THE
GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. X.

No. III.—MARCH, 1893.

ORIGINAL ARTICLES.

I.—MEASUREMENT OF GEOLOGICAL TIME.

By T. MELLARD READE, C.E., F.G.S.

MANY ways of measuring geological time have been attempted by various geologists of eminence; but however diverse their methods, so far as I know, all finally hinge upon either the rates of denudation or accumulation. It is urged as an objection to this that in past ages such actions have gone on more rapidly, and therefore the calculations based upon present rates are valueless. Physicists on the other hand have sought to put a limit to the age of the earth much below what geologists generally demand. Reasoning from certain data which are necessarily more or less hypothetical, they say, that from the thermal condition of the globe at present, it cannot be more than from ten to twenty million years since it was at a temperature in which life on it would have been impossible. Geologists can hardly be blamed if they attach greater weight to their own observations and data and to reasoning that is more familiar and appears more certain and satisfactory to their minds.¹

It is, however, quite unnecessary for me to elaborate this point, as Sir Archibald Geikie has so lately dwelt upon it in his usual lucid and telling manner.²

It appears to me after long study and various attempts on my own part to approximate to the length of geological time that the difficulty of getting at a satisfactory system of calculation does not arise from the unreliability of assumed rates of denudation, but from the want of a principle which will eliminate uncertain phenomena. If our modulus is the maximum thickness of all the formations we are naturally met with the objection that such a pile of strata nowhere occurs in nature. If we take as our gauge the actual thickness in any one place it may be reasonably objected that 10 feet of one set of strata may chronologically represent 1000 feet or more of another. In addition to this, how can the hiatus represented by unconformity be estimated? If, again, we start with the average thickness of the sedimentary rocks as our principal measure, it is obvious on the slightest consideration that this will give a result much below the actual time, as the particles of such sedimentary rocks have been used up over and over again, and to reach a correct result the number

¹ Since this was written Mr. Clarence King's paper ("The Age of the Earth," Amer. Journ. of Science, Jan. 1893), proves the final exception to the rule.

² Presidential Address to the British Association, Edinburgh, 1892.

of years which it would take to directly produce this sediment must be multiplied by the number of times the particles have been used. Let us see if we can apply these considerations in estimating a section of geological time.

For the sake of precision we will commence at the base of the Cambrian, as the underlying Archæan rocks are involved in some obscurity, though of late years a very considerable advance has been made towards their interpretation.

A MODE OF ESTIMATING THE TIME THAT HAS ELAPSED SINCE THE BEGINNING OF THE CAMBRIAN.

Area of Denudation entering into the Calculation.

Our point of departure being the time when the first Cambrian sedimentation began, it will be clear on a little consideration, that at the commencement, the area of denudation was necessarily the whole of the then land area of the globe, which for our calculation we will assume to have been of the same extent as now. But as time progressed and fluctuation of levels and mountain building began, these Cambrian sediments became land, and to a large extent supplied the sediment for succeeding formations. Thus the Silurian would be partly formed from the *débris* of the Cambrian, the Devonian from the Cambrian and Silurian, and so on through Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Eocene, Miocene, Pliocene, and Quaternary. It is thus evident that the pre-Cambrian rocks, as they became covered with newer rocks, must have supplied sediment to the succeeding formations in gradually decreasing proportion. What mean proportion these exposures of pre-Cambrian rocks throughout the time that has elapsed from the Cambrian inclusive to the present, bore to the total land area of the globe must be largely a matter of conjecture; but to these exposures, for our purposes, must be added all igneous rocks which have come to the surface since, and have by their denudation added to the post-Cambrian sediments. For the sake of our calculation we will assume that the pre-Cambrian and igneous rocks throughout this time were as a mean one-third the area of the whole land of the globe. This then will constitute the area of denudation, or quarry, so to speak, yielding the materials for building up the post-Archæan rocks, the other two-thirds being Cambrian and succeeding rocks yielding no fresh materials to increase the bulk of post-Archæan sediments.

Actual bulk of the sediments which have accumulated since the beginning of the Cambrian.

