EARTHQUAKE ORIGIN.

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Subsequent to the publication of my paper on this subject, in 1887, in which it was intended to convey an absolutely possible confirmation by the aid of submarine cables, of my theory that seismic disturbances are mainly due, in a direct sense, or result from, geological evolution or subsidences; many instances have occurred which tend to accentuate the the importance of continuing this line of research. Of course I do not refer to cases where the cessation of telegraphic communication has been caused by the interruption of cables laying across purely active volcanic regions, such for instance as those between Java and Australia in 1888 and in the neighbourhood of the Lipari Islands, where the new crater volcano sprang into existence last year, because we had the ocular proof that heat—water at very high temperature—had melted the gutta percha, destroying the cable's insulation and in consequence the communication. But I refer rather to those cases where the rupture was caused by a purely mechanical force, and to cables which lay across known earthquake centres and in purely non-volcanic regions. It is very necessary, however, to thoroughly recognize the distinction between earthquake shocks resulting from volcanic action, or preceding an imminent eruption, and those which arise from an unknown cause. In dealing with Japan the question does not admit of discussion, as there is no doubt about the origin of earthquakes in that country, but in Europe, chiefly in and near the Mediterranean, in certain parts of America, and along the western coast of Africa, quite 95 per cent. of the earthquakes are caused by geological disturbances, and invariably on the seaboard, such geological disturbances consisting of subsidences, silt and rock deposits, landslips resulting from erosion by under currents and many other mechanical forces which are continually being developed on the assumed bottom of the sea.

Unfortunately we have all been educated to believe, more or less, in one or the other of the persuasive, but by no means assured, theories of the origin of our planet, and the Laplacian one seems to have taken the strongest hold upon our minds; so that whenever we have some startling reminder of the kinetic condition of the earth we are apt to set it down immediately to volcanic action and trouble ourselves no more about the matter, whilst we are constantly hearing every peak on a mountain range or every isolated conical hill described as of volcanic formation or so many extinct volcanoes forgetting, or ignorant of, the great truths their very history reveals, of denudation and degradation, those two immense and destructive agents at work upon the "earth above the water." The age of our planet is comparatively a secondary consideration (always assuming of course that at the lowest computation a million years have elapsed since it began to revolve in its orbit round the sun) and whether it was originally a molten plastic mass left gradually to cool, or whether it was a pliable sphere entirely covered by water, or the result of the sun's action on organic gases ready and waiting for decomposition, is also of secondary importance. All we do know, because it is self evident, is, that those barren peaks and rocky hill ranges which now cover so large a portion of the earth's surface were once covered with deposits of the richest soil and clothed in luxuriant verdure, or plant growths, as wonderfully prolific as the constant tepid atmosphere, then existent, naturally assisted in developing. That the waters originally covered our planet, or rather that the nebulous mist of gases, which by the action of light were decomposed into their proportionate parts of liquids and solids and concentrated by the inexorable law of gravitation, is an undeniable fact, as is also that of the general and universal law of the receding of the waters, and it is reasonable to assume that a very long period elapsed, after our planet's creation, before it began to revolve in its orbit round the sun or before the dry land appeared sufficiently high enough to create atmospherical disturbances and mark the commencement of destruction. Directly, however, this epoch *was* established, denudation and degradation set in, the former being the result of purely natural causes, moving waters and tempests of wind and rain, whilst degradation resulted from natural inertia, self-gravitation, and the inherent settling down of detached bodies. Of course we do not positively *know* this, but the most self evident proofs that this process has ever been, and still is, going on, exist under our very eyes. The most fertile spots in the world are invariably those around the bases of barren hills or where the torrent has piled up the denuded soil detached in its course of trituration along the mountain bed, and we know also that the soil increases in richness the further we recede from the poles, both facts still further demonstrating the truth of the universal law of gravitation.

Of the solid and semi-solid masses still under water, very much is known from soundings, but their condition has not been sufficiently considered when prosecuting seismical research. That they bear an inverse appearance to the mountains and hills on dry land is very evident; and table-lands, marginal shelves, and mushroom shaped formations are generally to be found in those seas where geological evolution is still going on, and in consequent "earthquake regions." Immense deposits of silt and clay are carried down into the sea, and when once these reach a depth of comparative quiescence, very often form themselves into immense banks, overhanging tottering, precipitous rocks which periodically slip away and cause so large a number of earthquake shocks. To this must be added the erosive effects of bottom currents, which are peculiar to earthquake regions, eating away the submerged mountain ranges at their bases, and the cavernous hollows that mineral and other streams form, still further reducing the stability of the sea's bottom, which only ceases to evolve when perfect equilibrium is established.

It is a strikingly remarkable fact that non-volcanic earthquakes are only frequent in those parts of the world where the neighbouring seas show a great inequality of bottom. Northern regions, and those within certain latitudes are entirely exempt from these visitations, although there is direct evidence that they were sufficiently frequent in bygone times, and materially assisted in producing the even bottoms now found there. Starting from Portugal towards the west coast of Africa, and extending right away out to the Azores, the soundings along the bottom show a most wonderful irregularity.

