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Geochemical Mantle Evolution with an early-formed D” Reservoir

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Many geochemical observations point to a largely isolated, early-formed reservoir deep in the Earth, e.g. (1) well-known mass balances of highly incompatible elements, including the heat producers Th, U, and K, and of isotope ratios; (2) the occurrence of solar noble gases in the mantle, in apparent contradiction with the extreme degassing of this reservoir indicated by mantle xenology; (3) specific isotopic compositions of mantle He, Ne and Xe pointing to a reservoir with low $U/^{3}He$ and $^{136}Xe(Pu)/^{129}Xe(I)$ ratios, implying both early formation and low degassing of this reservoir. We have previously suggested that the core-mantle transition zone (termed D”) constitutes this reservoir. The material of D” may preserve an early mafic crust loaded with chondrite-like, late-accreting matter including a solar-wind irradiated regolith. After subduction, this material should accumulate in D” due to an intrinsic density contrast. Provided that it was not hydrated at the surface, so that subduction did not cause extensive volatile loss, it should have retained its geochemical characteristics including solar noble gases.

We examine the consequences of this scenario by transport models envisaging: (1) Earth accretion accompanied by mantle melting and fractionation, core segregation, formation and recycling of mafic crust, degassing, and gas loss from the atmosphere, followed by (2) crust-mantle evolution involving continent growth and recycling. Comparison of calculated and observed parameters allows a solution of the model. The D” layer is formed within about 40 to 80 Ma after formation of the solar system and comprises about 20% of the bulk silicate inventory of incompatible (including

heat-producing) elements. Because the bulk of the D” material (basalt) is fractionated, its apparent isolation allows a mass balance for ^{147}Sm-^{144}Nd and U-Th-Pb systematics to be achieved with whole-mantle convection (apart from D”). D” is an important ^{40}Ar*-, ^{129}Xe*- and ^{3}He- bearing reservoir in the Earth. After accretion, small amounts of D” material are entrained by convective flow thus contributing noble gases to the mantle: Rare gas modeling yields a low flux from D” into the overlying mantle, about 20% of the D” mass per 4.5 Ga, which is about 100 times lower than the rate of ridge magma production. Thus, D” remains a geochemically important, present-day reservoir.