Amerika und Eurafrika

The Origin of the Atlantic-Arctic-Ocean

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With 2 Figures in the Text

Summary. The Atlantic-Arctic Basin is antipodal to the Pacific. Powerful evidence is cited to indicate its development through Continental Drift, as suggested by PICKERING in 1907. Initiated from the Mesozoic Tethys and progressively enlarged during the Tertiary, its outlines were essentially determined by tensional-rifting oriented mainly N.E and N.W within a zone extending more than half round the circumference of the Earth, from the Antarctic to Alaska. During the Alpine diastrophism fold-linkages, that functioned as land bridges, were pushed up across the Ocean between the West Indies and Eurafrica and subsequently destroyed by the continued westerly drift of the Americas. Crustal stretching was accompanied by widespread volcanicity. The Mid-Atlantic Rise is recent and has an Isostatic basis. The Atlantic-Arctic stretch-basin is largely bordered by Fault-Line Coasts and by downwarped shores that show the marginal, entrenched, terrestially-evolved drainages known as "Submarine Canyons".

Introduction. — The Arctic Ocean forms the physiographical continuation of the Atlantic, and in discussing the evolution of the latter, the Arctic must be included. In the following account therefore the general term "Atlantic" will be taken to embrace the Arctic. Together they stretch over more than half the circumference of the Earth and, suggestively, are antipodal to the Pacific.

It is usually agreed that the Atlantic is a relatively youthful basin and that its bordering lands on east and west were, as shown by their terrestial life, united in one section or another at more than one period during the past. Attention cannot, however, be restricted to their framework, since the genesis of the Atlantic is intimately bound up with the far wider problem of Earth Evolution as a whole, that is to say the development of the Lands and the Oceans.

The various hypotheses propounded for its existence fall into two categories, involving either: — A, Sinking of a great north-south sector of the crust, or B, Continental Drifting or Displacement. Both concepts are simple, but the first, though generally favoured, is hard to reconcile with Isostatic principles, while the second, advocated by relatively few persons, is not generally acceptable owing to the apparent lack of a physical basis for the postulated horizontal forces. The author's viewpoint, supporting the second interpretation, has been set forth at length elsewhere (1) and he can add little fresh to that account; still, the problem having been narrowed down to one specific region, and on the kind invitation of Prof. H. CLOOS, the more relevant evidence bearing on the Atlantic Trough is summarised here. Before doing so one must breefly set down the chief reasons for accepting the doctrine of Drift, and thereafter interpret the history of that supposed "disjunctive rift" in the light of that hypothesis. Such preliminary is imperative, since the explanations thereby disclosed are so utterly and fundamentally different from those of current conception.

Merits of the Displacement Hypothesis. — Unlike any other theory this hypothesis can be tested on the basis of prediction, for, with the closer fitting that is postulated of particular landmasses, vital relationships necessarily show themselves, which can be verified or rejected in the field. It is moreover singular to observe how new discoveries would tend to fall into line with previous evidence or deduction. In Eastern Brazil, for example, V. LEINZ (2) has mapped an horizon of reddish tillite underlying the well known blue and green Itararé (Carboniferous) glacials, that duplicates in striking fashion the succession in South-West Africa, while the respective directions of ice-flow in the two countries are furthermore brought into accord.

There is a wealth of evidence — stratigraphical, lithological, palaeontological, etc. — in favour of these views, but, as such has been detailed elsewhere, they will, despite their significance be omitted from this discussion. The most important criteria are those based upon (a) Archaean Grain, (b) Intersection of Orogenic Zones, (c) Formational Phasal Variation, (d) Past-Climatic Zoning and (e) Faunas and Floras.

South America and South Africa were undoubtedly rigid masses that after their assumed separation experienced scarcely any internal distortion, and their reassembly as a portion of Gondwana is therefore not in doubt. On the contrary the great distortion produced during the Alpine diastrophism renders the fitting of North America and Greenland against Eurasia less easy, though such uncertainties will be reduced with further investigation.

Archaean Grain. — Noteworthy is the close agreement between the dominant foliation-trends in the platforms bordering the South Atlantic, for example between north-eastern Brazil and West Africa and eastern Brazil and southern Angola (Fig. 1).

Intersection of Orogenic Zones. — The value of such tectonic zones as reach near to the coasts mounts with the length and regularity in pattern of the visible extensions in the opposed lands. When not only structures, but stratigraphies, lithologies and datings agree closely, the likelihood increases that the so-called "free ends" disappearing into the ocean were more closely connected formerly. If two such zones of different ages converge or intersect in the opposed lands, that probability becomes enormously raised, while, if three or more such fold-zones are represented, such probability becomes a practical certainty, for the former spacing of the coasts can then be fixed approximately or even more closely, the precision depending largely upon geometrical considerations.

