, it has been repeatedly pointed out, that we must construct, not simply to resist vertically applied stresses, but carefully consider effects due to movements applied more or less in horizontal directions. This being the case, the more top weight we give to a structure, whether it is in the form of a heavy roof, an iron girder, a water tank, or an ornamental coping to a chimney, the more danger is there of collapse by the inertia of the upper part breaking the support beneath. In Italy, where there are regulations respecting building in Earthquake regions, the use of arch-work is forbidden,—arches being exceedingly strong in resisting loads placed above them, but readily falling apart when acted upon by sudden horizontal movements. The rules which have been formulated respecting construction to resist Earthquake motion are far too numerous for us to enter upon in detail, but such rules have been formulated, and it is to be hoped that, after the recent disasters, they may receive the attention they deserve.

An interesting investigation in connection with what has happened will be the determination of the suddenness with which various buildings were moved, and this being determined, to enter into calculations which are based on experiments already completed, as to the form which brick and iron piers, chimnies, and other structures, should possess in order to withstand such movements, should they ever be repeated.

As destructive Earthquakes are repeated several times during an average lifetime questions like the above are of national importance.

Other questions which seismologists are often required to answer, refer to the cause and to the prediction of Earthquakes. We have already said a few words respecting the cause of earth disturbances. Predictions based upon calculations relating to imaginary tides within the earth, do not appear to have been attended with anything more than accidental successes. Many persons believe that Earthquakes are preceded by a peculiar atmospheric condition. It is not likely, but yet it is possible, that seismologists when comparing the occurrence of Earthquakes with meteorological phenomena, may have made omissions. It is a well known fact that barometers and thermometers have sometimes shewn sudden changes before Earthquakes, but such changes are equally common when there are no Earthquakes.

There are many records to show that particular Earthquakes, have been preceded by phenomena of an unusual kind, as for example, by the change in the character of water at springs and by underground noises. We are naively told that the Earthquake about which we write, may have been announced by the fact that the seeds in persimmons, which grow so abundantly near Nagoya,—this year grew upside down.

Although in Japan, with the aid of microphones and telephones, we have listened to noises, the supposed result of greater movements deep beneath the surface, and have spent years in observing instruments recording those small continuous vibrations called Earth-tremors, we have never yet succeeded in fortelling the arrival of an Earthquake; still we do not despair.

There are several experiments, which, if the means for their accomplishment were at hand, seem reasonable in their conception, and promise to yield results of great importance. As an example of one of these investigations, we point out the advantages to be gained by observations on a change of level, which may be taking place in any Earthquake shaken district.

From the movements in astronomical levels and other delicate instruments, more general movements are suspected. We know that Earthquakes occur in regions where there is evidence of recent and rapid rise of the land above the ocean. Often an Earthquake is a movement so widespread, that it may be conceived of as a sudden yielding of an extended rocky mass,—as for instance during elevation,—rather than the effect of anything

originating at a point. The after shocks, are suggestive of a settling of disjointed strata. For this and many other reasons, it is not unlikely that Earthquakes represent interruptions in the general process of elevation or subsidence. If therefore we establish a sufficiently long line of water pipes, at right angles, say to an axis of elevation, and by means of photographic apparatus keep a continuous record of the level of the water at the two ends of the pipe; relative changes at the extremities of such a system, may be measures of the hitherto unrecorded movements.

Assuming such movements to exist they may possibly be connected with the frequency of Earthquakes, and further the study of them, might throw considerable light upon fundamental principles in Geological and Darwinian speculations. They might possibly also explain the perplexing movements noticed in the solid piers supporting astronomical instruments, they might assist in explaining some of the hitherto inexplicable results which crop up in trigonometrical surveys and even perhaps give factors respecting the shallowing of bays and the tipping of land, which would be of importance to engineers constructing harbors and waterworks.

Millions are spent annually in observing the movements of celestial bodies, the phenomena of the ocean and the atmosphere, and in mapping, measuring and determining the nature of the surface of the globe, but for investigations relating to the interior of the globe on which we live, very much is left to hypothesis and speculation.

The moon is cold and dead, but the earth by its shakings and eruptions, repeatedly announces the fact that it has heat and life. From time to time we are rudely shaken, and our attention is attracted to the fact that we exist upon a living sphere. For a moment all is excitement and we behave like a swarm of ants that had been suddenly disturbed. Our first thoughts are for the sufferers. Lectures are given and pamphlets written, but the perturbation is short-lived. The funeral services are scarcely over, the wounded healed and a few shelters erected, when the usual apathy for all that may be taking place within our mother earth, is again restored.

PLATE I.

BIWAJIMA.

PLATE I

BIWAJIMA.

PLATE I.

WE reached Nagoya the second night after the Earthquake and it is a night that will be remembered for many years. All the inhabitants were camped beneath temporary shelters which they had built in open spaces, and near the centre of the streets before the ruins or tottering remnants of their homes. With persuasion we obtained lodging in the remaining half of the Shukinro, a hotel of some pretentions, the other half of which had been crushed by the falling of a neighbouring brick building.

