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Source: *The Geographical Journal*, Vol. 40, No. 3 (Sep., 1912), pp. 294-299

Published by: geographicalj

Stable URL: <http://www.jstor.org/stable/1778946>

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THE ATLANTIC AND PACIFIC TYPES OF COAST.

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PROF. J. W. Gregory has recently* drawn attention to apparent contradictions in Prof. Suess' definitions of the two main types of coast exhibited on the globe, and the result of his inquiry is that, according to him, the original definitions should be modified. Taking the coast-lines of the world one by one and examining their history and position, it would appear that Prof. Suess' definitions explain so much and are so illuminating that it seems a pity to discredit them by bringing to bear on the question, which is one of broad outline, details which confuse the issue. According to Prof. Suess, the Atlantic is bordered by folded mountain chains which run out to sea and are cut off by the coast-line; the Pacific by folded mountain chains which run parallel to the coast-line. In addition, the folds of the Atlantic expose their backs to the ocean, and those of the Pacific their fronts; in other words, if the range is composed of Archæan, Palæozoic, and Mesozoic strata, the old Archæan base is exposed on the Atlantic side and the youngest strata on the Pacific side. A good example of this latter fact is represented by New Zealand and South Africa. In South island in New Zealand the folded ranges come from the north-east and meet on the south-west in a knot or *Schaarung* with the folds which come from the south-east. In the embrace of the folds lies a plateau of Mesozoic strata corresponding to the Karroo beds of South Africa, whereas on the side of the island facing the mainland—that is, Australia—the Archæan base is exposed. In South Africa the exact reverse is represented; the Karroo beds lying in the angle of the *Schaarung* are inland, and the Archæan base of the coastal mountains faces the open ocean.

There is, however, water between New Zealand and Australia; that is, the true continental border of the western side of the Pacific is partly

* “The Structural and Petrographic Classifications of Coast-Types,” *Scientia* vol. 11, 1912.

drowned and separated from the adjoining land. It is the purpose of this paper to show that the western borders of both the Pacific and Atlantic are drowned, whereas the eastern are elevated. The most convenient way to study the question is to take similar geographical units, such as the Mediterranean and the Caribbean seas, South Africa and South America for the Atlantic, and the Rocky mountains and the festoons of islands in front of China for the Pacific. These are described in detail in Prof. Suess' 'Antlitz der Erde,' and if it is conceded that the western sides of the oceans are drowned, then the need of a redefinition of the types of coast-lines becomes unnecessary. Why the western sides are drowned is that as the Earth continually is revolving from west to east under the sun, the attraction of this latter upon the outstanding ridges of the Earth's crust causes them in the course of ages to shift gradually from east to west, so that the eastern sides of the ocean basins are advancing and the western retreating. This secular earth-creep has not hitherto been universally recognized, as it was obscured by the theory of the permanence of ocean basins, which for a long time was accepted as a proven fact. If it be true that the Earth revolves and that matter attracts matter, then secular earth-creep must be a necessary consequence; but it is not the purpose of this paper to discuss causes, but rather to draw attention to effects.

The Mediterranean and Caribbean Seas.—The Mediterranean sea from the Gulf of Gabes to Gibraltar is bordered by the Atlas mountains; the folds turn round, pass into Spain across the Straits of Gibraltar, thence turn east-north-east in the folded ranges of Southern Spain, the Betic cordillera, through the Balearic islands to the Gulf of Genoa, thence down Italy in the Apennines and through Sicily to the Gulf of Gabes. A further portion, also between folds, is delimited by the Dinaric Alps, Mount Pindus, and the folds which thence run through Candia and Cyprus. The region between Sicily, Candia, and Cyprus and the Tripoli and Egyptian coasts lies in a sunken area of the plateau of Africa.

The Caribbean sea is surrounded by folded chains which trend from Yucatan through Cuba, Hayti, and the Lesser Antilles to Trinidad, thence westwards through the coastal ranges of Venezuela to the Lake of Maracaibo, and from here south-west to join the Andes. On the north-west, beyond Yucatan and Cuba, lies the Gulf of Mexico, which is a sunken portion of the plateau land of North America, similar in nature to the Mediterranean in the Tripoli and Egyptian areas.

The nature of the folds is of the Atlantic type in both cases—that is, Archæan on the seaboard and younger sediments inland, and, in addition, a chain of volcanic islands on the outer margin in the Archæan region. Taking the north coast of Africa as typical of the nature of the Mediterranean folds, we find gneiss and granite in the Great Kabylia, west of the Bay of Bougie, in Cape Matifon and Bouzarea, in the Bay of Algiers, at Oran and Melilla. The little islands off the coast consist of volcanic rocks, basalt, and trachyte, such as the islands Galita, Habibas, Raschgoun, and the

Zaffarin islands west of Nemours. Carboniferous rocks lie upon the gneiss in Oran ; elsewhere the stratigraphical series begins with a red Permean series. Trias, Lias, Juras, and Eocene beds follow the last, and of these the folded Atlas mountains are composed. The same arrangement is observed in the other circum-Mediterranean folds, although frequently one or more members of the series may be left out.

