Archaean TTGs derive from mafic cumulates buried within the roots of proto-continents

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Large amounts of juvenile crust with tonalite-trondhjemite-granodiorite (TTG) composition were added to the continental crust during from about 3.5 billion years ago (Condie et al., 2005). As most Archean cratons, this episode of crustal growth is also clearly recorded in the Archean cratonic core of the Fennoscandian Shield, which locally preserves 3.5-Ga crustal fragments and contains a substantial exposure of Neoarchean TTG crust (Hölttä et al., 2008). The rise of TTG crust in the Archaean is classically attributed to the start of modern-style plate tectonics (Moyen & Martin, 2012), which would be consistent with great melting depths indicated by high La/Yb and Sr/Y. The meaning of such proxies is nevertheless debated (Kendrick & Yakymchuk, 2020) and so is the general petrogenetic setting of TTGs. Many other processes, including delamination and intra-crustal differentiation, have been proposed to explain TTG petrogenesis (e.g., Bédard, 2006; Kamber, 2015). Each of these to some degree explains certain compositional features of these rocks, but they cannot all be correct. Progress in this regard requires quantitative constraints on the composition of TTG parental melts, and thus a means to distinguish primary compositional features from those caused by crustal assimilation and fractional crystallization. In this study, we present a new way of investigating TTG petrogenesis using high field-strength element (HFSE) systematics.

The Nb concentrations and Ti anomalies of TTGs show the overwhelming effects of amphibole and plagioclase fractionation and permit the first clear constraints on the composition of primary TTG melts. These melts are uniformly incompatible element-poor and characterised by variably high La/Sm, Sm/Yb and Sr/Y, and positive Eu anomalies. Differences in these parameters are not indicative of melting depth, but instead track differences in the degree of melting and fractional crystallisation. The HFSE signatures of TTGs show that these melts derive from mafic plagioclase-cumulates that melted to different degrees in the presence of residual rutile and garnet. These cumulates resided in the roots of the overthickened proto-crust, which underwent partial melting as a result of being magmatically loaded and buried. The partial melting of these cumulates is part of a causal chain that explains the rise of TTG crust during the Archaean and links TTG magmatism to the formation of sanukitoids and K-rich granites in ancient cratons.

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