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Differentiation of continental crust by ultrahigh-temperature metamorphism

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Stabilization of Earth's most enduring tracts of continental crust over billion-year timescales requires that the crustal inventory of heat-producing elements (HPE), U, Th and K, are concentrated close to Earth's surface. A long-held view is that melting of the deep crust drives this chemical differentiation via the dissolution of key accessory minerals, such as monazite and zircon, and subsequent upward melt transport. However, a growing body of empirical evidence challenges this paradigm (e.g. [1]) and implies that monazite, in particular, remains a restitic phase during melting at granulite-facies conditions. This contribution characterizes the effect of ultrahigh-temperature (UHT) metamorphism on the redistribution of HPEs. Peraluminous UHT metasediments of the Ivrea Zone, NW Italy, are depleted in U, Th, LREE and enriched in HFSE and HREE relative to non-UHT compositions ([2]; *this study*). Heat production decreases abruptly from 2-3 {\mu}W/m^3 in the non-UHT granulites (peak-T ~900 °C) to <0.2 {\mu}W/m^3 in UHT samples. Conservative behavior of Ti during melting, due to the stabilization of rutile at the expense of high-Ti biotite, allows for mass-balance constraints to be placed on the volumetric strain associated with melt loss across the section. Despite losing ~40 vol.% melt, the highest-T granulites preserve heat production rates similar to sub-solidus amphibolite-facies metapelites, whereas the UHT metasediments underwent only 5 to 10 % more melt-loss and yet experienced almost complete loss of the HPEs. Restitic UHT metapelites from the Ivrea Zone exhibit bulk-rock Ti/Th > 1000, controlled by the stability of rutile and dissolution of monazite; peraluminous metasedimentary xenoliths from the Basin and Range exhibit similar bulk-rock systematics, implying that the attainment of temperatures >900 °C is critical for the effective differentiation of continental crust. Thermal models show that regional-scale UHT metamorphism can be attained in: i) thickened, radiogenic crust and ii) in the lower crust following attenuation or removal of mantle lithosphere. Applied to the Neoarchean, the former mechanism accounts for the formation of large tracts of strongly differentiated crust during this time period.

[1] Alessio et al., (2018). *Geology*, 46(4), 335-338; [2] Ewing et al., (2014). *EPSL,* 389, 106-118.