Art. XIV.—A Contribution to the Theory of Earthquakes —By Rev. Mytton Maury, D. D.

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Trifling facts very frequently involve exceedingly important conclusions. The Fraunhofer lines which, to the observer, were mere meaningless curiosities, involve and have suggested the marvellous and prodigiously interesting laws of spectroscopic analysis; and the curious and once inexplicable phenomena which puzzled, not Fraunhofer alone, but for a long time such investigators as Brewster and Draper, are at this moment enabling us to explain the question, What are the stars made of? I need, I think, offer no further apology for asking the attention of this Society to a very insignificant fact which was brought to my notice on the occasion of a recent visit to the Steel Works at New Glasgow. A charge had just been drawn from the furnace, and the foreman was standing with me watching the process of casting the large ingots of steel. The pot, into which the molten steel was allowed to flow from the furnace, was provided with a hole in the bottom to permit the molten steel to pass into the casting moulds, and these were ranged in a row underneath a rail track, along which track the pot with its contents of 18 tons of melted steel was made to pass. One after another of these moulds was filled by the opening of the hole in the bottom of the pot. The necessary opening and closing of this hole were accomplished by the elevation and depression of a larger stopper cased with fire clay. The foreman observed how needful it was that the casing of fire clay should be thoroughly dried before use. On one occasion the upper portion had been very slightly damp. As soon as the white hot metal and floating slag filling the pot had reached the damp portion, instantly an explosion occurred. Suddenly, a certain very small quantity of moisture—only a few drops, indeed—had been enclosed by the rising mass of metal and slag as it rapidly filled the pot. The temperature of that moisture was raised to a point above 2,000 degrees Fahr. We know what occurs when the boilers of a racing Mississippi

steamer are overheated and the supply of water is low. A slight lurch of the boat will bring a quantity of water suddenly into contact with the heated wall of the boiler. Superheated steam is generated and an explosion occurs. Now the temperature to which such a boiler wall is raised does not of course compare with that of the molten steel and slag of the casting pot. And hence a similar result is perfectly natural, only that what occurred at New Glasgow was probably even more violent. It is not surprising that when the explosion took place portions of the circumjacent metal and slag were shot out of the casting pot high into the air.

I observed to my informer that this was an extremely interesting fact. He therefore went on to tell me that according to his observation, molten slag, when brought into contact with moisture, is productive of much more violent explosions than molten steel. Some time ago a casting from a small pot of steel had been made. The slag which remained in the bottom of the pot was carefully poured upon the ground. This was done very near the wall of one of the buildings belonging to the Steel Works. The foreman (my informant) was in a distant part of the works. He heard a violent explosive report like that of a heavy cannon, and ran to the spot from which the sound came. He imagined that the boiler of the engine had burst. He found that the explosion had been occasioned simply by pouring out an inconsiderable quantity of slag upon ground where there was a little ice or snow. Such, however, was the violence of the concussion that portions of the roof of the building, which was about twenty feet high, were ripped off and blown away, although the explosion, be it remembered, had taken place in the open air, outside the building.

Now let me ask your attention to what seem to me to be the weighty suggestions involved in these seemingly trifling facts.

You are well aware that two prominent theories are offered for the explanation of earthquakes. According to one they are the result of the sliding and grinding of immense masses of rock one upon another,—such sliding being itself a consequence of the secular cooling and shrinking of the crust of the earth.

Without desiring to exclude this as a possible cause of earthquakes, I incline much more strongly to the theory which connects earthquakes and volcanoes as closely related phenomena, — both mainly due to one cause, viz.: the explosive force of enormous volumes of superheated steam. The difference between the two, I believe to be largely this,—that in the case of volcanoes there usually is a vent already existing, while in the case of earthquakes there is none. My idea (not however at all exclusively my own) is, that water, percolating through the crust of the earth, finding its way from some superficial source, the ocean or a river, far down into the interior of the earth, encounters intense heat. It meets with those very elements in a state of incandescence or of fusion, which form the slag of the casting pot. It is not necessary that the water in question should descend to the depth of more than 2,000 or 3,000 feet to encounter such heat. If you walk a few hundred feet down into crater of Vesuvius, you will soon find the soles of your feet uncomfortably warm, while from orifices in the walls of the crater hot jets of gas suggest to you that there must be somewhere near, a blowing engine of enormous capacity unweariedly driving its current of heated gas. And if you descend into the shaft of the famous silver mine near Virginia City, you will find the heat at the depth of 2,500 feet so intense that the workmen labor almost naked, that they can work only a few hours at a time, and must have ice to apply every now and then to their wrists to keep down the temperature of their bodies. Between the strata of rocks situated near the scene of an earthquake, or near a volcano, especially if such strata are tilted, it requires no stretch of imagination to understand how water from the sea or river bed may glide into lower regions, where the materials of which rocks are made are in the molten state. A volcanic eruption or an earthquake would be the natural and necessary consequence.

I consider that this view receives corroboration from the fact that volcanic regions are generally in seaboard regions. Vesuvius, Stromboli and Ætna, the long line of Andean volcanic heights which bristle along the Pacific coast of South America, the volcanoes of Krakatoa, and her companions in the Eastern Archi-

pelago, all tell the same tale. Great oceanic cisterns, with copious supplies of moisture at all times ready to follow the grading surfaces of tilted rock strata are near them all.

The same is true of the scenes of our most noted earthquakes. Their law of distribution confines them to the vicinity of large bodies of water. I need only remind you of those which have occurred at Lisbon, in the south of Italy, in the valley of the Mississippi, at Charleston, on the South American shores of the Pacific, and in Japan.

I note in this connection, as shewing on a small scale the percolating power of water, an interesting fact mentioned in Brown's "Coal Fields of the Island of Cape Breton." He relates that "in working the main seam of the Sydney Mines, some years ago, the sea water found its way into the exploring levels which had been pushed out underneath the water of the harbor. It percolated through a thickness of 300 feet of strata," and insisted on pursuing this course so persistently, that, in spite of strong dams built to bar the entrance of the enemy, the mine had to be abandoned.

Besides all this, it appears to me, that while those who advocate the crust contraction theory, are persons entitled to great respect, the phenomena of earthquakes have characteristics which are better explained by the other theory. In the first place they are marked by great suddenness:—and secondly, in the case of the majority of the more important, they have not that duration which might naturally be expected, if they were the result of any such extremely gradual and continuous process as the cooling and contraction of the earth's crust must be. They are emphatically explosive. Lisbon and Caraccas were both destroyed in less than five minutes; and I am constrained to believe that such phenomena are fairly illustrated on a small scale by the slag explosions at New Glasgow.