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# Field observations, petrography, geochemistry, and phase equilibrium modelling: The four pillars of petrological investigations of crustal differentiation

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Phase equilibrium modelling has become a powerful and widely used tool for investigating the process of early Earth crustal differentiation. The earliest continental crust is thought to have been dominated by tonalite-trondhjemite-granodiorite (TTG) suites, which may have formed through anatexis of early metabasic crust. TTGs may therefore hold clues to early Earth tectonic regimes—including the onset of plate tectonics—as well as the evolution of crustal geochemistry. Forward modelling the production and evolution of TTG magmas by phase equilibrium modelling allows a variety of hypotheses explaining the origins of TTG geochemical signatures to be tested. The modelling possibilities are endless, however the results may be meaningless if they can not be replaced into their geological context. Therefore, selection of appropriate samples before any petrographic and geochemical study requires a solid understanding of the field relationships.

Here, we present two case studies on the petrogenesis of TTGs in the Kapuskasing Uplift in the southern Superior Province, Canada. This area represents a crustal cross section of Archean crust with upper-crustal supracrustal sequences, a mid-crustal TTG domain, and a lower-crustal anatectic metabasite unit. First, we test the hypothesis that plagioclase fractionation and accumulation could have generated the geochemical trends observed in mid-crustal TTGs. This idea originated from the observation of abundant plagioclase cumulate rocks within this mid-crustal domain. Follow-up work with phase equilibrium modelling and in situ trace element analyses of plagioclase lend strong support to this hypothesis. Second, we investigate the role of TTG magmatism in the Archean boron cycle. Modelling results suggest that production and subsequent migration of TTG magma may have efficiently mobilized boron from deep to shallower crustal levels. We test this hypothesis by conducting whole-rock boron analysis of a suite of samples (supracrustal rocks, TTGs, and high-grade metabasites) from across the Kapuskasing Uplift, and couple these results with in situ boron data collected from the major minerals in these samples. These case studies demonstrate the power and versatility of modelling, but more importantly the need to root our interpretations in the very same rocks that gave rise to our fascination with early Earth.