During the evening whilst taking our supper, we were continually alarmed by the hollow boom, as of a distant gun which announced a coming shake and the attendants stampeded for the open while we watched the already severely cracked building, ready to jump into the garden should the movement become severe. Next morning we visited one of the suburbs of Nagoya called Biwajima, which is practically one long street running from near the castle across flat ground towards the river. It is no exaggration to say that the destruction was complete.

The houses some tiled and some with thatch had for the most part fallen along the line of a street much as a row of propped up cards would fall. Here and there the buildings having fallen across the street, the road was impassable. On all sides the rubbish lay in acres, and often the wreck of the more poorly built houses was so complete, that it was difficult to conceive how the heaps of rubbish that remained could possibly have represented a dwelling.

Luckily the few fires that had occurred had been quickly extinguished by the soldiers.

PLATE II.

LIFE AFTER THE EARTHQUAKE.

PLATE II

LIFE AFTER THE EARTHQUAKE

KOYA LIFE.

PLATE II.

koya is a temporary structure used as a dwelling. In Yezo the convicts when engaged in road-cutting through the forests, live in large barn-like *koya* made with bamboo-grass. The *koya* in the Earthquake district were constructed of straw mats, pieces of cloth, fragments of paper screens, broken boards and any other suitable thing that could be gathered from the ruins.

Archdeacon A. C. Shaw writing of his camp-life amongst the *koya* when at Gifu says: "When I wakened up this morning there was a total absence of all the sounds that generally make the morning so lively in a Japanese town. No opening of shutters, for the shutters were employed keeping the rain from descending upon their owners' otherwise unprotected heads; no sound of flicking the paper slides with feather dusters, for the slides are all now needed as wind screens for the sides of the little huts, the sole protection against the outside weather."

PLATE III.

EMBANKMENT OF BIWAJIMA RIVER.

EMBANKMENT OF BIWABIK RIVER.

PLATE III.

THE BANKS OF THE BIWAJIMA RIVER.

PLATE III.

THE greatest destruction has taken place along and near the river banks, which being unsupported on one side, by their momentum have been shot forward, much in the same way that the last of a series of railway waggons is shot forward when a locomotive bumps against the other end.

The fracture shows the kind of destruction which has occurred along the banks for a distance of several miles near Biwajima. There are innumerable longitudinal clefts of all widths up to about two feet, and the inner half of the embankment has slid down towards the river to greater or less distances from a few inches to a number of feet measured vertically.

At one place the embankment is entirely gone for a couple of hundred feet or so, and here a very strange thing has happened. There was a large bamboo grove and a few pine trees just at the back—the side away from the river—of the embankment, and this little forest has slid,—been pushed or call it what you will—sixty feet back, yet the bamboos and trees remain upright!

One thatched roof, it will be noticed, has fallen intact, and it is in this manner that most of the farmers houses, which so thickly cover the Nagoya-Gifu plain, have given way and the country is now dotted over with these roofs, which from a distance present the appearance of gigantic saddles.

PLATE IV.

KOYA ON EMBANKMENT OF BIWAJIMA RIVER.

PLATE IV.

KOHN ON EMBRYOLOGY OF BIMANIAN KIDNEY.

BANK OF THE BIWAJIMA RIVER.

PLATE IV.

IN this picture we again see the movement which has taken place along the river bank. On the left are a few tiled houses yet standing, and on the right the temporary huts—called *koya*—built out of mats, screens, or whatever could be procured, in which the frightened survivors are living.

In the poorer quarters indeed, where the destruction has been complete, we saw some who were without even such poor protection as the *koya*, who had established themselves, with the few miserable belongings saved from the wreck, on a simple mat in the street.

PLATE V.

BIWAJIMA BRIDGE.

PLATE V.

BINAGAIN BRIDGE

BIWAJIMA BRIDGE.

PLATE V.

THE Biwajima-bashi, a wide wooden carriage bridge across the Shōnaigawa, has been completely wrecked. It lies in the bed of the river in a curious serpent-like twisted form. The river is very low, and the continuity of the bridge is nowhere actually broken, so it is possible to walk across, though the feat is not a very easy one on account of the angle at which the footway is canted.

From the picture of the bridge it appears as if a sudden movement up the river bed had taken place, and the inertia of the top load resisting this, it had been left behind,—the supporting piers being, so to speak, jerked from beneath the superstructure.

The river banks and the houses standing on them are fairly intact, suggesting the idea—which is, however, difficult to conceive—that the river bed had transmitted a greater quantity of motion than the banks.

PLATE VI.

NAGOYA SPINNING MILL.

PLATE VI

LINCOLN STATUE HALL

THE COTTON MILL AT NAGOYA.

PLATE VI.

THE Cotton Spinning Mill, is a large brick building with a cellar and two floors, and with a tower one storey higher, about half way from one end of the building and at one side.

The building is in a terribly wrecked condition; there are not more than about half the walls standing, and these are cracked, twisted, and half overset.

Out of 450 people, 35 were killed and 113 were more or less severely hurt. The doors for entrance and exit are all near the middle of the building, and the tower, in falling, had crashed through all the floors, right to the very cellar, just in the centre of the crowd struggling to get clear of the building. Mr. S. Hattori, the manager, missed the falling mass by only about two feet and escaped scathless.

