

**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**

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The crystalline core of the southern Black Hills (SBH), South Dakota, exposes an extensive, low *P*-high *T* aureole of garnet- to 2nd-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 ⁴⁰Ar/³⁹Ar dates of muscovite and biotite in diverse rocks from across the ~1000-km² metamorphic aureole and its plutonic center. About 20 biotite dates, sampled mostly near faults, are influenced by excess ⁴⁰Ar 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 ⁴⁰Ar/³⁹Ar 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**

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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.