WEEKLY EVENING MEETING,

Friday, January 23rd, 1880.

THOMAS BOYCOTT, M.D. F.L.S. Manager, in the Chair.

DR. WILLIAM B. CARPENTER, C.B. F.R.S.

Land and Sea considered in relation to Geological Time.

WHEN, in the summer of 1871, I placed before the First Lord of the Admiralty (Mr. Goschen) the scheme of the 'Challenger' Expedition, I ventured to say that "the key to the interpretation of much of the past history of our globe is at present lying at the bottom of the sea, waiting only to be brought up." This prediction has been most fully verified; but, as in the case of many another prophecy, in a sense very different from that in which it was uttered.

The first of the general objects specified in my programme was "the determination of the *Physical* condition of the Deep Sea in the great Ocean Basins, as to depth, temperature, composition, and movement," carrying out, over the Oceanic area generally, the inquiry which had been inaugurated by my colleagues and myself on the eastern margin of the North Atlantic. This object has been most successfully accomplished, by a series of observations taken along well-selected lines in the North and South Atlantic, the North and South Pacific, the Southern and Antarctic Oceans; which, combined with the observations taken in the recent Arctic expeditions—British, German, and Norwegian—afford a body of information as to the Physics of the Ocean, sufficiently complete to afford a safe basis for the scientific discussion of the remarkable phenomena now for the first time brought into clear view.

The second of the general objects which I specified was the determination of "the distribution of *Animal Life* on the Deep-sea bottom, and the relation of the Deep-sea Fauna to that of past Geological epochs." The inquiries previously carried out by my colleagues and myself had shown (1) that there is probably no limit to the *depth* at which Animal life can exist on the ocean-bed—a Fauna containing representatives of all the principal types of marine Invertebrates, having been found nearly *three miles* beneath the surface; (2) that *temperature* exerts a most important influence on the distribution of animal life on the sea-bottom; and (3) that many of the forms now

existing on the deep-sea bed so nearly represent Cretaceous types supposed to have long since become extinct, that we may fairly suppose them to be their lineal descendants. Hence, I went on to say, "the question of the continuity of 'descent with modification' will probably receive more elucidation from the study of the Deep-sea Fauna, than from any other line of scientific inquiry." This anticipation, also, is in course of complete fulfilment. An enormous amount of Zoological material has been carefully collected from various parts of the great Oceanic area, and at depths ranging downwards to from three to five miles; and this is being studied, with a view to all the determinations I have indicated, by Naturalists of the highest competency in their respective departments. The results of this part of the inquiry have so far been only disappointing to those who had somewhat unreasonably expected that, because Cretaceous types had been found still living in the deep seas of our part of the globe, the Ammonites of the Secondary period, and even the Trilobites of the Palæozoic, might be lurking in abyssal depths elsewhere,—an expectation which I never myself shared.

But whilst the past history of Animal Life on our globe will doubtless receive all the new light which I had anticipated from the scientific study of the 'Challenger' collection, an unexpected clue has been found in the examination of the *sediments* now in process of deposition on the Ocean-bottom, to the solution of a question in Physical Geology, second to none in importance and interest, which I propose now to bring before you.

Every tyro in Geology knows it to be a fact not admitting of a doubt, that all our existing Land has at some period or other been under the sea; and the converse proposition—that every part of the Sea-bottom has at some period or other risen above the surface—has been very generally accepted, even by geologists of the highest eminence. Thus Sir Charles Lyell, in his chapters on the vicissitudes in Climate caused by geographical changes, assumed it as a fact beyond dispute, not only "that every part of the space now covered by the deepest ocean has been land," but even that "the bed of the ocean has been lifted up to the height of the loftiest mountains;" and considered it proved that "if we had a series of maps, in which restorations of the physical geography of thirty or more periods were depicted, they would probably bear no more resemblance to each other, or to the actual position of land and sea, than does the map of one hemisphere bear to that of the other."—These statements, I may remark, are repeated without any qualification in the twelfth chapter of the latest edition of his masterly 'Principles'; notwithstanding that towards the conclusion of the same chapter, he distinctly recognized the enormous disproportion between the average elevation of the Land and the average depth of the Ocean-basins, whereby, while a vertical *depression* of 1000 feet would submerge a large part of the present continental land, a vertical *elevation* of from twelve to fifteen

times that amount would be required to raise any large areas of the ocean-bed above the existing sea-level.

Many Geologists who would not accept in all their fulness Sir C. Lyell's rather sweeping assertions, seem by their language to imply their belief in less extensive interchanges between Land and Sea; in fact, I think a general belief has been entertained of a sort of see-saw movement in the Earth's crust,—one portion going up while another goes down,—which has seemed to draw confirmation from Mr. Darwin's admirable researches on Coral Islands.

