A Si isotope investigation of Archaean melting processes

MADELEINE E MURPHY, JANE E MACDONALD,
SEBASTIAN FISCHER, DR. NICHOLAS J GARDINER,
RICHARD W WHITE AND PAUL S. SAVAGE

University of St Andrews

Unraveling ancient melting processes is key to understanding how the earliest, tonalite-trondhjemite-granodiorite (TTG)-dominated continental crust formed from partial melting of amphibolites. Applications of silicon isotopes to ancient crust [1,2,3] revealed that Archaean TTGs exhibit consistently high Si isotope signatures (δ30Si) compared to modern granitoids, attributed to seawater-derived silica introduced by either (a) anatexis of variably silicified basalts [2] or (b) authigenic silica-rich marine lithologies in the melt source [3]. However, both mechanisms can involve highly variable δ30Si [4], conflicting with the strikingly consistent δ30Si signatures of Archaean TTGs. This study investigates an alternative solution, whereby silicon isotopes fractionate differently during TTG melt formation compared to “modern” melting.

We measured δ30Si in component parts (melanosome and leucosome) of an Archaean (2.7 Ga) mafic migmatite and coeval amphibolites and mafic granulites from the Kapuskasing uplift, Canada, to explore how Si isotopes fractionate during incipient TTG melt formation. Our data reveal leucosome (i.e., melt) exhibits consistently high δ30Si values compared to a relatively isotopically lighter melanosome (i.e., restite). Inter-mineral silicon isotope fractionation factors derived for mineral separates agree well with those of ab initio estimates for Phanerozoic minerals [5], and the magnitude of fractionation between source rock and melt approximates that in Phanerozoic igneous rocks [6].

We conclude the effects of magmatic differentiation on δ30Si have remained consistent throughout Earth history. Further, like Archaean TTGs, our amphibolites and our mafic migmatite components have high δ30Si compared to modern analogues and coeval unmelted granulites. The heavy δ30Si of seawater and the high SiO2 content of amphibolites relative to coeval dry granulites imply seawater silicification is the source of high δ30Si we observe. Consistently heavy Si isotope signatures in Archaean melt products define a unique aspect of ancient crust formation: silicification of TTG source rock, implying the intrinsic involvement of a primeval hydrosphere.