II.—ON THE AGE OF THE WORLD AS DEPENDING ON THE CONDITION OF THE INTERIOR.

By the Rev. O. FISHER, M.A., F.G.S.

IN *Nature* of the 7th of March, Lord Kelvin reported the results of a series of experiments, which render it almost certain that Prof. J. Perry's hypothesis of the conductivity of rock increasing with the temperature is unsupported by evidence. He also stated that he had been led by later study to modify his original estimate of the age of the world, and to reduce it to about the same as estimated by Mr. Clarence King, viz. 24 million years. Thus geologists would find themselves restricted to a still shorter period for the evolution of the events of the world's history than they supposed.

It must, nevertheless, be carefully remembered that the estimates of the world's age above referred to proceed upon the hypothesis that the earth is solid throughout, whereas the more obvious interpretation of geological phenomena appears to point to the opposite conclusion, that the crust is comparatively thin, and floats upon a substratum of molten rock of rather greater density than its own.

The principal argument for the solidity and rigidity of the earth is derived from the existence of tides in the oceans; for it is held that, if the interior were liquid, there would be subterranean tides in it, which would carry the crust and the enveloping ocean up and down in concert together, so that the measurable depth of the water to the bottom would always remain unchanged; for, although a tidal deformation of the ocean surface would be present, it would not be able to be noticed. It is plain that this apparent obliteration of the tides would require that the deformation in the substratum with its floating crust and the deformation in the enveloping ocean should occur at any given place simultaneously and equally; that is to say, there would have to be high tide in the crust where and when there was high tide in the water, and low tide in the crust where and when there was low tide in the water, and in each case with the same range of rise and fall. This requires that the surface of the crust should be deformed to the exact shape that the moon's attraction would produce in a liquid globe, and that the same should be the case also with the surface of the ocean. But, seeing that a tide is formed by the local accumulation of matter by differential horizontal flow, it seems highly improbable that the exact form of the tidal spheroid could be produced in the crust, because the irregularities in the under-surface of it, corresponding to and supporting the continental elevations, would so break up and deflect the tide wave in the substratum on which it floats, that the exact form of the tidal spheroid would not be generally maintained beneath the crust, just as it is known not to be maintained at the surface of the ocean owing to the deflection caused by coast lines, whence arise the irregularities known as the "establishments of ports." Thus the exact form of the tidal spheroid would be

maintained in neither crust nor water surface, and tides would accordingly be observed. If this be a correct explanation, it would seem likely that, where there is an exceptionally large unbroken area of ocean, and consequently a comparatively smooth extent of under-surface to the crust, in such a region the proper form of the tidal surface might be more nearly preserved both for the subjacent liquid rock and for the water, and the measurable tide would consequently be small. Now such is the case in the central parts of the Pacific, scarcely any proper tide being observable at the Sandwich Islands.

No argument for rigidity can be drawn from a fortnightly tide, because observations hitherto made have not demonstrated that one exists.

If the above apology for believing in the possibility of a liquid interior can be admitted, it will follow that, the bottom of the crust being constantly laved by molten rock, we should have a mode of communication of heat from beneath which would continually delay the cooling and thickening of the crust, and have an effect upon the temperature gradient at the surface similar to that which would have resulted from Professor Perry's hypothesis, supposing it to have been true.

If we accept Professor Darwin's theory of the genesis of the moon, there are cogent reasons for believing that interior liquidity is more than probable.

It seems to be admitted on all hands that the earth was once a molten spheroid, rotating at a speed much exceeding the present of once in twenty-four hours. The theory is, that at some early period the moon was thrown off from the earth, and that since that time its distance has gradually increased to the present 239,000 miles. This increase in the moon's distance, implying a large amount of work done in opposition to the earth's attraction, has been obtained at the expense of the energy of the earth's rotation, through the medium of tides produced in the earth and in the ocean, but chiefly in the earth itself. The leverage by which the moon has acted on the tidally deformed earth has necessarily been greater at the circumferential than at the central parts. Consequently the retardation of rotation has proceeded from without inwards, so that the inward parts have always rotated somewhat more rapidly than the outward, and a consequent friction and generation of heat has been set up within, which has been much more considerable in the central than in the outer parts. The amount of heat so generated would have been, to use Professor Darwin's own expression, "prodigious," and, upon his estimates, "the whole heat generated from first to last gives a supply of heat at the present rate of loss for 3560 million years." With this enormous amount of heat being perpetually communicated to the inner parts (and there does not appear to be any reason why the supply should have hitherto entirely ceased) how could the globe have become wholly solid at the melting temperature for the pressure at every depth? It seems that, having been once liquid,

it can never have had the chance of becoming sufficiently cool to solidify. If this be the true statement of the case, no reliable estimate of the age of the world, based on considerations of the present temperature gradient at the surface, has hitherto been made.

If the interior be liquid, and the central parts have been constantly receiving greater accessions of heat than the parts more distant from the centre, convection-currents must have been set up, and must have played the chief part in the secular cooling. The age of the world would therefore be dependent upon the degree of their activity, which is not known. Another important consequence would follow, because the currents would necessarily have a horizontal flow in the parts of their course where the liquid had ceased to rise and had not yet begun to descend; and this would produce a horizontal stress on the superincumbent crust, acting more powerfully upon it at those places where the bottom was most uneven, as beneath mountains. Thus we should be able to account for one cause, at least, of the compressing force for which geologists are in search.

WOODWARDIAN MUSEUM NOTES.

III.—SUPPLEMENTARY NOTES ON THE DRYGILL SHALES.

By G. L. ELLES and E. M. R. WOOD, Newnham College, Cambridge.

IN the GEOLOGICAL MAGAZINE, 1887, Professor Nicholson and Mr. Marr drew attention to a group of fossiliferous shales detected in connection with the Borrowdale Volcanic Series.

At the request of Mr. Marr, we undertook the examination of larger collections of fossils made from the same locality, and the object of the following notes is to place these on record, and, in the light of further palæontological evidence, to assign to the beds a more definite horizon.

As Professor Nicholson and Mr. Marr showed, these beds occur on the north side of a great mass of Skiddaw Slates in what has been termed the Caldbeck Fells area. The shales to which we wish to direct attention are situated north of the intrusive masses of Carrock Pike and Great Lingy, and are of interest as lying between the Skiddaw Slates on the one hand, and the Volcanic Series of Caldbeck Fells on the other. They occupy the summit of the valley between High Pike and Carrock Pike, and are exposed in Drygill, whence Professor Nicholson and Mr. Marr have given to them the name of the Drygill Shales.

The following section is described by them in Drygill in descending order:—

1. Drab-coloured shales, unfossiliferous.
2. Blue-grey shales, weathering white.
3. Dark blue-grey or black mudstones.
4. Volcanic rocks.
5. Dark fossiliferous mudstones with Trilobites and Brachiopods.

The general dip of the beds is to the S.S.W., and the beds of the south fork of Drygill are probably the same as those exposed in the highest part of the main gill, since the faunas are almost identical,