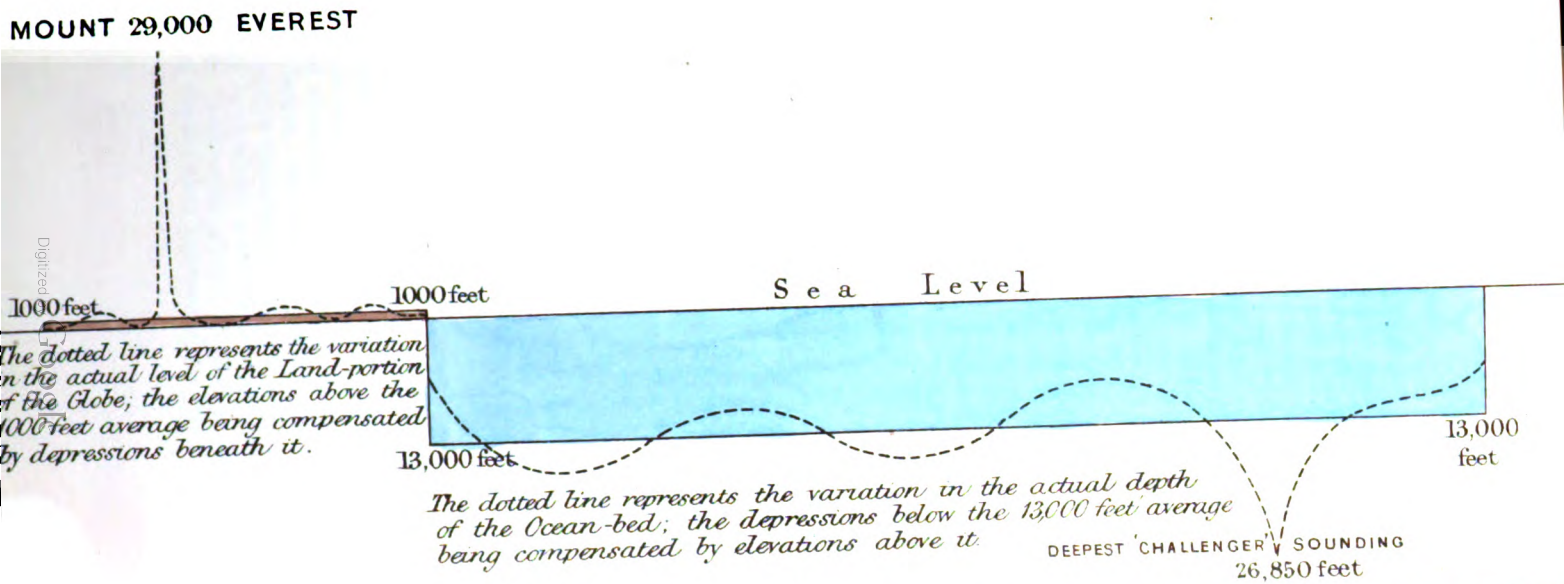
Some of the ablest among living Geologists, on the other hand, have been led by the convergence of several independent lines of inquiry—of which it is my purpose to give you a concise sketch—to a belief in the *permanence*, throughout all geological time, of what may be called the framework of the existing Continents, on the one hand, and of the *real* Oceanic basins on the other. According to this view, the repeated changes which have unquestionably occurred at various periods in the distribution of sea and land, have been generally produced by elevations and subsidences, for the most part of very moderate amount, in portions of elevated areas in the original crust of the earth, which occupied the general position of our existing Continents; the upheaval of lofty mountain-chains, and the formation of very deep local troughs, in which long successions of sedimentary deposits have been formed, having taken place in parts of those originally elevated areas, especially near their margins. The far larger Oceanic basins on this view, occupy areas of the crust which were originally depressed by an abrupt border, many thousands of feet beneath the continental platforms; and, like them, had a nearly uniform level, until disturbed by local upheavals and depressions occasioned by forces subsequently generated during the progressive contraction of the molten sphere within—these upheavals and depressions, when considerable vertically, being usually limited in area, and only breaking the general uniformity of bottom-level as the elevation of the Ural chain interrupts the uniformity of the great plain of north-east Europe and northern Asia.

I. Now the first consideration to which I would draw your attention, is the enormous disproportion which we now know to exist between the *depth* of the real Ocean-floors beneath the sea-level, and the *height* of the Land elevated above it; which, when taken in connection with the relative *areas* of the existing Sea and Land, seems to render it highly improbable that interchanges extending over large portions of the earth's surface could ever have taken place between them.—The proportion which the *area* of the existing Land bears to that of the Sea may be conveniently stated as about 1 to $2\frac{3}{4}$, or as 4 : 11; so that, if the entire surface of the globe were divided into fifteen equal parts, the Land would occupy only four of these, or rather more than a quarter, whilst the Sea would cover eleven, or rather less than three-quarters. But when we compare the *volume* of

Proportional Area of Sea to Area of Land, 11 to 4, or 2¾ to 1.

