PhD proposal : characterization of the structural framework and of the conditions of fluid circulations in the environment of the unconformity-related U deposits : example of the Cigar Lake deposit (Saskatchewan, Canada)

PhD at GeoRessources lab, Vandoeuvre-lès-Nancy, France

Supervizion : Y.Géraud (Université de Lorraine), J. Mercadier (CNRS), P. Ledru (Orano Canada)

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The objective of this PhD is to provide new constraints on the structural framework associated with the circulations of fluids in the environment of the unconformity-related U deposits in the Athabasca Basin (Saskatchewan, Canada). The goal is to understand how the different types of fluid circulated at the interface between a sedimentary basin (the Athabasca Basin) and an Archean to Paleoproterozoic basement, to form the highest grade U deposits on Earth.

Context : the unconformity-related U deposits of the Athabasca Basin was a priority target for exploration since decades due to their high grade mineralization (up to 20% for Cigar Lake or McArthur River deposits for example). Several models of formation were proposed through time based on the improvement of the scientific knowledge on these objects. Several first-order parameters are now accepted (like the nature of the mineralizing fluids for example) but several aspects are still in discussion, limiting the determination of efficient exploration guidelines. Among them, the geodynamic and structural contexts at the origin of the fluid circulations at the basin-basement interface and of the formation of the U ores are badly constrained. The circulation paths of the different fluids at the different scales (km to µm) and the associated physico-chemical modifications for fluids and rocks need to be defined. This PhD aims to provide answers to these questions via the 3 objectives proposed below, with an application to the Cigar Lake U deposit and its environment.

Objective 1 : building and validation of a 3D structurally-constrained geological model and characterization of the structures implicated in the circulations of mineralizing fluids

Identify and define the role and the dynamic of the different structures vectoring fluids in unconformity-related U deposits (chronology, geometry, deformation mechanisms, P-T conditions for deformation and reactivation), with a specific focus on structures controlling the mobility of the mineralizing fluids and their interaction with large-scale domains of the basement and basin at the origin of the deposition of uranium. The active conditions and of fluid circulations in the various faults and shear zones at Cigar Lake will be specifically studied. **One of the objectives is to test the potential**

analogy with the natural current active geothermal systems, geological objects currently much better constrained than the unconformity-related U deposits formed 1.5 Ga ago.

This work will be done by developing a 3D geological model based on pertinent structural, microstructural and petrophysical data on the different structures and mineralized zones in the area of the Cigar Lake U deposit, from the deposit to remote areas (as developed in the PhD of P. Martz done at GeoRessources). These data will be extracted from the database of Orano and supplemented by new data measured on selected samples. A specific structural study based on a complementary sampling will be done by the student and his supervisors on site to identify and characterize the first-order elements described above. A specific work will be done to define the chronology of the episodes of deformation and displacement, the geometry and architecture of the reactivated and newly formed faults, the permeability development of the structures and the infilling of the fractures to determine the nature of the fluids, their P-T conditions and their timing of circulation.

Objective 2 : Physical and chemical parameters of the vectoring structures for the mineralizing fluids at the scale of the Cigar Lake U deposit

After their identification and characterization thanks to objective 1, the vectoring structures will be implemented in a 3D model for an estimation of the values of various transfer parameters of fluids, matter and heat at the time of the formation of the deposits. Based on the concept of geothermal system, several parameters will be measured for these structures. Four zones will be defined: infiltration zone, charging zone, drainage zone and accumulation zone. For each of this zone, the detailed structural study done in objective 1 will be completed by the determination of the constituent elements of the porous network and of the petrophysical properties. This analysis will be done at multiscale (from µm to > m). For the faults and fractures, the aim is to decipher their organization, their distribution in length, orientation and opening to deduce the paleo-connectivity and paleo-permeability at the time of deposit formation. The estimation of the properties of storage (porosity) and transfer (permeability) will be defined by calculation. This work will allow classifying the structures and estimate the porous volume and the transfer properties for each of the defined zones. The analysis of images taken from thin sections will allow determining paleo-porosity and related properties. The specific measurement of electric resistivity, magnetic susceptibility and density at lab will be used to indirectly quantify the paleo-porosity and to interpret the geophysical data and data acquired from drill hole at a larger scale.