When constructing in an Earthquake country, it should not be forgotten that doors or means of exit should be easily accessible. The disaster at the Nagoya Mill furnishes a lesson from which we ought to profit.

In looking at the picture, it will be observed that, although the walls are fairly thick, from the way the bricks have separated we may imagine that the cohesive power of the mortar was not very great.

The cracks above the windows in the tower show that openings in walls form lines of weakness, and, as such, they require special consideration from the builder.

PLATE VII.

NAGOYA SPINNING MILL.

PLATE VII

THE COTTON MILL AT NAGOYA.

PLATE VII.

ON the illustration we see that the upper part of the tall chimney has been overthrown. On looking at the mass of ruins, the wonder is, not that some seven or eight per cent. of the people in the building were killed outright, whilst about a third were hurt, but that any escaped unhurt at all; for it seems there was not time to get out of the building before the walls had collapsed.

It is notable that the Earthquake was not particularly severe at the Spinning Mill, Japanese houses near it not having been much damaged.

The destruction of the upper storey was apparently occasioned by the sudden movement of the walls against the tie-beams of the trusses, which resisting this motion in consequence of the heavy roof-load to which they were attached, one wall was forced outwards on the side the roof fell, whilst the wall on the other side was canted inwards.

The broken chimney, which was evidently snapped in two,—much as we might snap a light fishing-rod by a sudden jerk,—presents an appearance similar to that of the chimneys which were destroyed in Tokyo, Yokohama, and other places.

One observer describes how he saw a chimney sway from side to side, then crack, apparently separate, and then, after one or two swings more, it toppled over.

LIFE AFTER THE EARTHQUAKE.

PLATE VIII.

HERE we have a temporary hut or *koya* in the foreground, whilst behind there is a sea of broken tiles; all that was consumable having been destroyed by fire.

We have said that Japan is a land of Earthquakes; we may add that it is also a land of fires. Each occurs separately, but the one is often consequent upon the other. In 1854 the destruction which was occasioned in Tokyo by the great Earthquake, was terribly increased by fire. At Ogaki, Gifu and other places immediately after the first great shock, fires broke out amongst the ruins, and many who might perhaps have otherwise escaped were burned alive.

PLATE IX.

ROAD FROM NAGOYA TO GIFU.

ROAD FROM ANCONA TO CITTÀ.

PLATE IX.

ON THE ROAD—NAGOYA TO GIFU.

PLATE IX.

THE road from Nagoya to Gifu is a series of villages, one running into the next, as is so common in this country; that is to say it is—or rather was,—a nearly continuous street of more than twenty-five miles in length. Now, November 3rd 1891, Gifu, except in a few places, is simply a narrow lane between two long heaps of debris that were once houses.

The interest, and perhaps even the novelty of a row of houses thrown over by an Earthquake, at first keeps the attention doubly occupied, but in the case of this never ending line of the same sort of thing, an appalling sensation is at last produced: it seems like a kind of nightmare.

One lesson that may be learned from the recent Earthquake is, that structures of wood, built on European models, have withstood the effects of the disturbance better than ordinary Japanese dwellings. In Japanese houses we have heavy roofs, no diagonal bracing, and light supports which by being cut away in making mortices and other joints are reduced to less than half their original strength. The swaying of the heavy roof causes a yielding at the base of its supports, and the whole structure comes down, crushing or burying all beneath.

It has been said that no city built of wood can secure continued commercial prosperity. The justification of this remark is, in our mind, a matter yet to be decided. San Francisco is certainly passing from wood to stone, but many of the beautiful residences of its richer inhabitants, testify to what may be accomplished with timber. Again, Wellington, the flourishing capital of New Zealand is a city of wood, this material being used in preference to masonry, on account of the frequency and severity of Earthquakes.

To resist Earthquakes, we may either build with wood or brick; the former, although liable to greater risk from fire, is cheap, and therefore suitable to the wants of ordinary people; whilst the latter, having to be made unusually strong, is expensive, and therefore only admissable for special kinds of buildings.

PLATE X.

TWISTED RAILWAY LINE AND KISOGAWA RAILWAY BRIDGE AFTER THE EARTHQUAKE.

PLATE X.

INVERTED RAILWAY LINE AND KISOCHIKU RAILWAY BRIDGE


木曽川鉄橋
南方線路


木曽川鉄橋ピヤ破壊

TWISTED RAILWAY LINE AND THE KISOGAWA BRIDGE.

PLATE X.

IN the accompanying plate there are several points which throw light upon the nature of the Earthquake motion which ought not to be passed without notice.

By a close examination of the foreground it is seen that either the rails and sleepers have been moved back and forth and from side to side in their gravel bed, or else they have remained at rest and the ground has moved beneath them. The result of this motion has been to pile up the ballast between the sleepers so that it presents the appearace of a parallel series of huge bolsters. The extent of motion between the sleepers and the surrounding gravel is in many places from 5 to 6 inches.