Now the Atlantic possesses two such transverse compound tectonic systems:

(1) North America—Europe. — Striking, as first pointed out by BAILEY (3), are the divergent palaeozoic fold-bundles on both sides of the ocean, even when one concedes a generous amount of space between the reassembled blocks (Fig. 1). If displacement be not

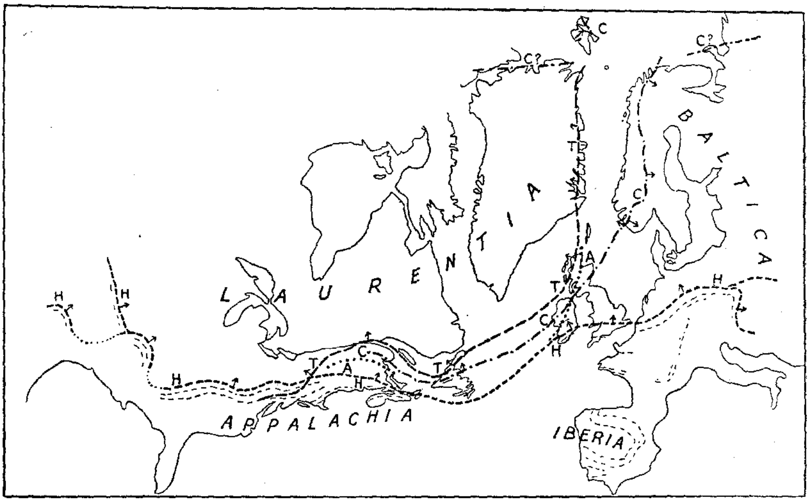

Fig. 1. Showing the Palæzooic Fold zones crossing the North Atlantic Ocean: T, Taconian C, Caledonian; A, Acadian; H, Appalachian-Hercynian. Arrows mark the direction of pressure

invoked, these four zones must be assumed to diverge eastwards at acute angles in eastern North America, to run thereafter more or less parallel right through the ocean, and in western Europe all to start radiating abruptly, though at wider angles. Failing that, one must assume the dying-out of one or more of the compression-zones and its replacement across the waters by a parallel or sub-parallel zone, which, in view of the scale and persistence of the folding, the stratigraphical similarities and other coincidences, is asking too much of credence. The relatively small angle of intersection in this system unfortunately introduces a rather large error in this attempt to reconstruct Laurasia.

(2) South America—South Africa. — In contrast here are largeangled intersections from four zones of widely differing ages forming two connected linkages (Fig. 2) that affect similar formations, the Permo-Triassic involving overfolding towards the north, the Mid-Cretaceous accompanied by strong down-faulting to the

south traced by WEAVER in Argentina to the Chilean border. The southerly linkage was first stressed by KEIDEL (4) in 1916, the northerly by MAACK (5) in 1934.

The plotting of these differently oriented trends enables the coastlines to be satisfactorily apposed and this section of Gondwana to be reconstructed with a probable error of about 400 km.

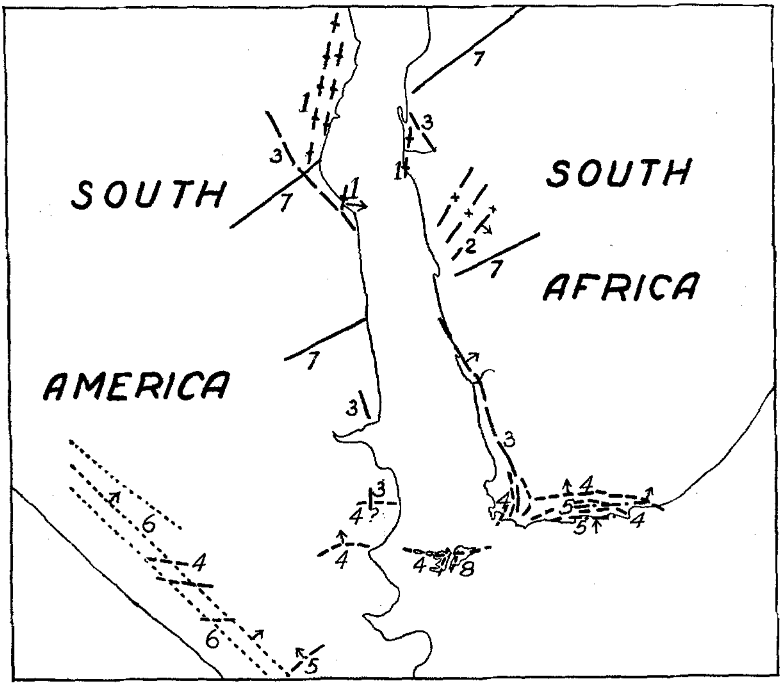

Fig. 2. Showing the Fold-Zones crossing the South Atlantic Ocean: 1 Archaean; 2 Pre-Cambrian; 3 Post-Cambrian; 4 Permo-Triassic; 5 Mid-Cretaceous; 6 Andean; 7 Axes of probably late Mesozoic Uplift; 8 Falkland Islands. Arrows mark the directions of pressure

