Geophysical Research Abstracts
Vol. 20, EGU2018-12454, 2018
EGU General Assembly 2018

Geochemical and mineralogical signature of fault zones in Archean basement rocks: characterizing a multi-episodic history of fluid-rock interactions

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East of the Paleoproterozoic Thelon basin (Nunavut, Canada), unconformity-related uranium deposits of the Kiggavik area, explored by AREVA, are hosted within Archean basement rocks (mainly gneisses and various magmatic intrusives). The study focuses on the Contact prospect, located along the NE-trending Andrew Lake fault and hosted within Archean granitic gneiss. There, the fracture network evolved in a brittle style from ca. 1830 Ma to ca. 1300 Ma for the main fracturing events. The successive fracturing events were associated with circulation of various fluids that interacted with host rocks and fault rocks and caused alteration of the protolith while precipitating new minerals, thus changing the elemental signature of the rock and giving each event a characteristic geochemical signature.
AREVA possesses a vast dataset of systematic geochemical analyses (1519 samples in the dataset of the Contact prospect) which, along with newly conducted mineral characterization (microscopy, SEM, microprobe) and fluid inclusions study (microthermometry, Raman spectroscopy, LA-ICP MS) allowed characterizing the geochemical signature of selected fault zones, hence of the fluids that traveled through them at the time of each fracturing event. Four major fracturing events were geochemically characterized: one occurring at ca. 1750 Ma before the emplacement of the Paleoproterozoic Thelon basin infill (1667-1540 Ma), and three occurring after (between 1540 and 1267 Ma). The first main fracturing event is characterized by circulation of Si-rich fluids likely of igneous origin that silicified the Andrew Lake fault system. Vapor-only fluid inclusions displaying low-salinity and high entrapment temperature are representative of the mosaic quartz breccia that sealed fault zones during this event. The fracturing events and associated fluid circulations occurring after this silicifying event were compartmentalized by a large quartz breccia zone. Fault zones of the second fracturing event are relatively narrow (<20m of damage zones-core zones), characterized by circulation of basinal brines and display moderate enrichment in W, Zn, Ni, As, Co, Mo, Pb, Ag, Bi, V, and Se, and low values of non-mobile elements like Al and Ti. These elemental variations are explained by alteration of host rocks and precipitation of new minerals as demonstrated by petrographic investigations. The third fracturing event is characterized by wider fault zones (possibly > to 50m) with moderate enrichment in the same elements, except for Fe, Mo, V and Se; they also display a higher content in non-mobile elements (Al and Ti) as a result of the loss of mobile elements during argillization. The fluids that circulated during these two fracturing events were oxidizing, sodic-calcic basinal brines of low temperatures ($\sim$200 °C), enriched in uranium. The fourth fracturing event is characterized by fault zones that drove reduced, likely acidic and hot fluids ($\sim$300 °C), that caused complete destabilization of iron oxides and also illitization of the host rock.
This kind of analysis sheds light on the complexity of the fluid circulation events that may have occurred in impermeable basement rocks, and provides a powerful tool to decipher fluid-fault interactions and to potentially distinguish successive fault zones in cores by their geochemical signature.