II.

Are Great Ocean Depths Permanent?

It has been suggested by the editor that English readers would like to hear my views on that much-debated question, the Permanence of Ocean Basins. I am rather at a loss how to deal with the subject, because this question involves so many difficult chapters in the history of our planet, and because I regret to see that discrepancy of views exists on fundamental principles.

Mr. Wallace begins by arguing from the principle that "on any large scale, elevation and subsidence must nearly balance each other, and thus, in order that any area of continental magnitude should rise from the ocean floor, ... some corresponding area must sink to a like amount." I venture with deference to reply that I cannot agree to this. It seems, on the contrary, as if two different types of movement had been going on since the first formation of the terrestrial crust. In the first place, there is folding, recently explained in a masterly way by Professor Lapworth, in his Address to the British Association. Secondly, there is the sagging-down or "effondrement" of smaller or greater parts of the crust, caused by the progressive diminution of the planet's radius. *This descent of parts of the earth's crust seems to be the true origin of the great oceanic basins.*

Sometimes the contour of the sunken area follows the trend of a folded mountain chain; at another time it may cut right across it. In smaller examples the outline very often takes a more or less irregularly circular or elliptical form. The descent of a considerable area, forming a large new depression, demands a certain part of the existing volume of oceanic waters for the filling of the new depth. The consequence is the sinking of the oceanic surface all over the planet, and the *apparent step-like rising of coast lines.* Thus is explained the apparently episodic elevation of whole continents, without any disturbance of horizontality, or the least alteration of the net of watercourses spread over the land. It is in this sense alone that a certain balance of "elevation" and "subsidence" might be conceded.

In the entire Pacific region the limits of the oceanic basin are traced out by the trend of long mountain folds. So it is from New Zealand and New Caledonia to the borders of Eastern Asia, to the Aleutians, and all along the western coast of both Americas. This is not the case in the Atlantic, nor in the Indian Ocean; here the coasts are not outlined by folded structure, except in the arch of the Lesser Antilles, and in the corresponding short arch passing through Gibraltar, which serves to connect the mountains of north-western Africa with those of the south of Spain. These are what we may call the Pacific and the Atlantic types of oceanic regions.

Indian geologists have shown how the immense Asiatic mountain waves, moving southwards against the Peninsula, have been dammed back by the resistent Peninsular mass, the Korána Hills, and the wedge-shaped mass of Assam; so that they actually form distinct arches, separated by deep angles receding to the neighbourhood of Tank, north of Dera Ismail Khan, to the Upper Jhelum and Brahmaputra Valley. In this case we call the Peninsula the "Vorland."

Now cast a look on the map of the North Pacific, and compare the receding angles which mark the western and the eastern ends of the Aleutian arch, where it abuts against Kamschatka and North-West America. You will remark that this part of the Pacific is a "vorland," and homologous to the Indian Peninsula, whilst the Yellow Sea, Behring Sea, and others lie within the folded region. You may also examine the Mediterranean, and observe that the western half lies wholly within a curved and folded mountain chain (Apennines, Sicily, North Atlas, Gibraltar, Andalusian Cordillera), and that in the eastern half all the part south of Crete and Cyprus and east of Sicily lies on the African "vorland," and the rest on the sunken parts of the Tauro-Dinaric arch.

In the Atlantic region the mountain folds, as a rule, break off against the ocean (*e.g.*, Brittany coast, Devon and Cornwall, south-west Ireland), or else have their folds facing away from the ocean, as in the case of the Alleghanies, and all other folded zones on the eastern side of North America as far as Newfoundland. The folds disappearing in south-west Ireland and in Brittany so very much resemble those rising from beneath the Atlantic on the coasts of Nova Scotia and New Brunswick, that M. Marcel Bertrand has ventured to publish a sketch-map, showing these chains trending right across the Atlantic.

There exists a curious tendency for a depression or a sort of valley to form in front of the great folds facing the "vorland." For instance, the depressions of the African desert in front of eastern Atlas, the river valleys in front of the high Indian chains, and the Persian Gulf in front of the Zagros chains. Quite recently the Austrian exploring ship "Pola" found a depth of 4,400 metres near the south-west coast of Greece, near the front of the Dinaric arch; and some of the greatest oceanic depths show exactly the same position in front of the arches of Japan, the Kuriles, and the Aleutians with Alaska. This is the homology, for example, between the Ganges valley and the Tuscarora depth, both marking the limit of the folded ranges and the "vorland."