AVERAGE DEPTH OF OCEANIC AREA 13,000 FEET
AVERAGE ELEVATION OF LAND, 1,000 FEET

PROPORTIONAL MASS OF SEA, 11 × 13 = 143
LAND, 4 × 1 = 4
OR 36 TO 1



the Land above the sea-level with that of the Water which occupies the Ocean-basins, a far greater disproportion shows itself. For the average elevation of the whole Land of the globe certainly does not exceed 1000 feet;—that of Asia and Africa being somewhat above that amount, while that of America (North and South), Europe, and Australia is considerably below it. On the other hand, the average depth of the Ocean-basins is now known to be rather over than under 2½ miles, and may be taken (for the convenience of a round number) at 13,000 feet. Thus the average depth of the ocean being thirteen times as much as the average height of the land, and the area of the sea being 2¾ times that of the land, *the total volume of the Ocean-water is just thirty-six times that of the Land above the sea-level.*

The Northern hemisphere is pre-eminently the *land* hemisphere, and the Southern the *water* hemisphere; and the distribution of the two components of their respective surfaces, so far from being "capricious" (Lyell), is found to have a remarkable symmetry. It is between lat. 30° and 70° that Water most predominates in the Southern hemisphere; the Southern Ocean forming a continuous girdle around it between Cape Horn, lat. 56° S., and the Antarctic continental platform. On the other hand, it is between lat. 30° and 70° that Land most predominates in the Northern hemisphere, girdling nine-tenths of its circumference between lat. 60° N. and the Arctic Ocean.

The great land-masses of the Northern hemisphere send down three extensions into the Southern, viz. South Africa, South America, and the Papuo-Australian continent; which last may be considered as the southward extension of the Asiatic, being connected with it by a nearly continuous though partly submerged continental platform, of which the peninsula and archipelago of Malaya are the most elevated portions. It is further remarkable that each of these southward extensions is almost entirely detached from its northern land-mass by an intervening sea;—South from North America by the Gulf of Mexico and Caribbean Sea; Africa from Europe and Asia by the Mediterranean and Red Seas; and the Malayan continental platform from south-east Asia by the shallow Yellow Sea, and by those smaller seas, some of them remarkable for their depth, that lie among the great islands of the Malay Archipelago—*the interruption in each case coinciding with an area of great Volcanic activity.*

On the other hand, the vast Oceanic area of the Southern hemisphere sends three great extensions northwards; the Pacific, the Atlantic, and the Indian Oceans, of which the two former are prolonged as far as the North Polar area.

But the existing borders of these Oceans by no means correspond with the borders of their real basins. The deep-sea soundings of the 'Challenger' have brought out this remarkable fact—that the ocean-floors present a uniformity of level which corresponds with that of our most level and extensive Continental plains; so that in long section-lines the differences of depth (when represented on true pro-

portional scale*) show themselves—except in cases of local disturbance—as undulations of scarcely perceptible gradient.

Again, we now know that the borders of these vast depressed areas are generally, if not uniformly, very abrupt; the *sudden* descent from a comparatively shallow bottom to a very deep one, which was first noticed in the line of soundings taken with a view to the laying of the Atlantic Telegraph cable, being not an exceptional but a general fact. Taking this as the *real* border of the North Atlantic Ocean, and looking to the smallness of the gradients presented by its sea-bed (except in the volcanic area of the Azores) until we come upon the like steep inclination at some distance from the American coast-line, which obviously marks the true western border of the oceanic area, we see that the term "basin" is a misleading one; a far truer representation of the Atlantic depression being a flat "waiter" with elevated sides, having an upward bulge along the median line of its bottom. On this view, the shallow band which generally intervenes between the edge of a deep Oceanic depression and the ostensible coast-line, is really to be regarded as a submerged portion of the adjacent Continental platform.

The contrast between the *real* and the *ostensible* borders of the Ocean-basins is nowhere more remarkably exhibited than in the seas which girdle the British Islands. These are all so shallow, that their bed is undoubtedly to be regarded as a continuation of the European Continental platform; an elevation of the north-western corner of which, to the amount of only 100 fathoms, would reunite Great Britain to Denmark, Holland, Belgium, and France, and would bring it into continuity with Ireland, the Hebrides, and the Shetland and Orkney Islands. Not only would the whole of the British Channel be laid dry by such an elevation, but the whole of the North Sea also, with the exception of a narrow deeper channel that lies outside the fiords of Norway. Again, the coast-line of Ireland would be extended seawards to about 100 miles west of Galway, and that of the Western Hebrides to beyond St. Kilda; while a little further west, the sea-bed shows the abrupt depression already spoken of as marking the commencement of the real Atlantic area. A like rapid descent has been traced outside the 100-fathom line in the Bay of Biscay (a considerable part of which would be converted into dry land by an elevation of that amount), and along the western coast of Spain and Portugal, where, however, it takes place much nearer the existing land-border. The soundings of the U.S.S. 'Tuscarora' in the North Pacific, have shown that a like condition exists along the western coast of North America: a submerged portion of its Continental platform, covered by comparatively shallow water, forming a belt of variable breadth outside the existing coast-line; and the sea-bed then descending so rapidly as distinctly to mark the real border of the

