Thallium isotope constraints on Earth's accretion

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The extinct radionuclide ^{205}Pb decays to ^{205}Tl with a half-life of 15 Myr. The former presence of ^{205}Pb in the solar system was recently inferred from a ^{205}Pb-^{205}Tl isochron that was obtained for seven metal samples from the IAB iron meteorites Canyon Diablo and Toluca [1]. New Tl isotope data obtained for eight carbonaceous chondrites are in full accord with this isochron [2].

Several lines of evidence (based on I-Xe and Pd-Ag chronology; e.g., [3, 4]) indicate that the IAB parent body crystallised about 10 to 20 Myr after CAI's. Based on this age, the IAB isochron yields an initial solar system ^{205}Pb/^{204}Pb ratio of about 1.5 x 10^{-4} and an initial Tl isotope composition of $\varepsilon^{205}Tl_0 = -2.8 \pm 1.7$ [1]. The latter is unlikely to be greater than -2.5, given that the Earth's mantle has a well-constrained present-day ε^{205}Tl value of -2.0 ± 0.5 [5, 6]. The available data thus indicates that the solar system was characterised by an initial $\varepsilon^{205}Tl_0$ of between -2.5 and -4.5.

Two scenarios emerge if these values and recently determined metal-silicate and sulphide-silicate partition coefficients for Pb and Tl [7] are utilised to model the Earth's accretion and core formation. (1) If $\varepsilon^{205}Tl_0$ is greater than -3.5, then standard accretion models yield unrealistic Tl abundances of >7 ppb for the bulk silicate Earth (BSE). This discrepancy can only be avoided if the Earth either experienced large-scale volatile loss at the time of the Giant Impact or accreted from volatile-depleted material characterised by a ^{238}U/^{204}Pb ratio of >2. (2) If $\varepsilon^{205}Tl_0$ is less than about -4.0, the present day composition of the BSE can be readily reconciled with standard terrestrial accretion models, providing they feature late-stage segregation of sulphides from the mantle, as was recently proposed by Wood and Halliday [8].

The presently available Tl isotope data for meteorites do not permit a sufficiently precise definition of $\varepsilon^{205}Tl_0$ to distinguish between these two scenarios. This indicates the importance of conducting further Pb-Tl isochron studies, which are able to provide a more precise estimate of $\varepsilon^{205}Tl_0$.

References

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