Impact-induced fractionation in the Bulk Silicate Earth chemical composition during its accretion

Allibert L.[1], Charnoz S.[1], Siebert J.[1,2], Jacobson S.A.[3], Raymond S.N.[4]

[1] *Institut de Physique du Globe de Paris, Université de Paris, 1 rue Jussieu, Paris, France*
[2] *Institut Universitaire de France*
[3] *Michigan State University, Earth and Environmental Sciences, 288 Farm Ln, East Lansing, MI 48824, USA*
[4] *Laboratoire d'Astrophysique de Bordeaux, Allée Geoffroy St Hilaire, Bordeaux, France*

Dynamical scenarios of terrestrial planets formation suggest that the terrestrial planets region was strongly perturbed by the giant-planets, leading to enhanced collision velocities, and thus, collisional erosion. The present paper aims to estimate this effect on the resulting composition of the Earth, and to determine how it could constrain its dynamical formation. The composition of the Bulk Silicate Earth (BSE, Earth's primitive mantle) is often considered chondritic for refractory and lithophile elements (RLE), which should not be affected by volatile loss or core formation. However, with collisional erosion involved in the Earth formation process, this might not be the case.
Here, we simulate the erosion of Earth's crust in the context of Solar System formation scenarios, including the classical model and Grand Tack scenario, which invokes a long-range orbital migration of Jupiter during the gaseous disk phase (Walsh et al., 2011; Raymond et al., 2018). We quantify the effects of erosion in both scenarios on several RLEs and notably on Sm and Nd that are very good tracers of crustal erosion. We find that the nucleosynthetic reservoir hypothesis, that precludes any significant collisional erosion during Earth's accretion, and the Grand Tack model with a late giant impact are mutually incompatible with each other. In conclusion, under currently discussed dynamical scenarios of the Earth accretion, only two options are conceivable: (i) the Grand Tack happened, along with a late Moon forming impact (after 50 Myr), but this requires the initial material reservoir to be homogeneous, thus, excluding nucleosynthetic anomalies or (ii) the initial planetary material reservoir was heterogeneous (due to nucleosynthetic anomalies) but Grand Tack cannot have happened, and only a low erosive dynamical evolution of planets is possible. We estimate the change in BSE composition for an entire set of other chemical elements in these two cases and show that collisional erosion systematically fractionate the BSE compositions. Accordingly, the effects of collisional erosion should be integrated in compositional models of the BSE and could provide insights on the accretionary processes and the nature of Earth's building blocks (e.g. by reconsidering the Earth volatile depletion trend).

Key-words : *Planet and star formation* & *Geo and cosmochemistry*