PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Concluding Remarks

Edward Bullard

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XXVI. Concluding remarks

By Sir Edward Bullard, F.R.S.
University of Cambridge

There have been two threads running through this Symposium: the interpretation of observations and the discussion of mechanisms. Nearly all the speakers concerned with the evidence derived from the comparison of the continents and from palaeomagnetism have interpreted their results in terms of movement of the continents. It is difficult not to be impressed by this agreement of many lines of study leading to compatible conclusions, though there have been some dissenting views.

The most troublesome differences of opinion about the interpretation of the facts relate to the distribution of plants and animals in the past. Perhaps it is not surprising that there should be differences here; the fossil record is incomplete both in time and in space and, if one believes that arbitrarily great changes of climate may have occurred in the past and perhaps also that the Earth's poles may have shifted, there is not much information left to determine whether the continents have moved relative to each other or not. For example there are Carboniferous evaporites in Spitzbergen and Permian evaporites in Greenland where they are not forming today. Conditions in the past must have been different from those of the present, but if one asks whether such different conditions existed in a belt running all round the pole in the latitude of Spitzbergen, and thus indicate a general change in climate, one cannot tell, because most of the area is occupied by Precambrian shields. Climatic change, continental movement and shifts of the pole, are all possible explanations.

The second theme of the conference has been the discussion of possible mechanisms of movement. Here there is no agreement as to whether movement is possible and great difficulty in providing a convincing discussion that does not involve arbitrary assumptions about the interior of the Earth. Such discussions are different in kind from discussions of the evidence for and against the movement of continents. There are phenomena, such as ice ages and thunderstorms, for whose occurrence there is incontrovertible evidence, but for which there is no theory that is not open to substantial objections. Difficulties in accounting for a phenomenon do not provide a proof of its non-existence, though they may give a strong indication that the evidence is being misinterpreted.

The only plausible theory that has been suggested to explain continental movement is the hypothesis of convection currents within the mantle. The existence of movement in the mantle implies that the material is capable of shear under small long continued forces. This is *a priori* quite reasonable as in the laboratory all substances creep at temperatures above a few hundred degrees. Widespread fields of excess or defect of gravity show that there are stresses in the mantle of the Earth, but do not show whether the Earth yields to them. A convection current should be associated with a gravity anomaly and with stress differences. In this connexion the negative correlation of gravity anomalies and heat flow is of interest and suggests that density differences, due to differences of temperature, are among the immediate causes of widespread gravity anomalies.

The difference between the observed ellipticity and that appropriate to hydrostatic equilibrium is a more serious matter. It corresponds to about 76 m in the height of the geoid or 12 mgal in gravity. These are not large amounts (the former is $1{\cdot}2 \times 10^{-5}$ of the radius), but they are well established and do constitute a serious difficulty for the hypothesis that the material within the Earth has a very small strength. In a sense the departure of the ellipticity from the hydrostatic value is no different from any other widespread gravity anomaly; there is, however, no evidence from the Earth's surface features to suggest the existence of a large scale motion describable by the spherical harmonic P_2. The heat flow observations do not show any significant P_2 term, but are not very well distributed to detect it.

A further difficulty for the hypothesis of convection currents comes from the observations of heat flow. The mean heat flows on land and at sea are about the same, but the radioactivities of typical oceanic rocks are much below those of continental rocks. Nearly all the heat emerging through the sea floor must therefore come from below the Mohorovičić discontinuity and that from the continents must come mainly from the crust. If the continents have not moved it can be supposed that the radioactive materials have been concentrated upwards beneath the continents but have remained at greater depths beneath the oceans. If a continent moves it will presumably not stay permanently over one piece of mantle and there is no obvious reason why the mean heat flows under continents and oceans should be the same. On the other hand, the distribution of heat flow and radioactivity is favourable to the existence of convection currents in that it requires the temperatures a few hundred kilometres beneath the oceans to be a few hundred degrees higher than those at the same depths beneath the continents. This will tend to produce rising currents beneath the oceans and sinking ones beneath the continents.

There are very real difficulties in explaining continental movement, but it must be remembered that the explanations and the difficulties depend on the composition, properties and temperature of materials within the Earth of which our knowledge is very indirect; also the history and processes in the Earth are doubtless more complicated than the theories. In view of the scanty and hypothetical nature of our knowledge of the Earth's interior, it seems best not to be too much influenced by the theoretical difficulties in the interpretation of the facts of observation. If the facts are correctly observed there must be some means of explaining and co-ordinating them and many precedents suggest the unwisdom of being too sure of conclusions based on the supposed properties of imperfectly understood materials in inaccessible regions of the Earth.

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