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Petrogenesis of cogenetic silica-undersaturated and -oversaturated rocks: quantifying the role of crustal assimilation

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Crustal assimilation during fractional crystallisation is commonly proposed as a mechanism to generate evolved silica-oversaturated (i.e. quartz normative) rocks from silica-undersaturated (i.e. feldspathoid normative) primitive melts. However, the amount of required assimilation, and the impact of varying crystallisation parameters (e.g. pressure, oxygen fugacity), remain poorly understood. To answer these questions, we apply simultaneous assimilation-fractionation calculations using new thermodynamic models for sub-alkaline to alkaline igneous rocks [1] to a case study of the younger `giant dyke' complex (YGDC) in south Greenland.

The YGDC is a Mesoproterozoic layered intrusive complex featuring cogenetic evolved silica-undersaturated and -oversaturated rocks, which was emplaced into Palaeoproterozoic granitoids as part of widespread magmatism in south Greenland associated with continental rifting [2]. For the previously suggested crystallisation conditions of the silica-undersaturated primitive basaltic melt (~1–2 kbar, oxygen fugacity near the fayalite-magnetite-quartz buffer), we show that 0–15% assimilation by mass of country rock granite can generate the compositional diversity of the complex. Using isotope calculations and thermal modelling, we demonstrate that such mass of assimilant is isotopically and thermally viable. However, our calculations show that a phase equilibria approach can more tightly constrain assimilant amounts, as thermal and isotopic approaches permit wider ranges of assimilation estimates.

More broadly, by modelling over a range of other pressures, oxidation states and starting compositions, we show that silica-undersaturated primitive melts crystallising at more reduced conditions and/or higher pressures require more crustal assimilation to become silica-oversaturated. An implication is that the formation of evolved intrusive silica-undersaturated rocks (which can host magmatic metal deposits, e.g. rare-earth elements) is favoured when fractionation occurs at lower oxygen fugacity and higher pressures, because magmas are more protected from the effects of assimilation.

References:

[1] Weller, Holland, Soderman, Green, Powell, Beard & Riel (2024), *Journal of Petrology* 65, egae098.

[2] Upton (2013) *GEUS Bulletin* 29, 1-124.