Geophysical Research Abstracts
Vol. 19, EGU2017-11541, 2017
EGU General Assembly 2017

Comparative chronology of Archean HT/UHT crustal metamorphism

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Attainment of high crustal heat fluxes and consequent partial melting is critical to the stabilization of continental roots. Understanding the processes and timescales behind partial melting of continental crust in the Archean is thus paramount for understanding Archean tectonic modes and how stable cratons formed. High-temperature (HT) to ultrahigh-temperature (UHT) metamorphic rocks can record evidence for dynamic processes that result in advective heat fluxes and a substantial deviation from normal crustal geothermal gradients. Examination of the pressure-temperature conditions and timescales of HT/UHT metamorphism is thus essential to understanding the tectonic processes behind extreme crust heat fluxes and the formation of stable cratonic crust. Here, utilizing both traditional and nontraditional petrologic and geochronologic techniques, we compare the pressure-temperature-time paths of two Neoarchean terranes: the eastern Beartooth Mountains of the Wyoming Craton and the Pikwitonei Granulite Domain of the Superior Province.

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, with ID-TIMS Sm-Nd garnet geochronology and laser ablation split stream (LASS) monazite geochronology suggesting that metamorphism occurred almost 100 Ma after entrainment by the LLMC [1]. Phase equilibria modeling and Zr-in-rutile thermometry constrain peak pressures and temperatures of ∼6-7 kbar and ∼780–800°C. Major element diffusion modeling of garnet suggest that granulite-facies temperatures were only maintained for a short duration, < 2 Ma.

In contrast, the Pikwitonei Granulite Domain consists of >150,000 km^2 of high-grade metamorphic rocks situated in the NW Superior Province. Phase equilibria modeling and trace element thermometry constrain peak temperatures in the southernmost part of the PGD to ∼760°C, while across the vast central and western parts of the PGD, peak temperatures range from 900-1000ºC. LASS monazite and zircon ages, combined with ID-TIMS zircon and Sm-Nd garnet ages range from ∼2720 Ma to ∼2600 Ma, and combined with the thermometry, suggest that temperatures of >700°C were maintained region-wide for over 100 Ma, and that this was punctuated by thermal perturbations exceeding 900-950°C and occurring over substantially shorter timescales.

The depths, temperatures and timescales inferred here suggest that although these regions were experiencing metamorphism within ∼100 Ma of each other, the primary driver for this metamorphism was different in each case. Timescale of metamorphism might be the most important constrained parameter here, highlighting the benefit of high resolution isotopic and geospeedometry approaches.

[1] Dragovic et al., 2016. Precamb. Res., 283, 24-49.
[2] Guevara et al., 2016. AGU abstracts with programs.