A more important feature is however the serpent-like bending of the line. Not only have the metals been deflected but the embankment has suffered a parallel deformation. It seems as if the country here,—and similar appearances are presented at other places,—had been subjected to a permanent longitudinal compression. At each of these bends, although not shewn in the present picture, to the right and left of the line, there is generally a slight depression in the general contour of the country, which possibly may mark the line of an ancient watercourse, in which we may imagine, that the materials are softer than elsewhere. The track crossing such depressions would be crossing lines of weakness, where yielding would be relatively easy, or along which a greater quantity of motion may have passed.

The Kisogawa Bridge which is shewn in the lower picture is 1800 feet in length, and ranks among the finest on this section of the Railway. The girders which are 200 feet in length are supported on brick piers

which are from 15 to 30 feet in height and have a cross-section of 20 feet by 10 feet. Each of these rises from two wells which are arched together at the water-line. It is through this arch, which it must be observed is the lowest part of the piers, where fracture has taken place.

The fracture has therefore been across or through the narrowest dimension of the columns. The lateral shifting of the foundations by which the distances between the piers have been reduced, has been the result of a permanent compression, which had the bridge been represented by a line across the river bed, would have been contorted into one or more snake like bends.

PLATE XI.

LIFE AFTER THE EARTHQUAKE.

PLATE XI

THE WATER THE EARTHQUAKE

LIFE AFTER THE EARTHQUAKE.

PLATE XI.

HERE we have a few *koya* of a better sort. A few pots and pans have been saved, and there is at least a slight protection against the weather. We have only depicted what we have seen, but the same conditions exist in every village and unknown hamlet throughout the devastated district, and half a million people have no better shelter than that which is shewn in the accompanying plate.

For many days, whilst shocks were still continuing, in all the towns, men and boys patrolled the streets from evening until morning, making night hideous by shouting, yelling, singing, banging sticks together, and beating drums.

When asked the reason for all this noise, they replied that it was intended to frighten away robbers, to warn the people to be on their guard against fire, and to keep them alive to the fact that severer shocks might come.

At one place they shouted "*jishin! jishin!*"—earthquake! earthquake!—and at another "*yonaori! yonaori!*"—implying that something has disturbed the universe (*yo* universe *naori* to settle).

PLATE XII.

BIWAJIMA RAILWAY BRIDGE AND GIFU AFTER THE EARTHQUAKE.

PLATE XII

THE PARTHÔNAKE
BIMBATANA RAILWAY BRIDGE AND CHOU WATER


岐阜縣下北方町嶺北

BRIDGE NEAR BIWAJIMA AND GIFU.

PLATE XII.

FOR several days after the Earthquake, before there had been any attempt to remove the debris, a brick railway bridge near the Biwajima river presented a singular appearance. The abutments, which originally had been perpendicular, had apparently been pushed backwards to the right and left, and the arch which they originally supported, lay in two huge quadrant shaped masses blocking up the roadway between them. One mass of the archwork is seen in the picture and indicates that the brickwork had been well put together. The rails and sleepers originally carried by the arch, yet remain in their original position.

One explanation of this disaster is that the embankments to the right and left first gave way and the thrust, due to the weight of the arch as it cracked and sank, acted like a toggle-joint, forcing the abutments backwards.

However, as the abutments supported the arch before the embankments were built, it is more likely, whatever part the toggle-joint like action of the arch may have played, that one or both abutments were first pushed backwards by the motion of the earthquake.

