III.

The Evolution of Oceans and Continents.

NATURAL Science is indebted to Dr. Wallace for clearing away some misconceptions which have surrounded the question of the permanence of Oceans, and for imparting some freshness to the controversy by adducing several new arguments in its favour. Hitherto the question has been discussed rather as if it were necessary to hold one of two extreme views; the one view being that the great continental plateaux and oceanic depressions were formed at a very early period of the earth's history, and have occupied their present positions ever since; the other view being that the movements of the earth's crust have been so frequent and so great that no part of it has remained either in the state of sea or land through many periods of geological time.

I will not stop to enquire whether Lyell believed in the possibility of such frequent interchange when he wrote that "continents, although permanent for whole geological epochs, shift their positions entirely in the course of ages." The extreme view may have been held at one time when little was known regarding the depths of the ocean, but few geologists of any repute would maintain it at the present time. On the other hand, the idea of the fixity of the oceanic and continental areas is supposed to have received strong confirmation from the investigations of the "Challenger" Expedition. It was argued that modern oceanic deposits differ so much from any rocks which form part of the continental plateaux that none of these rocks could be of oceanic origin, and consequently that oceans and continents could never have changed places. It was confidently stated that *all* ancient marine formations had been formed in comparatively shallow water, and it was even predicted "that representatives of the abysmal deposits of the central oceans are not likely to be met with among the geological formations of past times." [1]

The supposed absence of oceanic deposits from continental areas was regarded as proving that the interchange of sea and land was confined to areas within 200 or 300 miles of the continental plateaux where the water was less than 1,000 fathoms in depth. In this way 92 per cent. of the whole oceanic area was excluded from the regions of possible interchange. Against this view I have protested as being

[1] Sir A. Geikie. "Text Book of Geology," 1st edition, 1882, p. 608.

merely the other extreme of the swinging pendulum of scientific imagination.

Recent discoveries of oceanic deposits, such as must apparently have been formed in depths of from 1,500 to 2,000 fathoms, and including representatives both of "red clay" and radiolarian ooze, but now raised high above the level of the sea within the limits of a continental plateau, have shown the danger of depending on negative evidence. Again, a more accurate knowledge of submarine contours and the exigencies of explaining the distribution of animals have obliged Dr. Wallace to include much greater depths within the regions of possible interchange. He now says: "All that is necessary to maintain therefore is, that existing continents with their included seas and their surrounding oceanic waters as far as the 1,500-fathom, or in some extreme cases the 2,000-fathom line, mark out the areas within which the continental lands of the globe have been built up; while the oceanic areas beyond the 2,000-fathom line, constituting, according to Mr. Murray's data, 71 per cent. of the whole ocean, have almost certainly been ocean throughout all known geological time."

This is a great concession, and the "almost certainly" may foreshadow further admissions; 71 per cent. is very different from 92 per cent., and the extension of interchangeable areas to regions within the 2,000-fathom line enables us at once to speculate on the possibility of a former antarctic continent with such extensions toward New Zealand, South Africa, and South America as will explain the curious points of similarity in the modern faunas of these countries. The existence of such a continent has already been suggested by Dr. W. T. Blanford.[2] Dr. Wallace's present view also enables us to assume the former existence of a large continent in the Western Pacific with extensions southward to New Zealand and westward to Australasia. It also gives us great possibilities of change in the Atlantic Ocean, though hardly sufficient to account for all the palæontological evidence which has been or can be adduced in favour of old connections between the more tropical parts of Africa and America.

So far, therefore, Dr. Wallace has departed from the extreme views which have been held by the writers whom he quotes with approval, and which he upheld even in the second edition of his "Island Life," published only a few months ago. He therein argues against the deep-sea origin of chalk, and repeats the very erroneous statement that "deposits uniform in character and more than 150 or 200 miles wide were rarely, if ever, formed at the same time." Why does he vainly endeavour to deny the close similarity between chalk and foraminiferal ooze when in a later chapter he contemplates submergences of more than 1,000 fathoms in extent?