* The use of a *vertical* scale very many times as great as the *horizontal*, tends to mask this important fact.

vast Pacific depression. And as similar features present themselves elsewhere, it may be stated as a general fact that *the great Continental platforms usually rise very abruptly from the margins of the real Oceanic depressed areas.*

If, on the other hand, we inquire what would be the effect of a *depression* of the existing Land of northern Europe to the same, or even half that amount, we find that very extensive areas of what is now dry land would be overflowed by sea; the higher tracts and mountainous regions alone remaining as representatives of the Continental platform, to which, nevertheless, the submerged portions equally belong. This, as every geologist knows, has been, not once only, but many times, the former condition of Europe; to which a singular parallelism now shows itself in that great Continental platform, of which the peninsula and islands of Malaya are the most elevated portions. For the Yellow Sea, which forms the existing boundary of south-eastern Asia, is everywhere so shallow, that an elevation of 100 fathoms would convert it into land; while half that elevation would lay dry many of the channels between the Malay Islands, so as to bring them into continuity not only with each other, but with the continent of Asia. And Mr. Wallace's admirable researches on the zoology of this region have shown that such continuity undoubtedly existed at no remote period; its Mammalian fauna being essentially Asiatic. On the other hand, a like elevation would bring Papua into land-continuity with Australia; with which, in like manner, the intimacy of its zoological relations shows it to have been in former connection. The Indo-Malay province is separated from the Papuo-Australian province by a strait, which, though narrow, is so much deeper than the channels which intervene between the separate members of either group, that it would still remain as a fissure of considerable depth, even if the elevation of the two parts of the great area it divides were sufficient to raise each into dry land. The Malayan land-area would, however, be still broken by small Inland Seas of extraordinary depth. One of these, known as the Sulu Sea, which lies between the north-west coast of Borneo and the Philippines, and is elsewhere enclosed by smaller islands and reefs connecting them, ranges downwards to 2225 fathoms. Another, the Celebes Sea, which lies to the west of Borneo between Mindinao and Celebes, has a depth of 2050 fathoms. And the Banda Sea, which lies between the southern part of Celebes and New Guinea, with the islands of Ceram on the north and Timor to the south, has the still more extraordinary depth of 2800 fathoms. A general elevation of a few hundred fathoms would detach these Seas from the two great Oceanic areas which they now help to connect*; and yet they would still remain by far the

* The depth down to which each of them communicates with the Ocean outside, is determinable by its correspondence in temperature. Below the plane of continuity, the temperature of the enclosed Sea remains constant to the bottom (as in the Mediterranean), while that of the Ocean shows a continuous descent.

deepest of the smaller depressions anywhere occurring in Land-areas.

The occurrence of these gigantic pit-holes in this region of extraordinary Volcanic activity has a singular significance; especially when taken in connection with the fact that like depressions of the Ocean-bed which have been elsewhere met with, are also in Volcanic areas. Thus the first of the 'Challenger' soundings which showed a depth (3875 fathoms) greatly exceeding that of the ordinary floor of the Atlantic, was made not far north of St. Thomas's, in what may be regarded as a continuation of that "line of fire" which is so marked in the lesser Antilles. The sounding-wire of the United States ship 'Tuscarora' twice broke, without reaching bottom, in near proximity to the volcanic region of Japan, at depths considerably exceeding 4000 fathoms. And the deepest bottom sounded by the 'Challenger,' 4575 fathoms or 27,450 feet,—which seems to have been a local depression of a sea-bed averaging about half that depth, and was met with on the passage between New Guinea and Japan, not far from the Ladrone Islands,—was also presumably in a line of volcanic disturbance.

Again, the 'Challenger' observations enable it to be affirmed with confidence, that wherever Land shows itself * in the great Oceanic area, forming what are distinguished as "oceanic islands" from those which are merely outlying portions of continental platforms, those islands are all *volcanic*; their elevation having been due to forces acting only in limited spots or over particular lines, and not to any general uplifting of the bottom of the basin. So, on the other hand, the contours of the Deep-sea bed, so far as they have been determined, give no countenance whatever to the notion of such a general subsidence as would have produced the submergence of a great Continental platform in any part of the vast Oceanic area; and this negative conclusion receives striking confirmation (as will hereafter appear) from the entire absence, in the sediments at present in process of deposition at a distance from existing continental land, of any traces of land-degradation.