The structure of the earth's crust does not, therefore, tell us that the great depths must be very old or permanent; so let us compare the character of the sediments near the existing coasts.

The Old Red Sandstone is an extra-marine formation; yet the Old Red Sandstone runs out into the sea in the Orkneys, reappears in the Shetlands, and the same palæontological and extra-marine character is known in Spitzbergen. Old Red exists on the north coast of Lapland, and on the White Sea. The plant-bearing beds of the Karoo run out to sea in British Kaffraria; they are repeated in India and Australia. The fresh-water beds of the Wealden pass over from England to the Continent; they not only reappear in Hanover, they run out into the Atlantic in the lower Charente, and on the coasts of Spain and Portugal. Why must the continent which formerly bounded all these vast fresh-water basins have been limited within the existing 1,000- or 1,500- or 2,000- fathom line? The breaking down of the bed of the Ægean Sea, described by Spratt and Neumayr, is of Post-pliocene date, for Pliocene fresh-water deposits form parts of the coast; and yet the depths go far beyond 1,000 fathoms. In 1892 the "Pola" measured 3,591 metres in lat. 35° 52 36″, long. 29° 1′ 24″ E., quite near the south-west coast of Asia Minor, and close to the mighty Ak Dagh (10,000 feet); and this although the separation of the neighbouring island of Rhodes is so recent, that not only do the Pliocene fresh-water beds pass over from the Continent, but according to Bukowski also considerable masses of Middle Pliocene fluviatile conglomerates, originating in Asia Minor, have been deposited by a great river on this island.

Now suppose the existing quantity of oceanic water to decrease, say by evaporation into the ether, as Zöllner once thought, or in any other way; we might by this gradual diminution of the entire quantity attain a beach-line 500 fathoms below the present shores. The continents would appear so much higher, and dry land would extend. Plains would successively appear, more or less similar to Holland, and our present rivers Shannon, Seine, Loire, &c., would flow through these plains. In most cases the rivers would be caused to cut back their valleys, new transverse and parallel lines of erosion would appear, and the plain would be diversified into hills and valleys. The hills south of the Shannon would probably show the rest of those anticlines and synclines which dip below the ocean in south-west Ireland, and we should be able to see a greater part of the northern Armorican arch. The Scilly Islands would appear as another granitic laccolite within the continued Armorican region of Cornwall. The gneiss of Eddystone would come up within this northern Armorican arch, exactly as the gneisses of the Alps stand up within and behind the folded arches. In a similar way, in the south, the anticlines and synclines of French Armorica, which disappear north and south of Brest, would begin to be visible; but in the north-west of Ireland we should see a plateau, ending in a steep cliff, the abrupt boundary of a deep channel, separating the great island of Rockall from the European continent. And all this varied new-born land would be green and full of life, and people would not be at all willing to believe that it ever was not so.

Then we would descend to the new shore, and one of our great masters would tell us that ocean depths are permanent, that is to say, from 1,500 fathoms downward, or from 2,000 fathoms. The general impression resulting from the study would be the same as now, but the assumed permanent level would be reduced by 500 fathoms.

We might invite our master to undertake an excursion with us; we would go to Scotland. An isthmus, some 1,200 feet high at the narrowest part—Sir Wyville Thomson's ridge—would lead us first to some isolated peaks, nearly 3,000 feet high, and over a rising country to the high peaks of the Faröes. We would observe land-born coal-beds between the great coulées of basalt. Proceeding further, we would travel to the north-west, over a broad tract of rocky land some 1,200 or 1,300 feet high; then first meet an isolated mountain of about 1,800 feet, and from there ascend to the volcanic mass of Iceland, where we should see those vast fields of lava, dotted with active volcanoes, and observe the long faults and open rents cutting through the masses of lava and trending across Iceland in a broad arch, first from south-west to north-east, then northward, beyond the volcano Askja to Husavik; and beyond this broken and breaking zone we might gain the great "effondrement" or "Kesselbruch" of Faxafjord, beset all round by volcanoes and hot springs, from Snaefells Jokull to Reykjavik. In following the rents so well described by our indefatigable Thoroddsen, we might detect faulted plant-bearing beds, and recognise the equivalents of the Faröe coal-seams. If some younger and more impressible student be in our company he might well exclaim, in face of these plant-bearing beds, stretching on to Greenland and showing the existence of a vast dry land in late times, and in face of these rents and volcanoes: "Verily, Professor, the sagging-down of the North Atlantic is the most recent event; it is going on before our eyes; and as the highest mountain chains are the youngest, so also are the deepest parts of the planet the most recent." I fear I should not know how else to answer the student than, "Really, I do not know."