Into the gap — formerly land — the Falkland Islands fit both stratigraphically and tectonically (6).

Formational Phasal Variation. — Of high importance, best seen in the South Atlantic region, is the remarkable way in which the nearest outcrops of corresponding formations on the two opposite sides of the ocean resemble one another more closely than either one — because of the usual lateral change in phase — resembles its own actual extension within its own continent. Thus, the Siluro-Devonian sandstone formation of eastern Argentina and the western Cape, now 5000 km. apart, are more alike than their two extensions within the distance of 1000—1500 km. back from the Atlantic. The Lower Permian "Green Ecca" of the same two areas behaves in identical fashion transversely to the ocean, but in addition changes in the northerly direction in both lands into the "Red Ecca", which in each case is replaced by a third facies some distance inland. Such systematic variation, affecting strata of different ages and latitudes, can hardly be due to mere coincidence.

Past Climatic Zoning. — Of vital significance are the numerous and extensive formations, that reveal tropical, arid or glacial conditions respectively, in various lands and of various ages, and provide convincing evidence of past climatic zoning. As first clearly set out by KREICHGAUER and later by KÖPPEN & WEGENER, the deduced courses for the principal climatic zones, when plotted for each epoch prior to the Tertiary, prove wholly inconsistent with their present latitudinal positions and in certain cases seem indeed meteorologically impossible.

Reassembling the Lands under the Displacement Hypothesis, a fairly consistent picture of climatic zoning is not only disclosed, but "pole-wandering" becomes inevitable. Since a shifting of the Earth's axis is denied by geophysicists, a horizontal creeping of the crustal covering over the rotating core has to be presumed, which in turn implies Drift.

Faunas and Floras. — Much of the support for the principle of Drift has come from biologists, who in their intensive studies of scattered orders and familes, past as well as present, have found themselves unable satisfactorily to account for the distribution of forms, living and extinct, save by postulating some kind of continental displacement. Embracing extensive evidence from the most diverse kinds of life, such collective opinion cannot well be disregarded.

Reality of Drift. — Taking into consideration all these lines of evidence, as well as a host of supporting data, is has to be concluded that the lands of the New and the Old Worlds must have drifted apart and thereby produced the stupendous Atlantic-Arctic "Rift", as visualised by W. H. PICKERING (7) so long ago as 1907, in which he was long afterwards followed by TAYLOR and WEGENER.

Once that momentous conclusion is accepted, explanation is forthcoming for many geological and biological puzzles and it becomes possible to reconstitute period for period the approximate limits of the Atlantic Ocean with what is fancied to be a fair probability.

Continental Movements. — Right down to the Mid-Mesozoic the continents of Laurasia and Gondwana must have remained nearly intact, being parted by the roughly east-west, though fluctuating, Tethys. As the result of squeezing on several occasions during the Palaeozoic through pressures directed between N.W—S.E and N—S, there was induced approximately at right angles thereto, that is to say roughly E—W, an intermittent tension which reached its maximum during the later Cretaceous.

The Primitive Atlantic can be visualised as evolving out of two opposed furrows of crustal sagging that took out in the early Mesozoic from the Tethys, their margins determinable from the mesozoic fringes along the existing lands. The northern gulf progressed north-eastwards and then northwards between Greenland and Norway during the later Cretaceous and spread widely over the Arctic region, but failed to reach the Pacific. The southern one penetrated south-eastwards and then southwards between South America and Africa and before the close of the Cretaceous the fold-link between Argentina and the Cape had been ruptured, and Africa, which had already been severed on the south-east and south, by a similar gulf, had become surrounded by sea, though South America remained attached to Antarctica, India and Australia until the early Tertiary, when it drifted away westwards. The persistence of east-west crustal tension is shown by subordinate roughly north-south sea-ways, for instance the Ural trough and that between Tunis and the Cameroon, both of which were later short-circuited by the dominating rift of the Atlantic.

