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The following communication was made to the Society :—

PROFESSOR T. Mc K. HUGHES, *On the relation of the appearance and duration of the various forms of life upon the earth to the breaks in the continuity of the sedimentary strata.*

FEW subjects are more interesting than that of the first appearance of life upon the earth and the enquiry into the circumstances which have affected the duration of its various forms.

There are many difficulties in the way arising from the imperfect record we have in the rocks of any one district and the small knowledge of the surface of the earth which has yet been gained, so that we cannot tell how far one district supplements another.

If a continental area with its various rocks were to go down and the sea to cover with sediment the irregular surface, filling up hollows and creeping up hills, and if we could after all this has happened get a clean cut through this new continuously-deposited sediment to the old rocks on which it was laid, though the material might be of the same kind as that which made up the older rocks, we should find evidence that the older series had been upheaved, had suffered denudation and gone down again before the newer series had begun to accumulate over it, and we should see that a long time must have elapsed between the formation of those old rocks and the earliest part of the newer deposit, that there had been an interruption in the geographical conditions, and we should say there was a *break* between the two series.

On the other hand, if we examined the newer sediment itself we should find that although it was made up of various material, here a pebble-beach, there a mudbank, in one part a coral reef, in another a heap of shells, still that it all was formed continuously during a period of depression, i.e. that there was *no break* in the series. That is to say, difference of lithological character does not involve lapse of time as does an unconformity, and so when we are considering the changes in the forms of life, between two dissimilar rocks, Cretaceous and Eocene for example, we must remember that there is not in this difference any evidence of a break in time, such as we find between Silurian and Upper Old Red, or between Carboniferous and Mercian, but the conditions which gave rise to the formation of chalk with its myriads of microscopic marine organisms were very different from those which allowed the accumulation of the estuarian and fluviatile beds of the Lower Eocene, such changes in sediment being the usual sudden effects of gradual operations such as the silting up of hollows, destruction of headlands, and such like.

A period or area of upheaval is essentially one of destruction,

and the removed material is carried to the areas of depression for that period. So where we find in the rocks evidence of vast masses gone, we cannot *there* find traces of the life of the period, as there is there no sediment in which its remains could be preserved.

It is convenient to have a table of the known strata, and although we cannot arrange all the rocks of the world in parallel columns, and say that *ABC* of one area are exactly synchronous with *A'B'C'* of another, still if we take any one country and establish a grouping for it, we find so many horizons at which equivalent formations can be identified in distant places that we can generally make an approximation to homotaxis as Huxley called it. The most convenient grouping is obviously to bracket together locally continuous deposits, i.e. all the sediment which was formed from the time when the land went down and accumulation began to the time when the sea bottom was raised and the work of destruction began.

In the accompanying table (Plate VI.) I have given the rocks of Great Britain classified on this system, and bearing in mind that waste in one place must be represented by deposit elsewhere, I have represented the periods of degradation by intervals estimated where possible by the amount of denudation known to have taken place between the periods of deposition in the same district.

It is obvious that when the dry land goes down there is an end of exclusively terrestrial life over that region, and when the sea bottom has been upheaved there can be no more exclusively marine forms over that area till it goes down again, and when the one comes up or the other goes down it will be invaded from adjoining areas by those forms of life for which it from time to time becomes adapted. But they may not be the same as those that inhabited it before.

Supposing then a submergence along the axis of the Mediterranean were to move south, so that Africa would by degrees sink, being always encroached upon by a deep sea creeping over it from the north, the land sinking on the south and rising on the north, so that Europe followed, extending on the north side of the sea, as Africa was then swallowed up on the south. First, we might imagine that the Alpine plants, which according to Hooker still linger in the high mountains of Morocco, would never cast their seed and grow from year to year so as to get across the equator and they would all perish. Whether the Black Sea fish and Caspian seals could get away round by France or would all disappear might be difficult to answer. When the tropical part of Africa was submerged its snakes, its lions, its elephants might hold their own till the Cape of Good Hope was reduced to an island too small for them.

But we have assumed that there would be land on the north side of this sea, and such forms as could migrate and adapt themselves to the climate would follow the receding sea. The monkeys from Gibraltar and from India would take the place of the gorilla and chimpanzee of the Tropics. The rhinoceros of Sumatra and the Asiatic elephant might replace their African cousins. The kite and the kestrel, the dolphin and the tunny, the lion and the tiger might still be there, but the ostrich and the giraffe would have no representatives.

