RECENT THEORIES ON POLAR DISPLACEMENT.

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ABSTRACT. New theoretical considerations on large polar displacements were published by a few Dutch authors during the past war-years. A synopsis in English of the principal points of these new hypotheses is desired because two papers are in the Dutch language and one is moreover a thesis. In his discussion of the subject the present author gives his motives why he thinks the new theories on large polar displacement, as well as their predecessors, are unsatisfactory and should be abandoned.

THE earth's axis of rotation has not a fixed position in space. It exhibits the movements known as nutation and precession. But apart from these well defined movements the equator is thought to have made—since primeval times—an angle of 22° to 24½° with respect to the ecliptic. Anyhow astronomers think the position of the earth's axis not to have been subjected to large changes. And we may leave to them the question of how and when the remarkable inclination of the earth's axis on the plane of its orbit round the Sun originated. For the moment it is sufficient to know that no astronomer would agree with a hypothesis involving large alterations in this state of affairs since geological times. The rotating earth is like a spinning top or like a gyroscope which has a powerful tendency to keep the position of its rotation-axis constant. Any drastic alteration of its direction would cause a world-wide catastrophe. That nothing of the kind has ever happened is known from historical geology.

Another question is whether the outer elastic and rigid shell of the earth possibly moved as a whole over the deeper plastic layers of sima. This is the kind of polar displacement advocated by some geologists. Loading and unloading of icecaps, displacement of sediment by erosion, etc., are factors that may have had some influence of this kind though it is questionable whether these processes had far reaching consequences. At any rate some authors eagerly introduced large displacements of the crust, as they were struck by the climatic evidence in older strata differing from the present prevailing conditions. The resulting hypothetical displacements of the poles are widely known. Many textbooks on geology reproduce a figure showing an earth-globe with something like the track of a snake on it,

a curved line running from the area of the present Southpole (which would have been the site of the present north pole in pre-Cambrian times) towards its present position via the Pacific, Alaska, South- and East-Greenland. It represents the hypothesis of polar displacement of Kreichgauer. Another hypothesis mentioned in nearly every textbook is that of Simroth. There are a few others and, of course, every one knows the paleoclimatic maps of Köppen and Wegener. The reasons why their theory, too, has to be abandoned were set forth in another publication (Umbgrove, 1942, p. 95, 97).

It was mentioned there also that a mathematical treatise by Milankovitch pretended to furnish strong support to the theory of Köppen and Wegener (Umbgrove, 1942, p. 138). According to our opinion it would only mean the worse for that mathematical treatise. The question had to be left at this point. However, we may now add that it is much worse than we could have thought it at that moment. This appeared when, in 1943, H. Kuiper wrote a thesis which contains a critical re-calculation of the theorem treated by Milankovitch.

It will hardly be necessary to recall to memory that—according to the theory of Köppen and Wegener—the north pole shifted from a spot near the Hawaiian Islands towards its present position, since Paleozoic times. It was this suggestion that seemed to be confirmed by Milankovitch in such a remarkable way. Now, to begin with, this result was not so striking as many thought it to be. For Milankovitch based his calculations on certain premises, among which was the theory of Köppen and Wegener. However, Kuiper (1943, p. 54, 64, passim) showed that a very remarkable error has crept into one of Milankovitch's equations. If it is put in the right way it transpires that the north pole inevitably followed its path along the Hawaiian route in a direction diametrically opposed to the direction mentioned by Milankovitch and postulated by Köppen!

Since Kuiper's thesis will not be available to every one who is interested in it, and moreover as it is published entirely in the Dutch language, I will mention here the crucial question in some detail.

In each part of the crust $c = 2R^3\rho Dz_0$, R representing the Earth's radius, taken as constant; D the thickness of the floating crust (Fig. 1); and ρ its specific gravity. Hence the product ρD represents the mass of a column of special diameter

of such material. z_0 represents the distance of the centre of gravity of this floating part of the crust above the centre of gravity of the replaced column of the substratum. In com-

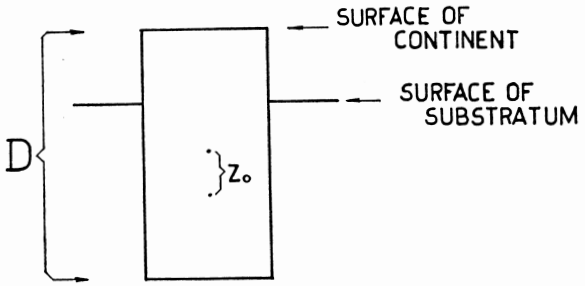


Fig. 1. Schematic representation of a column of Sial floating in a simatic substratum. Further explanation in the text.

paring equations of c_1 for the continents and c_2 for the oceanic sectors the question arises in which of these two cases the product $\rho D z_0$ is the larger one. Now doubtless this product is

