EVOLUTION OF THE SILICATE EARTH COMPOSITION INDUCED BY COLLISIONAL EROSION IN THE CONTEXT OF TERRESTRIAL PLANETS ACCRETION. L. Allibert[1], S. Charnoz[1], J.Siebert[1,4], S. N. Raymond[2] and S. A. Jacobson[3], [1]Institut de Physique du Globe de Paris, Université de Paris, 1 rue Jussieu, Paris, France, allibert@ipgp.fr, [2]Laboratoire d'Astrophysique de Bordeaux, allée Geoffroy St Hilaire, Bordeaux, France, [3]Michigan State University, Earth and Environnemental Sciences, 288Farm Ln, East Lansing, MI 48824, USA, [4]Institut Universitaire de France.

Introduction: Impact-induced erosion of the Earth's early crust during accretion of the terrestrial bodies is a mechanism that may have a high influence on Earth composition [1], [2]. Current models of the Bulk Silicate Earth (BSE = crust + mantle) composition are inferred assuming that Refractory and Lithophile Elements (RLEs) are in strictly chondritic ratios in the BSE [1]. However, the formation of the primitive crust induces unequal distribution of RLEs between the crust and residual mantle due to their specific solid-liquid partitioning behaviors. Accordingly, preferential collisional erosion of the crust can fractionate RLE compositions of the BSE with respect to chondritic compositions [1], [2], [3]. Quantifying the effects of collisional erosion is critical for providing insights on the mechanisms of terrestrial planets accretion (e.g. dynamical evolution of the accretionary disk) that set the current observed BSE composition and on the origin of Earth's building blocks.

Model: We test the effect of crustal stripping on the BSE composition with a realistic model of erosion integrated over entire Earth analogs accretion histories. The model is built from a coupling between (1) simple semi-analytical laws for eroded and accreted masses during an impact [4], [5] and (2) N-body numerical simulations of terrestrial planets accretion.

The erosion model is computed for a set of lithophile elements (i.e. rock loving elements) including major and trace elements (e.g. Sm, Nd, Hf, Lu, U, Mg, Si) covering a large range of degree of incompatibility (i.e. different affinities for solid or liquid phases during partial melting process such as crust formation).

Different dynamical accretion scenarios are tested (classical [6], Grand Tack [7] and Low Mass Asteroid Belt [8]) with different sets of initial conditions. It allows constraining the conditions of accretion that lead to substantial or negligible erosion of the crust. We identify notably two extreme cases that could be understood in terms of the Sm-Nd systematics : (i) the superchondritic Sm/Nd ratio resulting in a 20-ppm excess of the $^{142}Nd/^{144}Nd$ ratio of the BSE compared to chondrites can be fully explained by collisional erosion at the end of Earth's accretion [9], (ii) a negligible fractionation of the Sm/Nd ratio of the BSE is obtained at the end of accretion, compatible with recent studies enlightening the existence of nucleosynthetic anomalies in the accretionary disk that would be responsible for the excess in ^{142}Nd [10], [11], [12].

To do so, we track the ε parameter defined as:

$$\varepsilon = \frac{\left(\frac{Sm}{Nd}\right)_{BSS}^{end} - \left(\frac{Sm}{Nd}\right)_{BSS}^{ini}}{\left(\frac{Sm}{Nd}\right)_{BSS}^{ini}},$$

with BSS referring to "Bulk Silicate Shell" of a growing embryo. This is a direct measurement of the loss of Sm compared to Nd. The target value for explaining BSE measurements with collisional erosion only (extreme case (i)) is 0.05. To account for nucleosynthetic anomalies observations (extreme case (ii)), the ε target value should be 0 instead.

ε is also estimated for the elemental ratios: *Lu/Hf*, *Th/U*, *Mg/Si*, *Rb/Sr* and *Mn/Na*. Additionally, we follow the evolution of the final concentration of an element M compared to its initial value in the BSE, noted C_M^{BSS}/C_M^0, that provides direct estimation of the loss of a given element.

Results and discussion: For both classical and low mass asteroid belt scenarios [6], [8], the subsequent fractionation is too low to be responsible for the observed Sm/Nd BSE superchondritic ratio (ε = 0.029 ± 0.015 for the classical model and ε = 0.026 ± 0.018 for the low mass asteroid belt). However, even if the Grand Tack provides a similar fractionation for good Earth analogs (ε = 0.030 ± 0.015), we evidence a clear correlation between ε and the timing of the last giant impact occurring on the growing Earth analog (i.e. the Moon forming event). The later the last giant impact is, the higher is the fractionation (Figure 1).

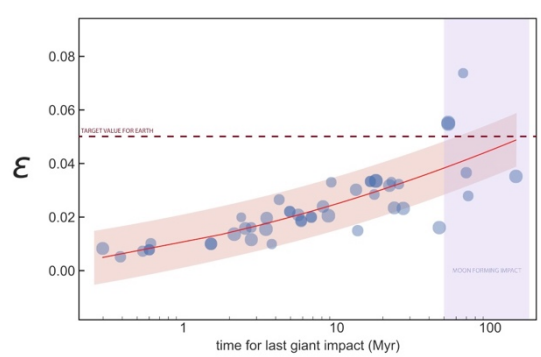

Figure 1

We show that both classical and low mass asteroid belt scenarios lead to a low fractionation, which would be compatible with nucleosynthetic anomalies identified in chondrites. A Grand Tack might produce a similar result if the Moon formed early. However, the combination of a Grand Tack and a late Moon-forming event (> 50 My) is incompatible with nucleosynthetic anomalies.

Furthermore, we show that collisional erosion systematically fractionate the BSE final composition with respect to chondrites due to the varying degrees of incompatibility of considered elements. The trend of depletion of elements in the final BSE composition as a function of the degree of incompatibility of elements is presented in figure 2, with D_M being the solid/liquid partitioning coefficient for a given element M. We find notably that highly incompatible elements such as U, Th and Rb are significantly depleted in the BSE with respect to chondritic proportion. 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).

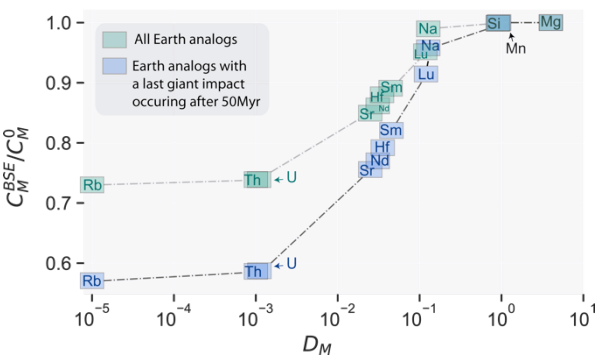

Figure 2

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