Ecole Doctorale des Sciences Fondamentales

Title of the thesis: The behavior of volatile elements (C, H, N and O) during impacts and planetary formation.

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Summary:

Meteoritic impacts contributed to the evolution of the primitive atmosphere of growing terrestrial bodies by supplying material to the impacted body, outgassing its deep material (Fig. 1) and eroding the pre-existing atmosphere. The competition between these 3 phenomena can thus lead to an increase in the thickness of the atmosphere or its erosion. The effectiveness of degassing or impact erosion is a function of the impact velocity (v_{imp}), the size of the impactor (R_{imp}), the size of the impacted body (R_p), the chemical composition and rheological properties (porosity, viscosity) of the materials involved.

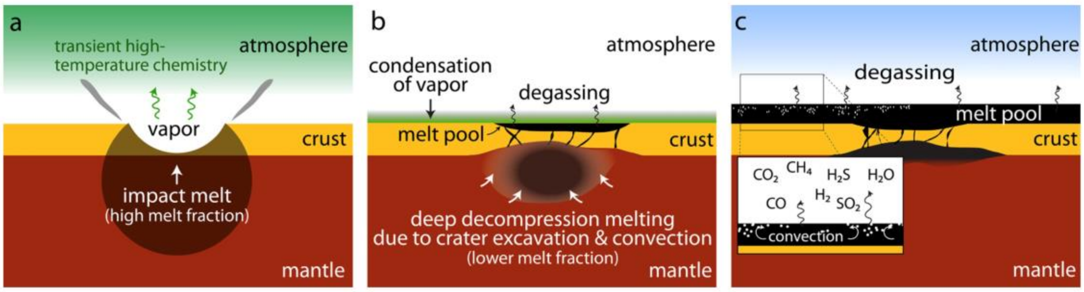

Fig. 1: Schematic cross section through an impact-generated melt pool and subsequent outgassing (Marchi et al., 2014)

The degassing by impact of volatile elements is still not very well constrained and attributed to the combined action of high temperatures, to an amplification of the diffusion or to the development of micro-fractures (*Zhang, 2014*). As the combination of these mechanisms is poorly known, the scaling laws needed to estimate the fraction of material degassed by giant impact from laboratory experiments on small volumes are difficult to obtain. In addition, there are still large uncertainties about the accretive history of the planets and the Earth in particular. However, the partitioning of volatile elements in the Earth's mantle is now increasingly constrained at high pressures and high temperatures. Moreover, thanks to numerical modeling, we can now more precisely describe the internal consequences of large meteorite impacts (*Ahrens et al., 1977, Pierazzo et al., 1997, Monteux and Arkani-Hamed, 2016, 2019*).

The scaling laws obtained from hydrocode models show that the pressure below the impact site can reach several tens of GPa on volumes comparable to that of the impactor (*Monteux and ArkaniHamed, 2016*). Then the pressure increase experienced during the collision decreases rapidly as one moves away from the point of impact. The accretion parameters could thus play a major role in the evolution of the thickness of this atmosphere (*Ahrens, 1993; Ahrens et al., 2004*). However, **at present, no quantitative model can integrate the effect of the outgassing of the mantle, initial gases and volatile compounds produced by the impact during the accretion of the planets** (*Zhang, 2014*).

The objectives of this project are to **develop numerical models** in order to constrain the primitive evolution of the atmosphere and the Earth's primitive mantle and in particular (1) to **follow the impactor material** within the impacted material, (2) to **constrain the evolution in volatile elements in the mantle** (C, H, N, O) during / after an impact and (3) to **propose a model of the composition in volatile elements of the primitive atmosphere and mantle** after accretion of the Earth depending on the properties of accretion (rate, duration, characteristic sizes). Numerical simulations will be carried out using the iSALE hydrocode model particularly suited to the study of large meteorite impacts (Monteux and Arkani-Hamed, 2016, 2019). By considering realistic chemical compositions, we will be able to determine for each impact the degassed volume as well as its composition. This will allow us to **follow the evolution of the early atmosphere in terms of composition and thickness**. At the end of this project, we will propose a numerical model in which it will be possible to choose the characteristics of the accretion of the Earth in terms of impactor size, impact velocity and accretion rate and to know the characteristics of the primitive atmosphere generated by such accretion. The information obtained by these models will be the thickness but also the composition of this atmosphere in elements such as C, H, N, O and S.

References:

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