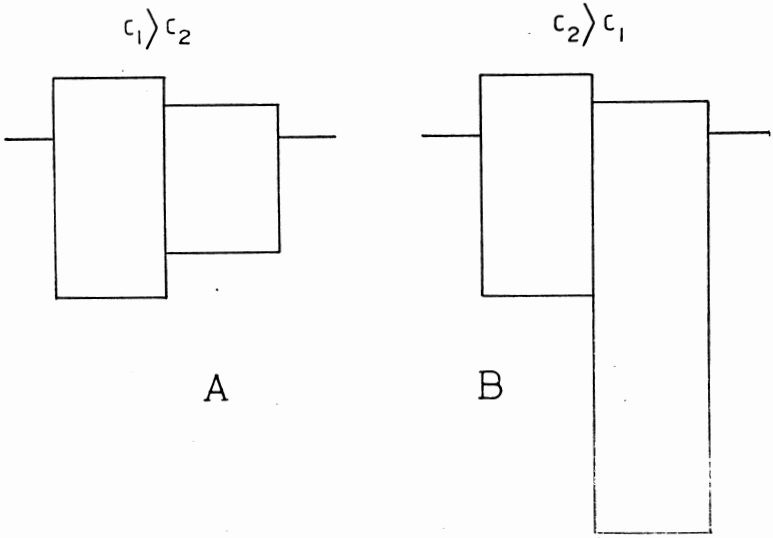


Fig. 2. Schematic representation of continental and oceanic columns of sial. A according to the usual conception; B according to the assumption of Milankovitch.

larger for the continents than for the oceans, since the surface of a continent floats at a higher level than the bottom of the ocean (Fig. 2A). And assuming the specific gravity of the

floating column to be the same in both cases, it follows that the mass of the continental column surpasses that of the oceanic column. So we get: $c_1 > c_2$.

Milankovitch, however, writes $c_2 > c_1$. In order to introduce this formulation—which apparently comes in conflict with everybody's common sense—Milankovitch assumes that the specific gravity of the oceanic crust differs only very little from the specific gravity of the substratum but very much from that of a continent. He chooses these values in such a way that the height of the crustal column in the oceanic sector becomes very large. Hence the mass of such a column and therefore the product ρDz_0 will surpass the continental value (Fig. 2B), So he writes: $c_2 > c_1$.

Now the high degree of improbability of this assumption is obvious since one would have to admit a crustal (sial) thickness of the ocean floors of some 80 kilometers. But Milankovitch's manipulation has an interesting background, because of the fact that the value of a so-called "Polfluchtkraft" depends on the values of c. If $c_2 > c_1$ the pole would travel in conformity with the theory of Köppen and Wegener, i. e. from Hawaii towards its present position. If, however, $c_1 > c_2$ the pole—under the acceptance of certain premises—will travel again along the Hawaiian track but in the opposite direction!

In Kuiper's thesis the problem of shifting poles seemed to have reached a safe resting-point. Indeed for one moment geological science seemed to be freed from the nightmare of hypothesis on wandering poles. However, only a few months later, the idea of large polar displacements was formulated once more in a new hypothesis by Vening Meinesz who investigated the stresses brought about by a change in position of the earth's rigid crust with regard to its rotation-axis. He assumes the crust to be everywhere of equal thickness and to behave as an elastic plate. The flattening at the poles, when displaced over the plastic substratum, must have given origin to the formation of shear-planes in the crust. It is further assumed that a clockwise rotation of the crust over 70° round a pole in the equator at 0° longitude happened to occur. The resulting curves of shear in the earth's crust, as determined by Vening Meinesz's equations are shown by Fig. 3. The net corresponding to a displacement of the pole—from near Calcutta over 70° along the meridian of 90° E. Long. in early pre-Cambrian times—shows some remarkable correlations to a series