It is no uncommon thing to find a bank of a few hundred fathoms, and immediately afterwards a depth of between two and three thousand—and until quite recently the whole of that seaboard was subject to seismic disturbances—Lisbon, a city built on silt and formed soil was entirely destroyed when the bank above an unequal bottom was no longer able to support the alluvium thereon deposited. The Azores were in a chronic state of earthquake as well as Senegal and the Cape Coast settlements for many centuries, and the reason for this was a purely geological one, and the movement only ceased when evolution had been accomplished. Coming into the Mediterranean we are met by the same irrefutable facts. The alluvium deposits on which Messina was originally built were acted on by those tremendous currents which sweep through the straits and which terminate at Scilla and Cariddi, those wonderful Katabothra which are never inactive. Similar inequalities of bottom in the neighbouring vicinities of towns built on alluvium deposits are to be found all along the coasts of Spain, France, and Italy; and whenever earthquake shocks have taken place on that seaboard direct evidence has been forthcoming to show that they originated in the sea. There is another very important fact which we must specially consider, and that is that all those islands and coast lines which are surrounded by or have before them a shallow bank of mud, clay, or other silt, and very deep water immediately beyond, are the very ones on which seismic disturbances are more frequent. The islands of Chios, Lesbos, Rhodes, Crete, and many others in the Turkish Archipelago are all surrounded by similar banks and very deep water immediately outside; and are all equally subject to more or less destructive earthquakes, whilst other islands in the same group which seem more solidly connected, enjoy absolute immunity from them. In Greece, notably in the Gulf of Arcadia, the whole coast line for some two miles out to sea has a shallow average depth of only 50 fathoms, but 300 and more are found just outside this distance, and not a gradual slope but a most precipitous one, and to this a little farther out succeeds another having a mean depth of 1,600 fathoms, and thus this gulf continues to rank as one of the most active centres of seismic disturbance in the whole of Europe. In the Filiatra shock of 1886, which entirely destroyed that town, we found by our broken cable, 30 miles away, that a depth of 900 fathoms existed where 700 previously was and some four knots of cable were covered over by the landslip. That this caused the shock was quite evident, and the sea wave caused by the displacement and the vibrative waves of mechanical force were distinctly felt by two English steamers passing over the spot at that moment. Zante, Cephalonia more especially, and Santa Maura all suffer from destructive shocks at certain stated periods, and they are all surrounded by banks of silt with very deep water beyond. Off Ortholethia on the western side of Cephalonia, a sudden depth of 400 fathoms is found within a mile of the shore, and a short way out we once found no depth at 1,400 fathoms. Cephalonia was destroyed in 1867 before there were any cables running over that ground, but the soundings were all found different *after* the shock from those taken by the Admiralty a few years before, and this alone would be sufficient proof to show where the centre of it was.

In my paper, published in 1887, I drew attention to these points in extenso, and more especially to the condition of the Gulf of Corinth as constituting one of the most prolific centres of seismic disturbances in the Levant, and although in 1861, when the town and neighbouring villages of Vostizza were entirely destroyed by the great earthquake of that year, there were no submarine cables running along the bottom of the gulf to show the exact spot where the shock occurred, the evidence of subsidence in the sea, as shown by the clear water far away out becoming suddenly both agitated and muddy, very conclusively demonstrated that a vast quantity of matter had been overturned. That the Gulf of Corinth is one of the most remarkable evidences of geological subsidence, and the inherent denudation and degradation of the coast surrounding it the world can afford, is generally admitted by even the most casual observer. Originally it was in all probability a vast, shallow lagoon, precisely similar to many others all over Greece, becoming at once by some tremendous subsidence and the consequent irruption of the sea at the narrows of Rio and Antirio, a part of the Gulf of Patras and the Mediterranean ; and an old sea level, inside the gulf, can be most distinctly traced at a height of 80 feet above the present one which shows that as the basin of the gulf deepened the water receded. The whole of the northern shore from one end to the other of the gulf is arid, bare, and precipitously steep, and with Helicon and Parnassus, with the strange gloom of Delphi's Mystery surrounding all, constitutes a marked and vivid contrast to the gloriously fertile shore on the opposite coast. All along this northern shore a considerable depth is found ; it then increases to 400 fathoms and an almost level bottom at that depth for the whole length of the gulf, and for four-fifths of its width, when it suddenly again shoals up to 150 and 100 fathoms and then shelves up gradually to the beach, except in certain places where underground rivers appear to exist, and there a depth, varying from 10 to 60 fathoms, and more, is found close in shore, with spits and shoals on each arm of the bays thus formed, such as is the case at Vostizza, which we shall presently consider. So, therefore, we may look on the conformation of this gulf's bottom as entirely consisting of a wide and deep valley of clay and mud with overhanging slopes of alluvium deposits brought down by the denuding torrents from the mountain range behind. At a distance of about 20 miles from the entrance of the gulf is situated the town of Vostizza already referred to, but why such a very unstable site was chosen for building a town is simply marvellously unaccountable. As this is the beginning of the long slip of alluvial soil which extends as far as east as Corinth and to the mountains behind to the south-west, and ends with those jutting into the sea to the north-west, their deposits were brought down more or less unevenly, and therefore the town is perched upon hillocks and slopes of simple earth and sand, frequently shored up with brickwork to prevent them slipping away. Foundations worthy of the name are not to be found, and yet the inhabitants are surprised when even moderate shocks bring down their otherwise substantial looking dwellings of stone and rubble. That the instability of this subsoil is also due to the assumed existence under the town of one of those underground rivers which are so frequently found all over Greece is very evident, because immediately after any strong earthquake shock the port becomes muddy beginning in the deep water close alongside and gradually extending outwards, and the very abundant water supply from wells and springs in the town is entirely cut off until, after a few hours, the earth, blocking up the torrent's path, gets washed out. The dotted line in the rough sketch will better explain this.