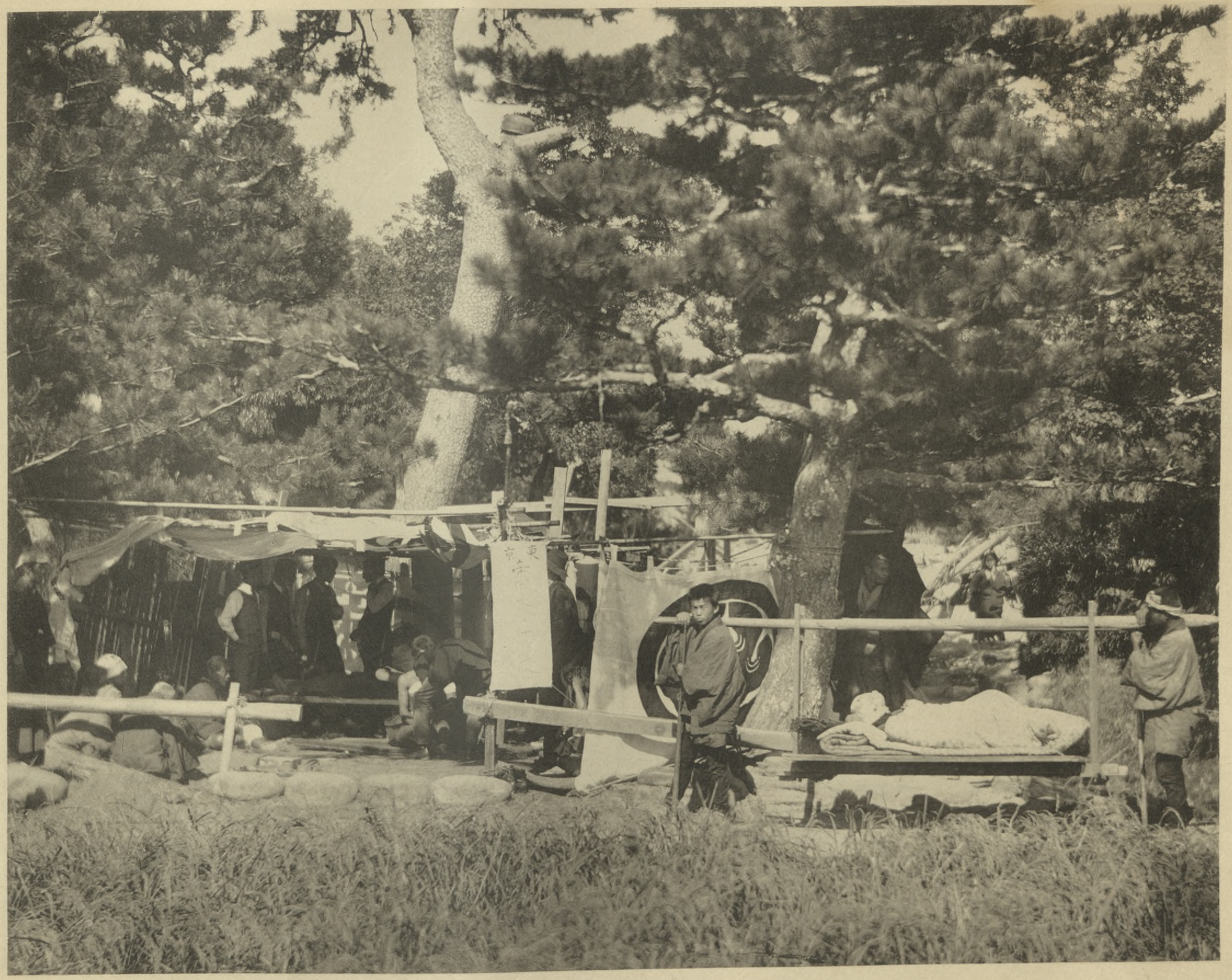
Whatever the cause may have been, it illustrates the unsuitability of arches to horizontal disturbances, and assists us in understanding the reason why, in several Earthquake countries, ordinary archwork is prohibited.

The lower picture shews a portion of Gifu that escaped the fires which, as we have already stated, broke out immediately after the first great shock.

PLATE XIII.

IMPERIAL UNIVERSITY HOSPITAL.

PLATE XIII



HOSPITAL AT KURODA.

PLATE XIII.

AT Kuroda for the first time we saw hospital work—hospital if it can be called,—it being merely a space of ground with curtains stretched around it on bamboo posts, so that the whole world might not look on, and one or two mats within the inclosure. There was nothing whatever in the way of furniture, but the necessary utensils, and instruments for performing surgical operations.

Whilst we were here patients were being brought in on extemporized litters and on hand carts. One very old woman was carried in on the back of a middle aged man, very likely her son. Goodness knows from how far he had carried her to this strange hospital which has to serve all the country for miles round. Whilst we were at the hospital cases were coming in more quickly than they could be treated by several surgeons, through this was the sixth day after the great disaster. It was mostly old people that we saw treated; and how wonderfully patient they were! One poor fellow, it will be seen, is having some operation performed upon his arm, whilst on the right a woman is being borne in on a temporary *Kago* or litter.

PLATE XIV.

IMPERIAL UNIVERSITY HOSPITAL.

PLATE XIV.

IMPERIAL UNIVERSITY HOSPITAL.

HOSPITAL OF THE IMPERIAL UNIVERSITY.

PLATE XIV.

ALTHOUGH the Earthquake took place early on the morning of the 28th, it was not until the 30th that the real nature of the disaster was realized, and then doctors were dispatched from all sides. The first in the field were members of the Red Cross Society, who a few hours later were followed by a staff from the Hospital of the Imperial University. Doctors from the Imperial Household, the Naval and Military Departments and from the Missions soon added to the number.

In the University Hospital—constructed out of, and upon, the ruins of fallen houses—Dr. F. Scriba and his colleagues during ten days treated 800 cases. By the first of December the number of patients at this establishment, which also had to serve the doctors as their home, rose to 1150, the daily average being 120.

Simple and compound fractures especially of the spine and pelvis were common. A great many of the wounds in consequence of neglect, were dirty and suppurating, some being covered with maggots. Numbers of the patients were feverish and suffering from tetanus and erysipelas. By strong antiseptic treatment and care good results were obtained, only four out of the 1150 having died.

When a European community has been overtaken by a disaster like the one about which we write, women become hysterical, men loose their nerves, many are mad with terror and one and all have lost their reason—after the Gifu Earthquake we learn on good authority that the results of nervous excitement shewed itself in the form of tetanus, spinal and other troubles rather than in any general mental paralysis. The fact that Europeans are more nervous and excitable than Japanese—may be partly accounted for perhaps, by the fact that the latter

nation has been cradled amongst Earthquakes and Volcanoes the manifestations of which rank amongst the greatest of nature's terrors.

If from time to time England or any other European country were shaken by the same terrible forces which so often shake Japan, London and other cities were levelled, the English coasts were inundated with sea-waves, the mountains flowed like water and everything which we now regard as permanent repeatedly demolished, we may ask the question whether such phenomena would or would not affect the national character?

