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ORIGINAL ARTICLES.

I.—SUBSIDENCE AND ELEVATION, AND ON THE PERMANENCE OF OCEANS.

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THE theory of permanent Continents and Oceanic basins, opposed as it is to the general teaching of text-books, seems to have given rise to comparatively little discussion. In the latest edition, for instance, of Lyell's Principles, we read: "It is not too much to say that every spot which is now dry land has been sea at some former period, and every part of the space now covered by the deepest ocean has been land." The new theory has been upheld chiefly by Sir Wyville Thomson, Prof. Geikie and Mr. Wallace. The latter especially has collected every kind of evidence together that seems to support it in his latest, and most admirable work, "Island Life." By a process of reasoning, supported by a large array of facts of different kinds, he arrives at the conclusion that the distribution of life upon the land, as we now see it, has been accomplished without the aid of important changes in the relative positions of continents and seas. Yet if we accept his views, we must believe that Asia and Africa, Madagascar and Africa, New Zealand and Australia, Europe and America, have been united at some period not remote geologically, and that seas to the depth of 1000 fathoms have been bridged over; but we must treat as "utterly gratuitous, and entirely opposed to all the evidences at our command," the supposition that temperate Europe and temperate America, Australia and South America, have ever been connected, except by way of the Arctic or Antarctic Circles, and that—lands now separated by seas of more than 1000 fathoms depth have ever been united.

Mr. Wallace, it must be admitted, has succeeded in explaining the chief features of existing life distribution, without bridging the Atlantic or the Pacific, except towards the Poles, yet I cannot help thinking that some of the facts might perhaps be more easily explained by admitting the former existence of the connexion between the coast of Chili and Polynesia and Great Britain and Florida, shadowed by the sub-marine banks which stretch between them. Nothing is urged that renders these more direct connexions impossible, and no physical reason is advanced why the floor of the Ocean should not be upheaved from any depth. The route by which the floras of South America and Australia are supposed to have mingled is beset by almost insurmountable obstacles, and the apparently sudden arrival of a number of sub-tropical American plants in our Eocenes, necessitates a connexion more to the south

than the present 1000-fathom line. Again, the geological evidence, as I have pointed out in the *Popular Science Review*, is far from being so favourable to Mr. Wallace's view, as he supposed.

Apart from the regions of less depth, which I think may have been more or less land during the Tertiary period, there is some reason to believe in the general permanence of the Oceans over the areas where they are now deepest. It is perfectly certain that the causes which lead to elevation and subsidence must react upon each other, and if these were exclusively the result of shrinkage, there would be no reason why the sea-bottom at the greatest depths should not have come to the surface. *With a layer fluid under a given pressure, resting upon solid, and sensitive to any increase or decrease of pressure, the chief effects of elevation and subsidence could be explained.*<sup>1</sup>

Many persons have been struck with the almost universal tendency to depression exhibited in areas occupied by deltas and estuaries. This fact has frequently been alluded to in the *GEOLOGICAL MAGAZINE*, and elsewhere, and has been most clearly expressed by Dr. Charles Ricketts,<sup>2</sup> that this subsidence is directly produced by the accumulation of sediment. However insignificant, some cause must initiate movement in the earth's crust, and as an incautious shout may bring down an avalanche, so even an accumulation of a few feet of clay over several square miles may create a disturbing re-adjustment, and eventually lead to a downward tendency. Supposing a sediment, 50 feet in depth and entirely submerged, to have displaced an equivalent of sea-water, we should have an increased pressure per square yard (taking the mean density of the materials composing a delta at 170 lbs. per cubic foot) of rather more than 25,000 lbs., or about 34,848,000 tons per square mile. When we see that deltas have accumulated to depths of perhaps even beyond 1000 feet, and extend, as in the Mississippi, to 19,450 square miles, it is easy to realize how vast a force is present.<sup>3</sup>

The hypothesis that added weight leads to subsidence may also to some extent be sustained by the continuous depression of Coral Islands. Great accumulations of ice in the Glacial period seem to have been accompanied by subsidence, and even Greenland at the present day may be sinking under its ice-cap.