The exit of this underground river is evidently at a point in the sea near to the spit of sand to the north, as I have often found, when sounding close inshore there, some rather sudden dips of about 16 fathoms with a strong current setting in from the N.N.W. towards Giftissa Point; indeed, on one occasion my sounding lead was swept out of my hand and sucked underneath the bank my boat was over, which when the water is clear, appears to overlap the greater depth below. Another cause for these periodical subsidences and land slips all over the Turco-Hellenic seaboard is undoubtedly the numerous quicksands everywhere existent. There is one inside the Gulf of Patras, close to the town, in fourteen fathoms of water, which has ruined the contractor who had undertaken to build a breakwater and harbour for that town. Some thousands of tons of rock have been thrown into the sea at that point and when, after two years continued labour, the level was reached, and the work seemed to be approaching completion suddenly the whole mass began to sink in and all had to be recommenced afresh. This occurred in 1884, and it was only in 1889 that the breakwater was completed, and for about 500 yards in length and 10 in breadth it now stands six or eight feet above water. It is impossible to calculate this mass of material thrown into the sea, which by its sheer weight has either filled up or bridged over the quicksands which when too late were found to exist in the very place chosen for the harbour works. This is only one example out of the numerous ones to be found all over this part of the world.

In recapitulating all these facts, we may safely say that there are excellent grounds for assuming that, given certain non-volcanic regions where earthquakes are prevalent, their origin may be reasonably traced to the causes I have endeavoured to explain. If also we bear in mind that, entirely unlike the earthquakes in volcanic centres, although shocks of very *slight* power are frequently occurring all over the Mediterranean, the *large* and *disastrous* ones are periodical and only occur at almost prophetical periods and generally every 25 or 30 years. Vostizza was destroyed in 1861 and again in 1888. Patras, Sta. Maura, Cephalonia, and Zante have all been more or less damaged every 30 years as also many other places in the Turkish Archipelago and along the Asiatic seaboard. There is also another important fact which is worthy of much consideration, namely that whereas large quakes may entirely destroy cities and towns situated upon alluvial deposits, their influence is hardly ever felt upon the mountain slopes or in places built upon a rocky soil. In the great Filiatra earthquake of 1886, Kyparissia, Gargaliano, and other mountainous towns suffered little or no damage, whilst Catacolo and Pyrgos to the north and Calamata to the east were simply wrecked, yet between the sea opposite Filiatra, whence the shock originated, and Calamata, there is a high and wide range of hills of apparently solid rock. This, however, is but another proof that mountain ranges *do not* stop the vibrative waves of force from an earthquake shock, but remain simply passive spectators of their progress, and this accounts for the fact that inland towns situated on a "made" soil are often seriously shaken by shocks which originate a long way off and in the sea.

Bearing all these facts in mind, I fully expected that after laying our first cable down the Gulf of Corinth in 1884 some valuable data would be obtained with the first following earthquake, but, although the usual small shocks occurred all along the seaboard, nothing worthy of observation took place until September 9th, 1888, when a very strong shock nearly entirely destroyed the town and adjacent villages of Vostizza. It occurred at four minutes past five in the afternoon and lasted only three seconds; and it was felt with decreasing strength and increasing duration as far as Corinth, the Piræus, and Athens. Simultaneously with the shock the cable between Zante, Patras, and Corinth became interrupted. I was in the office at the moment and carefully noted the time the suddenly increased deflection occurred (denoting what in telegraphy is termed "Dead earth") and all the other attendant phenomena of a broken cable. It is necessary to mention that the cable goes into and out of our Patras office also, so that whilst Zante is working with Athens any cessation of the passing signals is immediately detected and Patras breaks in. He did so in this instance, and was instructed to ascertain what was the matter with Athens, to which place there are also three aërial lines viâ Vostizza. It was found, however, that these were also interrupted, and I immediately assumed that some large earthquake had taken place, and proceeded to test the cable which I found completely severed right off Vostizza, two miles from the town, in about 200 fathoms of water. The reason the aërial lines were interrupted was because the telegraph office was thrown down, and full particulars of the quake were only learnt some two hours afterwards when they had been able to get out an instrument from the wrecked building. That the shock was close to the town and in the sea was certain, and its direction was from the shallow water towards the deeper from N.W. to S.E. The quake was described as "a mass of matter falling down" and precisely as in landslips and avalanches. A slight mass gave way first causing the usual warning shock, then the whole mass started, smashing the cable and overthrowing the unstable buildings on shore; the sea, quite clear before, become very muddy both inshore and far out, and a distinct wave caused by the displacement of the water was generally noticed, more especially over at Galatedi, fifteen miles N.E. of Vostizza. The water supply in the town was cut off for several hours, and even then the water was for some days more or less turbid. Neither in the villages *on the mountains* behind Vostizza nor in Patras only twelve miles distant across land, was the shock more than slightly felt nor, except at Galatedi (the only piece of made soil on that side), was the shock perceived on the northern shore of the Gulf. This confirms the idea that the slip or subsidence started at or near Vostizza towards the east and south-east. Several slight shocks occurred during the week following the big one, and attentive observers noticed they all came from the sea—*vide* map attached.

