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

Chemical Boundary Layers of the Mantle and Core [Abstract Only]

T. H. Jordan

Phil. Trans. R. Soc. Lond. A 1989 **328**, 441-442
doi: 10.1098/rsta.1989.0047

Phil. Trans. R. Soc. Lond. A 328, 441–442 (1989)
Printed in Great Britain

Chemical boundary layers of the mantle and core [abstract only]

By T. H. Jordan

Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, U.S.A.

There is now sufficient information from seismological mapping of the Earth's deep interior to draw some preliminary conclusions regarding nature of large-scale mantle flow. This paper examines three features of mantle heterogeneity.

Seismological studies confirm the existence of a thick (more than 300 km) thermal boundary layer (TBL) beneath the ancient cratonic nuclei. Petrological and gravimetric data imply that the continental TBL is stabilized against convective disruption by a buoyant, viscous, chemical boundary layer (CBL) depleted in Fe and Al relative to Mg. Geothermal constraints require high heat production within the CBL and low heat flow through its base, indicating that the CBL has been recharged by large-ion lithophile (LIL) elements after primary depletion events. Formation of this continental tectosphere cannot be simple conductive cooling, as in the oceans, but must involve several stages characterized by different timescales, terminating with crustal stabilization; the advective thickening of a basalt-depleted, LIL-rich CBL in episodes of compressive orogenesis (e.g. supercontinent assembly) may be an important mechanism for tectospheric consolidation. The stability and low basal heat flow of the cratonic CBL are evidence that the positions of the continents through time are coupled to the upward flow of material from the deep mantle.

In the transition zone and lower mantle, the aspherical variations in seismic velocities are dominated by the downward and outward flow of cold material beneath areas of active subduction. Residual-sphere analysis of P-wave and S-wave data from deep-focus earthquakes indicates the presence of anomalous high-velocity material extending into the lower mantle below the seismically active portion of the slab. The dimensions and orientations of these high-velocity zones are consistent with the hypothesis that essentially all slab material is sinking through the 650 km discontinuity into the lower mantle; this flux is sufficient to recycle the entire volume of the upper mantle into the lower mantle in less than 10^9 years and cannot be reconciled with chemical–convective stratification at this boundary. Global tomographic models and regional studies delineate high-velocity anomalies in the lower mantle beneath Cainozoic subduction zones consistent with the constraints established by the residual-sphere analysis.

Large-amplitude, low-wavenumber heterogeneity has recently been discovered in the vicinity of the core–mantle interface. As in the case of the free surface, it is difficult to account for the magnitude of the asphericity without postulating the existence of a laterally heterogeneous CBL on one or both sides of the core–mantle interface. The processes that potentially contribute to CBL formation include the accumulation of 'dregs' at the base of the mantle (e.g. subducted oceanic crust), the accumulation of 'slag' at the top of the outer core (e.g. from inner-core differentiation), chemical reactions at the interface, and primary chemical layering inherited from inhomogeneous accretion and/or core formation. This system of CBLs may interact strongly with mantle convection and play a crucial role in coupling it to convection in the core.

In summary, the low-wavenumber aspherical heterogeneity of the mantle and outermost core is dominated by boundary layers formed at the free surface and core–mantle interface, and chemical heterogeneity appears to play an important

role in governing the configuration of these boundary layers. The seismological data appear to be consistent with an Earth comprising four major dynamical systems: the two convecting shells of the mantle and core, and the two CBLs at the free surface and core–mantle interface. Strong interactions among the low-wavenumber states of these four systems offer new possibilities for explaining the Earth's large-scale, long-term behaviour.

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