# THE WEGENER THEORY

by

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In view of the great interest manifested in the Wegener Theory, the author of the present article has revised the text of a lecture given at Utrecht before the Geographical Society on the 30th January 1939, in order to present a brief summary of the present state of the problem. It does not presume to open up new horizons on this subject.

The Wegener Theory has several aspects: geological, geophysical, climatological and zoological — from this the difficulty of approaching it and making a critique. In what follows, we shall, nevertheless, examine only the geophysical and geological aspects.

We are still not in a position to pass a well-founded judgment on this theory. Much more research will be necessary before any degree of certainty can be reached on this subject, both in the positive and the negative senses. In any case, Wegener deserves high praise for his clear and comprehensive vision of the problems which are associated with his theory, shedding much light on all that is favourable to it, while that which cannot be incorporated in it has been left more or less in the background. Besides *Wegener,* who published his theory in 1912, one should name *Taylor* in 1908 and *Baker* in 1911, both of whom were advocates of a theory of continental drift.

There is general agreement on one point, namely : that the continents are rigid carapaces of sial which drift on the sima. According to JEFFREYS, the layer of sial is composed of granite to a depth of 10 kilometres, with an intermediate layer called tachylite below it. The combined layers reach a depth of 30 to 50 kilometres. According to him the layer of sima is composed of dunite. *Holmes* is of the opinion that the intermediate layer is composed of diorite and the sima of eclogite. The gravity investigations have shown that, in an approximate manner at least, the layer of sial is in isostatic equilibrium, and this has incited WEGENER to consider all vertical movements in the terrestrial crust as impossible; and, in consequence, he does not accept the effacement of the ancient land bridges (landbruggen). Since then, more recent gravimetric research has shown that there is no reason for such conception and that such vertical movements in the earth's crust are, after all, perfectly possible.

One objection raised against the hypothesis of horizontal movements lies in the difficulty of admitting that the bottom of the ocean offers such slight resistance to the drift of the continents and that they are able to move without breaking up. WEGENER admits that under the oceans the layer of sial is lacking and that in practice the bottom of the ocean behaves, in reality, like a perfect fluid, that is with the greatest pliability such that the resistance depends solely upon the velocity of the movement. For very low velocities, therefore, there must necessarily be produced very slight forces, and consequently very slight displacements. As cause of the movements, WEGENER admits the drift of the polar continents towards the equator, but this cause must doubtless be rejected in view of the slight magnitude of the forces involved. One objection to the above concept is that, according to currently accepted ideas, the basalts in the ocean bottom have a threshold resistance (i.e. a resistance below which no movement is possible), which is greater than the force of rupture of the continental granites. For this reason, the continent would rather be folded against itself than pressed against the ocean bottom. One might also conceive of a crystalline transformation in the superficial layers, such that under its influence there would be produced a process analogous to that of a perfectly supple fluid mass. We might conceive that this crystalline transformation would occur sooner with the basalt than with the granite; but, even under this supposition, one encounters the great difficulty, namely, that it is difficult to explain how the continents, in the mountainous formations, or even the borders of the continents, are pressed against each other; which would seem to prove that the continental shelves in that vicinity must offer less resistance than the adjacent ocean bottom.

On the other hand, according to recent data on the age of the rocky layers, we must admit that the velocity of movement required by the WEGENER hypothesis is only a few centimetres per annum; so that it is of the same order of magnitude as the movements in the earth's crust which occur in the interstratified folds on the mountainous formations. This gives one the possibility of admitting that in the intercompression of the continents, they have been able to partake either entirely or partially of a horizontal movement.

During the carboniferous age, that is, about 350 million years ago, there should, according to WEGENER, have existed only one continent. Then the Antarctic and Australia became detached, and finally during the cretacean age, an epoch estimated at about 100 million years ago, the present South American Continent detached itself from Africa. According to WEGENER, Greenland became detached much later than Norway; this occurred during the former quaternary epoch which has now been estimated at some 2 millions years ago. The strongest argument of a geological nature in favour of this concept is that during the carboniferous epoch and the permian, that is, about 300 million years ago, there existed the glacial period which has left its traces in South Africa, along the eastern coast of South America, in Australia, in New Zealand and in the British Indies. This is very difficult to conceive in the present position of these continents. In order to understand this explanation of WEGENER, it suffices to grant a velocity of movement of several centimetres per annum.

We might find other geological arguments in the concordance of the geological formations on either side of the North Atlantic Ocean and the South Atlantic Ocean; in Scotland and Nova Scotia, the caledonian folds; in Ireland and in Massachusetts, the hercynian folds; in the South, for instance, in the folds at the Cape which seem to conform closely to those in the Argentine. In a general manner, geology is satisfied, and in no case is it necessary to have resort to specious arguments. A short time ago, Dr. NIEUWENKAMP has again carefully compared the shape of South America with that of Africa which lies opposite, and has found that the coasts, for a distance of 3000 kilometres, do not show any discrepancy greater than 50 kilometres on either side. If we calculate the velocity here also, we arrive at a figure of about 5 centimetres per annum. According to the WEGENER hypothesis, the relative velocity of Greenland and Norway should have been much greater. With the present data concerning the age of the layers, we arrive at a figure which reaches one metre per annum.

The movement of Australia towards the Indies, assumed by WEGENER, is not supported by the geological research of KUENEN in the Netherlands East Indies : KUENEN is of the opinion that Australia has, for a considerable period of time, occupied the same relative position as to-day with respect to the Indies.