How many genera, how many species would be common to the Old and New Africa, whether we searched its blown sand or its fluviatile and lacustrine deposits? How many of the forms of life represented in the old upheaved bed of the Mediterranean on the north could be found in the waters and on the shore of the ocean in which the once midland sea was merged by the folds of earth's crumpling crust?

But the migration would not be necessarily, or even generally, *only* to the newly-submerged or newly-raised areas. An unsettling of the life stations in any area would cause those forms which could migrate to appear suddenly in adjoining areas where no movements were going on, so that their remains would appear in the middle of a continuous series of deposits. And the movement might not be from north to south across the equatorial region, so that many forms which could not endure extremes of heat or cold might travel on for ever round the earth if the movements did not necessitate their crossing unsuitable climes.

The short sketch I have just given is a fair sample of what has been going on over and over again on various parts of the earth's surface. If then we can read in the rocks the evidence of such succession of events as gave us many times sea where there had been land, and land where there had been sea, and we can find traces of the successive forms of life, it will be interesting to enquire what is the relation between the appearance upon the earth of distinct forms of life and the great changes in the physical geography of the areas over which they are found.

I can only gather a few examples here and there, but I think it will be seen that it is a line of enquiry for which a vast quantity of evidence is being rapidly accumulated.

Taking the oldest rocks of which we know anything in Britain, I refer you for a moment to that ancient series I brought before your notice on a former occasion, when I had just worked out their relations near Bangor and Carnarvon. These are the Pre-Cambrian rocks, perhaps the equivalents of the Huronian of America, but for the purposes of our enquiry to-day I refer to them only to dismiss them as we have not got a trace of life in them. It is true that in America traces of fossils are found in beds probably

far older than our Carnarvon and Bangor beds, but these not universally admitted to be of organic origin; and in Britain we have nothing of the kind.

These ancient deposits were crumpled, raised above water, went down again, and on the irregular submerged land the Cambrian rocks were laid with here and there a shingle beach, and here and there sand and mud.

Referring to the table of strata, you will see that I take together under the old name Cambrian, under which they were first described, all the rocks from the conglomerates at the base of the Llanberis and Harlech groups to the top of the Bala Beds. There were local checks in the movements as might be expected, especially in such a long time, but, on the whole, conditions were very similar over our area, and indeed very far beyond it during that enormous period of depression. The Silurian has at its base a stronger break than occurs between any of the subordinate divisions of the Cambrian Period, but still there is no great interval made out between the Silurian and Cambrian and they might with advantage be bracketed together, and take in also some beds which have passed as Old Red, and be all called by one of the old names, Transition Rocks or Greywacke Group.

Then comes a great interruption and waste of lands before the submergence which gave us the Upper Old Red conglomerates, the Devonian Rocks, and the Carboniferous, all, I take it, to be bracketed together as belonging to one set of conditions.

Then another great interval, and up and down over an enormous area. As we get on in the world's history, in Carboniferous times to some extent, but more in Mercian* times, and still more in the Anglian series, we find the deposits indicating distinct hydrographical areas, and this must influence the distribution of life.

Now with regard to the first appearance of life in Britain, there are some very curious facts to be noticed. In the earliest fossiliferous rocks, we have not anything like a common rudimentary form; but a large number of different families are represented, and represented by many genera and species.

They have turned up at different horizons, some low down, some higher up, but not in such a way as to suggest any grouping or order of succession, but rather to make it certain that it is only from our not having been able to find the remains preserved,

* This term Mercian I use for all the deposits from the Lower New Red or Permian up to the top of the Jurassic Series, leaving in doubt for the present whether some of the estuarian and freshwater beds which show a silting up of the basin and emergence at the close of the period should be bracketed with the Jurassic or form the base of a new series. Under the name Anglian I include Neocomian and Cretaceous, as the term Cretaceous has become somewhat unsettled. At any rate we are safe in commencing a distinct group with the Lower Greensand, and not attaching great importance to the break which seems probably to occur in some places at the base of the Upper Greensand.

that we do not get them abundantly all through, for they must have existed throughout the period.