It seems that ideas respecting permanency would be destroyed, a carelessness for the future be engendered and a general timidity be created which latter would prove to the weaker members of a community a serious obstacle in the general struggle for existence.

KASAMATSU.

PLATE XV.

THE foot bridge across the Kisogawa at Kasamatsu has simply disappeared, leaving nothing to show where it was. One crosses by boat, to the place where Kasamatsu was, but all that is left of the place is a reddish coloured plain of tiles and other uninflammable things, which, when we were there, were still smoking. Fire broke out after the Earthquake, and the town was completely destroyed.

In the foreground it will be noted that the survivors have been collecting a few unbroken tiles, evidently with the hope of at least saving something; whilst in the background one or two buildings yet remain standing. The large iron pan possibly belonged to some temple and was used for holding water or boiling rice; it may be what remains from a factory where *shoyu* (bean-sauce) was manufactured.

PLATE XVI.

TEMPORARY SHOP AFTER THE EARTHQUAKE.

TEMPORARY SHOP NEAR THE EARTHQUAKE

PLATE XVI

A TEMPORARY SHOP.

PLATE XVI.

HERE and there those who have something to sell, which may be a few balls of rice or some persimmons, have established stalls along the road-side.

On certain sections of the railway line, because it had suffered less than the roads and was therefore used as a pathway, these wayside stalls succeeded each other every few hundred yards. The principal things, which were and are yet (at time of writing) everywhere required, are food and clothing; and too much cannot be said in praise of the work done to meet these necessities by the government, the various missionary bodies, and individual workers like Messrs. Keil and Sim—Mr. O. Keil's name should be remembered in Japan for many years to come.

PLATE XVII.

KASAMATSU.

PLATE XVII.

KASAMATSU.

KASAMATSU.

PLATE XVII.

ALL that is said respecting the picture No. XV applies to this also.

In the illustration are several *koya* or temporary shelters, where people are sitting in the midst of a few tubs and pans saved from the wreck.

The large wooden tubs in the centre evidently mark the site of a *miso* or *shoyu* (bean sauce) factory. Two *kura* or warehouses, which have heavy roofs and are built of timbers with a wattle of bamboo filled in with mud, have fairly well resisted the motion.

Excepting these warehouses and the trees, everything has been levelled with the plain.

PLATE XVIII.

BRIDGE IN NEO VALLEY.

PLATE XVIII

BRIDGE IN NEW ANTLEY

NEODANI.

PLATE XVIII.

HERE we have a scene in the famous Neo Valley, where the disturbance was practically at its maximum. In some places the ground has sunk, and at others risen, and the people say that the mountains themselves have been depressed, so that from certain points hills formerly invisible now raise up their heads.

On the left of the picture a portion of a light cantilever bridge remains in position: The frame forming the middle span has fallen downwards, and two of its leg-like supports are seen nearly parallel with the cantilever. Restoring what was the horizontal portion of the bridge to its original position, we see that the second pair of supports, which must have occupied a position in front of the dark *Cryptomeria* standing amongst bamboo, in the background, and the right hand cantilever, have been swept away, the ground having either sunk, or been spread right and left by the violence of the shaking.

PLATE XIX.

BRIDGE IN NEO VALLEY.

PLATE XIX.

BRIDGE IN NEW ANTLEY

NEODANI.

PLATE XIX.

ABOUT five miles above Hinata we met with an unexpected obstacle. The river here had to be crossed but the centre of the cantilever bridge had been totally destroyed by the Earthquakes, and on account of the rain, the river was not fordable. One little bit of the central span is seen in the left hand corner of the picture. It is remarkable that the forces which had destroyed the bridge had failed to disintegrate the rubble wall supporting the pathway on the opposite bank of the stream.

It was along the Neo Valley that earth-movements were most severe. What may have been a fault, which runs for many miles along its length, is represented by an embankment like slope, the ground on the western side of the valley having sunk from twenty to fifty feet below that on the Eastern side.

PLATE XX.

IN NEO VALLEY.

PLATE XX.

IN NEO KALLEX

NEAR ITASHU, NEODANI.

PLATE XX.

IN one place a group of four or five houses has completely sunk into the earth. The ground where they rest has been depressed, for a small distance around them, to a depth of about 15 feet, the sides of the depression being quite abrupt, but the strangest thing of all is that the houses seem to have *punched* themselves, so to speak, into the ground of this depression, which is soft. Only the roofs are to be seen and, on looking under them, instead of the confused heap of rubbish found under other wrecked houses, there is merely the surface of the ground, the same level inside as outside! Those who were in the houses at the time of the Earthquake lie buried in the ground no one knows how deep. No attempt has been made to recover the bodies. The living had to be thought of before the dead.

PLATE XXI.

LAND SLIPS IN NEO VALLEY.

PLATE XXI

LANDSLIPS IN NEODANI.

PLATE XXI.

THE lighter coloured patches on the sides of the mountains shewn in the accompanying plate, are areas which have been denuded of grass and forest by landslips. One of the masses, carrying with it trees in an upright position, which has slipped from above, is seen in the foreground. These landslips, which in every probability have occurred in many parts of the mountains between Mino and Echizen, may possibly have created dams across the valleys into which they fell. Should water accumulate behind these to form ponds and lakes, and the dams subsequently give way as was the case in the same district after the Earthquake of 1854, the destruction which would follow might equal that of the Earthquake itself.