II. The progress of Geological inquiry has now made it apparent that the movements of elevation that have occurred from time to time in various parts of the Land-areas of the globe, have been the result of forces acting in two different directions—*vertical* and *horizontal*. Extensive platforms, of which European Russia affords a conspicuous example, have been several times raised into land (with alternations of depression) by a force that seems to have operated *directly upward*; and with such uniformity over a vast area, as to have produced very

* As in all the Coral islands in which basal rock shows itself, that rock is Volcanic, the same may fairly be presumed to be the character of the submerged peaks on which those "atolls" rest, above whose level platforms no rocky base now rises.

little change in the relative levels of its different parts. These alternations of depression and elevation have all been apparently of very moderate vertical amount. Over the vast area of Russia, we find, as a rule, that the sediments which have been successively deposited upon it exhibit a most regular stratification, and have undergone little or no metamorphic change; Silurian clay-slates being represented by hardened clay; and Carboniferous limestone showing itself as an aggregate of compacted (foraminiferal) *Fusulinæ*.

On the other hand, a force acting *horizontally* against the margin of a previously level area, will throw it into plications, of which the elevated portions will form mountain-ranges. The strata forming these ranges, which show by their contorted condition the enormous lateral thrust to which they have been subjected, always exhibit more or less of metamorphic change; and this metamorphism is now generally regarded as the effect of heat, acting in conjunction with moisture, and usually under pressure.* The source of this heat is to be found in the very mechanical energy which effects the plication; resistance to which, as in ordinary friction and compression, will cause it to take that converted form. This plicating process acts along definite lines and bands, the width of which is usually small in proportion to the vast area of the wide continental platforms; and thus it happens that notwithstanding the enormous height to which the most elevated peaks may be lifted (Mount Everest 29,000 feet), little is added by Mountain-making to the *average* level of any great continent. But, again, the operation of this lateral thrust is now generally recognized, not merely in the elevation of mountain-ranges, but also in Volcanic action; the fusion of the compressed rocks being, in fact, only a further stage of metamorphism, and being fairly attributable, like it, to the production of heat by the conversion of mechanical force.

III. The recent progress of Physical Astronomy, again—mainly through the application of the Spectroscope to the study of the physical and chemical conditions of celestial bodies in various stages of aggregation—seems now to have placed it beyond reasonable doubt that the earth has cooled down from the state of a molten mass; and the probable effect of the progressive cooling and shrinkage of its interior, upon the conformation of the crust which first solidified around it, have been very carefully worked out by Professor Dana;† an outline

* Professor Hull, the able Superintendent of the Geological Survey of Ireland, has shown that in the level tract of Carboniferous Limestone which there forms a great central plateau, the organic origin of the limestone is very distinct; whilst in these upheaved and contorted strata of the same rock which form the elevated borders of that plateau, the organic origin of the limestone is completely obscured by metamorphic change, which has given it a sub-crystalline texture.

† See the chapters on "Dynamical Geology," in the Second Edition of his 'Manual of Geology' (1875): and, for a fuller exposition of his views, his Memoir in the 'American Journal of Science,' June to September, 1873.

of whose theoretical views will show how entirely they harmonize with the conclusions drawn from inquiry into the present conditions of the great Oceanic areas:—"As the globe has cooled from fusion, it has been all through time a contracting globe; and this contraction of the crust has been the chief agency in determining the evolution of the earth's surface-features, and the successive phases in its long history." "The crust which should form over a melted sphere, as it cooled, would have the size the sphere had at the time. As it thickened downwards by the continued cooling, the added portions would contract; and this would occasion lateral pressure through the crust, which would increase as the cooling and thickening continued." Reasons are adduced by Professor Dana for the belief that the formation of the solid crust would not go on at the same rate all over the sphere; but that some portions of the surface would solidify into a layer several miles in thickness, whilst over other large areas the surface would still be liquid or in a state of only incipient solidification. The level of the latter would be gradually lowered by the contraction of the cooling mass beneath; and the crust of these depressed areas would constitute the Ocean-floors, whilst the elevated areas, rising by abrupt sides from their borders, would remain as Continental plateaux. The study of the geological structure of the North American continent leads Professor Dana to the conclusion that "in its very inception, not only was its general topography foreshadowed, but its great mountain-chains appear to have been begun, and its great intermediate basins to have been defined. The evolution of the grand structure-lines of the continent was thus early commenced, and the system thus initiated was the system to the end. Here is one strong reason for concluding that the continents have always been continents; that while portions may have at times been submerged some thousands of feet, *the Continents have never changed places with the Oceans.*"