Not at the base of the Harlech group, but where red slates come in, showing a local difference in the character of the sediment, we find a lingulella and several trilobites. Others come in at different horizons all the way up. Take for example the Trilobites Conocoryphe, Plutonia, Paradoxides, which occur down in the lowest beds. They appear, with many other forms, fully specialized and well developed. Just let us follow these up. Plutonia disappears at once; Paradoxides has its representative species in the Menevian, the next overlying group, and the genus then disappears; Conocoryphe has representative species in the Menevian, and allied forms appear in the Lingula Flags, Tremadoc and even Lower Bala Beds. Though it may be that the varieties with the more pronounced glabella, and indeed all the later forms may be separated from the typical genus, for our enquiry the name matters not. All allow that they are allied forms.

We might have taken Microdiscus and Agnostus instead of Paradoxides and Conocoryphe with similar result. Now except perhaps at the base of the Arenig, no one holds that there is any important break in the succession of strata over the area from which these forms have been procured. They do not appear immediately after an unconformity; they do not disappear just before one.

It is important to dwell upon the groups which appear in the earliest rocks yet discovered in Britain, for we shall see that so many forms of life are represented, and they range through subsequent periods to such varying lengths of time that there is nothing to suggest a different state of temperature, atmosphere, or other circumstances, which our recent experience tells us principally affect life.

The bivalve crustacea such as Leperditia are few and far between, and there is still less use calling in as evidence worm tracks which seem common to all periods or ill-understood fossils such as Oldhamia or the later Cruziana or obscure sponges. It is, however, very important to notice that in Theca we have the Pteropoda represented, and that although the small differences in that not very complex fossil have enabled palæontologists to assign different specific names to those which are found in almost every distinct horizon, and even to cut off Stenotheca and Cyrtotheca of the Menevian under different generic names, there is no unconformity between the horizons at which they occur and we follow the genus up into the upper beds of the Silurian without great variation of form; but of course free swimming oceanic creatures would be seldom affected by local changes.

Brachiopods appear among the first, being represented by the genera Discina, Obolella and Lingulella. The last which used

to be called Lingula reaches its greatest numerical development in the next conformably succeeding group, named from the prevalence of this shell the Lingula Flags, and is represented by a closely allied form L. anatina, at the present time; so it at any rate has tided across a good many unconformities.

To move a little higher in the strata and watch new forms appearing. The Menevian is bracketed with the preceding group. There is no break between them; the *general facies* of the fossils is the same, some forms are identical. Yet here, and as far as discovery has gone, no lower, we get the trilobites, Arionellus, Anopolenus, Erinnys, Holocephalina.

Cystideans are found in this formation, and an addition to the brachiopoda in that most important Cambrian and Silurian genus Orthis. Now let us follow the fortunes of this genus as the world goes on.

The genus Orthis is first found a long way from the base of the Cambrian, only 4 or 5 species having been yet determined from beds older than the Lower Bala. The species and individual specimens are most numerous in the Bala group, and they begin to die out in the middle of the Silurian, so that by the time we get to the top of the Ludlow Rocks, we find only some varieties of O. elegantula. The interruption at the base of the May Hill Sandstone, whatever its character or amount, makes less difference in the appearance and disappearance of species of Orthis, than the long time in which there is no marked break from the Harlech to the Bala Beds, or from the base of the Silurian to the top of the same continuous series. We see that in the time of the Upper Ludlow deposits, the day of the Orthides was past, but they were not quite killed off by the great movements which took place before the deposition of the Carboniferous group. A few are found in the Devonian, and O. resupinata gets well up into the Carboniferous. Then they disappear. In the Bala and May Hill periods species of orthis come in, reach their maximum, and disappear, often characterizing very limited horizons, e.g. O. protensa, O. hirnantensis, O. sagittifera, O. spiriferoides, O. insularis, &c.

Other genera of brachiopods, such as Strophmena, yield very similar results.

To return to the table of strata. The number of new species which have been found in the Lingula Flags as compared with the Menevian has induced palæontologists to draw a strong boundary line between the two formations. Perhaps the most important new genera are the trilobites, Olenus and Dikellocephalus. Now it will be useful here to call attention to the remark of Salter that Conocoryphe, which we have seen was one of the earliest trilobites, was intermediate between the Oleni of

the Middle Cambrian and the Calymenidæ of the Upper Cambrian and Silurian. Yet Olenus, of many species, and often very abundant in the Lingula Flags, has not been found below or with Conocoryphe, but is the characteristic fossil of a limited zone, coming in and going out in the midst of continuously and apparently somewhat uniformly deposited strata. The brachiopods of the Lingula Flags have had like most of the other fossils different specific names assigned to them from those in the underlying series.

