the earth can go on for ever as it is, illuminated by the sun from infinity of time past to infinity of time future, always a habitation for race after race of plants and animals, built on the ruins of the habitations of preceding races of plants and animals. The doctrine of the 'Dissipation of Energy' forces upon us the conclusion that within a finite period of time past the earth must have been, and within a finite period of time to come must again be, unfit for the habitation of man as at present constituted, unless operations have been, and are to be, performed, which are impossible under the laws governing the known operations going on at present in the material world."

There can be no necessity for pointing out the importance of this *dictum* from the pen of Lord Kelvin; it supports my own contention in the GEOLOGICAL MAGAZINE of July and October, 1891 (pp. 300 and 479-80). I will not intrude upon your space by reiterating what I have already put into print, but I trust you will, with your usual courtesy, allow me to refer the reader to such passages as are to be found in my little work.[1] In the light of what I have quoted above from Lord Kelvin it can scarcely be said that I spoke too strongly in animadversion on the Huttonian School, in the concluding paragraph of my "Note on the Airolo Schists Controversy" in 1890 (See GEOL. MAG. Dec. III. Vol. VII. p. 259).

The concluding paragraph of Sir A. Geikie's Presidential Address to the Geological Society for 1892 shows how opinion is veering at the present moment; and during the present session two papers of importance have appeared, one by Professor Bonney and Gen. MacMahon, another by Messrs. Dakins and Teall, in which attempts have been made to work out the history of the structural phenomena observable in igneous masses of particular areas on principles applicable to an universal magma, at a period of the Earth's history when the energy since dissipated by radiation into space was concentrated in the lithosphere. A great deal of what the writers referred to have now put forward was seen more than forty years ago by that sagacious geologist, the late Prof. John Phillips, F.R.S., as applicable to the crystalline rocks of the Malvern range (see Mem. Geol. Survey, vol. ii. part 1), which he saw, with an insight not befogged by the later mists of "regional metamorphism," to be in the main a truly igneous series. On the Malvern Crystallines I hope, after ten weeks' hammering at them, to have more to say anon.

A. IRVING.

WELLINGTON COLLEGE, BERKS,
11*th May*, 1892.

EARTHQUAKE SOUNDS.

SIR,—There are one or two points in Mr. C. Davison's paper on earth-quake-sounds I should like to draw attention to.

In most Italian tectonic earthquakes, the sound phenomena precede the mechanical disturbances, though the former overlap the latter the nearer the epicentrum is approached. This means that

[1] "Metamorphism of Rocks" (London, 1889), see pp. 18, 19, 22, 23, 70, 71, 94, 95, and 96.

their production is almost simultaneous, but the smaller sound vibrations travel at a greater rate than the larger mechanical ones.

The fact that the more destructive the earthquake, the less marked proportionally is the intensity of the sounds is easily explicable. The sound vibrations are more quickly used up in traversing a given thickness of rock, whilst the mechanical vibrations have hardly been influenced in the short distance travelled in the shallow focussed shocks that constitute the majority of the destructive earthquakes. For the same reason of the more rapid destruction of the sound vibrations by the rocks traversed the seismic area of sounds is much more limited than that of the quakes. It must also be remembered that during destructive earthquakes much of the noise is due to cracking and falling buildings, shaking trees, etc.

As to the cause of earthquake-sounds I believe they are very various in different earthquakes, and even in any one earthquake. Mr. Davison speaks only of fault friction, but rather neglects the actual initial fracture, which we should expect would produce a very loud noise. Next comes rock-crushing, such a common phenomenon in any mountain region, especially along the central ridges and troughs of anticlines and synclines. Then again we have to consider the fracturing or splitting of rock by the formation of igneous dykes, which may occur in a region free from surface volcanic phenomena. Is it possible that the hundreds of dykes that rent the old rocks of the northern counties of England and Scotland, and most of which never reached the surface, were not accompanied in their formation by earthquakes and *earth-sounds*.

