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Hydration and metamorphism of komatiites as a source of water for TTG formation in the Archean

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Water plays a crucial role in the formation of new crust on modern Earth. Today, new (on average) andesitic continental crust is created through arc magmatism by fluid-fluxed mantle melting above subduction zones. The aqueous fluid is derived from the breakdown of hydrous phases in subducted oceanic crust, with a large proportion sourced from dehydrating ultramafic rocks. However, in the Archean, felsic crust consisted of Tonalite-Trondhjemite-Granodiorites (TTGs). Previous studies suggest that the water-present partial melting of metamorphosed basalt at temperatures of 750–950 °C is required to produce large volumes of partial melt with TTG compositions. However, the source of such free water is open to discussion.

We propose that hydrated komatiites played a vital role in TTG genesis. Using petrology, mineral chemistry and phase equilibria modelling of representative komatiite samples, combined with analysis of a global geochemical dataset of komatiites and basaltic komatiites, we show that during metamorphism hydrated komatiites can release at least 6 wt. % mineral-bound water. The majority of this water is released by breakdown of chlorite and tremolite at temperatures between 680 and 800 °C. As the temperatures of komatiite dehydration are above the wet basalt solidus, the released water can trigger voluminous partial melting of basalt to ultimately create TTG batholiths. This considerable hydration potential of komatiites is due to their high XMg, which stabilises hydrous minerals during oceanic alteration on the seafloor, but also extends the stability of Mg-rich chlorite to high temperatures. During prograde metamorphism, the XMg, CaO and Al_2O_3 content of the reactive rock composition determines the proportion of chlorite vs amphibole, and therefore the volume of water, which can be transported to temperatures of > 750 °C. Therefore, we suggest that water released from dehydrating komatiites – regardless of their prograde P–T path (i.e., tectonic scenario) – provided the free water necessary to partially melt large volumes of basalts to form the prominent and expansive TTG suits in the Archean. Even though komatiites make up moderate portions of greenstone belts, they likely played a key role in early crust formation and the Earths' early water cycle.