When our repairing ship went to repair the cable, it was found completely fractured as if by some mighty strain, and exactly at the point my tests had placed it; both ends were frayed out and in my opinion the break was caused by the cable being suddenly tautened by a mass of clay and mud sweeping down from the 100 fathom bank towards the 300 fathom bottom on which the cable was found, or else since the gulf was last sounded, in 1860, the bank had extended so that the cable laid in 1884 was actually resting on it instead of the 240 fathoms assumed from the chart (no soundings were taken here when laying the cable) and that the sudden giving way of this bottom dragged down the cable, and, by its excessive tautness, fractured it. Certain it is that the ends and the cable for some length were covered up more or less firmly by what appeared when brought to the surface as fresh clay or mud. There was nothing volcanic either in the soil or in the action which destroyed the communication. Had there been any increase whatever in the temperature of the sea such as a volcano must necessarily cause, it would neither have permitted me to test it with such accuracy nor have escaped detection in previous and subsequent tests. We have thus every evidence that the centre of this shock was in the sea at a point very near the fractured cable, and that it was purely the result of mechanical force and nothing else. Some idea of the weight which was brought upon the cable before it parted may be gathered from the fact that this type is very strong, and will bear a strain of six or eight tons to the mile before giving way.

Owing to the increased traffic we had to lay a second cable direct between Zante and down the Gulf of Corinth in May, 1889, and I was thus able to get many more soundings than the old charts show. These fully corroborated the assumption of an increase in the general depth of the bottom, and also the existence of immense banks of mud and clay shelving down from the southern shore. This cable had not been down three months when it was fractured, together with the 1884 cable, by another shock, which had some very remarkable characteristics. It took place at 8.51 p.m. on August 25th, and the lines of vibrative force spread out from the Gulf of Corinth, near Patras, towards that town, right over to Zante where my Gray and Milne seismograph registered the shock as a distinctly double one (indeed we felt it so) and with a maximum duration of forty seconds. Missolongi, Agrinion, Sta. Maura, and Corfu, as also Otranto, felt the shock all more or less severely, but at the latter place it had almost exhausted itself.

Simultaneously with the first wave of vibrative force we were interrupted on both the Corinth cables, and the time was measured with the greatest accuracy from the cessation of the signals on the running slips, as Zante happened to be receiving messages from Athens on both lines at the moment the shock began. Owing to the severity of the quake, the Patras employés left the office, but shortly after returned and reported that much damage had been done in the town, and that the direction of the shock was distinctly from the Gulf of Corinth. I was very anxious about Vostizza, but was glad to learn that the quake was hardly felt at all there, although at Xylocastro (*vide* chart) some 20 miles east of Vostizza, and towards Corinth, the damage was very considerable. On testing for the ruptures, I found that the 1889 cable was a dead break off Lepanto, ten miles from Patras, and that the 1884 cable was also completely fractured off Xylocastro, forty miles away from Patras. That the first shock was that nearer Patras, and the second the Xylocastro one, seems very clearly established, and the one may possibly have resulted from the other as, from the nature of the bottom near Xylocastro there was most probably a large overhanging bank of silt only waiting the slightest impetus to topple over. Considering then the shock off Xylocastro as purely a local one we can form a better idea of the main quake further up the gulf, and, from certain facts which I hope to make clear, prove that its centrum was at the point indicated. Taking the Southern shore of the gulf to the westward, Rio and the few villages between there and Patras had their houses all more or less damaged. Like Patras itself, all these places are situated on made soil, and in the latter town, especially the new part, is simply built on reclaimed ground consisting of shingle, clay, and sand. The damage was excessive there, not a house escaping, and many massive stone and marble buildings on the newer soil facing the sea were completely wrecked, indeed if the oldest inhabitants are to be believed this earthquake was by far the biggest that the present century has witnessed in that neighbourhood and the wonder is that the whole city was not completely destroyed. My opinion, however, is that following up my theory the mass of matter which subsided or slipped away was very enormous and composed of mud and clay falling away into a comparatively small depth, *all at once*, and leaving nothing to be detached by any subsequent shock. This opinion is confirmed by the fact that at Patras and Missolongi only the one double shock was felt lasting but two or three seconds, short and sharp which hardly gave time to the buildings to take up any great momentum and that not a single subsequent shock small or great too place afterwards. I had already intended to say that the northern shore of the gulf of Patras, viz., Missolonge, Agrinion, Etolico, and Stamaura, consists of swamps, lagoons, or spits of silt with several known kalabothra. There are many steep and rocky hills in the immediate vicinity, and although the water has a fairly regular depth along the whole coast, there are indications of silt subsidences at various points notably around Astaco. The shock was very severe all along this line of silt, and did great damage but our cables between Zante and there were not touched.

