Earth Life Science Institute (ELSI)

Tokyo Institute of Technology

1- Three-dimensional simulations of early Martian hydrology at the landing sites of the future Mars rover missions.

Description: Knowledge on hydrological and geochemical cycles on early Mars is central for understanding the paleoclimate and habitability. In-situ analyses for sedimentary rocks by Mars rovers provide critical information to constrain the paleoenvironments; however, the information is limited only at their landing sites. To understand the hydrological and geochemical cycles surrounding the landing site, mesoscale hydrological modeling and its interpretation of the Mars rover's observations would be useful. This project aims to constrain the hydrological and geochemical cycles surrounding the landing sites of the upcoming Mars rover missions, ExoMars and Mars2020, by performing three-dimensional hydrological simulations on early Mars. We try to simulate the transport and diffusion of water near the landing sites and to predict the locations of upwelling water and distribution of sediments for given climate conditions. If time allows, we also try to predict water chemistry and precipitates (evaporates and oxides) of the paleolakes by performing laboratory experiments of chemical weathering of basement rocks. These results would be important to interpret the observational data by the Mars rover missions and to constrain the paleoclimate and habitability of this planet.

Supervisor: Yasuhito Sekine and Gabriel Tobie

2-Nitrogen cycling on rocky bodies.

Description: Nitrogen, in the form of N_2, is the major component of the present atmosphere of the Earth and corresponds to about a tenth of the estimated total nitrogen budget. Assuming a similar composition, Venus' atmospheric nitrogen represents about

80% of its total budget, although a minor component in the atmosphere. Comparatively, Mars' atmospheric nitrogen is both a minor constituent of the atmosphere and of the total planetary budget. What can those differences be attributed to? On the Earth, nitrogen is a crucial component of biology, which has evolved multiple ways of interacting with atmospheric and environmental nitrogen. For biological systems, it can be both a limiting nutrient and an energy source, depending on its oxidation state and abundance. As discussions about planetary habitability become more common in the context of observations of planets outside our solar system, it also becomes important to understand how major elements related to life cycle through planetary bodies with time.

We have initially constructed a very simple evolutionary model to understand the operation of a putative abiotic terrestrial nitrogen cycle, taking into account cycling between the mantle, crust, atmosphere and ocean reservoirs (Laneuville et al. 2018). To move forward, two approaches can be followed. First, work can be done to improve our treatment of some of the key processes in the cycle for the Earth (atmospheric photochemistry, ocean chemistry and water/rock interaction), but another approach is to use the diversity of observations we have from other terrestrial bodies. A single nitrogen cycling model should indeed be able to explain different planetary evolutions. The goal of this project is therefore to improve this model to take into account the specificities of Venus and/or Mars in order to develop a better understanding of nitrogen cycling on terrestrial bodies, with and without biotic processes.

This project will take place at the Earth-Life Science Institute (ELSI) in Tokyo under the supervision of Matthieu Laneuville and Henderson Cleaves. The current model is implemented using C++, so a good knowledge of that language and of the unix environment are required.

3-Evolution of the Martian core from an initially stratified state.

Description: Recent planetary formations studies have shown that planetary cores may form stratified both thermally and chemically (e.g., Jacobson et al. 2017). The specific strength of the stratification depends on formation model and may actually be removed by late giant impacts; however, it is still interesting from a theoretical point of view to understand the implication of such an initial state for core cooling and magnetic field generation. As heat flows both inwards to outwards to the mantle, a convective zone may

form close to the core mantle boundary and its spatial extent and lifetime depends both on the initial heat content of the core and cooling from the mantle.

The goal of this project is to construct an evolutionary model for planetary cores that takes into account both conducting and convecting regions. Mantle convection can be modeled using simple scaling laws (e.g. Turcotte and Schubert, 2002). In the core, conduction controls the timescale and convection can be approximated using an effective conductivity for the liquid taken from mixing length theory (Spiegel, 1963). We can then apply this model to the case of Mars to quantify how long a global magnetic field could be sustained in the liquid core as a function of the initial strength of stratification. Mars' global magnetic field is known to have stopped fairly early (Acuña et al. 1999) and this may be due to a transition in cooling mode.

This project can take place either in Nantes or at ELSI, with the participation of both Marine Lasbleis and Matthieu Laneuville. Arrangements (like two-part internship) are possible.