



# ÉCOLE DOCTORALE SCIENCES DE LA TERRE



Subject offered for a contract starting october 2014

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## **SUBJECT TITLE: Studying the origin of volatile elements by coupling Zn and Sn isotope geochemistry**

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Second Advisor/ Supervisor:

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Financing: Doctoral contract with or without assignment

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Presentation of the subject: The abundance of volatile elements (e.g. H, C, S) controls many fundamental characteristics of the terrestrial planets, including their ability to develop and sustain life as well as the geochemical properties that make each planet unique. But how and when budgets of volatiles were set in planets and the mechanism of volatile depletion in planetary bodies remains poorly understood and represents a fundamental obstacle in understanding the chemical processing of terrestrial planets. The major difficulty is that the terrestrial planets formed in the inner solar system close to the young Sun where temperatures were too high (>1000K) for volatiles to condense. Volatilization is known to fractionate isotopes while condensation only fractionates isotopes in some very specific cases; therefore, comparing the isotopic compositions of volatile elements is a very powerful tool to understand the origin of volatile element abundance variations (evaporation or partial condensation). Evaporation enriches the residue in the heavier isotopes while the absence of condensation is expected to produce limited isotopic effects. It is therefore theoretically possible to differentiate between evaporation or partial condensation by measuring the isotopic composition of a moderately volatile element. However, until very recent advances in Multi-Collection Inductively-Coupled-Plasma Mass-Spectrometry (MC-ICP-MS) it was not possible to measure the isotopic composition of volatile heavy elements at the necessary precision (i.e better than 0.1‰).

We propose to focus this thesis on coupling tin (Sn) and zinc (Zn) isotope geochemistry to study the volatile history of solar system materials such as meteorites, the Earth and the Moon.

Our previous work has shown that lunar material is isotopically enriched in the heavy isotopes of Zn (by about 1‰; Paniello et al. 2012, Day and Moynier 2014, Kato et al. 2015). This suggests that the volatile element depletion observed in lunar basalts could be a consequence of degassing either following the giant impact or during basaltic eruption. On the other hand, stable isotope fractionation can occur during planetary differentiation. An alternative interpretation is that Zn isotopes could have been fractionated during igneous processes on the Moon. An approach to solve this problem will be to investigate the isotopic composition of several well-selected volatile elements with different geochemical behaviors. Tin (Sn) is highly chalcophile and it has a similar

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volatility to Zn. Since Zn and Sn have similar volatility but different behavior during planetary differentiation, combining the measurement of their isotope composition will allow us to test the origin of the fractionations. During this thesis we will develop a method to analyze the Sn isotope composition of natural rocks, and apply it, together with the existing method for Zn to understand the origin of the volatile elements in the Earth, the Moon and the other terrestrial planets.

Our previous work has been documented that the moderately volatile element Zn (50% condensation temperature  $T_c=726\text{ K}$  [16]) is hardly fractionated during igneous processes but exhibits strong isotopic fractionation during evaporation-condensation process, which makes it a powerful tracer of the volatile histories of planets. We found that lunar samples are significantly depleted in light Zn isotopes, likely the result of evaporation from a massive impact event. While Zn is a lithophile element, Sn is primarily a chalcophile and siderophile element. Tin isotopes can bring additional constraints on the volatile history and accretion processes that have modified the meteorite parent bodies, planets, and their satellites.

Since every little is known on the Sn isotope cosmochemistry, we should also have several side projects once the method will be developed. For example, the nuclide  $^{115}\text{In}$  decays to  $^{115}\text{Sn}$  through the reaction  $^{115}\text{In} \rightarrow ^{115}\text{Sn} + \beta^- + \nu$ , with a half-life of  $4.41 \times 10^{14}$  years. Although the half life of  $^{115}\text{In}$  is much longer than that of  $^{147}\text{Sm}$  and  $^{238}\text{U}$ , luckily the natural abundance of the parent isotope ( $^{115}\text{In}$ ) is 95.71 %, while that of the daughter isotope ( $^{115}\text{Sn}$ ) is as low as 0.34%. We may therefore be able to develop a new dating techniques for minerals with high In/Sn ratios such as some sulfides. In addition, since the In/Sn ratio of the bulk silicate earth (BSE) is sufficiently low that over the age of the Earth, accumulation of radiogenic  $^{115}\text{Sn}$  in the BSE is negligible compared to the initial  $^{115}\text{Sn}$  of the BSE, and the  $^{115}\text{Sn}/^{118}\text{Sn}$  ratio remain unchanged. By the precise analysis of Sn isotopic compositions, model ages of old meteoritic sulfides could be determined.