There are several hamlets on the rocky hills behind these places, but they hardly felt the quake at all, and what is still more important the town of Lepanto, built on the slope of a mountain of rock and which is only *one mile off the very centre of* the shock where the cable was fractured, had not a single plaster wall cracked! I visited the whole neighbourhood within a few days after the quake and carefully noted all the aforesaid details, which, summed up, simply prove that wherever places are constructed on elastic subsoil in the vicinity of the sea, where an unequal bottom is found, and where earthquakes occur they must necessarily expect to be periodically destroyed. When we repaired these cables we found the 1889 one swept out of position, although the bottom was only from 50 to 100 fathoms deep, and over one knot of it was not recovered, a new piece being spliced in. This would indicate a mechanical force sweeping *down over it from the "point" on the northern shore due East of Lepanto* and in a S. W. direction. The mass might have been and probably *was* about one mile in length, and but for the comparatively shallow water it must have smashed the 1884 cable also about half a mile to the Southward. Any other force but this, or any other cause whatever for the quake must have smashed both cables at the same point. This very interesting and important fact is again found in the break off Xylocastro. The 1884 cable was ruptured in two places by either a subsidence or slip on a 10 to 450 fathoms bottom, and once there the geological evolution ceased because equilibrium was re-established, the bottom beyond being nearly level and consequently the 1889 cable parallel to the other escaped its force. I may just note here that an even temperature of 56 Fahr. was found at the bottom in both instances and this temperature was also registered when the cables were laid.

Where the next change in the Greek or Turkish seas will take place it is difficult to guess, but indications of silt deposits near Cephalonia warrant the assumption that that Island will be the next to be favoured with a visit from this dreaded phenomenon. Since beginning this paper I have received a copy of the very interesting one read by Prof. Milne before the Society on January 24th, 1889.

That earthquake shocks are rarely ever felt in the same way by people separated even by small distances from each other, is apparently an established fact, and on consideration it seems both natural and reasonable, because wherever seismic disturbances occur, whether of volcanic or non-volcanic origin, the subsoil is so very heterogeneous that groups of houses, quite close to each other, may individually experience a very marked difference in the vibrative waves of force passing along the surface of the soil. It is very gratifying to find that the assumed fact of low lying, soft ground being more liable to the destructive effects of earthquakes than the higher and more solid soil, is fully confirmed by Professor Milne, but we must remember that it is *only where low soft ground exists, on the sea coast line, beyond which very remarkable anomalies of depth and bottom are found,* that earthquake shocks ever occur. Lisbon, Messina, Port Royal, Asia Minor, the west coasts of Greece and Italy, the whole of the west coast of Africa, and a long tract of the west coast of South America, are all cases in point and all offer the clearest evidence of periodical geological evolution which will continue to occur until the entire process of denudation of the earth above the waters there has been completed. That the contrary results have occurred in Japan, viz., that the houses on dry hills or hard ground have suffered the most is in my opinion fully accounted for by the fact that the country is eminently volcanic, that all the shocks originate from or are the results of volcanic action, *pur et simpla,* a class of quake entirely separate from the other, resulting from a purely *mechanical* force. In all cases of big or small earthquakes in the neighbourhood of active volcanoes the shocks are always purely local and confined to a small area—proportionate of course to the extent of the volcanic seams, and the number of craters in action. Taking

Vesuvius, Etna, Volcano, or Santorino as examples, the earthquake shocks originating in these volcanoes are rarely or ever felt beyond an extreme radius of twenty miles, but any places *within* that radius and when the quake is a big one whether on low or high hard ground go down as if they were made of cards, but the sensations experienced are invariably found to have been different precisely according to the nature of the soil. Big volcanic earthquakes are generally subsequent to or immediately precede some more or less violent eruption, whilst small ones are characterized by a sudden puff, or series of puffs, of smoke issuing from the crater. This very clearly shows that the shocks are due rather to the concussion caused by falling masses detached by heat and consequent contraction than to internal explosion as generally assumed.

In the case of Vesuvius we have a clear example of degradation in an *inverse* sense to that due to atmospherical and other changes. Direct evidence is obtainable that the materials which supply the lava and the large and small stones ejected during any eruption of that volcano come from beneath the surrounding country and the city of Naples. The exterior of the mountain is of course in a proportional sense increased in extent and surface, but eventually the internal degradation and the lateral contraction of the crater's sides and thinly reduced upper crust becomes so great that it must and does periodically give way, entirely changing the conformation of the surrounding country.

In Professor Milne's paper entitled "The Stone Age of Japan' a quantity of evidence tends to show that during recent times the land there, partly by *elevation* and partly by settling, has rapidly been encroaching on the sea. Of course such cases of upheaval do occur in a purely local sense, and in volcanic regions, but we have no single piece of evidence to show that upheaval is at all general; on the contrary, we have direct and incontestible proof that the sea is receding all over the globe and the depth of it is increasing because the ocean bed has sunk and the waters with it. That the very conflicting theories have hitherto been a bone of contention between scientists is because we have never hitherto fully recognized the distinctive difference between volcanic action and geological evolution and volcanic and non-volcanic earthquakes.

