NOTES ON THE EARTHQUAKE AT ATAMI, IN THE PROVINCE OF IDZU, ON SEPTEMBER 29, 1882.

BY

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On the morning of Sept. 29, a severe and sudden shock of earthquake was felt at Atami, causing much alarm to the people and leaving after it, as the effect of its violence, considerable amount of damage in the town and its neighborhood.

Nobody seems to have felt any feebler shocks precede the heavy one, which startled us from our sleep about 5 o'clock or a little before. An intelligent fisherman told me, however, that when he was returning in a boat, in company with another, about the same time from the fishing port of Aziro, about 5 miles south of Atami, he distinctly heard a roaring sound in the mountains and immediately after, felt his boat shaken violently. As the time was early and almost every one was yet asleep, I found no one else to confirm his statement. I am sorry that I could not record a more definite time of the shock, on account of confusion caused by its severity and suddenness. The duration of the shock seemed very short, probably lasting only a few seconds. I felt as if the shock consisted of a series of rapid vertical thrusts. Servants in the house who were up at the time said that they all held on to something for fear of falling over. I may add here that bottles containing medicine fell off the shelf at the house of a town physician, causing so much damage that his patients were deprived of their medicines for two days till he obtained an extra supply from Odawara. On examining my *ando*, a Japanese lamp, the description of which would be familiar to every foreigner who

has been in Japan,* I found the paper which covered the side facing the sea or E. S. E. was saturated with oil showing that the oil was thrown out on the side toward the sea.

In order to show the effects which the earthquake produced, a brief description of the physical structure of Atami and neighboring coast is necessary.

Atami is built on the slope rising with quite a steep inclination from the sea in a valley formed by the spurs of Hakone ranges, which project out into the sea like arms, enclosing the town of Atami between them. On the south side particularly, the mountain terminates in cliffs of great height and abruptness. The houses are mostly on terraces, built successively from the sea. In fact, the coast of Idzu rises out of the water perpendicularly, thus making the roadway along the coast extremely difficult. The road from Odawara to Atami, a distance of about 16 miles, is cut through mostly along the sides of cliffs, in many places several hundred feet above the sea.

On going out to look for any damage that might have been done, I found that in numerous places, stones were thrown entirely down from their positions in the nearly vertical retaining walls of the terraces. In a similar manner, a solid retaining wall about 5 feet high above which one of the principal hotels, called Suzukiya, is built, was nearly destroyed on the side facing the sea. A little house in front of our hotel was twisted out of shape by the stones giving way beneath. I must not omit to say, however, that the stones are mostly rudely cut and loosely laid in the walls, without mortar, but those forming the walls at the hotel were well shaped and closely fitted, though not cemented.

I noticed that the greatest damage to the terraces, was in the sides facing the sea or E.S.E.; a few cases in those facing

