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Virtual Event
September 21-23
2020
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Mesoarchean high-temperature reworking of the Akia Terrane, North Atlantic Craton, West Greenland

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Summary

U–Pb zircon geochronology, field relationships, phase equilibrium modelling and trace element modelling are used to evaluate the tectonic setting of Mesoarchean granulite-facies metamorphism in the Akia Terrane of the North Atlantic Craton in West Greenland. Geochronology records metamorphic zircon growth at *c.* 3.0 Ga across the western portion of the Akia Terrane. Phase equilibrium modelling of two-pyroxene metabasite enclaves indicate temperatures of >800 °C at <0.9 GPa, consistent with a high apparent geothermal gradient. High-temperature metamorphism and partial melting occurred in the absence of pervasive ductile deformation as indicated by undeformed pyroxene-bearing leucosome in metabasite. Trace element modelling suggests that c. 3.0 Ga tonalite at the current exposure level in the Akia Terrane was generated at pressures of >0.8 GPa in the stability field of garnet. Zircon Hf isotope data is also consistent with a model involving protracted Mesoarchean magmatic growth with limited mantle addition during a prolonged period of high temperatures in a relatively stagnant tectonic regime prior to Neoarchean compressional tectonism in the Akia Terrane.

Methods

We use U–Pb zircon geochronology, whole-rock geochemistry as well as phase equilibrium and trace element modelling to evaluate the timing and duration of high-temperature metamorphism and investigate the implications for the source of Mesoarchean tonalite magmatism in the Akia Terrane of West Greenland and consequences for Mesoarchean reworking of the crust. Four rocks were analyzed for whole-rock major and trace element compositions (ICP-OES and ICP-MS at ALS Laboratories, Ireland) and metamorphic phase assemblages were calculated using the THERMOCALC software package. Trace element compositions of modelled melts were calculated using the partition coefficients from Bédard (2006). Zircon U–Pb geochronology was conducted using SHRIMP and LA-ICP-MS at Curtin University (Australia). Full analytical details and modelling methods are reported in Yakymchuk et al. (2020).

Results and Implications

U–Pb zircon geochronology from this study and previous work demonstrate that metamorphism occurred across the western portion of the Akia Terrane at *c.* 3.01–2.98 Ga (Fig. 1a). These ages are similar to those of tonalite crystallization in the Akia Terrane (3.06–2.98 Ga; Gardiner et al. 2019). Considering that zircon is expected to grow during cooling after the metamorphic peak (e.g. Kohn et al., 2015), the zircon ages are interpreted as the minimum age for the peak of metamorphism. There is no systematic decrease or increase in age across the investigated region, which suggests that high-temperature metamorphism was widespread and coeval. Together, the ages suggest long durations (>30 Myr) at high temperature conditions.

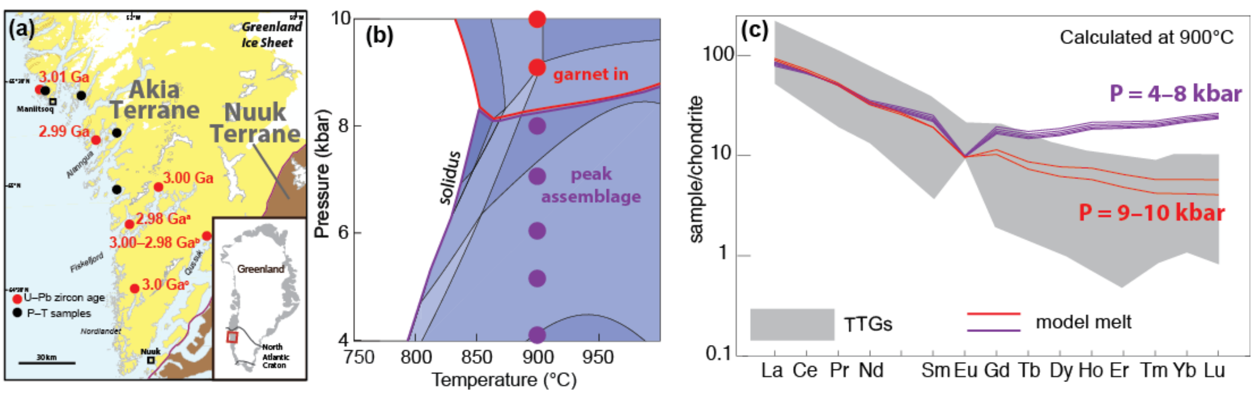

Figure 1. (a) Simplified geological map of the Akia Terrane (modified from Gardiner et al., 2019) showing the locations of U–Pb zircon ages associated with Mesoarchean high-temperature metamorphism. Sources are: [a]Garde et al. (2000), [b]Garde et al. (2012) and [c]Friend and Nutman (1994). (b) *P–T* pseudosection for a two-pyroxene bearing metabasite. Garnet is not in the sample but is predicted at slightly higher pressures. Coloured dots represent the *P–T* conditions used to calculate concentrations of REE in the model melt and compared with *c.* 3.0 Ga TTGs from Gardiner et al. (2019) in (c). (c) chondrite-normalized rare earth element concentrations of model melt from the metabasite as well as *c.* 3.0 Ga tonalities from the Akia Terrane. TTG: tonalite-trondhjemite-granodiorite

