Title of the thesis: Experimental study of the volatility of metals and metalloids in planetary magmatic systems

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Summary :

The origin and cycle of volatile elements are debated in Earth and planetary sciences. While major volatile elements (C, N, O, H, S) are at the center of the debates, the moderately volatile elements (mainly metals, metalloids, and Selenium) provide important information due to their large number and their very variable behavior depending on thermodynamic conditions. This project will focus on the volatility of metals and metalloids in the conditions of modern volcanism and in those, probably warmer and less oxidized, which prevailed during planetary accretion and the formation of the magmatic ocean. It will address the following questions: (1) Why metals and metalloids abundances are so variable in modern volcanic gases? What is the role of temperature, composition and oxidation of magmas? (2) Which thermodynamic conditions governed early magma-gas equilibria and the condensation of volatile elements during the accretion of the Earth and other rocky planets.

To answer these questions, the project will perform magma degassing experiments in furnaces at ambient pressure. It will simulate the primitive and current conditions by varying the temperature and the fugacity of oxygen and sulfur. Several experiments will be carried out: the first will consist in studying the degassing of the elements by mass balance from the degassed residual silicate. The second will study the condensation of elements along a temperature gradient. The third aims to develop the analysis of metals and metalloids directly in the vapors emitted during the experiments. This approach, which involves the coupling of the experimental furnace and the plasma source mass spectrometer, will allow us to detect elements present in very low amounts in the gas, and to quantify their vapor pressure in real time depending on the thermodynamic conditions of the experiment. This will enable, for example, the study of weakly volatile metals (such as rare earths) under the conditions of planetary accretion, or the progressive degassing of elements during crystallization. The experimental approach will be combined with analytical and theoretical approaches, which will involve the study of elements whose behavior is still poorly known (Selenium and Tellurium), the measurement of the fractionation of stable isotopes, and the modeling of degassing laws.

The thesis work will be organized around four major tasks including (1) the development and implementation of degassing experiments, (2) the chemical treatment of experimental samples in a clean room, and their chemical/isotope analysis on a plasma source mass spectrometer, (3) data modelling, (4) writing publications and thesis manuscript.

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