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Voluminous low-T granite: fluid present partial melting of the crust?

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Two general schools of thought exist for the formation of granites from predominantly crustal sources. One is that large-scale anatexis occurs via fluid-absent partial melting. This essentially thermal argument is based on the reasonable premise that the lower crust is typically fluid depleted, and experimental evidence which indicates that fluid-absent partial melting can produce significant volumes of melt, creating compositionally depleted residua that many believe are recorded by granulite facies terranes. The other school of thought is that large-scale anatexis can occur via fluid-fluxed melting. This essentially compositional-based contention is also supported by experimental evidence which shows that fluid-fluxed melting is efficient, including at temperatures not much above the solidus. However, generating significant volumes of melt at low temperatures requires a large reservoir of fluid. If fluid-fluxed melting is a realistic model, the resultant granites should be comparatively low temperature compared to those derived from predominantly fluid-absent partial melting.

Using a voluminous suite of aluminous granites in the Aileron Province in the North Australian Craton together with metasedimentary granulites as models for source behaviour, we evaluate fluid-absent verse fluid-present regimes for generating large volumes of crustally-derived melt. The central Aileron Province granites occupy 32,500km2, and in places are in excess of 8 km thick. They are characterised by abundant zircon inheritance that can be matched with metasedimentary successions in the region, suggesting they were derived in large part from melting of crust similar to that presently exposed. A notable feature of many of the granites is their enriched Th concentrations compared to typical Aileron Province sub solidus metapelitic successions. However, based on continuous transects within metasedimentary rocks from a number of different regions that record transitions from sub-solidus assemblages to supra-solidus rocks petrologically characterised by typical fluid-absent peritectic assemblages (central Aileron Province, Broken Hill Zone, Ivrea–Verbano Zone), fluid-absent partial melting does not deplete Th concentrations in the residuum with respect to their sub-solidus protoliths. If these compositional transects are used as a guide to the general behaviour of Th during fluid-absent partial melting, the voluminous Th-enriched granites in the Aileron Province are unlikely to be the products of fluid-absent partial melting. This contention is supported by phase equilibria modelling of sub-solidus metasedimentary units whose detrital zircons match in age the granite-hosted xenocrysts, which indicate that temperatures in excess of 840°C are required to generate significant volumes (ie $\geq$ 30%) of melt under fluid-absent conditions. However, zircon saturation temperatures for the granites have a weighted mean of 776 $\pm$ 4 °C (n = 220). Because the granites contain abundant inheritance, this is an upper-T limit that also suggests fluid-absent partial melting was not the primary mechanism for granite formation. We suggest that voluminous granite formation in the Aileron Province occurred in a fluid-rich regime that was particularly effective at destabilising monazite and liberating Th into melt. Because of the propensity of monazite to destabilise in the presence of fluid, we suggest that high-grade metasedimentary terrains that are notably depleted in Th may be residuum associated with fluid-fluxed melt loss.