In the Caribbean sea, owing to the submergence of the folds, it is difficult to find a place where the sequence can be studied. In the south of Cuba, however, the Sierra Maestra shows granite in the south, where it descends steeply to the sea. Elsewhere the granite base is submerged, and only the overlying Cretaceous and Tertiary beds appear, the younger on the convex outer arc of the islands, and the older beds on the inner side. In the lesser Antilles there are three zones, the innermost entirely of volcanic origin, and including the islands Saba, St. Eustatius, St. Christopher, Nevis, Redonda, Montserrat, the inner half of Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent, the Grenadines, and Grenada. The middle zone consists of the islands of Cretaceous walls and some Tertiary beds, and includes St. Croix, Anguilla, St. Bartholomew, Antigua, the eastern part of Guadeloupe, and part of Barbados. The outermost zone consists of low islands of quite late Tertiary beds, and includes the Bahamas, Natividad, Anegada, Sombrero, Barbuda, and part of the Barbados.

Both the Caribbean and Mediterranean seas, therefore, lie within a loop of folded mountains, with a coast-line of granite in which volcanic vents are situated. Above the granite are sedimentary beds, the youngest outermost ; but whereas the Tertiary beds of this outer zone in the case of the Mediterranean stretch out over Europe and Africa, in the case of the Caribbean they are for a large part turned towards the open ocean which has swamped all but a few remnants—the Atlas, the Betic cordillera, the Apennines, and Dinaric Alps form solid mountain chains which are part of the great continents ; on the western side of the Atlantic their counterparts are represented by a chain of islands, and even then in many cases the existence of the folded chain is only indicated by the volcanoes which have piled up their cones sufficiently high to reach above the water. In the Mediterranean the chains of mountains have formerly been isolated by water, and only recently have they become joined into a continuous mass with the continents, as the deposits of late Tertiary beds at their foot indicate ; in the Caribbean sea the chains have every indication that they were not long ago continuous, but that now they are drowned, and the highest peaks alone are above water.

South Africa and South America.—The western portion of South Africa is a fractured tableland with Mesozoic folding superadded. South America is a simple fractured tableland on the eastern side. In South Africa there is the Archæan basis with granite and gneiss ; above comes the Cape Formation beginning with a great sandstone series, then slates with Devonian fossils, and above another sandstone series with Lower Carboniferous

fossils. On top are the Karroo beds with *Glossopteris*. In South America there is the same sequence; granite and Archæan rocks forming the bases of the coastal regions, then a great step composed of sandstones thousands of feet thick with intercalated shales on top with Devonian fossils, and the Santa Catharina Beds with *Glossopteris*, corresponding to the Karroo beds, lying on the Archæan as in the north of Cape Colony. The Santa Catharina Beds apparently only occur in the coastal districts of Southern Brazil; the whole region represented by the south-western portion of Cape Colony on the east of the Atlantic is foundered beneath the ocean on the west, and only a remnant appears in the Falkland islands. In these islands the typical South African sequence is found; there are Devonian rocks with fossils identical with Brazilian and South African species, Lower Carboniferous fossils in the succeeding beds, and the usual types of fossils associated with *Glossopteris* in the rocks above.

Below the Falkland islands is a loop of folded mountains similar to that which circles round the Caribbean sea. The southern portion of South America turns sharply to the east, and the continuation of the folds is found in South Georgia, thence it sweeps round through the Sandwich group, back through the South Orkneys, to Graham Land. The southern border of the Karroo rocks in South Africa was some distance south of the present coast-line, and it was formed by a prolongation of the Madagascar ridge, but there is nothing above sea-level to the south of South Africa now to enable one to reconstruct the nature of this lost land; at any rate, there does not appear to have been much relief in the old land-surface, and hence there were not sufficient outstanding ridges for the attraction of the sun to act upon. In the Northern Atlantic, again, there is so much land that differential movement, due to ridges following the sun, would be small; as a matter of fact the vigorous forward movement of the Mediterranean area, and the backward one of the Caribbean area, seems to have resulted in a back wash in the North Atlantic, for in the two similar geographical units, the Hudson bay area and the Baltic area, it is the Baltic area that is drowned and the Hudson bay area which lies deep in the land. Scandinavia is now rising, and the anomaly appears to be in the process of disappearing. Secular earth creep, as a rule, would only be noticeable where a marked ridge like Africa or America runs longitudinally across the globe.

