Mechanisms for formation of the Archean sill-hosted Black Thor chromite deposit, Canada*

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The Black Thor Intrusive Complex (BTIC) is a semi-conformable sill-shaped intrusion located in the ‘Ring of Fire’ Intrusive Suite, within the ca. 2.7-2.8 Ga McFaulds Lake greenstone belt in the James Bay Lowlands, northern Ontario. The BTIC contains more than 102 Mt of chromite-mineralized material with an aggregate thickness up to 100 m of bulk ore at average grades of 31% Cr₂O₃. “Archean sill-hosted” or “conduit-hosted” chromite deposits of this type occur in many other locations (e.g., Kemi, Finland; Inyala and Railway Block, Zimbabwe; Ipueira-Medrado, Brazil; Sukinda, India), however, little is known about the genesis of this class of chromite deposits, which are different from traditional stratiform and all podiform type deposits. There is much debate regarding the formation chromite deposits in general, but especially deposits of this type that contain orders of magnitude more chromite than can be dissolved in a mafic-ultramafic magma. Several mechanisms for formation have been suggested, including: 1) physical transportation of slurries of finely dispersed chromite, with or without magmatic slumping; and 2) in-situ crystallization associated with over-saturation of chromite with oxidation, magma mixing, increases in pressure, hydration, and/or contamination by felsic rocks, carbonates, or iron-formation.

The BTIC comprises (from base to top): olivine websterite/lherzolite, interlayered dunites/lherzolites/websterites, a thinner lower chromitite zone (Black Label deposit), interlayered lherzolites/websterites, a dunite unit, a thicker upper chromitite zone (Black Thor deposit), and overlying websterites, feldspathic websterites, mela-meso-leucogabbros, and lesser anorthosites. Cycles and reversals in geochemical profiles likely represent multiple magma pulses, suggesting the intrusion was an open system that underwent periodic magma replenishment and/or mixing. However, the overall upward sequence of dunite, lherzolite, websterite, feldspathic websterite, and gabbroic rocks suggests that the BTIC also underwent some degree of in situ fractionation. Variations in the amounts of olivine-(chromite) vs. pyroxene accumulation are interpreted to correspond to variations in temperatures and magma flow-through rates. Flow rates decreased prior to the formation of the Black Label deposit (consistent with physical transport or magma mixing), but increased gradually prior to the formation of the Black Thor deposit (more consistent with physical transport of fine dispersed chromite).

Mechanically transporting very fine grained (0.1-0.2 mm) chromite, however, requires that it be extracted from another location and simply relocates the mass balance problem. One hypothesis to resolve the problem of how to generate so much chromite is to partially melt and assimilate the silicate component (chert/quartz and iron-rich silicates) of oxide facies iron-formation. Addition
of silica would account for the presence of orthopyroxene in magmas that would not normally crystallize orthopyroxene. Undissolved fine-grained magnetite would be easily transported in the magma and upgraded gradually to chromite through interaction with the magma. Using conservative abundances of Cr in the magma and partition coefficients, magma:chromite ratios as low as 100 (at the low end estimated for many magmatic Ni-Cu-PGE deposits) can produce Cr-rich chromites. Such a model could explain in systems of this type and possibly in other systems why the thickest chromitites are interpreted to occur in dynamic systems such as feeder sills and magma conduits.