There are several difficulties in estimating the *actual* bulk of the sedimentary rocks of the globe. These difficulties are of two kinds, as follows:

First as to thickness. It is usual in geological works to give the thickness compiled from the areas where the maximum development of the various formations occurs. Of course every geologist knows that at no one place on the earth's surface do all the formations occur together, much less in their greatest development. To put

the case clearly from the point of view of the present paper, if a series of borings were made over the great continents down to the base of the Cambrian, so as to enable us to estimate the mean thickness of all the sediments laid down since the beginning of the Cambrian, we should get the figures we require for our calculation. I am afraid that this is not likely to be done, at all events at present, either for scientific purposes, or by the wildest company promoter. We must therefore be content to adopt a minimum thickness. Considering that we have colliery sinkings all in one formation over half a mile deep, and numerous borings of half a mile, and one of a mile, through sedimentary rocks in various places, without reaching the Cambrian base, few geologists will cavil if we take the average thickness of the earth's sedimentary crust down to the Cambrian base at one mile.

Second as to area. In estimating the area of the sedimentary rocks, we are met with the difficulty that we have no actual proof of their extent under the ocean bed. There are two extreme, and some intermediate, opinions held by modern geologists. The one claim that sedimentary rocks underlie all the oceans, the other that they extend only a limited distance from the present coast-lines. It is, however, clear that the most strenuous advocate of the permanence of Ocean Basins will admit that there is sediment of one kind or another over the whole ocean bottom, though he is led from various considerations to believe that it has never formed land. Still it is sediment in part to be legitimately claimed as entering into our calculation of geological time.

For the purposes of this paper I will, however, take the bulk of post-Archæan sediment in and under the ocean as equal to that on the present land area of the globe, or, to state it in other words, the post-Archæan sediments of the whole globe are equal to the present land area two miles thick.

Rate of Erosion of Igneous Rocks.

There appears to be a consensus of opinion that one foot in 3000 years is a fair estimate of the mean rate of sub-aerial erosion over all land areas throughout all geological time. I am prepared to adopt these figures for Archæan and igneous areas also, though they are probably considerably in excess of what occurs now, the mean rate of erosion of igneous and gneissic rocks being less than the mean rate of erosion of sedimentary rocks, as is proved by their usually standing up as bosses amongst sedimentary rocks which have been stripped from them by denudation.

CALCULATION OF THE TIME WHICH HAS ELAPSED SINCE THE COMMENCEMENT OF THE CAMBRIAN.

The calculation now is a very simple one. The mean area of denudation throughout post-Archæan times being taken as one-third the entire land areas of the globe, the bulk of the post-Archæan rocks being expressed by the land area of the globe two miles thick, and the rate of denudation one foot in 3000 years, the time of accumula-

tion will be $5280 \times 2 \times 3000 \times 3 = 95,040,000$. *The time that has elapsed since the commencement of the Cambrian is therefore in round figures 95 millions of years.*

CONCLUDING REMARKS.

Although the foregoing computation of post-Archæan time is on a different principle to that adopted by Sir Archibald Geikie in his Presidential Address to the British Association referred to, it is satisfactory to find that the results come out much the same. It has been objected to the latter method that deposition goes on much more rapidly than denudation, because it is assumed by those who hold this opinion that material which is denuded is spread over a much smaller area than that from which it was derived, consequently it must accumulate more rapidly. Checked by the method adopted in this paper it would appear that the earth's age geologically speaking must be, as inferred in the Presidential Address, somewhere between 100 million and 600 million years.¹

This is a large margin no doubt, but it is an important thing to know. Different men may put different values on the three factors, bulk of sediment, rate of denudation, and area of denudation; but I think a fair and impartial examination of the reasoning involved in this paper will show that the principle of the calculation is sound.

II.—ON OOLITIC AND OTHER LIMESTONES WITH SHEARED STRUCTURE FROM ILFRACOMBE.

By FREDERICK CHAPMAN, F.R.M.S.

(PLATE V.)

Introduction.

IN 1886 the author, during a visit to Ilfracombe, obtained some specimens of Middle-Devonian limestones which, at the time of collecting, he supposed to be formed of *Syringopora*, on account of the granulated weathered surface, and especially since the coral named had been recorded from the locality.

After revisiting the spot in 1890, and making a somewhat extensive collection therefrom, principally for the hope of finding micro-organisms, this particular rock again attracted his attention by the peculiar granulate surface produced by weathering. A section of the rock was made which proved it to be a good example of a limestone formed of oolitic grains. Subsequently a series of specimens showing shearing in all stages was found, and these were capable of being traced back to their original source in the rock with oolitic structure.

It is the main purpose of this account of the limestones to point out the interesting changes due to dynamical and chemical agencies, in the form of shearing, silicification, and the growth of dolomite

¹ It must not be forgotten that to arrive at the earth's age Archæan time has to be added to my estimate of 95 million years, which very materially increases the margin of geologic time on which we are allowed to draw.