Now let us quit the coasts and examine the interior of a great continent.

Modern geology permits us to follow the first outlines of the history of a great ocean which once stretched across part of Eurasia. The folded and crumpled deposits of this ocean stand forth to heaven in Thibet, Himalaya, and the Alps. This ocean we designate by the name "Tethys," after the sister and consort of Oceanus. The latest successor of the Tethyan Sea is the present Mediterranean.

I asked Dr. Diener, recently returned from India, to give me his estimate of the thickness of the deposits in the Silakank region. Dr. Diener answers: From Dhauli-Ganga Valley, between Gweldung and Pethathali encamping ground above Silakank (19,265 English feet), to Sirkia River in Hundes; a complete section from (Cambrian?) Haimantas to the Gieumal Sandstone (Cretaceous), without a great discordance, gives, according to Dr. Griesbach:—

Haimantas	3,000—4,000 feet.
Lower Silurian	200 "
Upper Silurian	1,100 "
Devonian..	700 "
Carboniferous	1,200—1,400 "
Permian and Trias	3,600—3,900 "
Lias and Spiti Shales	1,400? "
Gieumal Sandstone	1,200—1,500 "
	12,400—14,200 feet.

The determination of the thickness of the Spiti Shales and Gieumal Sandstone is difficult, because these less-resistent beds are crumpled into local folds.

A parallel section across the Kurkutidhár range (Chor Hoti, about 18,000 feet), Shalshal encamping ground and Shalshal Pass (16,390 feet) to Hundes gives, without the Haimantas:—

Silurian	1,200—1,400 feet.
Devonian and Carboniferous	1,800—2,300 "
Permian and Lower Trias	200 "
Middle Trias	100 "
Upper Trias to Dachstein Limestone ..	1,400 "
Dachstein Limestone, Rhætic and Lias ..	2,200 "
Spiti Shales	1,000? "
Gieumal Sandstone	1,500? "
	9,400—10,100 feet.

These figures show that a great and deep ocean has been incorporated into the continent, and that the deposits of this ocean form part of the highest mountain ranges.

It may be remarked that within the eastern Alps Mesozoic limestones of different ages contain deep-water radiolarian chert. But the great and well-bedded masses of white Rhætic limestones of Austria betray distinct proofs of a continuous rising of the shore-line. It is also true that certain bright red enclosures within these white limestones seem clearly not to be red deep-sea clay, but true *terra rossa*, formed by atmospheric decomposition of the limestone; so that these beds must have formed reefs in the ocean. Therefore it is at present difficult to say whether in the Alps the Tethyan Ocean did at any time attain the total depth of, say, 2,000 fathoms; or whether deposits followed so rapidly and depression was so continuous that this was not the case.

The later Tethyan history, the recapitulation of the vicissitudes which led to the formation of the existing Mediterranean, forms certainly one of the most attractive chapters of historical geography. Marine deposits of Mediterranean type (Erste Mediterranstufe, Miocène inférieur) enter the Rhone Valley, surround the present site of the Alps, and continue far away to the East, to Persia, and have been met with by Griesbach near Balk, on the Oxus. Then these deposits were folded, in the Taurus, in Asia Minor, in Switzerland. Afterwards came the sagging-down of certain parts of these folds, near Vienna, in Hungary, &c., and all that varied series of consequent events. After the first Mediterranean came the formation of an immense horizon of salt deposits, stretching from Wieliczka to Persia ; then a second Mediterranean reaching far into the newly-formed depressions ; then the appearance of vast fresh-water lakes, lasting through a long period of time till the breaking down of the Ægean land and the re-conquest of the Black Sea.

Look at smaller examples of such partial subsidences ; see Margerie's instructive paper on the Corbières, showing the sinking down of the Pyrenees, Miocene beds passing beyond Narbonne, while south of Cape Leucate two more recent Pliocene "effondrements" form the Rousillon, described by Depéret, and the Golfe de Rosas.