For several days after the great disturbance, landslips were taking place, and visitors who saw them, were so impressed by the roaring noise and vibration, that they were regarded as a cause rather than as an effect of the mountain shakings, which, at places on the plain announced themselves by a distant rumbling or a cannon-like boom.

Prof. Tanakadate who carefully noted the intervals in time—which were from half a second to five seconds—by which the sounds at Nagoya and other places preceeded the shakings, shares the opinion with other seismologists, that the sounds are transmitted through the earth, and find their explanation in the minute waves which preceed and are continuous with the succeeding shakings.

PLATE XXII.

NAGARA GAWA RAILWAY BRDIGE.

PLATE XXII

ANCARA CAVA BALIANA BRDICE

NAGARA RAILWAY BRIDGE.

PLATE XXII.

ON this picture we see the broken cast iron piers lying on the dry shingly bed of the river, like pieces of a huge carrot, and also that the original line of the bridge has, in its central part, been deflected up stream.

Although the cracks in the banks being parallel to the river, seem to indicate a movement, or the component of a movement, at right angles to their length, yet here, as at other bridges, it would appear that the movements, especially in the central parts of the river beds, have resulted in extensive permanent displacements, either up or down stream. Whether it is possible for engineers to build bridges which will resist such large bodily displacements as have been experienced along the bed of the Nagara and other rivers is a matter of question. Had the piers risen from a broader base, been made of wrought iron and had an Eifel tower like form, although they might not have been fractured, it is difficult to imagine that lateral shifting and bending would have been avoided.

PLATE XXIII.

NAGARA GAWA RAILWAY BRIDGE.

PLATE XXIV.

ANCARA CAMA RAILWAY BRIDGE

NAGARA RAILWAY BRIDGE.

PLATE XXIII.

THE most notable thing between Gifu and Ogaki is the railway bridge over the Nagara-gawa, which has been totally destroyed.

The main part of the bridge consists of five independent trussed girders of wide span. The piers at the two ends of one of these girders are completely wrecked and the girders have fallen bodily into the bed of the river. The piers on either side of the two mentioned, are partly wrecked, and the girders between them and the first mentioned girders rest, each with one end in the river bed, the other, on the top of the partly destroyed pier. The remaining girders are in their original positions, or nearly so.

The cause of the collapse of this bridge is undoubtedly the failure of the piers. The girders, even those that have fallen, appear, on a casual inspection, to be straight and intact.

The piers each consist of a group of cast iron columns, built up in pieces, joined by inside flanges, and filled up with concrete, the group being braced together by wrought iron ties. In almost every case the columns have snapped at right angles to their length, immediately above, or below, the flanges.

It will again be observed that the portion of the bridge which has fallen, relatively to the part which remains standing, has been thrown some distance out of a straight line.

Examination has shewn that this displacement, is not simply a displacement of the upper-work of the bridge, but the ground with the screw-pile foundations has been shifted a distance of several feet up the stream.

PLATE XXIV.

NAGARA GAWA RAILWAY BRIDGE.

PLATE XXIV.

ANCARA CAMA RAILWAY BRIDGE

APPROACH TO NAGARA GAWA RAILWAY BRIDGE.

PLATE XXIV.

THE embanked approach to the Nagara Gawa bridge has been thrown into a regular series of undulations of such extent that, looking along the line eastward from the eastern abutment, the appearance is almost that of looking along a switch-back railway!

The origin of the long wave-like curves which are here shewn, may be explained on the assumption of a concertina-like compression along the length of the line, or by an actual subsidence beneath the depressed portion of the wave, or by a lateral spreading outwards of the embankment at certain points.

The disappearance of embankments, as for instance near to the abutments of many bridges, is undoubtedly due to the shaking away of the loosely cohering materials out of which they were constructed.

PLATE XXV.

NAGARA GAWA EMBANKMENT.

PLATE XXV.

ANCARA CAMA EMBANKMENT

GENERAL VIEW OF THE NAGARA BRIDGE.

PLATE XXV.

THIS picture gives a general idea of the destruction which has occurred at the bridge crossing the river Nagara.

There are five long girders, each of 200 feet span crossing the main part of the stream, and at each end, two shorter, and therefore lighter ones, supported on shorter piers.

The longer piers have suffered most. When looking at the illustrations of the railway bridges which were designed by Mr. C. A. W. Pownall, M.I.C.E. it must be remembered, that, for five years, not only have they withstood all ordinary traffic, but they have been subjected without injury to unusually heavy floods, which have devastated the surrounding country, and have withstood the force of typhoons which have overturned locomotives and caused the collapse of many brick chimneys and buildings.

Where river banks have not been levelled by the shaking outwards of the materials of which they were built, they have been fissured and reduced to the chaotic state shewn in the picture.

PLATE XXVI.

NAGARA GAWA RAILWAY BRIDGE.

PLATE XXVI

MACARA CAMA BAILWAY BRIDGE

NAGARA GAWA RAILWAY BRIDGE.

