Basement-Sandstone Interaction, Alteration Patterns in the Sandstone and Metal Sourcing, Athabasca Unconformity Uranium Deposits

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ABSTRACT

The role of an oxidized, high salinity, ~200°C, evolved basinal fluid in the Athabasca Basin has been documented by numerous workers over the past 18 years. This fluid appears to be the most dominant fluid involved in the formation of unconformity uranium deposits at about 1400 to 1500 Ma. Late meteoric fluid incursions at about 300 Ma have overprinted early paragenetic stages. These fluid events have been identified and characterized compositionally after integrated studies on mineral paragenesis, fluid inclusions in quartz, isotopic studies, and age dating of clay alteration correlated with ages of uraninite and paleomagnetic signatures of hematite. The basinal fluid has the ability to carry a significant proportion of the metal contributed to unconformity deposits; in particular uranium, copper, REE, and possibly Ni and Co.

At the same time, the characterization of a presumed basement fluid, thought necessary to reduce the basin fluid, has proven difficult. This fluid may be a reduced version of the basinal fluid after interaction with the basement or an independent fluid. Even more difficult to document is the mechanism of direct metal sourcing from the basement source advocates.

An abundance of passive margin metasediments including metal-rich metapelitic gneisses, their uranium-enriched anatectic derivatives, albitization features, and the intrusion of late Hudsonian uranium-enriched granites, particularly along major basement faults, are an appealing direct or indirect (into sandstone during weathering) metal source for uranium and other metals found in the deposits. These basement rocks have been cited by many exploration geologists over the years as a direct source of metal during formation of the deposits; if not for uranium, then at least for nickel-cobalt and arsenic. In terms of pelitic gneiss stratigraphy, there is a facies change from sulphide-poor and relatively base metal-poor pelitic gneisses in the eastern portion of the mineralized belt toward a significant proportion of sulphide-rich, pelitic gneisses with elevated base metal contents toward the western portion of the belt. Unconformity deposits are found in both facies suggesting structure and fluid flow patterns are more important than the metal tenor of the pelites.

Unconformity uranium mineralization took place ~300 Ma after these Hudsonian-related processes and after a period of extensive bedrock weathering. In terms of a direct source from the basement, two potentially large volumes of altered rock are present. These are the green zone of the "paleoweathering" profile and deep alteration systems associated with reactivated major Hudsonian faults. Based on past work, no significant trace element depletion has been noted in the background green zone of the paleoweathering profile. In the green zone, metamorphic sulphides in trace metal-enriched pelitic units are relatively unaffected by weathering solutions or the later effects of the higher temperature diagenetic fluids. In terms of the deeper portions of the reactivated fault systems (syn- to post-Athabasca movement), few holes are available to test deeper depletion patterns and characterize the nature of the fluid. It is evident along segments of two of these faults, the Collins Bay and Seal Lake structures in the Rabbit Lake area, that oxidization is not apparently significant; therefore, the ability to extract uranium in particular may be in question. Future work will focus on the nature of the fluid along these deeply altered structures.

Basement-sandstone interaction is evident over large areas of the eastern portion of the basin. This is particularly apparent during the pre-ore silicification-desilicification stages and associated potassic metasomatism which produced the northeast-trending regional and ore deposit-scale clay alteration patterns. The large regional illite anomaly in the southern portion of the basin (10 to 20 km wide), defined by drill holes and boulder surveys, is a result of sandstone-basement interaction along reactivated fault zones bounding Archean orthogneiss-pelitic gneiss and quartzite-pelitic gneiss. The western boundary of this regional illitic anomaly coincides approximately with the position of the Mudjatik-Wollaston boundary.

Two end-member sandstone alteration patterns are noted: desilicification-illitization and silicification-kaolinitization-dravitization patterns around deposits in the northern and southern portions of the Athabasca Basin respectively. In part, these differing patterns appear tied to basement stratigraphy and structural regimes as well as to the intensity of various stages of alteration including late meteoric events. For example, basement quartzites lying stratigraphically between the lower pelitic gneisses and the upper magnetic arkosic gneiss unit, form a significant basement component in the southern Athabasca deposit area, but are absent in the vicinity of the major northern Athabasca deposits. Desilicification is apparent in basement quartzites along the hydrothermally altered zones under the McArthur River deposit. In contrast, regional magnetics indicate the basement geology underlying

deposits in the northern area reflèct a distinct lithostructural style, perhaps transitional between the Wollaston and Mudjatik deformation. This lithostructural domain is bound to the southeast by the basement quartzites, the westernmost portions of the magnetic arkosic gneiss units, and possible extrapolations of the Collins Bay fault system. Within and along the edges of this block, the northern deposits are generally found associated with sandstone desilicification.