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A brief pulse of Archean granulite-facies metamorphism: the Beartooth Mountains of Montana, US

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Partial melting is an important process for stabilization of continental roots, and occurs most prevalently throughout the recent geologic record at plate tectonic boundaries. Understanding the processes behind partial melting of Archean continental crust is thus paramount for understanding Archean tectonic modes and how stable cratons formed. Since deviation from a 'normal' crustal geothermal gradient typically reflects dynamic processes associated with advective heat flux, and the pressure-temperature-time paths that are experienced by metamorphic rocks record evidence for this, studies of high-temperature (*HT*) Archean metamorphism can reveal particularly important information about Archean tectonic processes and rate.

The Beartooth Mountains of Montana, USA, expose Archean rocks of the Wyoming Craton that are dominated by an ~2.8 Ga calc-alkaline granitoid batholith known as the Long Lake Magmatic Complex (LLMC). The LLMC contains widespread, up to km-scale metasedimentary roof pendants, whose granulite facies metamorphism has previously been interpreted as a direct result of contact heating with the LLMC. We present here new field, geochronological and petrologic data suggestive of granulite facies conditions significantly after LLMC emplacement, requiring an additional phase of late Archean high crustal temperatures. Sm-Nd garnet ages reveal growth at 2.67–2.72 Ga (range encompasses eight samples, with average 2σ uncertainty of ~0.05 Ga on each), with no overlap of uncertainty bounds with those for zircon crystallization in the LLMC (e.g. Mueller et al., 2010). Metamorphic monazite is similarly late, implying that both garnet and monazite growth in the metasediments post-dated magma emplacement, and chemical and textural relations suggest that both phases grew as part of a prograde sequence that culminated in > 750 ˚C migmatite generation. We conclude, therefore, that a potentially widespread metamorphic event reheated the young crust of the Wyoming Province some 100 Myrs after its formation. This event left little obvious textural or isotopic imprint on the magmatic rocks, and knowledge of the depth and duration of its occurrence are important for deciphering geodynamic scenarios to which it could be related.

Phase equilibria modeling reveals that metasedimentary lithologies reached peak temperatures of ~780–800 ˚C and that their tonalitic hosts would have experienced minimal re-melting and zircon dissolution at these conditions. Peak depths of metamorphism were approximately 15–20 km, with tight clockwise *P-T* paths suggesting that peak temperatures and early phases of cooling occurred after ~3 km of exhumation. Preliminary diffusion modeling of major element zoning in garnet suggests that granulite facies temperatures were only maintained for a short duration (< 2 Myrs within ~25 ˚C of peak temperature) and that cooling to ambient mid-crustal temperatures likely lasted < 10 Myrs. Sm-Nd geochronology of micro-sampled growth zones of garnet porphyroblasts is currently underway and, combined with phase equilibria constraints, will help to reveal heating rates of samples from several locations within the Beartooth range, aiding elucidation of the mechanisms that drove *HT* metamorphism.

References:

[1] Mueller, P et al. (2010) *Precambrian Research* 183: 70-88