Palaeomagnetism and the Time of the Onset of Continental Drift

MY conclusion that Gondwanaland started to break up in the Permo-Triassic[1] should be regarded as an early limit. It depends partly on palaeomagnetic work on the vast Mesozoic basalt and diabase formations of the Gondwanic continents[2-6]. The procedure was to compute mean palaeomagnetic directions for each continent, namely, South America, Africa, Australia, Antarctica, and India. These directions correspond to the mean age of each formation, and, in the absence of evidence to the contrary, these ages were taken to be the same. On this basis it was concluded that the palaeolatitudes and palaeomeridian directions were inconsistent both with the present arrangement of the continents and also with their arrangement as adjacent parts of Gondwanaland[7]: the palaeomagnetic data were consistent with an intermediate arrangement of continents. The assumption that the mean age of igneous activity was the same in all the Gondwanic continents was a reasonable one to make initially. However, it is not adequate for more precise work.

Potassium argon ages have now been determined for the Serra Geral formation (South America) and are grouped round 140 m.y. and 120 m.y.[8,9]. Stormberg lavas (South Africa) have been dated at 190 m.y. and 154 m.y.[10]. Tasmanian dolerites have been dated at 170 m.y.[11] and Ferrar dolerites (Antarctica) at 163 and 147 m.y.[10]. Hence the ages of the rocks sampled for palaeomagnetic investigations in the Gondwanic continents could possibly differ by some tens of millions of years. If continental drift or polar wandering were rapid in those times, the conclusions drawn from the original surveys may have to be modified.

It is not possible to divide palaeomagnetic data at present available into radiogenically dated sub-groups. However, more complete surveys are now being carried out in South America and in Africa, and every lava flow and dyke used will have to be dated radiogenically.

In due course it should be possible to answer with more assurance the question of whether the onset of drift was associated with the first outpourings of lava 190 m.y. ago, whether it started rather earlier as I had concluded, or later (preceding communication).

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DEPOSITION OF STRONTIUM AND CALCIUM IN SNAIL SHELL

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THE chemical similarity between strontium and calcium has led to widespread use of ^{90}Sr–Ca ratios in interpreting the movement of ^{90}Sr in the environment and in metabolic processes[1-3]. While the ratios are useful in assessing the hazard to large sections of the population, they add little to our understanding of the fundamental relationship between strontium and calcium in organisms. Mollusc shell is considered to be a biogeochemical sink since incorporated materials are physiologically, as well as physically, isolated and unavailable for the animal's metabolism, which is not the case in the bone of rats or other mammals[5]. The amounts of newly deposited strontium and calcium in the shells of snails should therefore be related to the concentrations of these elements in experimental environments. The object of this research was to demonstrate precisely the relative effect of strontium and calcium concentrations in the environment on their uptake and incorporation into snail shell. This experiment with the freshwater snail, Physa heterostropha Say, differs significantly from other work on strontium and calcium uptake, in that the strontium and calcium concentrations of the experimental media were rigidly controlled by assay of the strontium and calcium content of all chemicals used. While there is a constant relationship between radioactivity and mass for a given radioisotope, a more useful comparison of the deposition of calcium and strontium may be obtained by using atom concentrations. In this experiment ^{45}Ca and ^{85}Sr were used as tracers and specific activities (radioactive atoms/total atoms of the same element) were used to determine deposition.

As the functional relationship between uptake of strontium and calcium in snail shell and the concentration

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of these elements in the environment is unknown, one can do no better than to approximate it by a general form. One such form is a truncated Taylor series expansion:

$$Y = \beta_0 + \sum_{i=1}^{2} \beta_i X_i + \sum_{i,j=1}^{2} \beta_{ij} X_i X_j + \varepsilon$$

in which Y is a response (either strontium uptake or calcium uptake), X_i and X_j are concentrations of strontium and calcium in the medium, β_0, β_i and β_{ij} are unknown coefficients, and ε is the deviation of the truncated Taylor series from the unknown functional form. From experimental evidence it is possible to estimate the unknown coefficients and to assess the significance of ε. An efficient way to accomplish this is to perform an experiment based on an experimental design of the factorial type. The second order rotatable designs of Box and Hunter[6] are especially suited to this purpose.

If the scales of strontium concentration and calcium concentration in the medium are transformed to equal scales, U_1 and U_2, a suitable design is obtained by selecting six combinations of U_1 and U_2 which are equally spaced on a circle in the U_1, U_2 plane together with that combination of U_1 and U_2 which is in the centre of the circle. If a number of snails are treated in each of the solution media corresponding to these points the several β's of the Taylor series may be estimated and the significance of the ε term assessed. In addition, the predicted response (that response calculated at a point in the X_i, X_j plane using the estimates of the β's) will have an uncertainty which is dependent only on the distance of the point from the centre of the design and not on its direction. Furthermore, this uncertainty will be relatively uniform throughout the experimental region if the centre point of the design is performed twice.