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The role of crystal fractionation in the formation K-granites: a modelling perspective

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Earth's earliest felsic crust is dominated by Na-rich granitoids ($K_2O/Na_2O < 0.6$) of tonalite-trondhjemite-granidiortic (TTG) affinity, which became more evolved towards the late Archean (ca. 3-2.5 Ga) as K-rich granites ($K_2O/Na_2O > 0.8$) started to appear. These K-granites mark the stabilization of the Earth's first continental terranes – i.e., cratons, however, the petrogenesis of this rock type remains elusive [1]. While it has been argued that Archean K-granites were derived from either felsic TTGs or mafic source rocks [2], it is unclear if they represents reworked crustal magma or fractionation product of mafic-to-intermediate composition magma. Here we coupled thermodynamic modeling with trace-element partitioning to predict the composition of melts derived from fractionation and partial melting processes, and then compared the composition of the modelled melt compositions against those of the natural K-granites [2]. Fractionation was modelled along isobaric cooling paths, and both basaltic (enriched Archean tholeiite; EAT) as well as TTG compositions were considered as primary melt compositions. The results show that basaltic melts tend to produce Na-to-Ca rich magma of tonalite to trondhjemite affinity upon fractionation of amphibole along with pyroxene and plagioclase, while TTG melts yield Na-to-K rich melts of tonalite to granite composition after the fractionation of orthopyroxene and plagioclase. Thus, the composition of fractionated melts from TTG source are comparable to those of Archean K-rich granites. Further, the fractionation of plagioclase results in negative Eu-anomaly, which agrees with the composition of Archean K-granites. We observed that irrespective of the starting melt composition, garnet becomes the dominant crystallizing phase above 10 kbar leading to LREE enrichment in the melt. This contradicts with the composition of Archean K-granites; thereby, constraining the maximum pressure of their formation at ~10 kbar in case they were a product of fractionation. Thus, our results suggest that low-pressure fractionation of felsic, TTG-type melts can produce K-rich granites, although the basaltic source rocks are not appropriate.

References

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