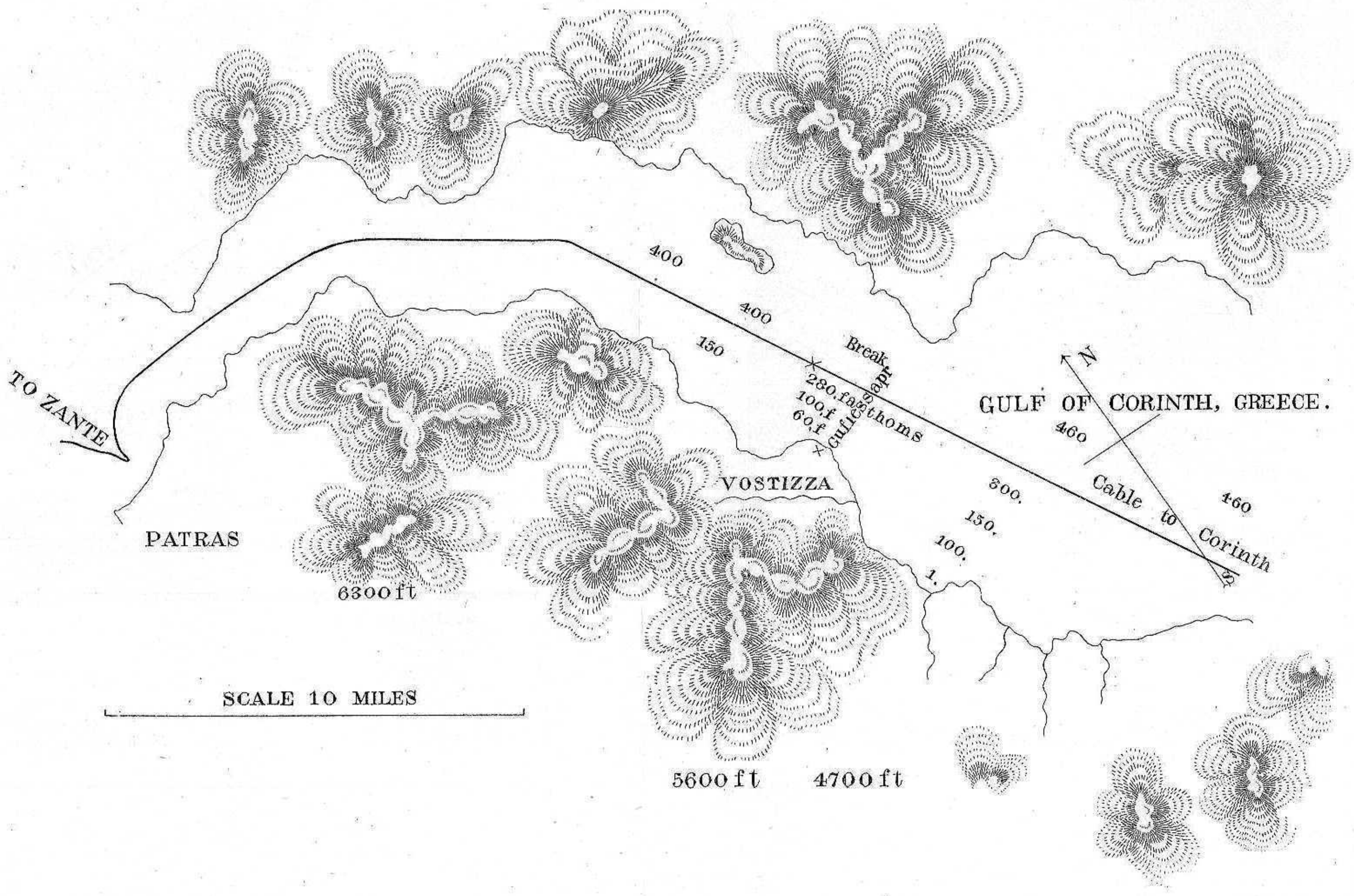
In conclusion, I would cite two instances of earthquakes which occurred in Italy last year, and which clearly show the two distinct classes of quake I accentuate. In October very excessive rains took place in certain districts around the Po, many parts of the surrounding country were flooded and landslips to an alarming extent occurred on the mountain slopes and in the valleys. Vast subsidences, of a purely local nature, however, subsequently took place, and within a small radius from their centres some very strong earthquake shocks were felt, many villages were more or less damaged and a general panic ensued. That the mountain torrents were, by filtration, or a direct flow, conducted into hollows, already existing by reason of the denuded silt of previous periods being unevenly deposited in these valleys, and that the excessive rush of water and consequent erosion undermined the soil, and the resultant subsidences caused the quakes, was clearly shown, because when the rains ceased and equilibrium was restablished nothing more was felt, nor was the district ever previously subject to earthquakes. Of volcanic earthquakes, a striking example was given in the month of January on the slopes of Mount Etna. A village situated at its base was seriously damaged by a series of shocks which occurred during one afternoon. A dull sound as of falling masses followed by many puffs of smoke (at long intervals) from the crater, would tend to show that, through contraction from heat, some masses from the side nearest to the destroyed village became detached, and their concussion' in falling, produced the quakes. That this *was* so is apparently confirmed by the fact that none other of the many villages around Etna were damaged nor do they appear to have felt the shock.

