Are old continental crusts of the Earth Theia-origin?: Implications for the origin of the Moon

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Crustal materials in the Archean continents (4-2.5 Gyr ago) often had elevated isotopic ratios of tungsten, i.e. the deviation of $^{182}W/^{184}W$ from its value for today's upper mantle $m^{182}W > 0$ holds, as is the case for the Moon. The elevated $m^{182}W$ together with the rather low content of highly siderophile elements (HSEs) in these materials are suggested to imply that the proto-Earth had high $m^{182}W$ and low HSE-content, that the materials ejected from the proto-Earth by a giant impact (GI) formed the Moon, and that $m^{182}W$ was reduced and HSE-content increased later in the Earth by the chondritic materials that accreted to the Earth as a late veneer [e.g., *Touboul et al.,* 2015]. However, convective current in the Earth's mantle has probably not been vigorous enough to make the upper mantle isotopically homogeneous on the spatial scale of hand specimen today by mechanically mixing the late veneer with the original mantle materials from the proto-Earth. Indeed, convective stirring of the mantle can dissolve its compositional and isotopic heterogeneity only at the spatial scale of 10^3 km or longer, and smaller scale heterogeneities often survive throughout the history of the Earth in my numerical models of mantle evolution caused by a coupled magmatism-mantle convection system [*Ogawa*, 2014]. Here, I propose an alternative model for the isotopic evolution in the Earth: (1) $m^{182}W$ was positive in Theia but was 0 in the proto-Earth before GI. (2) A part of the Theia-materials formed into the Moon, while the rest covered the surface of the proto-Earth at the time of GI. (3) As the continental crusts grow in the early Earth, the materials from Theia contaminated them. (4) The Theia-origin materials on the Earth's surface then recycled into the deep mantle. (5) Continental crusts have further grown after the recycling without contamination from Theia. The different $m^{182}W$ between the proto-Earth and Theia suggested here can be compatible with the classical GI model [e.g., *Canup*, 2014] and the multiple-impact model [*Rufu et al.,* 2017; *Citron et al.*, 2018] for the origin of the Moon, but is at odds with some other models, like synestia [*Lock* et al, 2018].

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