We must notice the appearance of Niobe in the Lower Tremadoc preparing us for Ogygia and Asaphus in the Upper Tremadoc, and itself disappearing at once. The same genera but different species of Pteropoda still prevail. So in the Upper Tremadoc the characteristic Angelina appears and is lost. With it we find Asaphus, Ogygia, Cheirurus, 2 genera and 3 species of Phyllopods, and Theca still among the Pteropods, but, in addition to Theca, we have now Bellerophon and Conularia, both of which genera last through long ages of Cambrian and Silurian, and, surviving the great geographical changes at their close, reappear in the Carboniferous. Conularia tides over another almost equally vast revolution, namely, that which preceded the New Red, and is last seen, not at the close of a period, but in the Lias, an early stage of the Jurassic epoch.

How long did it take to evolve the Cephalopoda with their cartilaginous cranium and optic ganglia? Hitherto we have found none in rocks older than the Upper Tremadoc. Salter, speaking of Cyrtoceras, remarks that many forms migrated in Cambrian times eastward from America, and are consequently of older date there than in Britain. But few, he adds, follow a reverse order of progression. Here, however, is the most hopeful line of enquiry, to seek in older rocks in other areas for the progenitor of the Tremadoc Orthoceras sericeum. The genus does not die out with the close of a period as far as evidence has yet been collected at home or abroad, for well down in the Carboniferous we lose it in Britain, and well up in the Hallstadt Beds we find it abroad.

In the next series we have disputed ground, some having bracketed the Arenig with the Lingula Flags and Tremadoc Beds, others having thought them, though continuous with the older rocks, so much more closely connected palæontologically with the overlying series that they have bracketed them with the Bala group, while some believe that there is an unconformity at the base of the Arenig. This opinion is partly founded on the large number of species found in the Arenig and not in the underlying series, but in this case it is more obvious than usual how valueless are percentages of species in common where there is not

a fair representative series in each. In the Woodwardian Museum Catalogue (published 1873), there are 59 species recorded from the Arenig, and only 17 from the Upper Tremadoc; when that was drawn up it was clear we must have had 42 not common to both. In the newer Catalogue just published by the Museum of Practical Geology, there are 97 recorded from Arenig and only 23 from Upper Tremadoc, shewing 74 that must be peculiar to the Arenig.

However, after making allowance for this, there do seem to be a large number of new forms appearing for the first time in the Arenig beds. To begin, we have here the most characteristic group of Cambrian and Silurian fossils, the graptolites, 17 to 23 species are counted; all the most complex forms are here with single rows of cells, double rows, four rows back to back; graptolites branching once or many times, symmetrically or irregularly, all are represented*. Such a full complement of variously developed forms does certainly make one suspect that the group will be found in older beds, probably as low down as the base of the Cambrian at least, wherever suitable conditions prevailed.

The many branched forms soon disappear and the twin Graptolites do not get above the Lower Bala Beds. There is certainly no unconformity there. The Diprionidian forms survive the break at the top of the Cambrian, and die out *in the lowest beds* of the Silurian in Britain as in Bohemia. The apparent exception Retiolites which runs much higher belongs to a distinct group. Before we get to the top of the Silurian they have all completely gone.

We might take almost any of the genera or species of Arenig trilobites, and we should, in the same way tracing them on, find that some dropped out sooner and some later, but that they in no marked way ended their appearance at a recognised physical break, except perhaps the genus Trinucleus, which has not yet been shown to have got back into our area after the interval between the Cambrian and Silurian.

Lamellibranchs in the Arenig, represented by Palaearca and Ctenodonta, form a more conspicuous group in the Bala Beds, and increase in importance up to the top of the Silurian. For it must be noticed that although there may be a larger number of species of lamellibranchs in the Wenlock, the species of the Ludlow Rocks bear a much larger proportion to the rest of the life of that period.

Another group must be noticed though not so suitable for our purpose. Corals are not common except in the limestones, which

* There was a suspicion of an allied form in the older rocks in Dictyonema sociale, and Mr Clifton Ward believes that beds from which he has obtained graptolites in the Lake district are of Tremadoc age.

of course they have largely helped to form. So Corals come in with the Limestones of Llandeilo and Bala, and as at present arranged there is hardly a genus which does not cross the gap between Cambrian and Silurian, and turn up again in the Wenlock Limestone; but here as well as in the case of the Echinoderms, we must remember the richness of the Wenlock in other fossils and their wonderful state of preservation, and also the ease with which they can be obtained.