Such work will lead to a 3D model of plumbing system at the origin of the Cigar Lake deposit. These data will used for THMC (Thermo-Hydro-Mechanical-Chemical) modelling done in parallel of the PhD with the implication of a post-doc (2020-2021).

Objective 3. Towards a model at the scale of the Waterbury Cigar project and potential applications to other case studies

The analyses from the scale of samples to the structures and the definition of the different physical and chemical parameters will provide a new view on the permeability network of the Cigar Lake area, which will be used for 3D and THMC modellings (see objective 2). The extension of the modeled area in the regional framework of the hydrothermal field will necessitate the integration of the regional geophysical and geological data to establish the appropriate conditions for the building of a model at a larger sc ale. This regional modelling at the scale of the Waterbury-Cigar project will be based on the geophysical, petrophysical, geochemical and drill hole data from Orano. The determination of the permeability model at the scale of the project and the characterization of the pathways for the circulations of the brines and their interaction with the surrounding rocks is the final objective of the PhD.

Expected results

- Building of a 3D geological model, structurally-constrained, for the Cigar Lake U deposit

Definition of the role played by the different structures in the plumbing system at the origin of the Cigar Lake U deposit

- Quantitative qualification of the chemical and physical parameters of the plumbing system of the Cigar lake U deposit

- New view on the Cigar Lake deposit with an approach based on geothermal systems, and comparison with active geothermal systems

- Generation of first-order data for 3D and THMC modellings

- Classification of the structures and definition of new targets for future exploration program.

Working conditions : This PhD will be achieved in close collaboration between scientists from GeoRessources lab and the geologists and gepophysicists of Orano. This PhD will be firstly based on field work, done during several field missions at the Cigar Lake U deposit. These field work will allow studying selected drill holes, to make specific measurements and to sample materials to be analyzed at the lab in Nancy. The field work will be supervised by Orano geologists in charge of the exploration program at Cigar Lake and by the academic supervisers. The field work periods will be associated to stays at Orano headquarters (Saskatoon, Canada) to interact with geologists and geophysicists of Orano to properly understand and study the geological and geophysical frameworks of the area. The selected samples will be studied at GeoRessources lab, where all the needed equipment is available. GeoRessources has a specific team dedicated to 3D modelling.

GeoRessources is the French reference academic laboratory for the study of ore deposits, with almost 200 people (*georessources.univ-lorraine.fr*). The laboratory relies in particular on the CREGU, a private company at the interface between private companies in the field of mineral and energy resources and the academic world. The CREGU is a world-recognized scientific center on the geology of uranium, with more than 40 years of research on this metal. Our institution is part of the Université de Lorraine (http://welcome.univ-lorraine.fr/en), 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.

Prerequisite: the candidate will have a Master degree in Earth Sciences or a related scientific disciplines. The candidate will have a solid scientific background, with knowledge in structural geology, mineralogy, and/or geothermal system. The candidate will like to work in team and in different scientific environments. The candidate will work on the field. The candidate will have an English level allowing him to discuss with native English speakers and write scientific articles in the best English-speaking journals. One of the objectives of the PhD is the publication of articles in the best scientific journals, and the presentation of the results in international conferences.

Contacts : CV, cover letter and name of two references to be sent to Yves Géraud (yves.geraud@univ-lorraine.fr), Julien Mercadier (julien.mercadier@univ-lorraine.fr) and Patrick Ledru (patrick.ledru@orano.group)

Deadlines

PhD funding already available, hiring upon receipt of a candidate of interest