Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 283

The Helium-Heat Flow Paradox Re-visited: Whole Mantle Convection with a He-rich Core

Arthur Calderwood (acalderw@eos.ubc.ca)

University of Nevada @Las Vegas, Dept. of Physics, 4505 South Maryland Parkway, Las Vegas, Nevada, 89154-4002, USA

Recent tomographic models clearly document that oceanic lithosphere subducts to the core-mantle boundary. Mineral physics models using the latest thermoelastic data demonstrate that a uniform pyrolite composition can satisfy the radial profiles of density and velocity throughout the whole mantle when calculated along a self-consistent adiabatic geotherm whereas chemically layered models with an mid-mantle thermal boundary layer cannot. Thus, plumes must originate at the core-mantle thermal boundary layer. Both results are consistent with a simple picture of whole mantle flow. This view conflicts with the traditional isotopic and rare gas interpretations that the mantle is chemically and convectively layered with the 660 km discontinuity being a boundary to flow. In this scenario, the lower mantle is a chemically distinct reservoir rich in K, U, Th and primordial ^{3}He. It is claimed that the ^{4}He degassing flux at mid-ocean ridges is much less than the oceanic heat flux under the assumption that both heat and ^{4}He are produced from U and Th decay. Furthermore, the low $^{4}He/^{3}He$ ratios of ocean-island basalts, relative to MORB's reflects an excess of ^{3}He, presumably from the primordial lower mantle reservoir and requires that the ^{3}He source lie at or below the thermal boundary layer from which plumes arise. These two arguments are used to support a chemically layered mantle where heat produced in the lower mantle easily diffuses across a 660km chemical and thermal boundary layer, but that ^{4}He produced in the lower mantle, does not.

To reconcile the helium and mineral physics and seismic views of mantle structure I carefully re-evaluate the helium-heat flux paradox. I find that the claimed helium-heat flux paradox is based on total mantle concentrations of U, Th, and K that do not produce enough radiogenic heat to satisfy the global heat flux, in spite of claims to the contrary. Thus, the layered mantle structure advocated to solve the helium-heat flux paradox cannot be correct. Instead, I use a K, U, and Th mass and heat balance model for the distribution of these elements within the Earth that explicitly accounts for the concentrations in the crust, lithosphere, depleted mantle, and if required, the core reservoirs. In this model the whole mantle is depleted, consistent with seismic and mineral physics constraints on mantle structure. The reduced mantle heat flux is 32.94TW. The depleted mantle concentrations are U:Th:K = 2.5ppb: 6.45 ppb: 31.75ppm, with the heat flux from U and Th being 1.60 TW and the ^{4}He production rate being 5.10 x 10^{9} atoms/m^{2} sec. For an assumed depleted mantle $^{4}He/^{3}He$ production ratio of 10^{8}, the ^{3}He production rate is 51 atoms/m^{2} sec. This represents 4.85% of the reduced mantle heat flux but 96.6% of the global ^{4}He flux and 0.07% of the global ^{3}He flux. The core is assumed to possess a solar $^{4}He/^{3}He$ ratio of 2,564 and contributes a ^{3}He flux of 69,580 atoms/m^{2} sec (99.93% of the global ^{3}He flux) and a ^{4}He flux of 1.78 x 10^{8} atoms/m^{2} sec (3.38% of the global ^{4}He flux). The present day mantle secular cooling heat flux is calculated independently using updated parameters (9.99TW), while the depleted mantle K radiogenic heat flux is 0.43TW. The core radiogenic (due to potassium) and non-radiogenic heat flux totals 20.95TW. Thus, most of the reduced mantle heat flux (95.14%) is not due to the decay of mantle U and Th, but instead largely comes from the core or secular cooling of the mantle. This model, where the whole mantle is depleted, can account for both the observed global heat flux and helium fluxes without any discrepancy between the mantle production rate of ^{4}He and heat. Thus, there is no requirement for a mid-mantle chemical or thermal boundary layer that permits heat to pass, but not ^{4}He. Therefore, it is possible to reconcile mineral physics, seismic, heat flux, and rare gas models of mantle structure with the whole mantle being depleted, where the ^{3}He rich reservoir for mantle plumes corresponds to a helium-bearing core which has solar $^{4}He/^{3}He$ ratio.