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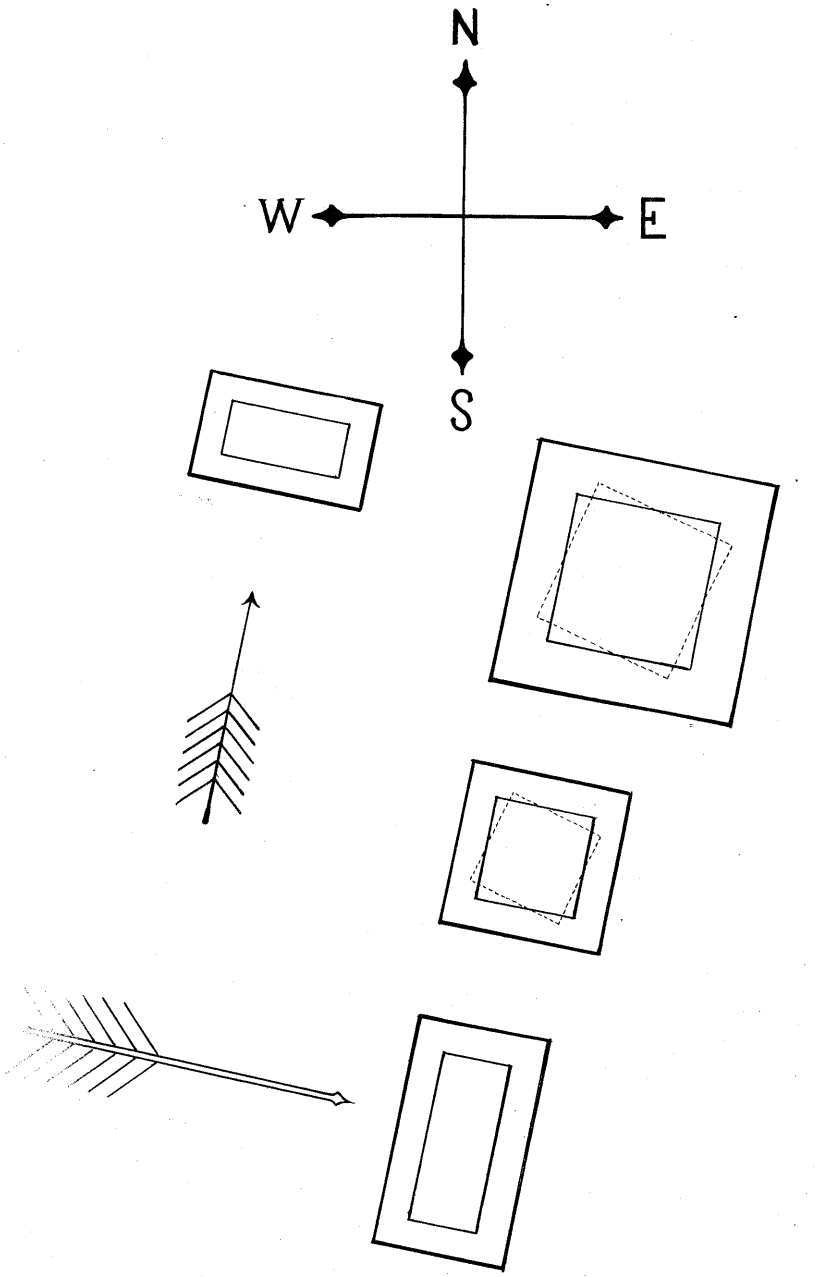
** The lamp I had essentially consisted of a shallow box about one foot square with four small posts about three feet high, erected in its corners and braced together at the top by pieces of wood; above the middle, this framework was papered over, having in the inside a narrow piece of board fixed across to hold a copper saucer containing oil with a little wick hanging over the edge.*


N
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N.E. & S.E. but scarcely any in those facing S. or S.W. As the land rises towards the W. and N., I found scarcely any walls facing in those directions and no cases of damage in them.

Although most of the walls face E.S.E. and therefore we can hardly tell by the amount of damage, the side which suffered the most, yet it appears most probable that the side facing E. S. E. had to bear the greatest shock.

I have come to the same conclusion as to the direction of the shock by the consideration of the fall and rotation of tombstones in the graveyard of Onsenzi, which I was fortunate enough to observe in their displaced positions, as the workmen were already employed in replacing them properly.

The temple of Onsenzi is located quite a distance up from the sea in an elevated situation with terrace walls on N. N. E. and E.S.E. sides. Just in front of the temple a monument erected in memory of a historical personage Fujiwara Fujifusa, facing N.N.E., fell forwards and was broken. It was a broad irregular flat slab about 6 inches thick, measuring about 5 feet high and 3 feet wide, set into a hole made in the stone base.

Some of the smaller tombstones, which simply rested on flat bases and through bad cutting or disintegration were unstable fell from their pedestals, all toward E.S.E., with the exception of two flat ones facing N.N.E. which fell forwards in the same direction as the monument.

I observed also the interesting case of tombstones rotating on their bases, all in the same direction as that of the hands of a watch. The tombstones all stood in rows parallel to each other and the approximate displacement and the directions of the fall can be seen in the accompanying diagram, the dotted lines indicating the rotated positions; the large arrow shows the direction of the fall of the tombstones and the small arrow that of the monument and the two tombstones mentioned above.

The maximum amount of rotation observed was about 20°, the amount apparently decreasing as the weight of the stones increased.

The simple explanation of rotation of columns given by Prof. Milne in Vol. I of the transactions of this society can be

applied to this case, regarding the movement as caused by a direct shock, or we can imagine this singular movement as due to the rotary motion of the ground, probably caused by the interference of transverse waves. If we consider the shock as coming from the direction of the sea, the production of the reflected waves could reasonably be accounted for, by the sudden reflection against the dense rocks of which the mountains are composed. The comparative violence of the shock felt here may also be due to the same cause, or to the fact that the origin of the shock was comparatively near.