Cystideans appeared early though few and far between, from the Protocystites of the Menevian to the Echinosphaerites and Sphaeronites of the Bala. Encrinite stems occur sometimes plentifully in the Bala Beds. But it was in the Wenlock of all the older rocks that the tribe of stone lilies flourished most, while the starfishes are most developed in the Ludlow. Encrinites appeared abundantly now and then in later times, often characterizing deposits of small extent horizontally and vertically; Woodocrinus, for instance, having been found only at Richmond in Yorkshire, and E. liliiformis being confined to the Muschelkalk. Representative forms exist at the present day. Changes of currents, of temperature, and of their floating food, &c. must have caused them to disappear from the areas where they were once so abundant, for though Encrinites were fixed they did not grow like a plant, and got no more nourishment from the soil where they flourished than an oyster from the outside of an old bottle on which we find them sometimes growing. Encrinites could not migrate, but as in the case of oysters their spat might.

Though several genera of Gasteropoda occur at various horizons in the Bala Beds, they are never sufficiently numerous to allow us to infer anything from their absence elsewhere.

I have followed Orthoceras as the earliest Cephalopod through its range, but if we take any other Cambrian or Silurian form, and notably Lituites, we shall see how common forms begin and end in the middle of uninterrupted deposits. Phragmoceras certainly begins with the Silurian, but seems to be the only genus of the Cephalopoda that does so.

Quite at the base of the Silurian (i. e. in the May Hill Sandstone including Lower and Upper Llandovery) a number of new forms are seen for the first time. All that marked group of brachiopodous shells, the Pentameri, and with them Stricklandinia, are here first strongly represented. They have not all been found down to the base of the group. Stricklandinia lens appears early. Pentamerus oblongus and P. globosus hardly occur below the upper division. But though they come in suddenly after a break they go out suddenly in the midst of continuous deposits, before we get fairly into the Wenlock. Another species, the Pentamerus Knightii, a large and well-marked form just appears in the middle

of the Ludlow Rocks, being almost confined to the Aymestry Limestone. Of Meristella we may tell the same tale (just expressing a doubt as to Meristella angustifrons). It is a genus very characteristic of the base of the Silurian, dying out by species as we ascend. The genera Leptaena and Strophomena have a long range, but rarely either generally or specifically are their appearances coincident with any physical breaks.

I will not dwell much more on the details of the Silurian fossils, many of which I have already commented upon in tracing types up from the Cambrian, but I may remark in passing that the evidence we obtain from them is just the same. New forms or striking modifications of old forms appear in the Wenlock which succeeds the May Hill Beds quite conformably, and again in the Ludlow, which passes so gradually into the Wenlock that in the absence of the Wenlock Limestone it is almost impossible to draw a line between them. When we get into the Limestone the immense abundance of corals, encrinites and cystideans, as before pointed out, though they swell the number of species, do not form fair ground of comparison with non-calcareous strata. Many new forms of Trilobites appear, Sphaerexochus, Acidaspis, Cyphaspis, &c., and whatever they be, there is no suggestion of any unconformity in this series, even carrying it over the great Lamellibranch zone at the top of the Ludlow, and far above the Silurian through the Ledbury shales into the Lower Old Red.

Let us notice what becomes of the Trilobites eventually. Several old genera, as Bronteus, Homalonotus, Phacops, Proetus, get into the Devonian, tiding over what is locally at any rate a great unconformity, and that is the last seen of those genera. All the family of Trilobites die out long before the close of the Carboniferous, in which Phillipsia and Griffithides represent that abundant family to which we had principally to refer in classifying the Cambrian and Silurian Rocks.

It is true that where the Trilobites die out the Limuli, represented long before by Neolimulus falcatus of the Wenlock, become more common, but there is a great gap between these two groups; and there was not in the last Trilobites any approach to the Limuloid type.

It seems that the evidence so far, making allowance for the imperfection of the record and the limited search which has been made in many areas, goes to show that whether we consider the smaller groups, as varieties and species, or the larger as genera, new forms appear at various horizons in *uninterrupted deposits*, and that they die out in the same way; and that after a long lapse of time, as measured by deposition, there is *caeteris paribus* as great a change in the life of the period as we find after a similar interval measured by denudation.

