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Modelling the production of linear trends in granitoids using the Magma Chamber Simulator: a case study of the Jindabyne Suite from the Lachlan Fold Belt, Australia

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Understanding the causes of major and trace element variations of granite samples as well as their isotopic signatures is central to attempts to place these rocks in the context of broader geologic processes and continent evolution. For the granites of the Lachlan and New England Fold Belts (LFB and NEFB) of Australia there has been great debate between competing petrogenetic models. The open-system view that the isotopic variability and within-suite compositional trends can be accounted for by magma mixing and fractional crystallisation stands in contrast to the restite unmixing model, in which the geochemical features of certain granites are inherited from protoliths that underwent partial melting to produce magmas entraining varying proportions of residual material. Reconciling all aspects of the geochemical data in a mixing model is contingent on a plausible fractionation regime to produce the observed consistently linear (or near-linear) trends on Harker diagrams; however, the plausibility of existing fractional crystallisation models for LFB granites has not previously been tested with consideration of phase equilibria.

The Magma Chamber Simulator (MCS) models fractional crystallisation alone or with assimilation (AFC), constraining phase equilibria using MELTS and accounting for the thermal budget. This sophisticated modelling tool was used to conduct a case study of the I-type Jindabyne Suite of granites from the LFB, testing whether thermodynamically feasible geochemical trends matching the observed linear variations can arise through fractional crystallisation (with or without assimilation of supracrustal material). The results of 112 MCS models show (1) that for major elements liquid lines of descent (LLDs) may be sensibly linear over limited compositional ranges, (2) that the involvement of assimilation extends the range in which trends are relatively simple and near-linear, and (3) that, despite these observations, neither fractional crystallisation nor AFC are able to correctly reproduce the geochemical evolution of the I-type Jindabyne Suite granitoids as an LLD (contrary to existing models), instead persistently producing curved and kinked trends. The output of these simulations were further used to explore models in which: (a) crystal-bearing magmas evolve via fractional crystallisation or AFC (with chemical isolation assumed to be achieved through crystal zoning) and undergo varying degrees of melt-crystal segregation at different stages to produce the sample compositions; and (b) in situ crystallisation occurs via fractional crystallisation within the crystallisation zone, driving the evolution of a liquid resident magma, which the samples represent. These models are able to reproduce the Jindabyne Suite

trends reasonably well. The modelling implies that fractional crystallisation, or some variant thereof, is a viable explanation for the linear trends in Jindabyne; however, tendency for grossly non-linear LLDs highlights that it should not be assumed that fractional crystallisation can generally explain linear trends in granites without careful modelling such as shown here.