From what has been recorded we have evidences to infer that the general direction of the shock was either W.N.W. and E.S.E. or W.S.W. and E.N.E. or nearly E. and W. which agrees with the direction indicated by Prof. EWING's astatic lever seismograph in the engineering laboratory of the *Daigaku* on the morning of that day. The seismographic record shows that there was hardly any motion of the lever which traces the N. and S. component, whereas the one indicating the E. and W. component undulated considerably through the comparatively long interval of 69 seconds. On making inquiries about the earthquake at every place where I stopped, I found that the intensity was less and the duration longer than was felt at Atami; at Kanagawa, a man particularly remarked about it, as an unusually long shock. Whether the earthquake recorded in Tokio is the same as that felt at Atami is doubtful, yet it is reasonable to believe that they were the same or at least had originated from the same source as a shock was felt everywhere about the same time, on this side of the Hakone as far as I could ascertain.

We had several smaller shocks after the heavy one I have described; I have recorded one at about 9 and another a little before 12 in the morning of the same day. We were alarmed again about 2 A.M. of Oct 1 by a shock. In the mean time I am certain of feeling slighter ones whose times of occurrence, I have not recorded. About 10 A.M. of Oct 5th I felt a distinct shock.

The frequency of the shocks felt, the comparative violence of the first one with the short duration of apparently rapid

vibrations, all favor the supposition that the origin of the shocks was near; the waves may have been propagated from a source somewhere in vicinity of Atami, decreasing in amplitude and energy in proportion to the distance traversed. Friends of mine who were in Kiga on the Hakone mountains tell me that they do not remember of feeling any shock that morning, which shows at least that the origin was not in that part of the range.

Being interested in the nature of the mineral springs, I made immediate inquiries as to the action of the big spring or *Oyu*, after the shock. I found that there was no change in the usual periodicity and amount of discharge until two days after, when, on Oct. 1, the discharge continued unceasing for the whole day, which I was informed happens very rarely. This fact may be explained by supposing that the large amount of infiltrated water, derived in great part from the extraordinary heavy rain of Sept. 30th and Oct. 1st, produced an unusual amount of steam and boiling water sufficient to cause this continuous discharge under the influence of unusually great subterranean heat, which might likely prevail at the time of earthquakes, as is evidenced by the sudden increase of temperature in the certain thermal springs; as for instance, at the time of the earthquake of the island of Ischia in the bay of Naples in 1828 the hot springs of Rita which was near the centre of the movement, were ascertained by M. Covelli, to have increased in temperature.(1) After the great New Zealand earthquake in 1855, the natives alleged that the temperature of Taupo hot springs was sensibly raised just before the catastrophe.(2) Concerning the elevation of subterranean temperature, Lyell says "Thermal and mineral springs are abundant in countries of earthquakes and active volcanos. Lastly, springs situated in districts considerably distant from volcanic vents have been observed to have their temperature suddenly raised or lowered, and the volume of their water increased or lessened by subterranean movements. etc. etc."

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(1) *Lyell's Principles of Geology vol. II p. 94*
(2) ,, ,, ,, ,, ,, ,, *p. 87*

On the 3d, however, the spring had resumed its normal condition. Some say that the rainfalls generally increase the amount of discharge, which if true goes to show that the spring is not entirely of marine origin.

It seems quite reasonable to infer that the spring water owes its origin partly to the sea water and partly to the fresh water infiltrations.

Although a digression, let us compare by the use of the following table, the composition of the spring water as analysed by Dr. MARTIN at Shiyakujo and those of the varieties of sea water collected at different localities, to show the analogy existing between them without discussing them in detail.

(*Contained in 1 litre*)

Localities	Na	Cl	Mg	Ca	K	So_4	Br	Co_3	Fe	Mn	Sio_2	org. mat.	Residue	Authors
Atlantic Ocean 41° 18′ N—36° 28′ W	gr. 11.719	gr. 20.840	gr. 1.1981	gr. 0.5568	gr. 0.6682	gr. 3.029	gr. 0.3878	gr. ,,	gr. ,,	gr. ,,	gr. ,,	gr. ,,	gr. 38.400	BIBRA, *Ann der Chem. u. Pharm.* t. LXXVII
Pacific Ocean 3^m, 50 from the surface	10.262	18.950	1.3151	0.4719	0.6038	2.786	0.3102	,,	,,	,,	,,	,,	34.700	BIBRA, *loc. cit.*
Black Sea South side of Crimea	5.512	9.574	0.6622	0.1305	0.0975	1.2505	0.005	0.2475	0.1271	,,	,,	,,	17.605	GÖBEL, *Poggendorff's Ann., suppl.* t. I, P. 187
Sea of Azof between Kertch and Mariopol.	3.997	6.585	0.4010	0.0908	0.0670	0.8045	0.004	0.0695	0.0358	,,	,.	,,	11.900	*Ibid.*
Atami Big Spring (Oyu)	1.491	6.034	0.5894	0.6945	0.9493	0.1362	trace	0.0053	0.0009	trace	0.1100	trace	10.010	MARTIN, *Mittheilungen der Ostasiat. Gesellschaft* July 1876
Caspian Sea South West of Pischnoi	1.144	2.737	0.4098	0.1916	0.1397	1.337	?	0.0773	0.0401	,,	,,	,,	6.296	GÖBEL, *Poggend. Ann., suppl.* t. I

We find that the total residue of the spring is much less than those of the different samples of the ocean waters generally. Now, we ought rather expect it more on account of concentration by evaporation etc, but the fact that it is less seems to indicate that the sea water is considerably diluted before being discharged.