We speak of higher and lower forms of life. It is not meant that the higher is better fitted for its surroundings than the lower, but the term higher is applied to those forms which have a more complex arrangement of organs for discharging the varied functions of life. And there certainly seems to have been an increase of higher forms as time went on. So it is interesting to take note of the first appearance of some of these and test its bearing upon the question we are considering. In the Lower Ludlow, i.e. high up in the Silurian Rocks, we have the earliest yet known remains of fishes. Yet we ought to have found them had they been there, for the head shield of Pteraspis, for instance, was a thing easily preserved and recognised.

Quite at the top of the Ludlow Rocks we have a bone bed full of remains of Onchus and Thelodus, which from their likeness to sharks we may suppose to have had a high brain organization. There is a considerable difference between this group and that which occurs in the Upper Old Red or base of the Carboniferous series, but a long time, measured by long deposition and enormous intermediate denudation, has elapsed between the two periods. When we find the Cambrian fish, which I fully expect we shall, we shall see that they too are very different from those of the Ludlow Rocks.

In the succeeding Devonian and Carboniferous periods they abound. But the doubts as to the grouping of the Old Red and Devonian, and the limited distribution and range of this group, renders it less suitable for our present purpose. As far as the evidence does go it quite confirms the inference we have already arrived at: that lapse of time, whether measured by deposition or denudation, generally is accompanied by the introduction of new or modified forms of life.

Whatever may be said of the extension of the classification here adopted, as far as I am inclined to apply it, it is clear that we may consider a great part of the Devonian as a basement series to the Carboniferous; and bearing this in mind we will take as an example the genus Producta, and trace it back to see whether it comes in after an unconformity. We do, it is true, find it low down in the Mountain limestone, even when that rests on the upturned edges of the Silurian, as in the Craven area in Yorkshire; but unless we recognise it as represented in the Productella of the Devonian or the Chonetes and Leptaena of the Silurian and Cambrian, it is not found in earlier beds.

When the Carboniferous sea basin, in which the coral and the encrinite grew and the Productidae thrived in thousands, was being silted up or raised, then the animals of the clear sea or their spawn migrated to less unfavourable areas, and appeared as new forms in the midst of locally continuous deposits. As to what were the forms from which they were originally modified we have

only rarely a suggestion. For instance, the Cephalopoda are, in the Devonian, modified in the position of the siphuncle and other characters, so as to foreshadow the two great groups of the next period; the Goniatites, with its dorsal siphuncle, leading up to the Ammonites and the Clymenia to the genus Nautilus. What variation in character was produced in the process of acclimatisation in the new home of each part of their race we seldom can examine closely enough to enquire, but we may hope by and bye to get from this line of enquiry also some evidence bearing upon the great geographical changes our earth has undergone.

It seems perfectly clear that there are and always have been earth movements going on which have perpetually unsettled the condition affecting life, and that these movements are slow and more or less regular in their action.

The sequence of life upon the earth, showing a gradual incoming of new or modified forms all through, and not a succession of total extinctions and replenishments, points to the persistence of oceanic and continental areas, as an interruption in the continuity of suitable land and climate or of water of the required temperature, salinity or depth, would be destructive to life. Therefore the movement must have been of the nature of an earth-wave, the land rising on one side and sinking on the other of a given area.

Stratigraphical evidence shows that the submergence which allowed of the accumulation of sediment often commenced earlier over one part of the area than another, and that the direction of the movement of such troughs was not always the same. The foregoing palæontological considerations confirm this. Only some forms of life succeed in migrating because some directions are more fatal than others, namely, those which necessitate travelling across greater extremes of conditions affecting life.

It is only reasoning in a circle to define formations palæontologically and then to speak of the incoming and outgoing of species as nearly coincident with the beginning and end of the formation, but as denudation and deposition are necessarily equal, and no denudation can take place until the solid matter of the earth's crust has been lifted up within reach of the denuding agents, the periods of these earth-waves must somewhat coincide with the periods of deposition and denudation as given in the accompanying table, and these form our geological measures of time.

Whether the transference of the immense masses of denuded material always to the coastline of continents is the cause or effect, or modifies the direction of the earth-waves, is a question as yet unanswered.

TABLE OF STRATA.

Scale, 1 inch to 16,000 feet.

Maximum European thicknesses taken.