Heatflow and mantle convection in the triaxial Earth

Anne M. Hofmeister
Robert E. Criss
Department of Earth and Planetary Science, Washington University, St. Louis, Missouri 63130, USA

ABSTRACT

Perception of the Earth as vigorous rests on substantial overestimates of global heat flux and Rayleigh numbers. Weak, layered mantle convection is indicated by downward revision of these parameters and by new theoretical models and measurements on the variation of thermal conductivity (k) with temperature (T) and depth. Revision of the global heat flux from a model-dependent estimate of 44 to 31 terrawatts, obtained directly from measurements, is necessary because hydrothermal systems near the ocean ridges are too weak to perturb seafloor older than ca. 1 Ma. The lower estimate is consistent with recent compositional models and nearly uniform release of heat over the surface, and compatible with our aged Earth's now being quasi–steady state. Rayleigh numbers have been overestimated by assuming whole-mantle convection, which is inconsistent with evidence of chemical layering. Different dynamical styles above and below 670 km are required by k(T) because T depends on depth, implying layered mantle convection. Geodesic and tomographic studies indicate that lower-mantle flow is dominated by a double torus. We propose that the upper-mantle system is organized in reponse to the nonhydrostatic triaxial stress field arising from convective motions of the lower mantle. Simple conjugate shears in the lithosphere resulting from triaxial deformation of this stiff outermost layer are occupied by oceanic ridges and make a striking "X" pattern in polar projection. Their orientation creates alternating thermal and mechanical couplings between the upper- and lower-mantle systems, leading to largely east-west continental drift and to longitudinal concentration of subducting slabs and continents. Upper-mantle magma production is attributed to thermal runaway and near-solidus temperatures rather than to material exchange with lower mantle, which is strongly impeded.