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# Concentric Slow Cooling Of A Low P-High T Terrain: Evidence from 1600-1300 Ma Mica Dates in the 1780-1700 Ma Black Hills Orogen, South Dakota, USA

Peter Dahl

Kent State University - Kent Campus, pdahl@kent.edu

K. A. Foland

Ohio State University - Main Campus

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**Concentric slow cooling of a low *P*-  
high *T* terrain: Evidence from 1600-  
1300 Ma mica dates in the 1780-1700  
Ma Black Hills Orogen, South  
Dakota, USA**

P.S. DAHL<sup>1\*</sup> AND K.A. FOLAND<sup>2</sup>

<sup>1</sup>Department of Geology, Kent State University, Kent, Ohio  
44242 USA (\*correspondence: pdahl@kent.edu)

<sup>2</sup>Department of Geological Sciences, Ohio State University,  
Columbus, Ohio 43210 USA

The crystalline core of the southern Black Hills (SBH), South Dakota, exposes an extensive, low *P*-high *T* aureole of garnet- to 2<sup>nd</sup>-sillimanite-zone schists centered on the plutonic core of the 1715 Ma Harney Peak Granite (HPG). This paper demonstrates regional patterns of apparent age observed for 52 <sup>40</sup>Ar/<sup>39</sup>Ar dates of muscovite and biotite in diverse rocks from across the ~1000-km<sup>2</sup> metamorphic aureole and its plutonic center. About 20 biotite dates, sampled mostly near faults, are influenced by excess <sup>40</sup>Ar and obscure the regional trends. The remaining dates reveal radial patterns of apparent younging from outer aureole toward inner granite, with previously unrecognized, elliptical age zones centered on the main HPG pluton and its outliers. The regional pattern of <sup>40</sup>Ar/<sup>39</sup>Ar cooling ages indicates non-uniform slow cooling of the mid-crust between ~1600-1250 Ma. This scenario of delayed slow cooling from aureole to pluton is consistent with published cooling ages for muscovite (Rb/Sr) and apatite (U/Pb), which range from 1690 to 1550 Ma and from 1700 to ~1500 Ma, respectively. To explain these results, it is likely that ambient pre-granite temperatures of the country rocks were ≥350 °C at the ~10-14 km depth of granite emplacement, as previously proposed, and that the entire complex resided at this depth and cooled slowly from aureole to granite for 100's of m.y. Alternatively, or in addition, the HPG and inner aureole were not uplifted until ~1480-1330 Ma, whereupon they finally cooled through ~350-300 °C.

An age compilation representing diverse SBH minerals reveals a composite sequence of relative isotopic closure comparable to that commonly observed elsewhere: monazite (Pb) > apatite (Hf) > hornblende (Ar) = apatite (Pb) = low-Rb muscovite (Sr) > muscovite (Ar) > biotite (Ar) = apatite (Sr). Likewise, for a given mineral, the retentivity sequence is consistent with ionic radii and/or experiment (cf. Hf, Pb, and Sr in apatite; Sr and Ar in muscovite, etc). This systematic behavior underscores the crystal-chemical basis for isotopic closure phenomena, as formalized elsewhere.

**Molybdenum isotope variations in a  
redox-stratified lake; Removal  
mechanism and preservation in  
euxinic sediments**

T.W. DAHL<sup>1</sup>, A.D. ANBAR<sup>2</sup>, G.W. GORDON<sup>2</sup>,  
M.T. ROSING<sup>1</sup>, R.E. FREI<sup>1</sup> AND D.E. CANFIELD<sup>1</sup>

<sup>1</sup>NordCEE and Geological Museum, Univ. of Copenhagen,  
Øster Voldgade 5-7, 1350 Copenhagen K, Denmark

<sup>2</sup>School of Earth & Space Expl. and Dept. of Chem. &  
Biochem. Ariz. State Univ., Tempe, AZ 85287, USA

The chemical behavior of Molybdenum (Mo) is investigated in a sulfidic lake system to understand the potential of using Mo isotopes as a paleo-redox proxy in euxinic sediments.

Meromictic Lake Cadagno in Switzerland displays a redox gradient with sulfidic bottom waters, which acts as a perfect trap for Mo. Concentrations are elevated by more than 2 orders of magnitude (130ppm) relative to rocks in the catchment area. Isotopically, Mo in the sulfidic water column ( $\delta^{98/95}\text{Mo} = 1.8 \pm 0.1\%$ ) is about 1‰ heavier than the riverine source where it adsorbs to >0.2µm particles.

The isotope systematics is complicated by a subaquatic source appearing from dolomitic bedrock. A simple model suggests Mo isotope fractionation at the chemocline is associated with conversion of molybdate to particle reactive thiomolybdate, hence the residence time for Mo in the sulfidic zone is comparable to the slow kinetics of these reactions [2]. The isotopic composition in the sediment is constant and we conclude that Mo isotopes are preserved in sulfidic settings through early diagenesis.

[1] Tossel J. A. (2005) *GCA* **69**, 2981-2993. [2] Ericksson & Helz (2000) *GCA* **64**, 1149-1158.