Phase equilibrium modelling of three two-pyroxene metabasite samples yields estimates of peak metamorphism at pressures <8 kbar and temperatures >800°C (e.g. Fig. 1b). These *P–T* estimates equate to thermal gradients >1000°C/GPa, which implies high temperatures at relatively low pressures and is consistent with high-temperature metamorphism in a thin crust.

Trace element modelling predicts melt with high concentrations of the heavy REE that are inconsistent with *c.* 3.0 Ga tonalite gneisses in the Maniitsoq region (Fig. 1c). However, deeper in the crust (9–10 kbar) the same metabasites yield model melt compositions that are depleted in the HREE and have compositions consistent with the tonalities (Fig. 1c).

Considering the similar ages of granulite metamorphism across the western portion of the Akia Terrane, the high apparent thermal gradient inferred from the phase equilibrium modelling, and the absence of field evidence for syn-tectonic melting, we infer that the geological setting was a stagnant lid environment at 3.0 Ga. The generation of melt with similar compositions to the tonalites in the region is modelled to occur at 1–2 kbar below the current exposure level. Hafnium isotope ratios in zircon are also consistent with derivation of the tonalities from the metabasite rocks exposed in the Maniitsoq region (Gardiner et al., 2019). Stagnant reworking of the Akia Terrane during 3.0 Ga high-temperature metamorphism was followed by Neoarchean compressional tectonism at *c.* 2.86–2.7 Ga (Kirkland et al., 2018). The transition over ~200 My from stagnant lid to compressional tectonism is also broadly compatible with the results of numerical geodynamic modelling of Archean tectonics (e.g. Sizova et al., 2010). Consequently, we infer that the Akia Terrane records a change from stagnant-lid craton reworking to horizontally-driven accretionary craton growth at the transition from the Mesoarchean to early Neoarchean.

References

Bédard, J.H., 2006. A catalytic delamination-driven model for coupled genesis of Archaean crust and sub-continental lithospheric mantle. Geochimica et Cosmochimica Acta 70, 1188-1214.

Friend, C.R.L., Nutman, A.P., 1994. Two Archaean granulite-facies metamorphic events in the Nuuk-Maniitsoq region, southern West Greenland: correlation with the Saglek block, Labrador. J Geol Soc London 151, 421–424.

Garde A.A., Friend C., Nutman A., Marker M. 2000. Rapid maturation and stabilisation of middle Archaean continental crust: the Akia terrane, southern West Greenland. Bulletin of the Geological Society of Denmark 47, 1–27.

Garde, A.A., Whitehouse, M., Christensen, R., 2012. Mesoarchean Epithermal Gold Mineralization Preserved at Upper Amphibolite-Facies Grade, Qussuk, Southern West Greenland. Econ. Geol. 107, 881–908.

Gardiner, N.J., Kirkland, C.K., Hollis, J., Szilas, K., Steenfelt, A., Yakymchuk, C., Heide-Jørgensen, H. 2019. Building Mesoarchaean crust upon Eoarchaean roots: The Akia Terrane, West Greenland. Contributions to Mineralogy and Petrology 174, 20.

Kirkland, C.L., Yakymchuk, C., Hollis, J., Heide-Jørgensen, H., Danišík, M., 2018a. Mesoarchean exhumation of the Akia terrane and a common Neoarchean tectonothermal history for West Greenland. Precambrian Res 314, 129–144.

Kohn, M. J., Corrie, S. L., Markley, C., 2015. The fall and rise of metamorphic zircon. American Mineralogist 100, 897–908.

Sizova, E., Gerya, T., Brown, M. and Perchuk, L.L., 2010. Subduction styles in the Precambrian: Insight from numerical experiments. Lithos 116, 209-229.

Yakymchuk, C., Kirkland, C.L., Hollis, J.A., Kendrick, J., Gardiner, N.J. and Szilas, K., 2020. Mesoarchean partial melting of mafic crust and tonalite production during high-T–low-P stagnant tectonism, Akia Terrane, West Greenland. Precambrian Research 105615.