MEASURES OF TRUE POLAR WANDER

| Data set . . . | implies ancient motion of . . . | relative to . . . | assuming that . . . |
|---|---|---|---|
| Palaeoclimatic | The Earth's surface | ▶ Climate zones | — |
| | | ▶ Rotation axis | Rotation axis has determined climate zones |
| Palaeomagnetic | Lithospheric plate on which site is located | ▶ Palaeomagnetic dipole axis | — |
| | | ▶ Rotation axis | Rotation axis coincides with average palaeodipole axis |
| Palaeomagnetic, common to all plates | Entire lithosphere | ▶ Palaeomagnetic dipole axis | — |
| | | ▶ Rotation axis | Rotation axis coincides with average palaeodipole axis |
| Hotspot tracks | Lithospheric plate on which site is located | ▶ Underlying mantle | — |
| | | ▶ The Earth | Hotspots are fixed with respect to deep mantle |
| Hotspot tracks and palaeomagnetic | Rotation axis | ▶ The Earth | Preceding assumptions |

bring together the dynamics of TPW and those of convection, the underlying flow of the Earth's mantle which drives continental drift.

Mantle convection reflects the dynamics of the Earth as a heat engine: hot, relatively light mantle material wells up from the deep interior, spreading out beneath the rigid, plate-like top layer of the Earth and carrying sections of the rigid lithospheric layer (and continents embedded within them) as it does so. When the laterally flowing mantle material, and overlying oceanic plates, have cooled sufficiently, they are dense enough to sink back down — convective 'beetles' of slight excess mass diving back into the deep mantle.

Spada *et al.* model the convective return flow, which begins at lithospheric subduction zones in the uppermost mantle, as a sequence of randomly located downward-moving beetles, generated at a fixed time interval that could be either 2 or 10 million years. The Earth's total mass is conserved at each instant as the mass anomalies sink through the mantle, and a nonlinear version of the angular-momentum equations is used so that large-amplitude displacements can be accurately computed. The authors' conclusion is robust: regardless of the details of 'beetle activity', the typical rate of true polar wander should be very large (5°–10° per million years) if the mantle viscosity is uniform. Only if the lower mantle's viscosity is at least 10 times greater than the upper mantle's could the rate of TPW be as small as 0.5° per million years; a viscously thickened lower-mantle fluid would slow both the rate of beetle descent and the rate of bulge migration.

Although the net displacement of the actual pole is inferred to have been negligible during the past 50 million years, a combination of palaeomagnetic and hotspot data[5] (see table) suggests that further back — during the early Tertiary/late Cretaceous epochs — the Earth apparently underwent a period of comparatively rapid TPW, at rates amounting to 0.5° per million years. In both cases, the rate of TPW falls into the theoretical category of Spada *et al.*, requiring a thickened lower mantle. Whether the new analysis can be applied to the real Earth may depend on the extent to which actual convective flow — during which density variations, and so mass anomalies, are somewhat gradual and continual — can be represented by discretely sinking randomly generated beetles. Random beetles may also promote more of a destructive-interference cancellation of TPW effects (see Fig. 2 of Spada *et al.*) than would a realistic, nonrandom distribution of subduction mass anomalies. But if this is true, the implications are even more robust. Thus it appears that, even with innumerable sources of excitation throughout the Earth's history, the rheological structure of the lower mantle has dampened the Earth's true polar wander response. □

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DAEDALUS

# Forced food

**COOKING has three main functions. It has to degrade toxins and kill bacteria in the food; it has to render it digestible, mainly by breaking or weakening cell walls to make their contents accessible; and it has to develop an appealing flavour. With the development of the microwave oven, this last purpose is fast falling into abeyance. Traditional cooking imposes a steep temperature gradient across an item of food. This generates a wealth of intriguing tastes and smells, ranging from those of extreme pyrolytic degradation on the outside to the savour of almost unchanged ingredients in the middle. By contrast, uniform microwave heating produces a tasteless, pallid, warmed-up product whose flavour has to be supplied by chemical additives.**

**So Daedalus is developing an entirely new cooking technology. He recalls a clever trick which molecular biologists use to extract proteins from *Escherichia coli*. To avoid the heat and violence of conventional grinding or ultrasonic agitation, they simply burst the organisms by explosive decompression. DREADCO chefs are now adapting this technology to food preparation.**

**Their novel 'pressure cooker' simply pressurizes the food with cheap, safe carbon dioxide, a gas which can even be taken super-critical at room temperature. It is then such a good solvent that it enters, softens and plasticizes the toughest tissues. When the pressure is released, it expands back to gas. Every cell in the food swells up and bursts. All contaminating bacteria are killed, all cell contents are released, all coherent structures are disrupted by the violently expanding gas.**

**This wonderful process works on the most dubious raw material. Offal and vegetable waste which cannot even be made into sausages or dog food, even general biological debris like grass cuttings and leather fragments, can be safely 'popped' by the DREADCO process. It doesn't matter if it is contaminated by bacteria, or even rats — they are popped too. The whole awful mess is broken down into an open, fibrous powder, sterile but nutritive, and rather like damp sawdust; DREADCO's 'Popped Pabulum'. The consumer will never know what he is eating; and it won't matter.**

**Fast food will thus attain its ultimate development. All potential food, however revolting, will be instantly recoverable. Popped Pabulum will multiply the food resources of the world many times. Suitable synthetic flavour additives could even make it quite palatable. Toxins and viruses in the raw material will, however, survive unaltered. They will be destroyed in the subsequent microwaving.** David Jones