PhD Proposal – Geochronological framework of the formation of high-grade uranium deposits in the Athabasca Basin (Canada)

The laboratory GeoRessources, the Institut Terre et Environnement de Strasbourg and Orano Mining are collaborating within the framework of the GEOMIN3D Industrial Chair, sponsored by Orano and the French National Research Agency, in order to develop new tools for the exploration of high-grade uranium deposits from the Athabasca Basin. The proposed PhD thesis will be part of this 1.4 million euros Industrial Chair which began at the end of 2021 for a period of 4 years.

Context : The Athabasca Basin is considered the world benchmark for high-grade unconformity-type uranium deposits. The formation of these exceptional deposits required the conjunction of processes of very high efficiency and the currently accepted model considers that they result from massive circulations of fluids in structural and physico-chemical traps located at the intersection between graphite-rich structures rooted in the basement (called graphitic conductors) and the unconformity surface of the Athabasca Basin. These hydrothermal deposits are thus all spatially associated with the unconformity between the basin and the crystalline basement, and located along the graphitic conductors. The structural reactivation of these conductors after the basin deposition is the key process for the mobilization of fluids from their reservoirs (basin and/or basement) and then their circulation along drains (graphitic conductors and other associated secondary structures). This reactivation allows the reaction of fluids with the host rocks favorable to the formation of mineralizing fluids and alteration envelopes. Uranium then precipitates massively from these mineralizing fluids according to various proposed mechanisms: interaction of hydrothermal fluids with reducing agents of the solid (rock), liquid and/or gas type present in or near the graphite conductors.

Despite the extensive research programs undertaken to date on these objects and decades of exploration, **several unknowns limit our scientific understanding of the formation mechanisms of these deposits, and therefore our ability to define the favourability criteria that can be used in exploration to discover them**. For example, only a limited fraction of the graphitic conductors have economic uranium mineralization, which is themselves distributed over limited portions of these conductors: **what are the specificities of these fertile zones compared to the sterile zones?**

The research work undertaken to date demonstrates that the notions of time and duration are a key point in understanding these deposits:

- Known geochronological data suggest that fluid circulations in hydrothermalized graphitic conductors have not been basin-scale synchronous, with ages distributed in a potential time span of several hundred million years. In this extremely wide time span, were there specific geological periods for the formation of high-grade deposits, and are they, for example, different from those generating barren uranium hydrothermal zones?

- Have the graphitic conductors been reactivated and mineralized at different geological periods according to their specific properties (orientation, dip, length, etc.)?

– What are the geological drivers of the reactivation of these structures located in the center of the Canadian Shield and formed approximately 1.8 billion years ago? Was there one or more large-scale geodynamic event(s) active at the margins of this shield specifically favorable to the formation of uranium deposits?

- The mineralization and associated alterations resulted from circulations of hydrothermal fluids whose durations and periodicities are very poorly constrained. Are high-grade deposits linked to longer fluid circulations than lightly mineralized zones (and if so over what duration(s)), or only to higher mineralizing fluid flow rates (more efficient plumbing)?

– Can the formation of giant U deposits that began 1.6 billion years ago in the Athabasca Basin be comparable to the reactivation processes of current active faults, and if so for how long?

Research plan: **The objective of this project is to provide new data on the geochronological framework of the formation of unconformity-type uranium deposits in the Athabasca Basin**. This doctorate will provide key information leading to a detailed and exhaustive understanding of the processes at the origin of these deposits. **Several objectives are targeted:**

- *Establishment of a database compiling all the ages available in the Athabasca Basin*. Several isotopic dating methods (U-Pb, Rb-Sr, K-Ar, Ar-Ar…) have been applied for 50 years on different minerals (uranium oxides, clays,…) present in the Athabasca Basin . The first objective of this PhD study is to compile them and then critically evaluate them (analytical quality, spatial representativeness, context [absence or presence of mineralization]). This compilation will be based on data published in the literature as well as unpublished data available at the GeoRessources laboratory and at the partner Orano.

- *Definition of the analytical approach and geological targets*. From this database, priority working axis will be defined: choice of geological targets, minerals to be dated (oxides, silicates, carbonates, phosphates), isotopic methods (U-Pb, K-Ar, Ar-Ar, Rb-Sr,…) and tools (in-situ approaches or whole-rock via dissolution). The choice of geological targets will be validated with the doctoral students, post-doctoral students and geologists working on the Athabasca basin within the GeomIn3D chair, partner projects and at Orano.

– *Field mission on the selected targets*: field missions will be done on the Athabasca Basin in connection with the industrial players active on this site, making it possible to study these targets in detail and to take the key samples which will be studied in Nancy

- *Application of geochronological methods*. The dating of samples will be carried out at the GeoRessources laboratory and at partner laboratories (CRPG Nancy, ETH Zurich, GFZ Potsdam, Geosciences Montpellier, Geosciences Rennes). This work may be based on the development of new dating methods which will be done in association with researchers and engineers. The objective is to provide the most precise time constraints possible according to the available material. The notion of duration will also be considered via attempts to apply different dating approaches within a deposit. Highly mineralized deposits and poor to non-mineralized zones will be compared to define the possible specific temporal episodes at the origin of rich mineralizations.

Working conditions*:*

The PhD student will be employed by the CNRS. The thesis will be carried out at the Université de Lorraine, at the GeoRessources laboratory. Missions to Orano Châtillon and Orano Canada in Saskatoon will allow good coordination with the actions underway at the industrial partner. Specific missions in the Athabasca Basin will allow the sampling necessary to carry out this work, in addition to the samples already available in Nancy and at Orano. Missions in partner laboratories will be carried out to supplement the instruments and methods available in Nancy. This PhD thesis is part of the GeomIn3D Industrial Chair which supports several research actions (thesis, post-doctorate, engineer) targeted on the Athabasca Basin. The doctoral student will work in close collaboration with the doctoral and post-doctoral students carrying out these actions, and will be integrated into the LabCom CREGU laboratory (Center for Research and Study of Uranium Deposits) which brings together in a broader framework all the actions of research on uranium in Nancy.

GeoRessources is part of the Université de Lorraine (http://welcome.univ-lorraine.fr/), which is one of the leading higher education institutions in Europe with more than 55,000 students and 60 research laboratories. The Université de Lorraine ranks 17th in the Shanghai 2022 ranking in the "Mining and Mineral Engineering" category, the first European university in this field of activity, thanks to the activities of GeoRessources. Nancy is one of the largest geoscience training centers in Europe, with 4 laboratories hosting more than 300 researchers and 1,000 students. Georessources is the French academic laboratory of reference for the study of the Earth Sciences targeting energy and societal transitions (http://georessources.univ-lorraine.fr/).

The PhD student will benefit from access to an analytical facilities dedicated to Earth Sciences among the largest in France with the presence of several dedicated platforms. The PhD student will use instruments such as scanning electron microscope, micro-XRF, micro-tomography, electron microprobe for the selection of minerals to be dated, and on laser ablation coupled with an ICP-MS, the ion microprobe and ID-TIMS for isotopic dating.

Applications: The application must be received before **October 1, 2022**, for a start of the PhD thesis at the earliest. It will include the following documents: (i) a letter of motivation mentioning research experience and areas of interest, (ii) a detailed curriculum vitae including a list of publications, (iii) the names, addresses and telephone numbers of two referees, (iv) the Master 2 report. It should be sent by e-mail to: Julien Mercadier (**julien.mercadier@univ-lorraine.fr**)