Linking volcanic and plutonic records in the early Earth: TTGs are silicic crystal mushes

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The Earth's earliest continental crust is dominated by granitoids of the tonalite-trondhjemite-granodiorite (TTG) suite. Their bulk-rock compositions are considered to reflect those of "chilled liquids" and as such, widely used to infer geodynamic settings of magma formation. However, crystal-liquid segregation processes play a significant role in shaping the geochemistry of igneous plutonic rocks. Previous studies overlooked these processes in the case of TTGs because these usually occur as deformed, polyphased grey gneisses in which magmatic structures are barely identifiable.

In contrast, the Barberton terrane (South Africa) hosts a well-preserved Paleoarchean (3457 Ma-old) plutonic-volcanic system consisting of trondhjemites with minor diorites, tonalites, granites and felsic volcanic rocks. The plutonic rocks span the entire compositional range of global TTGs. All rock types are coeval within less than one million years based on new ID-TIMS U-Pb dating and are co-genetic based on zircon Hf isotopic signature and geochemistry. Textural and geochemical evidence show that the trondhjemites represent a plagioclase-rich silicic crystal mush containing interstitial granitic liquid. The latter was extracted and either crystallized at depth to form the granites, or erupted to form the volcanic rocks, where it is preserved as quartz-hosted melt inclusions similar to high-Si rhyolitic glass from modern ignimbrites.

Stochastic mass balance modelling shows that the entire plutonic-volcanic system plausibly results from the differentiation of a single parental magma, similar to the tonalites and diorites. This magma fractionated plagioclase and amphibole to form an evolved granitic liquid, parental to the trondhjemite mush. The apparent "high pressure" signature of the latter (high Al, Na, Sr/Y, La/Yb; low Nb, Ta), initially proposed to reflect melting of subducted or delaminated mafic crust, can in fact be entirely attributed to variable extents of plagioclase accumulation in the mush. These results therefore call for a unifying model of Archean continent nucleation by intra-crustal TTG formation.