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Two-stage melting and noble gases

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The AGU Fall 2007 meeting had several papers on diffusion of noble gases under mantle conditions (e.g., Hart et al. - U21B-0407, Watson et al. - U21B-0410, Albarede - V43F-07). Here we show how diffusion combined with our plume-based model of a plum-pudding mantle, a plume-fed asthenosphere, and two-stage melting (first to make OIBs above a rising plume and second to make MORBs by melting asthenosphere which is the residue from the first-stage of melting) can explain the rare gas patterns seen in OIB and MORB. In this abstract, we focus on the observation that the ratios of 3He/22Ne and 4He/21Ne are higher in MORBs than in OIBs. [3He and 22 Ne are both stable, primodial isotopes. 4He and 21Ne are both produced by the decay of uranium and thorium; 4He is directly produced by this decay, 21Ne is produced by an occasional alpha particle reaction 18O(a,n)21Ne. In mantle silicates, the production ratio is one 21Ne for every 2.2x10ˆ7 4He.] So how can there be more 3He/22Ne in MORB than OIB, and similarly more 4He/21Ne in MORB than OIB? We think diffusion of helium between neighboring components in the plum-pudding mantle is the simplest physical mechanism to explain this. The primordial 'plums' contain more 3He, 20Ne, 22Ne, 36Ar; but the helium (and not the larger neon, argon, and heavier noble gases) diffuses out from the concentrated plums into neighboring components. Thus in the first-stage melting at a rising plume, the easy-to-melt but small-volume fraction components that melt to produce OIB contain less He than the heavier noble gases (because some He has diffused away into neighboring more barren components). In the second, more-extensive melting that makes MORB, the more barren material will partially melt and release this helium, resulting in the MORB having relatively more He than the heavier, less diffusive noble gases. Similarly, in non-primordial components with enrichments of uranium, thorium and potassium (recycled continental crust, recycled oceanic crust), helium but not 21Ne or 40Ar, etc.

has diffused out from the concentrated lumps that melt in the first state, again resulting in lower-than-the-average He in OIB but higher-than-the-average He in MORB. Other aspects of this model will be presented.