The comparatively large amount of silica, SiO_2, in the spring is due, no doubt, to the decomposing action of the hot water upon the trachytic rocks underlying Atami through which it has percolated, as is the case in the majority of thermal springs passing through silicious formations.

It seems to be of great value for the proper discussion of the subject to have the analyses of the spring water and those of the sea water near the coast, made from time to time through the varying seasons of the year.

After the shock, however, the little spring called *Kobayashi no yu* which fed the bath of our hotel, was nearly stopped up, discharging but a small amount of muddy water to the general dissatisfaction of the guests and the alarm of the host. On examining the spring, I found that the water did not rise high enough in the basin to be conveyed by the aquaduct. They lowered the aquaduct, which involved considerable trouble, but by doing so the usual supply was obtained. On examining the action of the spring, which is generally intermittent with the interval of 2 minutes or so, I found that it had accelerated its eruptions becoming almost constant but apparently decreased in force.

This fact might be explained by supposing that the tube which conveys the water was distorted and contracted by the recent earthquakes thus hastening the interval of eruptions, just as BUNSEN explained the action of geysers, the truth of which was afterwards experimentally confirmed by Dr. TYNDALL; that is, the tube itself being sufficiently accountable for the production of periodic eruptions, any obstruction of the tube would, by causing the heat to accumulate, tends to hasten the eruptions.

The large amount of boiling water discharged periodically from the *Oyu* accompanied with clouds of steam and growl-

ing subterranean noise is the object of much wonder and speculation to all who see it during its action. The eruptions take place quite regularly about 5 times in a day lasting for half an hour or more. A few hours before the final eruption clouds of steam begin to issue from the mouth of the tube and the water rises to the rim of the basin, and for a considerable length of time the level of the water in the basin oscillates up and down. The oscillations increase in frequency and force till followed by a number of minor eruptions of shorter duration, the water receding into the tube after each outburst, and commencing again the similar actions with added force and increase in the volume of the discharged water, and so repeating itself again and again tills it ends in the final eruption.

This peculiar oscillating action of the spring does not essentially contradict, even if it does not favor, the theory that the intermittency is due to the formation of steam in the lower part of the tube, as proposed by BUNSEN and others to account for the action of the geysers.

The percolated water coming in contact with heated rocks or superheated steam, would be partly converted into vapour, which in turn will heat up an additional amount of water till the tube full of water will be raised to a high temperature. As the water in the lower part of the tube receives more heat, a sudden rise of temperature, however slight, may cause the water to overcome the pressure and flash into steam which would tend to rush up the tube, carrying the column of water with it; but the enormous pressure of the column would condense part of the steam, which will cause the column to sink down again into the tube. This conflict, so to speak, of steam and the pressure of the water would last for some time and may give rise to the oscillatory movement above described.

At length, however, the tension of the steam becomes so great that the column of water is no longer able to resist it, and it will be pushed out, at first, spasmodically; but as the lower portion becomes relieved of part of its weight and is rapidly converted into vapor, the action will become more violent, till the whole of the column is expelled.

When the expansive power of steam is thus exhausted,

the sea water may rush into the tube through the underground fissures and may partly full up the tube; at the same time the rain water may be infiltrating into it. The existence of underground fissures from the bottom of the sea near the coast, is evidenced by the fact that the sailors and fishermen often feel the hot water bubbling up from the bottom.

On my way back, I found that the road between Atami and Odawara had suffered some damage, landslips obstructing the passage in many places, which were, no doubt caused by the recent rain aided by the previous earthquake, as in Atami where we found that the rain greatly extended the damage begun by the earthquake.

I must say that as the construction of the houses, terrace walls, &c, is rough and primitive with few exceptions, the amount of damage done here would be far greater than the same intensity would have produced on level ground or in more solid structures or in places where stone constructions are few.

Having no intention of writing this brief note at the time, I must apologize for the inaccuracies both as to time and measurements.