[2] Pres. Address to Geol. Soc., 1890, p. 104.

He now advances certain arguments against the wholesale interchange of oceanic and continental areas, but the force of his reasoning is greatly weakened by a misconception which appears to underlie the whole of it. He seems to think that those who oppose the theory of the permanence of oceans must believe in the possibility of a brand new continent rising whole and complete from the ocean depths while an older continent was compelled to vanish beneath the waters in order to preserve the terrestrial balance. I am not aware that anyone has ever propounded such an audacious hypothesis. I have ver seen it seriously suggested that an entire continent has been contemporaneously submerged, nor has any modern geologist contemplated "the building up of a continent the size of Africa from the mean depth of the ocean." Certainly Dr. Wallace is not warranted in imputing such crude ideas either to Dr. Blanford or to myself, and every geologist will admit that "the remarkable parallelism and completeness of the series of geological formations in all the best known continents indicates that none of them have risen from the ocean floor during any portion of known geological history."

Those who oppose the doctrine of permanence say that the present continents are the outcome of a long series of geographical mutations, and I would add that each phase was an episode in a long process of geographical evolution. There is good reason to believe that even in Pliocene time the outlines of the continents were very different from the present, some areas now below the sea being then above it, while other tracts then beneath oceanic waters have since been raised into dry land. We know that Miocene geography differed still more greatly from that of to-day, and it is not therefore unreasonable to suppose that in the Cretaceous period large parts of the modern oceans were land, and large parts of the modern continents were portions of the ocean, the continental connections being totally different from what they are now. In short, the interchange we believe in is the frequent interchange of small portions of oceans and continents, till, in the course of time, the accumulated changes have accomplished great geographical mutations.

Against this view of interchange it does not seem to me that either the first or the third of the considerations mentioned by Dr. Wallace are very powerful objections. With respect to the second argument, that there are no irregularities on the ocean floor corresponding to those on land, I would point out (1) that it applies most completely to the deeper and consequently to the oldest portions of the ocean floor, (2) that we really as yet know very little about the details of sub-oceanic contours, (3) that long-continued deposition must tend to obliterate any pre-existent irregularities, (4) that such inequalities are likely to have been much smaller than those shown in continental areas, because the continents are probably those

portions of the earth's crust which have been subjected to the greatest pressures and disturbances; while the deeper parts of the ocean are probably those where the crust has long been in a state of tension and comparative quiescence. It is true that the tension might, and probably has, led to the production of faults; but the faults developed at any one epoch would be small, and if they formed a system of trough-faults the surface features produced would be quite insignificant. (5) Lastly, if there be any truth in Mr. Fisher's idea of the frequency of sub-oceanic outpourings of lava, such extravasations would largely account for the comparative smoothness of the ocean floor.

Here, so far as Dr. Wallace's arguments are concerned, I might leave the subject, but I wish to make a further suggestion, and, following Dr. Wallace's example, to advance another *à priori* consideration.

All who have hitherto discussed the question of the permanence of oceans have done so on the basis of the present physical conditions of the globe, and have assumed that the volume of ocean water, and consequently the mean depth of the ocean, have always been the same. But are we justified in making this assumption?

The Rev. Osmond Fisher has done a great service to the science of Geology in showing that the contraction theory is totally inadequate to account for the inequalities of the earth's surface, and in placing the hypothesis of a thin crust with a liquid substratum upon a sound basis by his suggestion that water in the state of gaseous matter is associated with the liquid magma. In this way he explains the presence of water among volcanic products, which has always been a physical difficulty. But, if his theory be true it follows that every eruption which has taken place on the globe during the long ages of past time has contributed a certain amount of water to swell the volume of the ocean. Hence the oceans have been gradually increasing in depth and extent throughout all geological time, and the area of the land has been as gradually diminished.

