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Basement to surface expressions of deep mineralization and refinement of critical factors leading to the formation of unconformity-related uranium deposits

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Under the Targeted Geoscience Initiative Four (TGI-4) program operated by the Geological Survey of Canada, a collaborative project between government, academia and industry is examining unconformity-related U ore systems in the Proterozoic Athabasca (Phoenix, Millennium McArthur River and Dufferin Lake zone), Thelon (Bong) and Otish (Camie River) basins in order to refine genetic models and exploration tools for these U deposits.
Examination of basement graphite-depleted zones underlying U-bearing zones at the Dufferin Lake zone has revealed the presence of low-ordered carbon species (carbonaceous matter) that may be interpreted as products of graphite consumption (± later carbon precipitation) by oxidizing Athabasca Basin fluids that migrated downward into the basement. This may have produced a mobile reductant (gas or fluid), which could then have played a role in deposition of UO2. Alternatively, new numerical modelling supports a previous hypothesis that fluid overpressures may have caused hydrocarbons generated from oil shale at the top of the Athabasca Group to migrate downwards to the sites of U precipitation. A preliminary Fe and Mg isotopic study of the basement-hosted Bong deposit revealed that elevated δ57Fe and δ26Mg values are associated with U-bearing alteration and a red hematitic zone that is often ascribed to 'paleoweathering'in the literature. The higher isotopic values correlate with depletions in molar Fe2+, indicating that the processes that formed both alteration zones mobilized Fe2+ while enriching the fluids in the lighter isotopes of Fe and Mg.

Petrological, geochemical and isotopic studies of intense alteration concentrated along the P2 fault hosting the McArthur River deposit reaffirm previous studies that the alteration overprinted earlier paleoweathered and diagenetic altered horizons along the unconformity and that the fault served as a conduit for basinal fluids to modify basement rocks through fluid-rock interactions. This fault-control is also manifested regionally, with new 3D modeling of the unconformity surface highlighting the influence of northeast-trending reverse faults in formation of a narrow ridge between the Phoenix and McArthur River deposits. Regional clay anomalies documented in previous studies, associated with the majority of deposits and prospects, are also broadly aligned with this feature.
Athabasca Group sandstones overlying the Phoenix deposits show relatively high concentrations of U, B, Pb, Ni, Co, Cu, As, Y and REEs above the deposit up to the uppermost sandstones and along the WS shear zone. In support of previous studies, some of the metals (U, Mo, Co, Ag and W) also occur in elevated concentrations in humus and B-horizon soil overlying the Phoenix and Millennium deposits. However, these new results enhance the sensitivity of these surficial geochemistry detection methods for deeply-buried (ca. 600–750 m) uranium deposits. The locations of these anomalous metal concentrations coincide with surface projections of the reactivated shear zones, consistent with the fault conduit model. Similar to elevated levels documented in earlier studies in the eastern Athabasca Basin, elevated levels of 4He overlying the deeply-buried Millennium deposit indicate focused mobility of these gases within the water table.

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