The progressive shrinkage of the internal mass, as its cooling proceeds, must produce a falling inwards of the crust formed around it; and the lateral pressure thus exerted through the whole crust will necessitate a yielding somewhere. The *lateral thrust* is likely to be exerted most advantageously from the floors of the depressed Oceanic areas against the sides of the elevated Continental plateaux; and this is borne out by the fact that "the continents have mountains along their borders, while the interior is generally low"; and that "the volcanoes of the continental areas are mostly confined to the sea-borders." Further, "the largest and loftiest mountain-chains, greatest volcanoes, and other results of uplifting and disruptive force, characterize the borders of the *greatest* oceans, showing that the lateral pressure from the direction of the oceans was approximately proportional to the extent of the oceanic basins." Thus, in North America the lofty and massive Alleghanies are raised up on the Pacific side; the minor Appalachian chain on the Atlantic. In South America, the great chain of the Andes, with its lofty volcanoes, is in like contrast with the comparatively insignificant mountains of Brazil. So, on the Euro-

pean side of the Atlantic, the mountains which border the Oceanic basin correspond in scale with those on its western border, rather than with those on the Pacific slope of the American continent. On the western side of the Pacific, on the other hand, the Malayan Archipelago constitutes (as already pointed out) a region of extraordinary volcanic activity; and this is probably the greater on account of the comparative narrowness of this continental plateau, so that it is subject to the lateral thrust of the sea-bed of the Indian Ocean in addition.

But the lateral thrust exerted by these floors, being resisted by the buttresses presented by the continental plateaux, will tend to produce an upward bulging of these floors themselves, especially in their median portion. And this, again, corresponds with fact; such an upward bulging showing itself in the median portion of the bed of the Atlantic, both north and south; while the force which raised this, also manifests itself in the volcanic action which has pushed up the Azores and Tristan d'Acunha in corresponding positions. So, in the North Pacific, we have the remarkable volcanic Hawaian group, occupying the same relative position as the Azores in the North Atlantic; while over the still wider expanse of the South Pacific, there seem to be several of these upward bulgings, that have exploded (so to speak), here and there, in local volcanic action.

I must not follow Professor Dana's masterly hypothesis into further detail, but must content myself with noticing one point which seems to me of singular interest—namely, the explanation he gives of the depression of portions of what he regards as the original continental platforms, over which long series of sedimentary deposits have been formed, of course implying a subsidence of their base to an amount at least equal to their total thickness. The first step in ordinary mountain-making by lateral thrust, is affirmed by Professor Dana to be a *downward* bend of the crust, or "geosynclinal." "In the making of the Appalachians, there was first, under the lateral pressure, a slowly progressing subsidence; it began in, or before, the Primordial period, the commencing era of the Silurian, and continued in progress until the Carboniferous age closed. As the trough deepened, deposits of sediment, and sometimes of limestone, were made, that kept the surface of the region near the water-level; and when the trough reached its maximum, there were 40,000 feet of thickness of stratified rock in it, and this, therefore, was the depth of the trough. The Green Mountains began in a similar subsidence, and at the same time; and the trough was kept full with deposits as it progressed. Such facts are in the history of many, if not all mountains."

The foregoing arguments may be thus combined:—

A. The enormous depth of the Oceanic sea-bed, as compared with the height of the Land above the sea-level, renders it very unlikely that any subsidence of a Land-area should be compensated by such an uplifting of a portion of the Ocean-floor as would raise it above that level. Thus, supposing that all the Land of the globe were to sink down to the

sea-level, such subsidence would be balanced (according to the current idea of compensatory alternation) by an elevation up to that level of a portion of the average Ocean-floor, amounting to no more than 1–36th of its existing area. On the other hand, the sinking of such an area as that of Papuo-Australia (which forms about 1–17th of the existing land-surface) to the depth of the average *Ocean-floor*, would require to balance it an elevation of the whole remainder (13–14ths) of the existing Land to *double* its present average height above the sea-level.

B. Wherever the uniform elevation of an extensive Land-area indicates its upheaval by a force acting *vertically* throughout, the amount of such elevation seems to have been very limited,—no such level area showing itself at any considerable height above the sea. Conversely, there is no adequate reason to believe that any extensive area has ever uniformly subsided beneath the sea-level, to any greater depth than that at which lie the submerged portions of some existing Continental platforms.

C. On the other hand, all *great* elevations, whether rising from Continental platforms or from the Oceanic sea-bed, are clearly attributable to *lateral* thrust; and such are everywhere of very limited extent, forming mountain-chains or high table-lands in Continents, and volcanic islands in the Oceanic area,—in neither case having the least resemblance to continental plateaux. And, conversely, the very deep depressions in which long series of stratified deposits have accumulated, only occur as consequences of the lateral thrust which produces plication, and which elevates mountain-ranges as part of the same operation. Local subsidences of this kind, therefore, give no support to the idea of such vast *general* subsidences, as would be required to create a deep Oceanic depression over any area now occupied by a Continental platform.—Inland seas, in fact, may be regarded as troughs of this kind, which have been formed in regions of extraordinary disturbance, in which the troughs have been formed more rapidly than they can be filled by the accumulation of sediment from the elevations of which they are the complements. The largest of them (the Mediterranean and Central American) may possibly have been *original* breaks in their Continental platforms.

