Chemical thermodynamic modelling of ruby-forming metasomatic systems: Not anomalies but regional geological indicators

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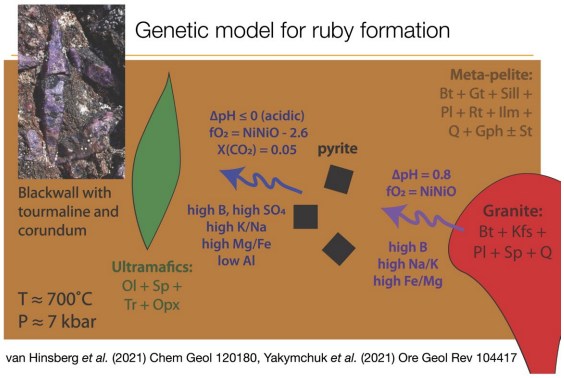

Gemstone occurrences in metamorphic rocks are commonly regarded as anomalous, and representing events that are distinct from the overall geotectonic history. However, rubies in high-grade metamorphic rocks in southeast and southwest Greenland and in the Massif Central in France have been shown to be very much part of the geological history, a direct result of the juxta-positioning of contrasting lithologies during regional tectonism and magmatism [*e.g.,* 1]. As such, they can provide key insights into these processes, from their *P-T-X* conditions to their timing, aided by mineral assemblages that are distinct from typical bulk rock compositions. Unfortunately, traditional phase equilibria modelling is not well suited to the extreme mineralogy and mineral compositions commonly encountered in these metasomatic rocks. Mineral compositions are generally near-endmember, *e.g.,* An-dominant plagioclase and high X_{Mg} biotite, which are outside the calibrated range of geothermobarometers, and in a steep dG/dX domain of thermodynamic solid solution models. Moreover, activities of one or more components may be externally controlled [see 2].

Here, we present a thermodynamic framework to model these metasomatic lithologies, centred on determining the thermodynamic properties of all phases present at the stage of interest. The equilibria among these phases then allow for reconstructing *P-T* conditions and fO_2, and, by equilibrating these solid phases with a H_2O-CO_2-Cl±S solvent, fluid pH and composition. We apply this approach to contrasting ruby-forming environments, including Maniitsoq and Storø in SW Greenland, Nattivit in SE Greenland, and the Haut Allier area of the French Massif Central, showing that ruby can form in a diversity of geotectonic settings and bulk rock compositions, and in equilibrium with distinctly different fluids. However, in all cases, metasomatism and ruby formation is an expected and integral part of the regional geological evolution, and provides valuable lithologies to constrain this regional history.

[1] Korzhinskii DS (1960) The discussion of the systems with perfectly mobile components and their thermodynamic potentials. *Izves Akad Nauk SSSR Ser Geol* 5

[2] van Hinsberg VJ, Yakymchuk C, Jepsen ATK, Kirkland CL, Szilas K (2021). The corundum conundrum: Constraining the compositions of fluids involved in corundum formation.