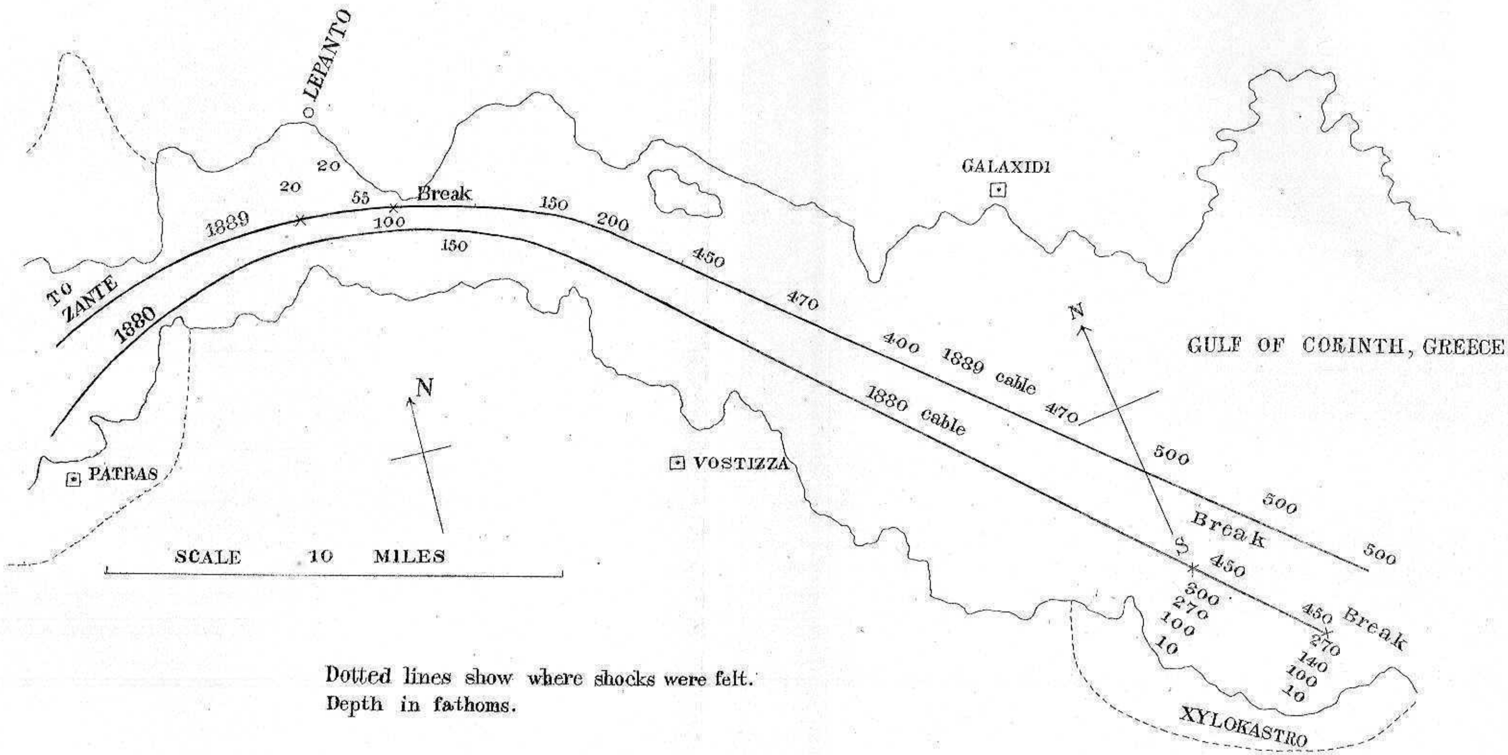
The effects of falling bodies as productive of earthquake-like sensations has already been proved by Professor Milne with the heavy ball experiments some years back, and a more striking example was experienced last year in Glasgow when a large factory suddenly collapsed causing everybody in the houses close at hand to rush out crying that an earthquake had occurred, and as some time elapsed before the actual cause of the shock was really known people all over the city had taken data of what was considered the duration of the earthquake. It was particularly noticed that the vibrative wave of force lasted longer with an ever-decreasing strength, proportionately as the distance was from the fallen buildings.

This is but an instance of a small mass comparativeiy speaking falling over a few feet and in one heap; we can therefore pretty clearly see what we get and why, when some thousands of tons of matter fall over many hundreds of feet at the bottom of the sea.

Zante, Greece, March 1, 1890.