But this is only part of the Tethyan history. Michelin's and Duncan's palæontological studies in the West Indies have revealed the European character of certain deposits. It is the "Gosau type" of the Cretaceous which appears in Jamaica, and the Castel-Gomberto horizon of Upper Oligocene (warm type of Sables de Fontainebleau) is known in several other isles. In regions still further off, one of our first masters, the venerable Dr. Philippi, has shown that the present molluscan fauna of the Chilian coasts is of quite recent origin, and that until the beginning of Quaternary times the European Mediterranean molluscan types stretched far down the western coast of South America. At the same time the Mesozoic deposits of Chili, and those recently discovered at Taylorville in California,[1] show purely European characters, and the Neocomian of Bogotá is the exact equivalent of that of Barrême.

These facts teach us that an ocean-bed existed, but that some coast-line, maybe only an interrupted line, once stretched across the present Atlantic, and permitted the Gosavian and Oligocene corals, and the Miocene shells also, to cross. I do not overlook the fact that Dr. Philippi himself, struck by the analogies existing between the flora of Chili and that of Europe, recently refused to accept the hypothesis of a "bridge" to Europe, and preferred to suppose that identical climatic and other external causes produced analogous and even identical species of terrestrial plants. I refer to what has been excellently said by Mr. Blanford on this theory, a few years ago, in his address to the Geological Society of London. I believe that the parallel correspondence of the marine faunas up to the Quaternary period gives a more correct clue to the correspondence of the existing terrestrial floras in Chili and in Europe.

So I think that we must not only concede the extinction of a great

[1] See Hyatt and Dillen on the Jura and Trias at Taylorville, California. *Bull. Geol. Soc. America*, 1892, pp. 369—412.

Palæozoic, Mesozoic, and Tertiary ocean in south-western Eurasia, but admit also great recent changes in the middle or southern Atlantic. Geological evidence, therefore, does not prove, nor even point to, a permanence of the great depths, at least in the oceans of the Atlantic type.

Let me remark in a few words that, although I believe in the possibility of the formation of large new depressions, I do not hold with the old opinion, lately taken up again by M. Faye, that the continued sinking of the ocean beds may force chains of mountains to appear all round. This view could only be propounded for the Pacific basin; but the Pacific chains are folded in the direction *towards* the ocean, and not *from* the ocean. They are easily divided into arches, each of which presents the *convex* side to the ocean, so that the Pacific everywhere presents the character of a "vorland."

Let me, at the end of this long note, allude to a broad biological fact. In the higher beings we see *lungs* always preceded by gills; so it is even with the human child. The adaptation for breathing our atmosphere is of a later date; and we conclude that the whole terrestrial air-breathing fauna is a *derived* fauna, derived from amphibious forms quitting shallow water. This fact evidently points to a long existence of dry land, long enough to permit this accommodation to be effected; the accommodation clearly has been going on since Palæozoic times. Still there exists no proof that individual continents always remained the same, and we even know for certain that such was not the case with by far the greater part of these continents.

A similar lesson is also taught by the *eyes* in all the higher organised beings of the deep sea. The optical apparatus of abyssal species is profoundly modified by the exceptional environment, while the normal types of eyes are met with in the same genera within moderate depths. Therefore, we must also regard these deep-sea forms as *derived* forms. The blind and blinded Trilobites of Cambrian beds, the blind Trinuclei and the widely-expanded eyes in certain species of Aeglina in Lower Silurian strata teach the same lesson. At the same time, they show that deep-water must have existed over Bohemia, and over a good many other Palæozoic tracts, and that the depths were considerable enough to call forth these same abyssal metamorphoses of the eye.

We might, therefore, rather be induced to infer that in Prepalæozoic times there may have existed a universal hydrosphere or panthalassa covering the whole of the planet. Only with the first appearance of dry land began the deposition of clastic sediments. The higher forms of life may have been developed in waters of moderate depth and may successively have spread to the sun-lit continents, and to the dark depths, while the slow elaboration of the existing inequalities of the terrestrial surface was going on.

But this elaboration is still in progress. I believe with Reyer, Fisher, Jukes, and many others that the great depths are mostly covered with volcanic products, with lava and ashes forming immense plains and overlain eventually by the deposits of the abyss; but I see no reason why parts of the ocean or even of the dry land may not to-morrow sink to form new depths, or why we should believe that all the great ocean basins have been continuously covered by water since panthalassic times. So far as the Atlantic is concerned, there even exists some evidence to the contrary.

But all this is unripe fruit. Our scholars will some day know more than their masters do now; so let us patiently continue our work and remain friends.

EDW. SUESS.