The origin of these sounds is no doubt the smaller vibrations produced by the mechanical disturbances in fracturing and slipping or grating in the tectonic earthquakes. In the case of volcanic or plutonic shocks the sound is in the first place due to splitting and fracturing of the solid rocks. It is then followed by the friction of the injected fluid magma, and the sudden sharp arrest of this against the walls of the cleft. The phenomenon is very similar to the sounds produced by suddenly pumping water into a collapsed leather hose-pipe, closed at the opposite outlet. We have in such a case first a gentle rush followed by a sharp snack as the water is arrested by the fully distended walls. Very similar sound-phenomena may be heard on closing sharply a tap through which water, under considerable pressure, is flowing. There is yet another source of sound in such earthquakes, and that is the vesiculation of any aquiferous magma when allowed to expand through a newly formed fissure just filled by it.[1] All these sounds are practically simultaneously produced, and their combined effect with the predominance of one or another would explain the variable nature of the audible phenomena of an earthquake.

The mechanism of production of earthquake sounds I fully discussed years ago,[2] whilst experimental researches on this question

[1] This may possibly explain the boiling cauldron sound so often mentioned in earthquake descriptions.

[2] See my monograph of the Earthquakes of Ischia, pp. 82, 89, and Proceed. Roy. Soc. Dublin, 1886, pp. 120, 124.

have been published not long since by Italian investigators, who have shown the conclusions arrived at by myself and others were correct, that sound-waves travel faster than the coarser mechanical vibrations when traversing most rocks.

7, Chiatamone, Naples. H. J. Johnston-Lavis.

THE TEMPLE OF JUPITER SERAPIS IN PUTEOLI (POZZUOLI).

Sir,—It is well known that the ruins of this Temple have been looked upon as the most striking example of subsidence in historic times. Although it has taken place within the Christian era, the date has been but vaguely known. Babbage, in his article, Geological Transactions, vol. iii. (1847), mentions an inscription of Alexander Severus on the Temple asserting it to have been adorned by his munificence. As Alexander Severus reigned from A.D. 222 to 235, at that time the Temple must still have have been above sea-level. In Lyell's Principles, vol. ii. p. 173, there is a quotation from Loffrado which proves that in 1530 a great part of the site of modern Pozzuoli of ancient Puteoli, was under water. The city was captured by Alaric A.D. 410; then by Genserie 455; then by Votila 545 (E. H. Bunbury in Smith's Dict. Geog. art. Puteoli); but we have no information as to whether the Serapeum was then above or under water. The Temple of Serapis then was above water in 230 and below water 1530, and during the intervening 1300 years there seems no reliable information.

However, in the *Acta Reta et Pauli*, Greek forms, dating according to Lipsius from the fifth century, we have the following passage—I quote from Walker's Translation Ante-Nicene Library, vol. xvi. p. 258:—"And Paul being in Ponteole (Puteoli) and having heard that Dioscorus had been beheaded, being grieved with great grief gazing into the night of Heaven said 'Oh Lord Almighty . . . . punish this city and bring out of it all who have believed in God and followed His word.' He said to them therefore 'follow me.' And going forth from Pontiole they came to a place called Baias (Baiae) and looking up with their eyes they all see that city Pontiole sink into sea-shore (*εἰς τὴν ὄχθαν τῆς θαλάσσης*) about one fathom (*ὡσεὶ ὀργυίαν μίαν*) and there it is until this day for a remembrance under the sea." It is evident that when the Greek of the *Acta Petri et Pauli* was written Pozzuoli was under water, as it was in the days of Loffredo (though perhaps not so deeply submerged), and had been so for so long that the memory of the subsidence and the circumstances attending it had been utterly lost. If we allow a century to have been sufficient to have caused this utter oblivion, we have then reduced the 1300 years to about 150. In other words somewhere between the middle of the third century and the middle of the fourth this event must have occurred. The phrase "into the sea-shore" (*εἰς τὴν ὄχθαν τῆς θαλάσσης*) supports Babbage's theory that the Temple first sank in a lake of brackish water. This is confirmed by the assertion that the city sank a fathom (*ὡσεὶ ὀργυίαν μίαν*).

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