PLATE XXVI.

FROM the results of experimental investigations, if we know the nature and dimensions of a column or wall, and the load it carries, the jerk or acceleration it will resist, may be calculated; and *vice-versa*, assuming the greatest suddenness of motion to be expected, and knowing the load we have to carry, and the height at which it is placed, dimensions for the supports may be determined. The greatest strain coming at the point where the structure leaves the ground, the strength or dimensions should there be greater than at higher levels.

If near a river bank, where the piers are short and have stood, we can say, that the suddenness with which they were moved must have been *less* than so many feet per second; whereas, in the middle of a stream, where the piers are relatively high and have been fractured, the suddenness of motion must have been *more* than so many feet per second.

A bridge which has been partially destroyed by an Earthquake therefore becomes a seismometer, and leads to the determination of the rate at which motion was applied, a factor of considerable importance in designing future constructions.

PLATE XXVII.

LIFE AFTER THE EARTHQUAKE.

PLATE XXVII.

LIFE AFTER THE EARTHQUAKE.

LIFE AFTER THE EARTHQUAKE.

PLATE XXVII.

THE picture shews two women carrying between them a few treasures they have discovered amongst the sea of tiles. In the background there is an enclosure where at one time there may have been a temple. Throughout the Nagoya-Gifu plain destruction like this extends for miles and miles. In the towns it chiefly fills the streets,—Japanese houses on account of the front side being open and therefore weak having fallen forwards. Where streets have been narrow,—and narrow streets are a feature in Japan,—escape from a house only meant death outside.

At Ogaki where this picture was taken, out of 8000 houses only about 30 remained, and the ruins having been destroyed by fire it was difficult to construct *koya*.

The scenes the traveller met with when passing between and over these oceans of debris were curious and touching. For instance it was not uncommon to meet with a group of babes and children installed upon a mat placed upon the ruins of a fallen house; and there they were, with toys improvised from bits of tiles and sticks, chattering and playing sitting upon a ruin which might represent their parent's grave. Mr. Burton describes one little girl he saw sitting amongst a heap of broken tiles tending a few chrysanthemum blossoms she had in a vase of water. From whence she had procured them heaven knows.

PLATE XXVIII.

LIFE AFTER THE EARTHQUAKE.

PLATE XXVIII.

THE WATER THE EARTHQUAKE

RUINS AT OGAKI.

PLATE XXVIII.

WE have here a scene that was common amongst the ruins of many cities for several days after the Earthquake. It is that of more or less famished survivors going over the ruins turning up tiles and fragments of timber in search of food. Signs of distress and even starvation were met with at many places. Mendicancy in Japan, excepting at a few holiday resorts, is rare, but here old women, men and children asked for money to buy food. Although the picture shews through a haze of smoke the castle yet standing in the distance, the whole town was practically shaken down and then consumed by fire, many hundreds of the wretched inhabitants being burned alive beneath the fallen ruins.

PLATE XXIX.

EFFECTS OF EARTHQUAKES IN ITALY AND MANILA.

PLATE XXIX.

EFFECTS OF EARTHQUAKES IN ITALY AND MALTA.


1


2


3


4


5


6

EARTHQUAKE EFFECTS IN MANILA AND ITALY.

PLATE XXIX.

1. *Casamicciola.*—On August 28th 1883 during the height of the bathing season when Casamicciola was crowded with visitors, a distant noise like the rumbling of a carriage was heard, which was almost immediately accompanied by a tremor; there was then a crash and 5,000 human beings lost their lives.

   Although the plate may be regarded as illustrating the unsuitability of archwork in Earthquake countries, it will be observed that the masonry is mere rubble-work.

2. *Casamicciola.*—Here we have an example of the ruin of the last house in a row, which being unsupported at one end has been shot forwards.

3. *Casamicciola.*—This plate shews the giving way of a corner: two walls at right angles not having synchronized in their vibrations, they have consequently been mutually destructive.

4. *Manila.*—The more or less vertical fractures in this building shew that a series of openings in a wall constitute a line of weakness; and when a building so constructed is shaken back and forth, a rending action takes place.

   Perforations are made in a sheet of postage-stamps to facilitate rending. To obviate an action of this sort in buildings, iron or wooden lintels should be buried in the walls above openings like doors and windows.

5. *Manila.*—This picture represents one kind of destruction which occurred in July 1880. It is apparently due to the weight of a heavy roof and an upper storey acting upon the masonry walls beneath, which, as they moved to and fro, were unable to overcome the inertia of the load they supported.

6. *Casamicciola.*—The beautiful island of Ischia is of volcanic origin and consists of a central volcano surrounded by numbers of parasitic cones. The marine shells on the sides of the mountain, shew that the island has only been recently lifted above the sea bottom. On March 11th 1881 a subterranean noise was heard and in an instant the upper part of Casamicciola had crumbled.

A report on the disaster states that the destruction was chiefly due to bad construction, most of the houses being built of rubble.

MAP OF JAPAN

Lines of volcanoes ——

Isoseismic Lines ----------

130

140

40

30

Sendai

GIFU

NAGOYA

Tōkiyo

Yokohama

Kōbe

Nagasaki

Engr. by K. Ogawa.