The response of palaeomagnetic data to Earth expansion

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Received 1979 July 30

Summary. Attempts to estimate palaeo-radii of the Earth, using palaeomagnetic data have necessarily been based on simplistic Earth models. It has been asserted that real geological processes are too complex to enable us to approach the problem quantitatively, and such attempts yield invalid results. We examine this and argue that, to the contrary, it appears that errors introduced by allowing for more realistic behaviour of the continents, e.g. 'orange-peel effect' and crustal extension, are smaller by an order of magnitude than the response of palaeomagnetic data to simplified expansion models.

From a qualitative argument, it is shown that the observed Late Palaeozoic and Early Mesozoic palaeomagnetic data are not what should be expected from an expanded Earth. We conclude that it appears unlikely that the Earth has expanded significantly since the Early Mesozoic.

1 Introduction

Recently there has been renewed interest in the hypothesis that the Earth has expanded (Carey 1973, 1976; Owen 1976; McElhinny 1978; McElhinny, Taylor & Stevenson 1978). Although Egyed (1965) first realized that palaeomagnetic data should reflect any significant expansion, the most readily applicable method was developed by Ward (1963).

Ward's minimum dispersion method of palaeo-radius determination compares the scatter of palaeomagnetic pole positions calculated from coeval data as a function of ancient radius. The maximum value of $k$, the best estimate of the Fisherian precision parameter $k$, is taken as corresponding to the most probable palaeo-radius for that time.

The problem of testing the statistical significance of the variation in $k$ is similar to that of comparing dispersion before and after a folding correction has been applied. McElhinny (1964) has published 95 and 99 per cent confidence limits of the ratio $K_k / K$ for various sample sizes.

Applying this test to $k$ values determined by Ward's method (Van Andel & Haines 1968; McElhinny et al. 1978) for $R_k = R_a$ and $R_k = 0.8 R_a$, it is apparent that in most cases the variation in $k$ is not significant at the 95 per cent confidence level. Any one determination of palaeo-radius by this criterion, therefore, must be regarded as inconclusive. However, the large number of independent palaeo-radius determinations from all periods, now available,
The diagram shows a geometric representation, possibly related to a mathematical or physical concept. The text surrounding the diagram might be explaining or referring to the properties or calculations demonstrated in the figure. Without being able to read the text, it's difficult to provide a precise description of the content.
with the necessity of conserving the area covered by the continent, which tends to tear radially, thus changing the inter-site angles subtended at the continent centre. The extent of tearing can be estimated as follows.

The surface area of a spherical cap subtending angle \( \theta \) at the centre of an Earth of radius \( R \) is

\[
A = 2\pi R^2 [1 - \cos (\theta/2)].
\]

(6)

As the Earth expands, the cap flattens to a spherical cap with a sector missing. Since the distance from the centre to the edge of the continent is unaltered, the angle subtended for radius \( R' \) is \( \theta' = \theta R/R' \). If \( f \) is the fraction of a full circle about the continent centre still covered by the continent after expansion, conservation of area gives

\[
A = 2\pi R^2 (1 - \cos \theta/2) = f \cdot 2\pi R'^2 (1 - \cos \theta'/2)
\]

\[
\therefore f = (R^2/R'^2) [(1 - \cos \theta/2)/(1 - \cos \theta'/2)].
\]

(7)

The total angle taken up by wedge-shaped tears is therefore \((1 - f) \times 360^\circ \) and this could find its expression in one or two gaping rifts, which could correspond to Carey's sphenochammas. Such rifts would probably be recognizable and thus omitted from the analyses or corrected for; or else they would be distributed more or less evenly right around the continent leading to an insidious perturbation of site longitudes which would be difficult to detect and allow for.

However, the effect is small (except for very large expansion) as illustrated by taking \( R'/R = 1.25 \) for a continent originally subtending 90° at the centre of the Earth. Then \( f = 0.38 \) and the maximum change in relative longitude of two sites is 7°. If a single tear takes up the effect, or 3.5° between sites 180° apart in longitude if the effect is spread uniformly around the continent. In the worst case, this corresponds to pole positions being offset by 3.5° sin (45°/1.25) = 2°. Since the gross effect of the expansion on the calculated poles is given by \( \Delta \alpha = 18^\circ \) for this case, the 'orange peel effect' is seen to be relatively unimportant. For smaller continents it is completely negligible, even given the greater precision of the data. For example, no detectable pole shifts have been noted for Pangea, the supercontinent. However, it should be noted that Ward's method breaks down for sites greater than 90° apart from the point of zero strain, as with a hemispheric continent, for example. None of the published applications of Ward's method are affected by this limitation, which is a consequence of the gross departure of the model from reality for very large inter-site distances.

3 Pole position invariance under expansion.

A corollary to the undetectability of radial expansion of palaeomagnetic sites (\( \Delta \alpha = 0 \) above) predicts that if the continents have dispersed radially then their pole paths should remain practically coincident, notwithstanding the second-order effects. Consider two rock units, of the same geological age, residing upon an expanding globe and dispersing radially. Their co-latitudes \( \nu = \cot \frac{\pi}{2} \) are given by their magnetic inclinations \( \nu \) and the dipole equation

\[
\tan \nu = 2 \cot \beta.
\]

(8)

No matter what expansion occurs, their co-latitudes and pole positions remain invariant. This is depicted in Fig. 2 when, at some time after their formation, the rock units are rifted apart during expansion, but their calculated palaeomagnetic pole positions remain in agreement. This fact does not appear to be generally appreciated, but in qualitative fashion should be the observed consequence of the expansion hypothesis. The pole positions certainy should not be in better agreement after reconstructing the continents on the 'expanded' globe. However, it is an inescapable conclusion that the Magnetic poles of the globe are in much better agreement after reconstructing Pangea (Irving 1964; McElhinny 1973). Carey (1976, p. 3) indeed recognizes this in stating palaeomagnetic 'observations leave no doubt that the continents have separated'. The implication is that palaeomagnetic observations are necessary to explain the present distribution of the continents. Continental dispersion through Earth expansion could have played only a minor role.

4 Conclusion

From both quantitative and qualitative arguments, significant Earth expansion since the Late Palaeozoic is unlikely. If expansion of the order required by Carey's model has occurred at some time during the Earth's history, then from palaeomagnetic data it would appear to have occurred before Late Palaeozoic times.

References