If, therefore, we accept this hypothesis (and it affords by far the most satisfactory basis for the explanation of terrestrial physics that has yet been imagined), we must look back to a time when the oceans were very much smaller and shallower than they are now. Further, if we accept Mr. Fisher's view of the manner in which continents and mountain chains have been ridged up by the pressure of the horizontal connection-currents in the substratum, it seems probable that there has been a tendency toward the condensation of land masses into continental areas, and we may look back to a time when the continental plateaux did not rise so high above the mean level of the ocean floor as they do now.

It would appear, then, that a geologist is justified in supposing the total area of land in early Palæozoic time to have been equal to or greater than that of the sea, both being more equally distributed,

so that there were neither great oceans nor isolated continents in our modern sense of the terms. From this condition of geographical equality, it seems to me there has been a gradual tendency to the development of high continental plateaux, while the deeper sea-troughs have been merged into oceans, and the volume of the surface waters has been continually increased by the extrusion of the water-substance from the interior of the earth.

On this hypothesis we can at once explain the rarity of extensive oceanic deposits of the modern type among the great series of stratified rocks, for in the comparatively narrow and shallow seas of Palæozoic time no such deposits could be formed. Now, as a matter of fact, while deep-water muds are common among Palæozoic rocks, no rock which is likely to have been analogous to a modern abyssal ooze has yet been found, for the radiolarian chert of Ayrshire can hardly be claimed as such, either in character, thickness, or extent. Coming down to Mesozoic time, we find the Cretaceous Chalk, which does in all three respects bear great resemblance to a modern calcareous ooze, but it is not associated with abyssal deposits of the red clay and radiolarian ooze types. When, however, we reach Tertiary times the West Indian deposits furnish proof that the oceans were deep enough for the formation of all the modern types of oceanic deposits.

On this hypothesis of the gradual evolution of oceans and continents we can imagine the former existence of continental land where the ocean now rolls, without depressing any modern continent below the ocean to produce it. In short, we may believe that the places of our continents have *nearly* always been occupied by land or by shallow seas without assuming that the land areas have always been restricted to the present continental plateaux. We may likewise believe in the great antiquity of the deeper parts of the oceans, without assuming that these oceans have always been either as deep or as extensive as they now are.

In his Appendix (p. 9), Mr. Fisher thinks it probable that his conclusions as to the structure of the sub-oceanic crust do not apply to the borders of the oceans, and that the one type of crust changes gradually into the other type, "so that there is an intermediate belt of which we cannot assert that it belongs exclusively either to the oceanic or to the continental type." This allows us a certain amount of latitude; but I do not think he goes far enough, and believe his own conclusions must eventually lead him into the very theory of evolution which I have just suggested. For instance, he accounts for the greater density of the upper layer of the typical sub-oceanic crust by supposing it to consist of extravasated basic lavas; but the extravasation of these lavas must have gone on *pari passu* with the compression of the continents, and hence the very construction of a special type of sub-oceanic crust must have been a process of gradual development. In dealing with geological time, Evolution, as distinct from

Restorative or Catastrophic Change, must be our principle of interpretation.

Here, however, it may be objected that Mr. Fisher has supported the theory of the permanence of oceans, and that he assigns to the sub-oceanic crust a structure which differs from that of the continental crust. In his Appendix, however, he has partially altered his conception of the structure of the sub-oceanic crust, and he has recently read a paper before the Cambridge Philosophical Society in which he arrives at results which tell strongly against his speculation about the origin of ocean basins; in this I much rejoice, for that chapter in his book had never commended itself to me.

It must be remembered, too, that Mr. Fisher has not attempted to enter into the history of the sub-oceanic crust. His position is simply this; his calculations show that, if his hypothesis be true, there are large tracts of crust which must have the special structure he ascribes to them; he does not assert that they have always had that structure, but he does see a difficulty in supposing that, having acquired that structure, they can ever again become continental land.

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