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A multi-mineral approach to understanding the tectonic evolution of Precambrian terranes in the southern Superior Province USA

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Precambrian rocks provide a record about the origin of Earth's continents. However, the geologic histories of Precambrian terranes are difficult to ascertain because of overprinting by numerous tectonothermal events since initial formation. Precise constraints on the timing of these igneous, metamorphic, and deformational events are necessary to ultimately understand the processes underlying crustal evolution on early Earth. One approach to deciphering the multi-stage histories of these terranes is use of multiple geo- and thermochronometers (apatite, monazite, titanite, garnet) and isotope systems (U-Pb, Lu-Hf, and Sm-Nd) sensitive to a range of metamorphic conditions, in conjunction with microstructural observations (electron backscatter diffraction). To demonstrate the utility of this approach, we focus on the Archean and Paleoproterozoic terranes of the southern Superior Province (MI, WI, MN). Published zircon U-Pb data document several stages of igneous crystallization of basement orthogneisses from 3.5 to 2.7 Ga. Our titanite U-Pb ages and trace element compositions in basement gneisses reflect Archean metamorphism at 2550±46 Ma (2SE), followed by varying degrees of titanite recrystallization during Paleoproterozoic deformation. Apatite U-Pb and garnet Lu-Hf ages of overlying Paleoproterozoic metasupracrustal rocks record the onset of peak metamorphic conditions at 1837±7 Ma near the end of the Penokean orogeny (1880–1830 Ma), continuing until 1782±15 Ma. Corresponding garnet Sm-Nd ages of several samples are ~70 Ma younger, reflecting a period of cooling and exhumation between 1752±10 and 1738±9 Ma during the Yavapai orogeny (1760–1720 Ma). This period of exhumation is broadly consistent with the U-Pb ages of syn-kinematic titanite at 1713±32 Ma, as well as the Sm-Nd and Lu-Hf ages of re-equilibrated pre-kinematic garnets. Apatite U-Pb ages at 1592±26 Ma reflect reheating of the system during the Mazatzal orogeny (1650–1600 Ma). These data document a history spanning from crust formation in the Archean, to modification and ultimate stabilization in the Paleoproterozoic, when basement gneisses were exhumed into the upper crust. These results facilitate more precise comparisons between the Paleoproterozoic accretionary systems across North America, and highlight a case study where multiple geochronometers and isotope systems can be integrated with microstructural observations for deeper understanding of crustal evolution in Precambrian terranes.