Transatlantic Linkings. — The Alpine Orogeny is conceived as having involved not only the mutual approaching of North America and South America and of Europe and Africa — with the throwing up of subparallel E—W marginal foldings —, but the drawing away of North America from Europe and South America from Africa — with the consequent stretching of the transatlantic chains just produced. Stratigraphical considerations show that the three main tectonic phases of the Upper Cretaceous, Oligocene and Pliocene did not exactly synchronise throughout this vast region.

One therefore obtains the picture of the progressive rising of complex fold-chains between the West Indies and Spain and between Venezuela and Marocco respectively and of their subsequent distortion and dismemberment through the continuance of drifting. In the Upper Cretaceous compression was dominant in the Mid-Atlantic region, in the Oligocene tension had become of importance, while in the Pliocene the basin had become too wide and the compressive forces too feeble to maintain the transatlantic ridges and new V-shaped linkages were accordingly built up between the West Indies and Venezuela and between Spain and Marocco respectively.

The former existence of isthmian connections or islandchains produced in some such way must indeed be postulated to explain the observed close resemblances between the terrestial life and shallow-water marine faunas of the West Indian and Mediterranean regions during the first half of the Tertiary, a resemblance that fades out after the Miocene. This is incidentally the sole section of the Atlantic across which land-bridges could on geophysical as well as tectonic grounds have been built up and destroyed during the Tertiary. Here alone could South America and Africa have once more been linked together since their severance in the south at the close of the Cretaceous. In the extreme north, at a much later date, however, Greenland seems to have become joined to Scandinavia, Iceland and the British Isles by the gigantic ice-body of the Pleistocene. In the far east the Alaskan-Siberian connection was maintained throughout most of the Tertiary, and only submerged temporarily in the late Miocene and finally in Recent times.

Crustal Fracturing. — Progressive rifting in the Arctic proceeded no further than Behring Strait, where it ended against the Alpine compression-zone girdling the Pacific. This deep-rooted barrier it only succeeded in bending, though not in severing. Several lines of evidence, such as the "Plateau Basalts" of Siberia, suggest that the Arctic basin may have commenced opening somewhat earlier that the section between Greenland and Norway, possibly through the flowage of Siberia and Alaska towards the Pacific. Novaya Zemlya was bent, the westerly drift of Spitzbergen led to the Tertiary folding in that island, while Davis Strait opened and the Canadian archipelago became defined.

Tensional enlargement of the North Atlantic is suggested by the ubiquitous Tertiary fracture-pattern in that region, as splendidly developed in Scandinavia (SEDERHOLM) and the British Isles, the shatter-lines subsequently picked out by ice-action in higher latitudes. Noteworthy is the lengthy graben system of Europe, traceable from southern Spain through the Rhine area to Sweden (G. RICHTER) running parallel to the axis of the Atlantic. It may causally be connected with the drifting away of Labrador and Greenland. With the European block weakened in that fashion, the youngest Alpine pulses would have been enabled to push northwards and so reach the British Isles.

Long ago OSMOND FISHER proved mathematically that tensional forces set up in the crust of a rotating earth would reach their maxima in low and middle latitudes across planes making angles of 45^0 with the equator. Assuming that the Alpine foldgirdle was developed more or less equatorially across the Atlantic, an explanation is obtained for the prevalent fracturing within belts to north and south of it along azimuths approximately N.E and N.W, and hence for the zig-zag shape of the Ocean. The Cameroon Volcanic Line can be cited. Such fracture-pattern is well brough out in a diagram by SONDER (his Fig. 7) (8), which, though not intended to support the idea of Drift, is distinctly suggestive in that direction.

Remarkable again is a slight bending of Africa, revealed by tension on its eastern side, as evinced by the Great Rift System, and by local post-Eocene compression on its western — Benguela and Southern Nigeria —, a feature conceivably due to drag at its north-western corner by the Tertiary linkage with South America.

Igneous Activity. — Spectacular ist the abundance of basic effusives, especially plateau basalts, within the northern part of this immense fracture-region, erupted partly from volcanos, though more extensively from fissures, now represented by dyke-swarms following the dominant fracture-systems. Included, though not quite central, is the series of volcanic islands ranging from Wrangel to Bouvet. Admitting Drift, a much smaller Tertiary lava-field would be demanded, while the extruded magma could be regarded as the product of such crustal dispersal. It is significant too that those spots, where measurements have indicated a change in longitude, are situated in this area.

Accepting the generalisation that alkalic differentiates tend to characterise regions of tension and calcic ones neutral areas or regions of compression, it is impressive to observe the abundance of alkalic or sub-alkalic types within or along the shores of the Central and Southern Atlantic, where they may cut through older neutral kinds or contrast with the calcic types of the transverse Alpine compression-zone both to east and west, e. g. Marocco (Middle Atlas) and West Indies.