Thus, then, all our knowledge of the existing relations between Continental plateaux and Ocean-basins, and of the forces by which those relations might probably be disturbed, points distinctly to the inference that these relations have never been very different from what they are now. And the entire conformity of the results of this reasoning from the present to the past, with those of Professor Dana's reasoning in the contrary direction from the primal assumption (which no man of science would now call in question) of the Earth's original fluidity, affords strong confirmation of its validity.

I am far from affirming that considerable *local* changes may not have occurred in past epochs, which may have had very important

effects upon the distribution of Plants and Animals; so that, on the one hand, Land-continuity has been established where there was formerly a complete interruption; whilst on the other, continents now for the most part separated by Oceanic areas, or islands cut off from neighbouring continents by deep channels, may have been at one time in continuous connection. My contention is that such connections have been formed by the elevation of mountain ridges (terrestrial or submarine) by lateral thrust; and not by the vertical elevation of a great area of sea-bottom into a continental plateau. Thus, there appears to be valid evidence that the surface-connection between North and South America is comparatively modern; a communication between the Atlantic and Pacific basins having formerly existed where now interrupted by the Isthmus of Darien, the elevation of which probably does not date back further than the early Tertiary period. So, in the North Atlantic, the extension of the European platform to the west of the Shetland Islands, the existence of a ridge at only about 200 fathoms' depth beneath the surface between the Faroes and Iceland, and of another ridge at a greater depth between Iceland and Greenland, renders it not unlikely that at some former period Europe and North America may have had a band of connection along this line. On the other hand, the knowledge we now possess of the configuration of the more southerly part of that Oceanic area, seems to preclude the probability of the former extension of a great continental platform (the hypothetical Atlantis) between Europe and America in the parallel of the Azores. So, as it seems to me, the remarkable relations pointed out by Sir J. D. Hooker between the Floras of New Zealand, Tasmania, and South America, may be accounted for by connecting ridges raised by lateral thrust, without supposing the existence of a vast Antarctic continent now deeply submerged.* And the former connection of Madagascar with the African continent, distinctly indicated by the distribution of animal and vegetable life on the western portion of the island, might easily have been established by an elevation of the bottom of the Mozambique Channel by lateral thrust. There are even indications, in the groups of volcanic islets lying to the north-east of Madagascar, that this great island may have been once in connection through them with the Asiatic continent.

Such limited and local changes, I again repeat, are perfectly consistent with the doctrine of general permanence. And I have now, in conclusion, to show how remarkably this doctrine is confirmed by comparison of the deposits ascertained by the 'Challenger' soundings to be now going on upon the real Ocean-floors, with those in process of formation on the shallow bottoms near land.

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* We still know too little about the configuration of the Sea-bed of the great Southern Ocean, to enable any definite opinion to be at present formed on this point. All that can be said is, that no physical evidence of the former existence of such a connecting continent has as yet been obtained.

IV. The examination which Mr. Murray has made of the samples of the Oceanic deposits brought up by the 'Challenger' soundings and dredgings, affords conclusive evidence, that the floor of the real Oceanic area, unless in the near neighbourhood of the Continental platforms, is not, and never has been, covered with sediments formed by the degradation of the existing land; such sediments being deposited only on the shallow bottoms not far from shore, which (as already pointed out) may be considered as in reality submerged portions of those very platforms, and as not belonging to the true Oceanic area. With the exception of certain patches of clay, which there is strong evidence for regarding as a product of the decomposition of pumice ejected from volcanic vents, all the sediments now in process of deposition on the Oceanic sea-bed are of *organic* origin: a *calcareous* ooze, resembling chalk, being produced by the decomposition of the continually accumulating shells of Foraminifera; and a *siliceous* ooze being formed by the like accumulation of the skeletons of Radiolarians in the warmer zones, and the loricæ of Diatoms in the colder. Although volcanic sand was of course met with over the volcanic areas, *ordinary siliceous sand*, resembling that of our own shores and shallow bottoms, *has nowhere been detected on the deep-sea bottom*. And thus, if this bottom were to be raised into dry land, it would be found entirely destitute of those inorganic sedimentary deposits, which constitute by far the larger part of the succession of stratified formations with which geological inquiry has made us familiar. I can best make obvious to you the full significance of this fact,—which, as Professor Geikie has recently remarked, is of the profoundest interest for geologists and geographers,—by citing the views of that eminent geologist as to the mode of formation of the long succession of stratified rocks, which originated in the deposit of sediments formed by the degradation of pre-existing land. "Among the thickest masses of sedimentary rock—those of the ancient Palæozoic systems—no features recur more continually than the alternations of different sediments, and the recurrence of surfaces covered with well-preserved ripple-marks, trails and burrows of annelids, and polygonal and irregular desiccation-marks like the cracks at the bottom of a sun-dried muddy pool. These phenomena unequivocally point to shallow and even littoral waters. They occur from bottom to top of formations which reach a thickness of several thousand feet. They can be interpreted only in one way, viz. that the formations in question began to be laid down in shallow waters; that during their formation the area of deposit gradually subsided for thousands of feet; yet that the rate of accumulation of sediment kept pace on the whole with this depression; and hence, that the original shallow-water characters of the deposits remained, even after the original sea-bottom had been buried under a vast mass of sedimentary matters." The same he holds to be true of the relatively thin and much more varied formations of later date. So it is evident that the materials of these sedimentary rocks must have been deposited in near proximity to the land by