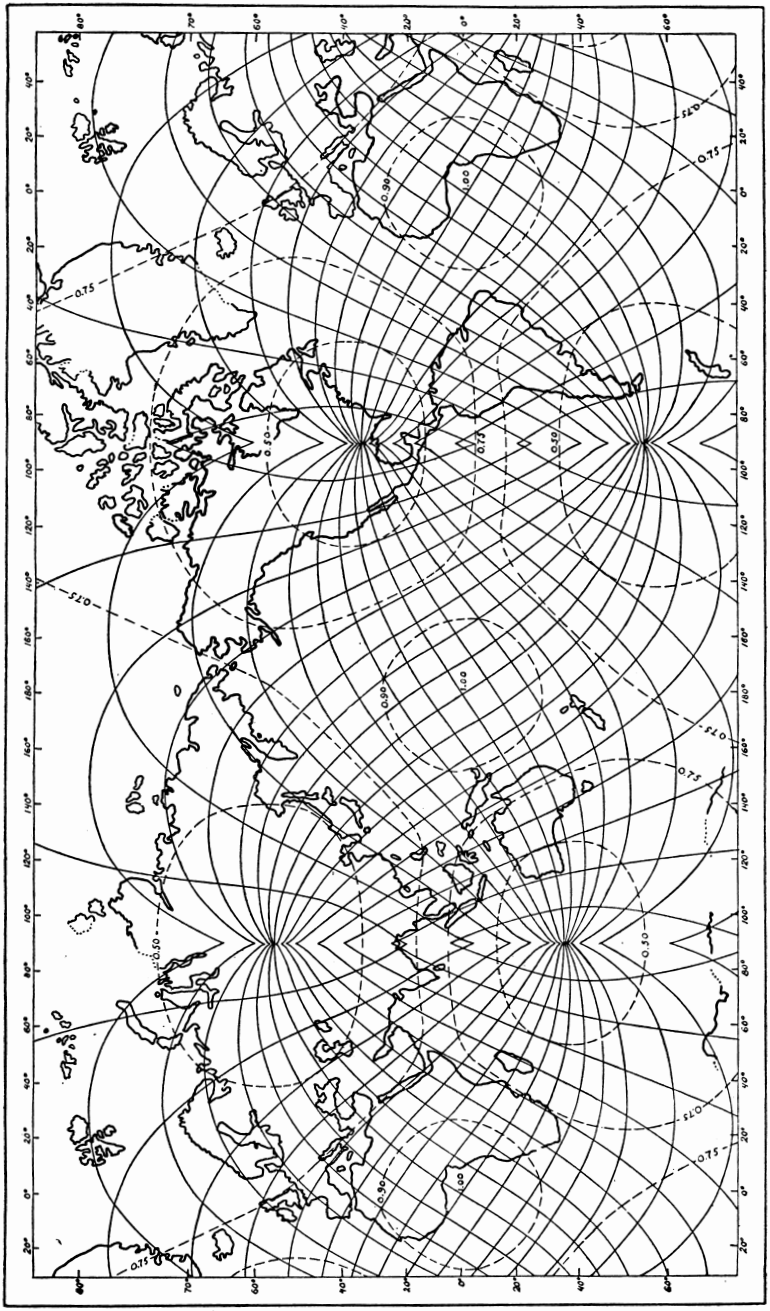


Fig. 3. Net of shear-lines resulting from the assumption of a displacement of the pole from near Calcutta over 70° along the meridian of 90° E. L. (after Vening Meinesz).

of topographic configurations and structural lines of the earth's surface. His theory asserts that probably the crust indeed shifted with regard to the poles in the manner just mentioned and that the crust underwent a corresponding block-shearing. The direction and the amount of the polar displacement were chosen by Vening Meinesz in a special way. A short time before he had studied the lineaments of the Azores and the sea-floor in the vicinity of these islands (Vening Meinesz, 1942). He therefore chose the theoretical displacement of the pole in such a manner that the shear-net would coincide with the prevailing lineaments of the Azores. Once the shear-net was completed, he was struck by the fact that many other lineaments fit rather well in the net of shear-lines. A number of striking coincidences could be enumerated.

The question at once arises whether we are dealing with a case of fortuity or with a correlation of far reaching consequences regarding the structural history of the earth. A statistical investigation of morphological lineaments in the topography of the ocean-floors—taking directions up to 12° on either side of the net's trend as positive correlation—induces Vening Meinesz to believe that it is not a question of fortuity.

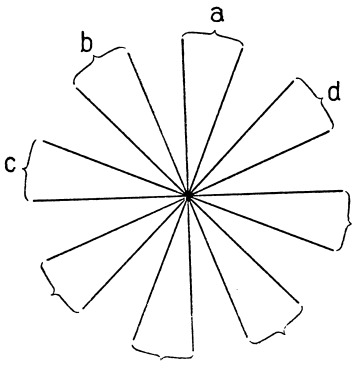
I agree with him that the congruence is not fortuitous. But I am very doubtful in respect to the idea that this would be in favor of the theory of a large polar displacement, and that the earth's linear structures could only be explained by such a happening. Suppose we should construct another net that consists of two bisecting series of lines running more or less diagonally in respect to the meridians. Whatever the motives of its construction it will show positive correlation to the earth's diagonal lineament-system. Take for example a shear-net as it would happen to originate by a change in the earth's flattening at the poles. Such a net if tested with regard to the terrestrial lineaments undoubtedly shows some striking coincidences. They are discarded by Vening Meinesz from a further discussion since he regards them of no value for interpretation. Indeed, it shows two zones in higher latitudes which are devoid of shear lines. Any shear that could have occurred in these circumpolar belts could have been solely parallel to the external lines of the net. Therefore it is abandoned. But are there no reasons to abandon the net of Fig. 3 as well? The coefficient of its positive correlation with the morphology of the sea-floor is somewhat higher than in the net based on the assumption of a change of

