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The tholeiite-TTG connection during Eoarchean crust formation in Isua, southern West Greenland: the role of subduction processes

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The processes and the geodynamic settings that generated Earth's oldest parts of continental crust are still a matter of debate. A pertinent issue is the genetic relationship between the tonalite-trondhjemite-granodiorite (TTG) suite and the mafic fragments that are found as inclusions within this felsic crust. Here we propose a coherent model for the geodynamic evolution of the oldest (3.65 to 3.85 Ga) continental crust in southern West Greenland.

Within the Isua Supracrustal Belt, the best preserved and largest fragment of mafic Eoarchean crust worldwide, tholeiitic and boninite-like amphibolites dominate the sequence, both yielding trace element patterns consistent with a subduction-related origin. The tholeiites yield correlated trace element variations in Nb/Th, La/Yb, Gd/Yb, Zr/Nb, in agreement with a subduction zone setting where a depleted mantle source is overprinted by melt-like slab components (Hoffmann et al., 2011a). Boninite-like rocks in Isua are derived from ultradepleted sources with epsHf(3720) of up to ca. +12.9 (Hoffmann et al., 2010).

Petrological phase equilibrium modeling combined with trace element modeling suggests a relationship between the typical Isua arc tholeiites and the TTGs (Nagel et al., 2012). Notably, Hf-Nd isotope signatures between the two lithologies overlap (epsHf(t) = -0.7 to +2.5; epsNd(t) = -0.8 to +4.4), both showing the characteristic decoupling of initial Hf-Nd isotope compositions. Systematically elevated 142Nd anomalies of tholeiites and TTGs are also in agreement with a related origin of both rock types (e.g., Caro et al., 2006). Trace element modeling shows that the Isua TTGs likely formed by melting of thickened mafic arc crust with tholeiite compositions (Hoffmann et al., 2011b) and that the decoupled Hf-Nd signature is likely an inherited feature from melting of the tholeiites. This is also underlined by new Hf and O in zircon data from TTGs in the area (Næraa et al., submitted) that indicate melting of a thickened mafic crust to form the TTGs.

The cause for the decoupled behavior of the Hf and Nd isotope compositions is most likely a subduction-related mantle source overprint, because Nd behaves more mobile in subduction components compared to the less mobile Hf (Hoffmann et al., 2011a). Other scenarios explaining the Hf-Nd decoupling may include cumulate segregation processes in an early magma ocean or an early metamorphic overprint during intrusion of the TTGs might also (Hoffmann et al., 2011a; Rizo et al., 2011). These scenarios are possible, however, they are only very difficult to reconcile with all observed trace element and isotope features of Isua rocks.

Overall, we therefore propose that the most likely geodynamic setting to form the TTGs in the Isua region is an arc-arc collisional model, where the arc tholeiites melt at 10-20% of partial melting to form the TTGs.

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