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The role of fault intersection in fluid flow patterns and the formation of world-class unconformity-related uranium deposits, Athabasca Basin, North Canada

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The epigenetic uranium deposits in the eastern part of the Athabasca Basin are classified as unconformity-related ore deposits. Their explicit spatial association to reactivated basement faults is observed within the regional structural NNE trend Wollaston-Mudjatik transition zone, marked by elongated dravite, illite, and chlorite alteration zones. Accordingly, geochemical studies have advocated a circulation and focalization of large amount of one or more fluids to carry and precipitate aqueous chemical materials. At the deposit-scale, the uranium deposits are found mainly at the intersection between two or more fault sets, and described as elongated-like bodies varying in orientation from E-W to NNE direction along the regional transitional zone. Furthermore, some orebodies show a change of orientation and dip of their structures. Thus, what is the hydro-mechanical response of reactivated and inherited fault architecture (e.g., intersection zone) under different stress states (e.g., reverse, strike-slip, and normal faulting regime), and its potential contribution to the shape and orientation of orebodies at deposit scale?

Using hydro-mechanical numerical modeling, this project demonstrates the role that fault intersections play in controlling mineralized fluids by examining the various fluid flow patterns observed when reactivated intersected faults are under various stress states. Numerical modeling is performed using 3-Dimensional Distinct Element Code (3DEC). The numerical models are subdivided into two categories: 1) simplified 3-D models of two intersecting faults, 2) 3-D complex models of fault network at different deposits sites (e.g., the Cigar Lake deposit). While the first simple models attempt to evaluate the effects of intersection angle, burial depth, fluid pressure, basin permeability and stress states on the fluid flow patterns; the second models investigate the stress state under which certain orebodies may have formed.

Our preliminary results from simplified models show that at defined intersection angles, the fluid flow deviates from the main fault toward the secondary fault at their intersection point. The deviation in fluid flow is referred to the value of intersection angle at which the shear stress varies along the secondary fault, leading to the opening of secondary fault. Additionally, the burial depth does not affect the flow along the basement faults, whereas, the overlying highly permeable basin

reduces the horizontal flow along the basement faults toward the intersection zone, and reorients a part of the flow toward the basin. In the complex models (the Cigar Lake model), considering a compressional regime, the E-W fault set is reactivated once the maximum stress is oriented N40W to N65W, which is in agreement with field observations.