To apply the theory to a wider field, we frequently observe signs of subsidence on the sea-coast. We meet on every shore with vestiges of submerged land vegetation and with traditions of submergence since historic times. Though raised beaches exist, it should be remembered that these are local and always rendered conspicuous, while depressed beaches seldom or never attract attention. Forests have been depressed beneath the sea-level and no trace of them has ever come to light, except at low spring-tides and in

<sup>1</sup> According to Lyell, all known rocks would fuse under a pressure of from 20 to 25 miles, whilst greater pressure would reconvert them to solids with a high specific gravity.

<sup>2</sup> *GEOL. MAG.* 1872, Vol. IX. p. 119.

<sup>3</sup> See *Permanence of Continents*, J. S. Gardner, *Popular Science Review*, 1881, p. 125.

exceptionally rough weather. We have generally to trust to foundations and well-borings near the coast, and these, as far as I am acquainted with them, have invariably shown that our sea-shores are steadily sinking. If this were not so, our land would be surrounded by extensive shoals of uniform depth, for the whole of the sediments from the wasting of the shore are thrown down almost entirely upon a belt 30 miles wide. The moving power of waves is not felt to a greater depth than forty feet, tides appear to have no permanent action in removing sediment, and shore currents of sufficient power are local and merely cut channel-ways. The rapidity with which silt accumulates may be seen by the manner in which wrecks become lost to view, and in the discolouration of the sea during rough weather produced by particles from the shore held in suspension. This shore deposit does not find its way to the depths of the ocean, and if its constant accumulation is not balanced by subsidence, what becomes of it? <sup>1</sup> A glance moreover at any stratified rock composed of littoral deposits, will show from its thickness, which often exceeds the depth of water in which it is supposed to have been deposited, that it must have been deposited in a subsiding area. No conclusion but this can be drawn in working through our Eocenes, and it is sufficiently obvious that no thick littoral deposit can take place in an area of elevation.

If the theory that sedimentation directly causes subsidence is pushed still further, we discover a physical reason for the permanence of Ocean basins. If permanent, deposition must have been continuous since Palæozoic times, and would to a large extent have filled in even the very greatest depths of the ocean, unless compensated by constant and gradual depression. The mean of four experiments made on the "Challenger" Expedition, determined the quantity of carbonate of lime in the form of living organisms in the surface waters to be 2.545 grammes, so that if these animals were equally abundant in all depths down to 100 fathoms, it would give 16 tons of carbonate of lime to each square mile of 100 fathoms depth. <sup>2</sup> There is no reason, however, why organisms contributory to sediment should not extend to, and even become more abundant towards the bottom. In the absence of knowledge as to the duration of life in such minute marine organisms as *Globigerina*, we are without data for estimating the rate of deposition in deep seas. Although at great depths shells of Foraminifera are reduced to bicarbonate, this does not seem to result in loss of material, for the samples of deep sea-bottom that have been dredged, and our own Chalk formation, tend to show that the supply of lime is not kept up to any extent by the dissolution of dead organisms.

The continuously increasing weight of sediment and of water

<sup>1</sup> Sir J. Herschel was of opinion that the weight of sediment displaced by the sea produced elevation and depression along coast-lines (*Phys. Geogr.* p. 116).

<sup>2</sup> This would deposit, if replenished annually, one inch of sediment in 8,000 years. If life extended equally to 2,000 fathoms, one inch would be produced in 400 years. If 12 generations were produced per annum, one inch would result in 33 years, and this might be more than doubled by the decay of life at the bottom.

must exercise enormous pressure, tending to make the *greatest depths* of the sea permanent, and to continually elevate lines of least resistance into ridges or banks, resulting, where the state of tension is extreme, in isolated volcanic outbursts. The lines of absolute least resistance would probably, however, more generally coincide with sea-margins, because these would be the nearest lines to the area of depression, free from accumulating sediment. Upon coasts, therefore, while we might expect, and actually find, a tendency to local depression, owing, as I suggest, to littoral sedimentation; at a few miles inland there should be found a far more important and preponderating tendency to elevation.