the degradation of which they were produced. "From the earliest geological times the great area of deposit has been, as it still is, the marginal belt of sea-floor skirting the land." This double process of degradation of old land, and deposit of materials for the new, "belongs to the terrestrial and shallow oceanic parts of the earth's surface, and not to the deep and wide oceanic basins." The 'Challenger' explorations have now furnished absolute proof, that the deposits now in progress on the floors of the ocean-basins have no real analogy among the past sedimentary formations which geological inquiry brings into view. "We now know by actual inspection, that the ordinary sediment washed off the land sinks to the sea-bottom before it reaches the deeper abysses; and that, as a rule, only the finer particles are carried more than a few score of miles from the shore." On the abyssal depths the sedimentary deposit gathers so slowly, that the particles of meteoric iron—the star-dust which falls from outer space—form an appreciable part of it.

"From all this evidence," continues Professor Geikie, "we may legitimately conclude that the present land of the globe, though consisting in great measure of marine formations, has never lain under the deep sea; but that *its site must always have been near land.*" "The present Continental ridges have probably always existed in some form; and as a corollary we may infer that the present deep Ocean-basins likewise date from the remotest geological antiquity."*

It is now nearly eleven years ago, that I first ventured in this place to break ground in regard to a subject, for the discussion of which my previous pursuits might have been thought to give me no special qualification. I then made known the conclusion which had been arrived at by my colleague Professor Wyville Thomson and myself, that no essential change had taken place in the great basin of the North Atlantic since the elevation of the Chalk of Europe and America into dry land; and that the globigerina-ooze now accumulating on its bottom is not a *new* chalk-formation, but a continuation of the *old*, which has there gone on uninterruptedly through the whole of that Tertiary period, during which a long succession of varied formations has been in progress of deposit round the margins of the continental lands. But I somewhat incautiously adopted the expression of my friend, "that we might be said to be still living in the Cretaceous epoch." This brought down a storm of geological indignation on our heads. We were accused by one of our very highest authorities, of attempting to disturb the well-established doctrines of geological succession; and were represented by another as showing a complete ignorance of what a geological "epoch" really meant. When, however, we explained that all we contended for was the persistence of a deep Ocean-basin in the Atlantic area, and the

* Lecture on 'Geographical Evolution,' delivered before the Royal Geographical Society, March 24, 1879.

continued formation of globigerina-ooze on its bottom, from the Cretaceous epoch, through the whole Tertiary period, down to the present time, our accusers began to think our doctrine worthy of consideration; and not many years elapsed, before it came to be generally accepted as (to say the least) not improbable. The progress of Deep-sea research, and my own further reflection on the vast disproportion between the mass of the Land above the sea-level and the volume of the Water beneath it, made me think it probable that this view would bear extension to all the great Ocean-basins.* When I found it advocated, on quite other grounds, by a geologist so distinguished for his combination of vast practical knowledge with profound theoretical ability, as Professor Dana, I naturally felt increased confidence in it. And now that Professor Geikie has formally pronounced it to be in his judgment the only one that is consistent, on the one hand, with the facts revealed by geological inquiry as to the conditions under which the past sedimentary deposits were formed, and on the other with the facts determined by the 'Challenger' observations as everywhere presenting themselves over the real Oceanic sea-bed, I venture to present it to you with some degree of assurance, as a doctrine which is likely to take rank as one of the fundamental verities of Geological Science.

[W. B. C.]

* See the article *Atlantic* in vol. iii. of the ninth edition of the 'Encyclopædia Britannica.'

WEEKLY EVENING MEETING,

Friday, January 30, 1880.

WILLIAM SPOTTISWOODE, Esq. M.A. D.C.L. LL.D. Pres. R.S. Vice-President, in the Chair.

JOHN MARSHALL, Esq. F.R.S. &c.

Proportions of the Human Figure.

(Abstract deferred.)