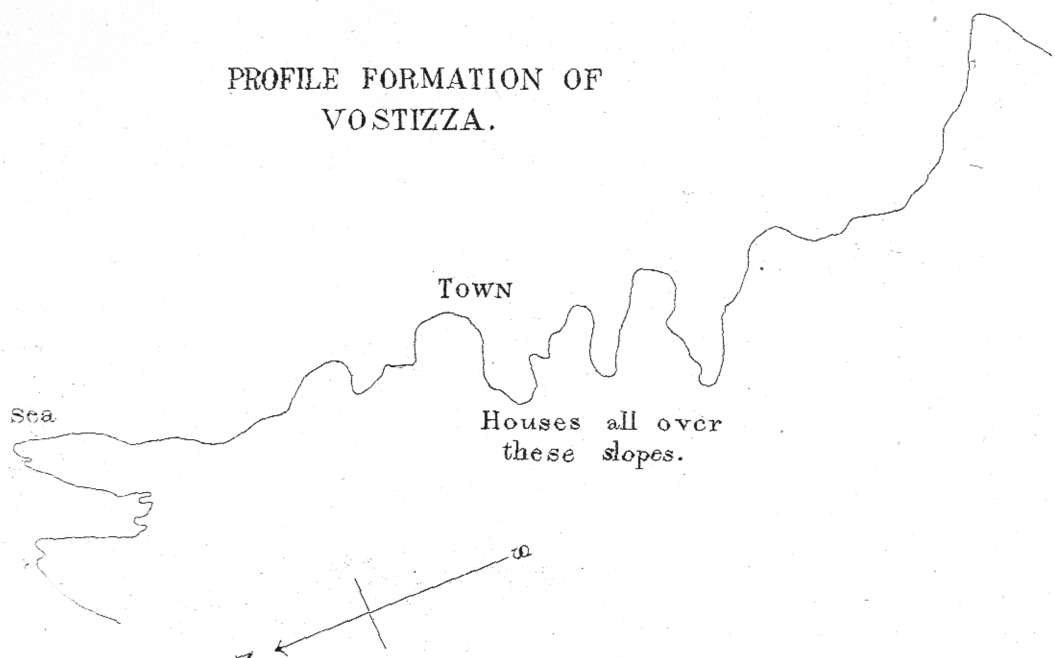
Dr. Knott was of opinion that, in his very interesting treatment of non-volcanic earthquake origins, Mr. Forster had been a little hasty in some of the generalizations with which he began his paper. For instance it was very refreshing, after long years of surmisings and doubtings, to be told by a gentleman who had never been in Japan that there was no doubt about the origin of earthquakes in this country. It was refreshing but it was not convincing, unfortunately. Of course we know, in a generally vague way, that an earthquake means a displacement or explosion somewhere underground. But further than that the problem I fear has not been solved. Mr. Forster seems to be of opinion that our Japanese earthquakes are all of "volcanic" origin, in contradistinction to the "Geological disturbance" or *displacement* origin, with which his paper is chiefly concerned. It is quite possible, however, that many Japanese earthquakes, originating as they frequently do somewhere under the Pacific off the coast of Japan, may be classed along with those so ably described by Mr. Forster. Then again, in his second paragraph, Mr. Forster makes some general statements against which I would enter a caution. I do this the more readily as they do not really affect the value of his paper as a contribution to earthquake literature. For the sake of the unwary reader, however, whose immature mind might be dazzled by Mr. Forster's picture of cosmic evolution, I would simply say that there are absolutely no facts in support of the view that light and gravitation assisted in the manner described in the evolution of our earth's surface condition from a nebulous mist of gases. There is no doubt of course as to the inexorable law of gravitation; but I should be inclined to reckon rather on the effects of radiation from the cooling earth itself than on the decomposing action of light from the sun. But here doubtless the nebulous mist is still darkening our scientific vision; and I may well leave Lockyer to fight these nebulous mists with his meteor swarms. That "the most fertile spots in the world are invariably those around the bases of barren hills or where the torrent has piled up the denuded soil" is a statement whose truth will depend largely upon the definition of a barren hill. But in any case I cannot in the least understand in what way the universal law of gravitation has its truth demonstrated by the inferior richness of the soil in polar regions. Richness of soil is largely an effect of climate, which depends on multitudinous geological and meteorological conditions. Richness of soil is, indeed, more directly affected by sunshine and moisture than by gravitation attraction. Outside those rather doubtful generalizations, however, Mr. Forster's paper is to be welcomed as a very important contribution to our knowledge of earthquake origins. As I have just hinted, we in Japan here may, in spite of Mr. Forster's own expressed sentiments, take his theory as directly applicable to some of our earthquakes of Pacific origin. His numerous facts regarding the snappings of cables and the sudden changes of depths seem capable of only one explanation, that given by him. Honey-combed sea bottoms, overhanging ridges, steep descents, and broken contours seem to be a feature of certain seas and oceans; and there certainly landslips will occur from time to time, causing earthquakes throughout the surrounding material. Of course there is the more ultimate question as to the origin of this peculiar structure itself. Probably the crust of the earth is honey-combed and vesicular more or less all through; and it is easy to see that subterranean collapses and landslips might readily enough occur in the more unstable regions, started possibly by a volcanic explosion. We should naturally expect such vesicular structure to be more pronounced in regions that have been or still are volcanic. Every such change of configuration must result in the falling of material to lower levels, that is, if we neglect direct volcanic agency. Mr. Forster considers that, as such material near the surface of the bed of the sea falls in, its place is filled by water, causing a sinking of the sea-level. Hence will result an apparent rising of the land. However true a description this may be of what may be taking place in the Ionian Sea, it would be difficult to apply it generally to the great fact of the increase of land area throughout geological time. The ordinarily accepted view that the sea-level is a steadier surface than the surface of the dry land, and that the continents have risen as the ocean beds have sunk and the ocean channels contracted, is one of those very rational scientific views that took long to penetrate the mind of man; but once there, it will not be easily dislodged.


GULF OF CORINTH, GREECE.
TO ZANTE
PATRAS
VOSTIZZA
400
400
150
Break
280 fathoms
100 f
60 f
460
300.
150.
100.
1.
Cable to Corinth
460
N
6300 ft
5600 ft
4700 ft
SCALE 10 MILES



Dotted lines show where shocks were felt.
Depth in fathoms.

PROFILE FORMATION OF VOSTIZZA.



Vostizza
Sectional formation.