Earth science

Dynamics of a stratified mantle

from Raymond Jeanloz

EVIDENCE is mounting that the Earth's mantle may be stratified; that is, that the upper and lower mantle are separately convecting regions. The presence or absence of mantle stratification has profound consequences for the thermal evolution of the Earth, and for the inferred pattern of tectonic movements deep beneath the surface. One purely geometrical characteristic of stratification, for example, is that mantle flow is confined within a region of large aspect ratio: the upper mantle is a mere 700 km deep, but lithospheric plates are of the order of 5,000 km wide. How could a flow pattern be maintained in the upper mantle, and what might be the geodynamic consequences of stratification? In a recent article, Greg Houseman addresses some of these questions and concludes that convection in the upper mantle can be modelled quite naturally as a large aspect-ratio flow that is predominantly driven by a mean horizontal temperature gradient¹.

A pattern of equant convection cells, with aspect ratio of about one, has been produced by a number of fluid dynamical calculations on mantle flow. Some workers have thus concluded that convection must extend through the whole mantle, without stratification. Houseman points out, however, that the nature of the flow pattern is sensitive to the boundary conditions imposed, and the appropriate boundary conditions defining flow within the Earth are not well known: convection in a stratified mantle is by no means ruled out. The presence of moving lithospheric plates at the surface, for example, could be a major factor controlling the flow in large aspect-ratio cells in the upper mantle (presuming, of course, that plates are mechanically coherent).

Another factor, which is emphasized in Houseman's work, is the horizontal temperature difference between the mantle underlying ridges (hot) and subduction zones (cold). Houseman explores the effects of varying the Peclet and Rayleigh numbers on convection in a large aspect-ratio region simulating the upper mantle: in his formulation, these parameters are varied by changing the velocity of the upper surface and the heat flux from below respectively. He finds that the horizontal temperature variation can drive the flow quite effectively, with only a 250°C average temperature difference across a large convection cell — of the same scale as would occur under the Pacific plate.

In order to determine which is the more important driving factor, the moving upper boundary or the horizontal temperature gradient, Houseman calculates the surface topography and gravity anomalies associated with his models. He

concludes that observations made at the Earth's surface can only be matched by his models if the horizontal temperature variation is the dominant driving force in the upper mantle. The results are sensitive to the parameter values that are estimated (for example, mantle viscosity), and indeed Houseman's calculations are representative of only a particular choice of boundary conditions which are not wholly realistic for the Earth's mantle (for example, assumptions of constant viscosity and zero velocity at the lower boundary; and by necessity, the use of two-dimensional computation). Nevertheless, systematic studies of convection in the upper mantle, such as Houseman's work, are gaining importance due to the increasing evidence that the mantle is stratified.

What is the evidence? First, the observed density and compressibility of the lower mantle are not well matched by values that are calculated for a mineral assemblage with the average composition of the upper mantle^{2,3}. In contrast, new elasticity data⁴ reinforce the conclusion that the upper mantle and transition zone make up a simple unstratified region to first order (if one ignores lateral heterogeneity, in particular). Further evidence is provided

by the fact that the 670-km discontinuity, which marks the top of the lower mantle, is much too sharp to be explained in terms of known phase transformations⁵: a change of composition, and hence stratification, is apparently required. Also, there is the classical observation that subduction-zone earthquakes end by 700 km depth, thus suggesting that downgoing slabs penetrate through the upper mantle but not into the lower mantle (for example ref. 6, although see ref. 7). These results are in accord with geochemical models, based on isotopic, trace element and rare gas measurements, in which the upper mantle is viewed as a depleted reservoir that has been distinct from the undepleted lower mantle for billions of years (for example, refs 8–10). Thus, studies of the large aspect-ratio flow patterns expected to occur in a stratified mantle are likely to be of crucial importance for understanding the dynamics of the upper mantle. □

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Genetics

DNA hybridization — beware

from Roger Patient

Two papers recently published in *Nature*^{1,2} described the apparent detection of 'extra' major histocompatibility (HLA class I) antigens on the surface of human T-cell leukaemia/lymphoma virus (HTLV)-infected cells and suggested that the viral envelope (*env*) protein was similar enough in structure to HLA class I proteins to have been responsible. The latter claim was based on nucleic acid hybridization data and has now been questioned by Jennings and Even³ in the light of subsequent sequence comparisons (see p.85 of this issue of *Nature*). One is reminded of the hybridization-versus-sequence conflict described by Beverley Griffin in her *News and Views* article of 18 months ago⁴, but there are a number of differences.

Clarke *et al.*² probed HTLV, cloned in bacteriophage λ , with an HLA gene, cloned as its cDNA, that only differed from HLA-B7 by 1 amino acid out of the 48 determined by DNA sequencing⁵. The only hybridizing region in the HTLV clone was localized to the *env* gene, which hybridized to a region spanning the first three exons of HLA, enclosing the extracellular domains

of the protein. From that it was concluded that the HTLV envelope protein exhibits homology to the extracellular domains of HLA-B7; that herein lay a possible explanation for the 'extra' HLA class I specificities detected in HTLV-infected cells; and that such a masquerade on the part of HTLV would aid in the evasion of host immune detection and facilitate tumorigenesis.

After Clarke *et al.* had submitted their manuscript, the complete sequence of HTLV was published⁶. Jennings and Even searched the sequence for amino acid homologies with both HLA-B7 and the closely related HLA-A2 but found none, thus calling into question the conclusions based on the nucleic acid hybridization data of Clarke *et al.*, who in reply raise the formal possibility that the antigenic determinant might be sufficiently small to be missed by amino acid sequence comparisons. But would it then be sufficiently large to be picked up by nucleic acid hybridization? Are we faced with nucleotide homology that is not reflected at the protein level, and if so what does this