PhD proposal – Sulfur, iron and carbon cycles and role for the formation of unconformity-related U deposits

Objective : understand the role of sulfur, iron and carbon and their geochemical cycle for the formation of unconformity-related U deposits

State of the art and scientific problematic : Sulfur, iron and carbon are ubiquitous elements in uranium deposits, and are present as different forms (sulfides, sulfates, carbonates, graphite, organic matter, oxydes, …) and in different phases (mineral, fluid, gas). These elements have long been considered as key for the formation of uranium deposits as potential electron exchangers for the reduction of U6 + to U4 + and therefore precipitation of mineralization. U-Fe-S-C associations have been previously studied with numerous studies focusing, for example, on the reactivity of sulfur (dissolved or mineralized) with respect to uranyl for applications mainly dedicated to the storage of radioactive waste. The involvement of bacteria on S-U reactions has also been studied, particularly for low temperature (25 ° C) and low salinity uranium deposits. On the other hand, few data are known concerning the role of carbon, iron and sulfur in the formation of unconformity-type deposits although these elements are particularly present and mobile in these hydrothermal deposits (125-200 ° C) involving highly salted fluids (brines). An achievement of the previous scientific and geological studies is the demonstration that these world-class uranium deposits are formed at the unconformity between a sedimentary basin and a basement, in spatial correlation with a specific lithology of the basement rich in sulphides and graphite (called graphitic shear zone). Different theories are now proposed as to the action of Fe-S-C without clear constraints validating their relevance, which poses a major problem as to the definition of the processes associated with the formation of these deposits with exceptional grades (up to 20 % U content).The aim of this PhD is therefore to specifically define the role of sulfur, iron and carbon in the formation of unconformity-type deposits. The chosen geological target is the Athabasca Basin in Canada, which is hosting the largest number of unconformity-related U deposits in the world. This work will be carried out in collaboration with Orano, a world leader company in the uranium cycle.

Research plan : The PhD will focus on two research axes: a petrographic and geochemical axis and an experimental axis. The first axis will target the qualification of Fe-C-S cycles in these deposits via a succession of petrographic and geochemical works, of which an important part will relate to the isotopic characterization of the different Fe-C-S carriers (mineral, fluid, gas). Specific work on the evaluation of C-Fe-S variations in graphitic shear zones at the scale of the Athabasca basement will be carried out with the aim of proposing a classification of the reducing potential for this lithology. The experimental axis will be based on autoclave tests in order to define the reactivity of the different Fe-C-S phases and species with respect to uranium under known geological conditions for the formation of unconformity-related U deposits. One objective of this work is to propose reaction mechanisms as well as mass balances which will be compared with the observations and geochemical balances made in axis 1. The data obtained will then be used to feed physico-geochemical models using dedicated softwares.

Working plan and conditions : Field missions to various Orano exploration sites in the Athabasca Basin will be carried out to study on-site drilling samples and to collect samples for laboratory work (Pending feasibility due to sanitary situation). Laboratory work will mainly be carried out at the GeoRessources laboratory in Nancy, as well as in collaboration with the CRPG (Nancy) for isotopic measurements and IsTerre (Grenoble) for the experimental component. The project is based on an important analytical component (microscopies, electron and ion microprobes, Raman, XRF, LIBS, LA-ICP-MS), whether in the laboratory or in the field, for which all equipments are available in Nancy.

GeoRessources is one of the French reference academic laboratories for the study of ore deposits, with almost 200 people (http://georessources.univ-lorraine.fr/), with long-term collaborations with major mining and petroleum companies. GeoRessources is considered one of the reference centers for academic research on uranium deposits, with more than 40 years of research on this topic. Our institution is part of the Université de Lorraine (http://welcome.univ-lorraine.fr/), which is one of the leading institutions for higher education in Europe with more than 55,000 students and 60 research laboratories. The department of Earth Sciences is one of the most important in Europe, with 4 laboratories hosting more than 300 researchers and 1000 students. Université de Lorraine was ranking 11th in the 2020 Shanghai Ranking for the category “Mining and mineral engineering”, first European university in this field of activity.

Academic supervision: J. Mercadier, P. Ledru, R. Michels, M. Cathelineau (GeoRessources, Nancy)

Orano supervision: R. Chemillac (Orano Canada) and M. Brouand (Orano France)

Collaborations : C. Card (Saskatchewan Geological Survey, Canada), L. Truche (IsTerre, Grenoble)

Timeframe : end 2020-end 2023

Contacts: Julien Mercadier (julien.mercadier@univ-lorraine.fr, + 33(0)372745559); Patrick Ledru (patrick.ledru@univ-lorraine.fr, +33(0)372745523)