Journal of Applied Geochemistry
Vol. 14, No.4 (2012). pp 509-527

GLOBAL SURFACE HEAT FLOW AND ITS IMPLICATIONS ON MANTLE STRUCTURE

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Abstract

The structure of mantle and mode of convection is still debatable in the scientific community. Geochemical approaches strongly suggest layered mantle structure comprising of depleted upper mantle (DM, source of mid-ocean ridge basalts) and the lower mantle reservoir (LM, source of ocean island basalts); the depth of compositional barrier is at~ 1700 km (Kellogg et al., 1999). However, global seismic tomographic images showing slabs penetrating the 660-km seismic discontinuity up to the core-mantle boundary (D" layer) is argued in favour of whole mantle convection. We use present-day observed global surface heat flow (46±3 TW) and concentration of heat producing elements U, Th, and K in silicate Earth reservoirs and perform mass-heat energy balance estimates to constrain compositional layering and style of convection in the mantle. Our preferred model gives convective Urey ratio (Ur, fraction of the mantle heat loss attributed to the radiogenic heat in the mantle) Ur ~ 0.7, close to that preferred by parameterized models of mantle convection and cooling history. This agrees with numerical estimates of mantle cooling rate (100 $K.Gyr^{-1}$ for the present-day) that attribute ~ 70% of the present-day surface heat flow to the radiogenic heat. Considering whole mantle to be DM composition given by Salters and Stracke (2004), Ur becomes 0.12±0.04, suggesting ~ 90% of heat from secular cooling only and a present-day mantle cooling rate of ~ 280 $K.Gyr^{-1}$. This indicates a catastrophic thermal history of the earth and predicts an incredibly hot Earth during the early history. The implication is that whole mantle convection is only possible if HPE concentrations are substantially underestimated for the MORB source, which seems unlikely. Our results suggest significant compositional stratification in the mantle similar to that proposed by Kellogg et al. (1999).

Keywords: Mantle structure, Depleted upper mantle, Core-mantle boundary, Heat flow.

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