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Punctuated HT/UHT metamorphism during prolonged Archean orogenesis in the Pikwitonei Granulite Domain revealed by garnet petrochronology

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Fundamental to every modern continent's early (Archean) history is the generation of high temperature conditions required to produce the dense, strong, relatively anhydrous rocks that comprise most of Earth's stable cratonic crust. While the thermal gradients supported in Archean terranes are better understood, the timescales over which these conditions occur are more enigmatic.

Garnet petrochronology allows for the interrogation of a semi-continuous record of these tectonometamorphic conditions, by linking pressure-temperature-fluid conditions (using phase equilibria modeling, trace element thermometry, stable isotope geochemistry) to a precise chronologic/chronometric record (e.g. high-precision Sm-Nd geochronology, geospeedometry of major and trace element diffusion profiles). Here, we utilize techniques from this burgeoning field of study to elucidate the rates and conditions of high temperature/ultra-high temperature (HT/UHT) metamorphism in the ∼2.7 Ga Pikwitonei Granulite Domain (PGD).

The PGD represents over 150,000 km2 of dominantly granulite-facies metamorphic rocks situated at the NW edge of the Superior Province. Peak temperatures in the region range from ∼760ºC in the southernmost part of the PGD, to 900-960˚C in the central/western PGD (∼40-60 km apart). Previous studies have suggested that metamorphism was long-lived in the region, occurring over 100 Ma, from ∼2.71-2.60 Ga [1, 2, 3]. High-precision garnet geochronology on microsampled garnets provides a detailed growth history of several lithologies across the region. Where necessary, bulk garnet analysis (i.e. dating based upon multiple whole garnet crystals rather than portions thereof) was also performed. While cooling from HT/UHT will result in some degree of intra-mineral age resetting, a detailed isotopic study of a range of large garnet porphyroblasts from the PGD (those which would be variably reset depending on peak T, grain size, and initial cooling rate) can retain information about both prograde, peak, and initial cooling history of the region. For example, fifteen Sm-Nd garnet ages were determined from a ∼7cm garnet from the southern PGD (peak T of 760˚C). The initiation of garnet growth was calculated to be 2666 ± 3 Ma, with the termination of garnet growth at 2610 ± 2 Ma, providing a growth duration of 56 ± 3 Ma. Across the larger, hotter, central and western parts of the PGD (peak T of 900-960˚C), major element zoning is preserved in garnets from throughout these localities, implying ultrahigh-temperature conditions over significantly shorter timescales. This suggests that while HT metamorphic conditions can be maintained region-wide for tens of Myr, punctuated UHT conditions that last for Myr to sub-Myr timescales occur locally.

By integrating these petrochronological techniques to decipher P-T conditions and timescales, on samples from across the PGD, we seek to provide insight into the mechanisms for diachronous crustal heating and the formation of stable cratonic lithosphere.

[1] Smit et al., 2013. EPSL, 381, 222-233.
[2] Heaman et al., 2011. Can. J. Earth. Sci., 48, 205-245.
[3] Guevara et al., 2016. AGU abstracts with programs