That such a tendency has really existed is apparent from the positions of the chief mountain chains. Considering the very different distribution of seas which prevailed during the periods of elevation of some mountain chains, and the complicated forces at work, it is remarkable how the chief mountains of the world follow the existing, or recently existing coast-lines. In Europe we have the Icelandic mountains on its southern shores, and formed probably when Iceland extended some way north. The Norwegian chain, and the Welsh and Irish mountains follow the coast-line, and were chiefly formed perhaps, when England and Scotland were united to the Continent. The Sierra Nevada, the Cantabrian mountains and the Pyrenees; the Corsican, Sardinian and Sicilian mountains, the Apennines, Maritime and Dinaric Alps, and the Alps themselves, were formed when Eocene seas washed their bases. In Asia we find the Mediterranean, the Red Sea, the Gulf of Aden, the Persian Gulf, and the south shore of the Caspian, margined by mountains. Both sea-boards of Hindustan are followed a little way inland by the Eastern and Western Ghauts, and the Himalayas skirted the sea at the time of their formation. The Malay peninsula is a mountain ridge, and mountains follow the sinuosities of the Eastern coast of Asia from Singapore to Behring's Straits. Eastern and Western Australia also have their coast ranges.

In Northern Africa there are almost continuous mountains from the south of Morocco to Suez. The Kong mountains follow the coast of Liberia to the Slave Coast. The Cape mountains stretch north at least to Mozambique, and hills seem to line the coast from Zanzibar and meet the northern range at Suez. In America a magnificent range follows the Western coast from Alaska to Cape Horn, and on the east are the Alleghany and Rio de Janeiro mountains. Unless we believe that the principal chains of mountains follow present or past coast-lines by a mere coincidence, we must recognize that some definite law is at work.

But even more conclusive evidence is derived from the position of active volcanos, for these prove that the fluid layer is actually forced nearest to the surface along coast-lines. The Pacific is almost encircled by a marvellous chain of volcanic vents; and earthquake regions are also generally in proximity to the sea.

If the sedimentation going on annually at the bottom of the ocean really produces depression, that is, displacement of the fluid

layer, it must force up mountain chains along lines of least resistance. The sustained pressure would continually keep fresh layers of the solid interior or of its own material at the liquefying point, and press them out in turn—imperceptibly deepening the ocean basins where they are deepest and raising the shallower parts to higher levels, thereby slowly lessening the surface area of seas. On the other hand, the dry land would extend in a corresponding degree, and its surface become more diversified, for new mountain chains would perhaps in succeeding ages have a tendency to reach greater elevations. Geology itself supports this hypothesis. The records of the Palæozoic rocks point to a comparative uniformity in the earth's surface in remote times, there being neither evidence of great depths in the sea, nor of mountainous elevations in the land, and palæontological evidence shows these conditions to have been progressively modified until the present day. If mountain chains and volcanic outbursts were caused only by the cooling of the earth, we should find, instead of the uniformly shallow sea of the older Palæozoic rocks—and the almost uniformly level land of the Carboniferous—evidence of even greater inequalities of surface than now exist.

While therefore upon this theory the *greatest depths* of the ocean may always have been permanent, the banks and ridges of less depth with islands occasionally rising to the surface, and crossing the Atlantic and Pacific, must either be rising or sinking. If they do not mean changes of level in the sea-bottom, whether of past or present elevation, what do they mean? Forces are unceasingly acting, and there is no reason why an elevating force once set in action in the centre of an ocean should cease to act until a continent is formed. They have acted and lifted out from the sea, in comparatively recent geological time, the loftiest mountains on earth. Mr. Wallace himself admits repeatedly that sea-beds have been elevated 1000 fathoms, and islands have risen up from depths of 3000 fathoms; and to suppose that the upheaving forces are limited in power is, it seems to me, to again quote from *Island Life*, “utterly gratuitous, and entirely opposed to all the evidences at our command.”

In conclusion, I will only add that these ideas are obviously put forward tentatively, and await further proof or disproof. I propose next month to make the subject clearer by means of a diagram.

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