With regard to the measurements of the movements made during our time, we might say that neither the precise measurements of longitude executed at numerous points during 1926, nor the Danish longitude determinations effected during the past 15 years between Greenland and Denmark, have revealed any reciprocal movements in these two continents (1). It seems highly improbable also that one would be able to deduce anything similar from the results furnished by the radio time signals to the different observatories of the world. With regard to such results and the accuracy of measurement, one may state that the reciprocal movements could not exceed at a maximum, about 20 centimetres per annum. If the movement had been greater, it would probably have been perceived. One cannot place credence in the former measurements which apparently yield much greater movements.

On the other hand, it is not impossible that there may have been periodic phenomena involved in the movements of the earth's surface; according to the theory of JOLY, which was taken up a short time later by KIRSCH, there should have been a periodic fusion of the terrestrial crust beneath the oceans, followed subsequently by solidification. During one of these periods of fusion, the movements of the continents might have occurred easily and rapidly. The author of the present article believes, however, that such periodic fusion is difficult of acceptance, and, consequently, there is every reason to doubt the validity of this theory. But we cannot doubt that the geological history of the earth's surface, for instance, reveals an epoch manifested by periodic transgressions of the oceans on the continents followed by recessions of the water, this within a period of the order of some

(1) *See the present Review of this year, page* 126.

tens of millions of years. Similarly, the phenomenon of the folding of the continents seems to have taken place periodically; and finally still, UMBGROVE has again confirmed the hypothesis that these phenomena have generally taken place during a period of regression, that is, where the waters have receded in such a manner that there seems to exist some connection between the two groups of phenomena. One cannot state definitely that during one of these periods of folding, the greatest drifts of the continents have occurred, but that this fact is conceivable is beyond doubt.

Following the seismological study of the velocity of propagation of oscillatory waves in the superficial crust of the earth, like those produced by earthquakes, it seems that these have a definitely greater value than on the continents only in the Pacific Ocean. We may assume that under this ocean, the granite layer is lacking or that it has a thickness of several kilometres only. As we have stated elsewhere, there is reason to doubt if this means that the resistance to the movement in this locality ought not to give an indication of the threshold value.

The gravimetric investigations do not yield any argument regarding the value of the WEGENER theory, but they do so indirectly. First the isostasy, on which the theory is based, is only in its infancy and it would appear that there are still many points which need harmonising. One fact is the strip of strongly negative anomalies of the Netherlands East Indies, which is directly connected with the folds of the earth's crust manifested in this region. These anomalies are, on the one hand, of the same magnitude on the side towards the Indian Ocean as towards the Pacific Ocean, as well as there where the strip touches Australia, and consequently this should indicate that the resistance of the terrestrial crust of the bottoms of the two oceans is the same as that offered by Australia. This is an argument against the idea that, in recent times, Australia has approached the Indies and that the great folds which have occurred in the crust have necessarily brought about the approach.

One important fact is constituted also by the presence of the extended field of gravimetric anomalies which is found in the oceans. Above the deep basins in the Atlantic and the Indian oceans, as well as above certain parts of the Pacific Ocean, we find an excess of gravity with respect to the continents; that is, certain discrepancies in the isostatic equilibrium. It is extremely improbable that these anomalies in the equilibrium, which extend over regions covering several thousands of kilometres, can be explained by a relatively thin terrestrial crust which must of necessity be fragile; we are, therefore, compelled to admit the existence of the anomalies of equilibrium in the deeper plastic layers. This shows that in these layers there are currents manifested and in comparing them to the movements of viscous fluids, it follows that consequently they have, under the fields of excessive gravity (and therefore under the oceanic basins), a component directed downwards, and elsewhere, that is, under continents, a component directed upwards. With regard to the cause, we cannot as yet make any statement with certainty, but it may be conjectured by HOLMES, SCHWINNER and others in connection with other studies involving the earth. The cooling of the globe must certainly have produced a certain unstable distribution of temperature in the earth — the lower temperatures being above and the higher temperatures below — and further, in the horizontal sense, probably unequal also. The crust of sial is certainly more strongly radio-active than the subjacent layers and for the continents, it is certainly thicker than under the oceans; thus making it probable that under the continents there exists a higher temperature than under the oceans. From this, it would follow that there are currents of the same character in the plastic layer of sima as those which we have assumed in the layer above; directed upwards under the continents and directed downwards under the oceans. This fact should have a certain number of consequences: first — the vertical movements of the terrestrial crust, such as those which have been calculated, seem to have a magnitude of several kilometres; and secondly, — the horizontal components of the currents, on which the terrestrial crust rests, should exert great horizontal forces in it. This should make admissible the great forces which are required for the comprehension of the WEGENER drift theory. On the other hand the possibilities of vertical movement make conceivable the rising and falling of the land bridges (landbruggen). Finally, it is strongly admissible that the horizontal forces compel the terrestrial crust as a whole to drift on the inner core, which would involve the displacement of the poles with respect to the terrestrial crust.

We are obliged here to leave open the question of determining whether it is possible to explain the permian glacial period by a displacement of this nature of the poles without

a corresponding drift of the continents. BROOKE has outlined a climatological theory by means of which he claims to be able to make admissible such a large extension of the glacial ice-cap in the southern hemisphere, that even with the present position of the pole, the phenomena of the glacial epoch can be readily explained. Thus, it is conceivable that a combination of these concepts with that of the displacement of the poles may give a plausible explanation of the permian glacial period, without the necessity of assuming, in addition, a correlative displacement of the continents.

In conclusion, we may say that in the present state of geophysical knowledge, we are still not in a position to give a precise indication on the subject of the WEGENER theory. We may as well see in them some indication which militates in favour of the horizontal movement of the continents as those indications which make plausible the hypothesis of the terrestrial bridges (landbruggen). Possibly we may find later that the history of the earth's crust is more complicated and that the two kinds of movements have both occurred during the course of the long geological periods.