flattening at the poles. But on the other hand it has some other disadvantageous properties. To mention only a few: the areas bounded by the 0.50 line are regions where the stress is only half of its maximal value. According to the theory this means that no serious stress-phenomena have to be expected within these boundaries. Nevertheless the great San-Andreas fault, the enormous Bartlett deep and several other large faults are situated within this area. And there is some congruence along the east and south coast of America where the lineament along which Appalachia subsided, coïncides with a non-useful "shearing line." Similar difficulties arise when Central Asia is examined. If these regions were structurally different from other parts of the globe—e. g. if they revealed much fainter lineaments—that would fit well into the theory. Now, however, these regions stand as evidence that opposes the suggested explanation of polar displacement. Moreover, if the usual tectonic phenomena and lineament-sets could originate in these regions without the action of a well pronounced shear-net due to polar shift, why should we need such a hypothesis to explain similar phenomena in regions outside the 0.50 line?

Therefore, I suggest that the congruences found are not a merit of this special shear-net, but that the congruence is simply inherent to the fact that the main trends of the net are diagonal. And further: that each net of diagonal lines will show a certain degree of positive correlation simply because one of the earth's lineament-sets runs diagonally!

This, in fact, brings us to a further difficulty. Authors like Cloos, Daubrée, Hobbs, and Sonder, who made a special study of the linear patterns of our globe agree that two systems of significant lines may be distinguished in the morphology and tectonics of the earth's surface. One system runs approximately N-S and E-W. It is dissected diagonally by another system which displays an average NE-SW and NW-SE trend. Granted for a moment that the diagonal system of lineaments could be explained by a large polar shift as suggested by Vening Meinesz, then, what shall we say about the system of meridional and east-west lines! It finds no explanation in the theory and therefore would imply a second planetary effect which caused—among others—some of the most powerful rift-zones of our globe, some conspicuous lineaments like a part of the Mid-Atlantic Rise etc. East-West lineaments may be seen even on the Altair-chart of the Azores which formed the start-

ing point of Vening Meinesz's considerations. As a further illustration, a concrete example is reproduced in Fig. 4. It shows the four principal directions of the major lineaments of Western Europe (Umbgrove, 1945). With some good will two of these four sets—viz. those marked c and d—might be correlated with the directions P1 and P2 of Fig. 5, which rep-



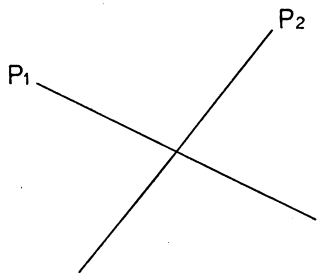


Fig. 4. Principal directions of the four major lineament groups of western Europe.
Fig. 5. Directions of shear-lines in western Europe according to the net reproduced in Fig. 3.

resent the trends of Vening Meinesz's shear-net for this area. But the directions *a* and *b* remain unexplained. They belong, however, to the most important lines in the structural history of the western part of the European continent since at least the Paleozoic, and probably since much older, pre-Cambrian times.

Another difficulty of a quite different nature arises if we would accept the hypothesis of polar displacement. The present "tetrahedral arrangement" (Umbgrove, 1942, p. 81) of continents and oceanic depressions clearly demonstrates a correlation to the position of the earth's axis of rotation. Now there are two possibilities. One is that this situation has come into being after the pole migrated to its present position. If this view be accepted it would be incomprehensible why the shear-net is correlated to the arrangement of the continents and ocean-bottoms. The other possibility is that the tetrahedral configuration already existed before the beginning of a polar displacement. In that case, however, it would be incomprehensible why the earth shows exactly that coincidence of its rota-

tion-axis with the line that connects the center of the Antarctic continent and the Arctic basin; in other words, that the earth's axis reveals a correlation to the tetrahedral pattern of our globe's surface. I suppose not many would like to ascribe this remarkable coïncidence to mere fortuity.

These are the principal reasons why I cannot adhere to Vening Meinesz's interesting hypothesis of a large shift of the poles in the early pre-Cambrian. In one respect this means that—according to my conviction—the pole surely did not wander, not even from Calcutta to its present position (after all why should it have been so capricious once in the earth's youth and never since?). On the other hand it means that the origin of the planetary lineaments remains an unsolved problem. For all that in my opinion can be said with some certainty is that they originated in the earth's early infancy. Probably we might add that in some way their origin was connected with the formation of a world-encircling solid, elastic and rigid crust. And, finally, that the old planetary pattern was repeatedly rejuvenated during the later history of the earth's crust.

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