The Northern Pacific.—The Northern Pacific is bordered by the straight coast-line of North America on the east and by festoons of islands on the west. The eastern border begins with the Rocky mountains which bound the prairies on the west. Then westwards there are the plateaux of Utah and Colorado, forming a sort of gigantic gridiron of elevated strips with steep fault-valleys between, then the Sierra Nevada, and finally the coast ranges of California; all these are connected and form part of the mainland. On the western side of the Pacific the coastal ranges are sub-merged and are represented by the Loo-Choo, Japan, and the Kurile

islands with Kamchatka. The actual border of the mainland is composed of an inner chain corresponding to the Rocky mountains on the east, the intervening country having been submerged. One of the most instructive instances here is the Sechota-Alin, which is all but separated from the mainland by the lower Amur and its tributaries and by a number of lakes, and by Peter the Great bay on the south and Ulban bay on the north ; it looks almost like a portion of the continent just about to float away and form one of the detached island festoons in the advancing of the ocean westwards. In geological features there is a difficulty here. On the western side of the Atlantic the Mesozoic is completed towards the ocean, and is capped on the outside by Tertiary beds as in the usual Pacific type, but on the eastern side there are mica-schists and granite on the coast. This feature is a constant one right down the coast of the Americas to Tierra del Fuego ; in the last place, Darwin, in 1851, in his observations on South America (p. 239) remarked that the Cretaceous took on a Palæozoic aspect, and (p. 154) he says, "I am tempted to believe that where the clay slate (of which the Cretaceous rocks are here composed) has been metamorphosed at great depths beneath the surface, gneiss, mica-slate, and other allied rocks have been formed." This view is shared by many American authors, and Whitney contends that the granite, at any rate, is of Tertiary age, and other authors ascribe a like age to the mica-schists. Certainly the sequence of the beds in California, with their great bands of Serpentine, recall the Cretaceous rocks of Hayti and Cuba, or of Cyprus, only that the mineral constituents have been recrystallized. If these metamorphic rocks are taken as Archæan, as Prof. Gregory does, then the whole structure of the American continent becomes obscure and Prof. Suess's definition of Pacific type of coast-line misleading. If, on the other hand, it be conceded that the metamorphic rocks are Mesozoic, then the Tertiary rocks lying upon them complete the series towards the ocean as they do on the other side of the Pacific, and the broad structure of this part of the world becomes plain.

In the Indian ocean the same drowning of the western border may be seen, but here only half the length of the continental ridges is exposed to the ocean, the northern halves are merged into a solid whole by the transverse ridge of the Himalayas and associated chains ; nevertheless, in the east, Australia thrusts out a broad mass to the west, as does Africa and South America, and on the western side of the Indian ocean there is the drowned land of which Madagascar, Mauritius, Rodriguez, the Seychelles, Comoro islands, and Aldabra are the remnants.

The net result of the application of the theory of secular earth-creep is that coast-lines are advancing on the east and retreating on the west of the oceans. Although the simple conception of Prof. Suess that a Pacific type, for instance, has folded ranges parallel to the coast, is frequently found to be erroneous in certain localities, this is accounted for by the movement which, owing to local resistance in the Earth's crust, may disturb the

arrangement. Again, the true Pacific type of coast-line in the drowned western side is not found in the coast-line of the mainland, but in the fringe of islands off the coast. The ultimate simplified conception of the two types of coast-line implies that the Pacific is a broad qua-qua-versal syncline like a dent in a ball, whereas the Atlantic is a bulge, the centre of which has given way along faults, so that the ocean basin lies between fractures. The full and complete exposition of this structure existed in late Tertiary times, but since then secular earth-creep has been modifying the outlines; enough, however, remains to bear witness of the truth of the brilliant generalization of Prof. Suess.

ON THE CAUSE OF THE JAMAICA EARTHQUAKE OF JANUARY 14, 1907.

By VAUGHAN CORNISH, D.Sc., F.R.G.S., F.G.S.

THE *Geographical Journal* for March, 1908, contains an account of my experiences at Kingston during the Jamaica earthquake of January 14, 1907, and the results of my investigations in Jamaica in May-July of the same year. A map is appended to that paper showing in detail the relative intensity of the shock in different parts of the island. The outstanding feature of that map is the narrow zone crossing the island at its narrowest part between the lines Harbour Head to Buff Bay on the east and Port Royal to Enfield on the west. This was the zone in which buildings fell. It was generally in the eastern half of the zone that the damage was worst.

From the evidence of the earthquake itself, combined with that of the after-shocks, I came to the conclusion that there were two regions from which the tremors of the earthquake originated, viz. one near the shore south-of-east from Kingston, and the other, less precisely located, in the mountainous region within the triangle formed by the points Newcastle, Buff Bay, and Glengoffe.

In the above-mentioned paper I did not attempt to describe further how the earthquake was brought about. That there was fracture or faulting of rock near Harbour Head, and probably also somewhere in the neighbourhood of Hardware Gap, I take to have been pretty well established by the facts I set out, but I was not able at the time to discover evidence of any physical action by which these fractures had been produced.

It 1907 I had looked for a subterranean agent, and my attention was fixed on the geological map and sections, upon the outcrop of strata, the folds of the mountains, and the position of known faults. The conclusion I came to was that the earthquake had shown a cynical disregard for these things.

Further, if we were to suppose that the island was being folded or