Ocean Floor. — The relief of the Atlantic bottom shows all the characters of a stretch-basin — particularly in the symmetrically-set, though crooked, Mid-Atlantic Rise with its lateral branches that reach out to either shore following north-easterly and north-westerly trends. The writer has viewed the Rise as a youthful and secondary feature initiated in mid-ocean because the sedimentary loading would have been least there, but aided perhaps by uplift in such position through light igneous differentiates, as suggested by VAN BEMMELEN (**9**). A similar rise traverses the Indian Ocean.

It can scarcely be doubted that continental rocks extend out far into the ocean, presumably with fracturing, stretching and thinning. That the basement must include above the sima acid to subacid materials — either stretched crustal rocks or lighter magmadifferentiates — is indicated by the behaviour of earthquake waves and by gravity anomalies. The depth of Isostatic Compensation of the west coast of Africa is unusually deep, 150—200 km. (MEISNER).

Physiographical Evidence. — The border-lands present phenomena that point furthermore towards tension. Impressive is the Great Rift System of Eeast Africa running N—S for about 5000 km. from Syria to the Transvaal, and due to the opening of the basin of the Indian Ocean in the same way as that of the Atlantic. Considerable sections of the lands fronting both these oceans show at a distance back from the shore of from tens up to some hundreds of kilometres a scarp facing seawards surmounted by a peneplained surface tilted gently away from the ocean, for example, South Africa, Brazil, Spain, Labrador, Greenland, etc. Its planing-down was done essentially during the later Mesozoic, though continued in places during the Tertiary.

From analogy with "Rift Valley" abutments the writer (**1**, p. 256) has regarded these back-tilted surfaces as due to powerful faulting of the continental margins as the Atlantic "Rift" was produced. The fractured edge of the continental block would thereupon have been uplifted and the peneplain tilted inland in accordance with Isostatic and Paramorphic principles and the fault-scarp exposed to active erosion. Such fault-line coasts are characteristic of the Atlantic and Indian Oceans. The hypothetical boundary fault could be expected to lie close to or else beyond the edge of the Continental Shelf, and suitable geophysical methods would probably serve to determine its position.

In the considerable period that has since elapsed the primary fault-scarp has retreated far inland and a new littoral zone of peculiar topography developed at its base. Such lightening of the block coupled with general erosion would have induced isostatic uplift of the block, while deposition of the waste therefrom off-shore would have loaded the ocean floor adjacent, wherefore a downwarping along the coastal strip would have resulted, excellently illustrated round the southern end of Africa, which shows a history rather like that of the Eastern United States. Such flexing would have been accentuated by further sub-oceanic stretching, and modified by faulting, uptilting and erosion.

The author (**1**, p. 226) has already suggested that those very remarkable features, the Submarine Canyons, so typical of the Atlantic, might in part at least mark the original cuts made sub-aerially by the existing rivers through the primary up-tilted boundary scarps. Some display all the characters of normal river gorges. Certain too were cut in late Tertiary or Pleistocene times. The land surface with its deeply entrenched ravine became thereafter downwarped and depressed below sea-level with steepening of the canyon gradient. During the Glacial Period — just as in the case of the Coral Island Platforms — the Continental Shelf was evolved by marine erosion plus some deposition, and such feature proceeded to the downtilted (or nearly horizontal) surface and its contained canyon and in extreme instances severed the latter from its headwaters. This would explain the many cases where the head of the canyon starts suddenly within the Shelf. The outer margin of the Shelf could under these views be wholly or in part built up of detritus. It is certain that local conditions would have played an important part and that the datails would have varied in particular cases. Admittedly several difficulties remain to be met under this new hypothesis.

Only through acceptance of the Paramorphic Principle with all its implications does it seem possible to explain the enormous depths to which these apparently terrestially-evolved and normal ravines have been sunk, yet almost within sight of land that merely shows erosion-surfaces inclined faintly seawards. Despite to-day's consensus of opinion some tectonic agency that affected the coast along its length and not across it, as suggested by a few, has to be invoked and the only one to hand is Sub-oceanic Stretching and Coastal Downsinking. Submarine mud-flow could have been effective in keeping such canyons clear of sediment, but is not thought to have been responsible for their actual formation. A corollary is the rapid oceanward sinking of the crystalline basement beneath the Shelf, which has definitely been proved in two cases of the eastern part of the United States.

To conclude this very brief review, it will perhaps come to be better appreciated that the Atlantic Region offers a most fascinating field for scientific research and that it provides answers to many of the major problems of Earth Evolution.

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