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Th–U redistribution during fluid-absent partial melting of the crust

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Metamorphism involving partial melting is a fundamental process leading to the geochemical differentiation of the Earth's crust. A primary expression of this process is the formation of granites that contain a component of crust within them, and the generation of granulite-facies metamorphic rocks that reflect residuum left behind after extraction of granitic melts. It is well known that granites are typically enriched in the heat producing elements (HPEs) K–Th–U compared to average crust, so it stands to reason that residual granulites should be depleted in those elements (Bea 2012, Mareschal and Jaupart 2013).

However, there are cases where residual crustal granulites retain high radiogenic heat production, which demonstrate that the deep/lower crust is not necessarily always depleted in radiogenic heat production during partial melt extraction. Moreover, it has been shown that monazite (the chief Th reservoir in rocks) is able to retain Th in the residuum (Stepanov et al. 2012), meaning that granulite-facies crust may be characterised by high radiogenic heat production. Such a view is in direct contrast with the standard view of geochemical differentiation of the crust and would potentially result in granitic melts with comparably low HPE concentrations.

In this study, K–Th–U concentration data and phase equilibria modelling have been used to monitor the changes in crustal heat production associated with progressive up-temperature metamorphism, resulting in melt production and loss. The study has been undertaken on 4 separate metamorphic terrains that have experienced progressive metamorphism culminating in fluid-absent partial melting: the Reynolds Range and Mt Stafford in Central Australia, Broken Hill in Eastern Australia, and the Ivrea Verbano zone in the Alps. The data shows that in most cases Th concentrations increase in the granulite residuum and in some scenarios, U concentrations also increase compared to their lower grade equivalents. Monazite geochemistry from Reynolds Range shows an increase in Th concentration with increasing metamorphic grade, indicating temperature controlled progress of the monazite–huttonite solid solution, effectively concentrating Th in the residuum.

These data suggest that the melts extracted from these terrains could not have produced granites with Th–U concentrations that are elevated over average crust. Instead we suggest the crustal source regions of Th–U rich granites involve fluid-assisted melting that destabilises monazite.

References

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