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Comparative isotopic and chemical geochronometry of monazite, with implications for U-Th-Pb dating by electron microprobe: An example from metamorphic rocks of the eastern Wyoming Craton (U.S.A.)

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ABSTRACT

Polygenetic monazite grains in diverse Precambrian crystalline rocks from the Black Hills, South Dakota, have been analyzed in situ by ion and electron microprobe methods (SHRIMP and EMP), to evaluate the accuracy and precision of EMP ages determined using a new analytical protocol that incorporates improved background acquisition and interference corrections. Parallel evaluations were conducted by comparing EMP chemical and SHRIMP isotopic ages at regional-, rock-, and grain-scales. The monazite data set includes 354 EMP chemical analyses from 26 grains in six metamorphic rocks, which resolve into 54 age-composition domains, and 31 SHRIMP isotopic ages from 13 grains in one of the rocks, with six grains microanalyzed in common by the two methods. The data set also includes monazite-bearing garnets in two of the rocks, whose isotopic compositions were analyzed using Pb stepwise-leaching (PbSL) methods. Both the EMP and SHRIMP data sets reveal a continuum of apparent monazite ages spanning a ~1790–1680 Ma timeframe, with a relatively high probability of ages at ~1755 and ~1715 Ma that correspond spatially to core and rim domains. PbSL ages of ~1742 and ~1734 Ma obtained from monazite-bearing garnet in two rocks are intermediate compared to the corresponding EMP ages, and are thereby interpreted as mixed ages. EMP data for two grains in the structurally deepest of the six rocks record ~1785 and ~1755 Ma ages in the cores and (higher-Y and lower-Th) rims, respectively, and these results are duplicated by SHRIMP ages in these and/or other grains from the same rock. Overall, the EMP, SHRIMP, and PbSL ages are internally consistent at the various scales of observation, which serves to validate EMP chemical dating as an accurate and precise method of discerning monazite age populations in polymetamorphic terrains.

The EMP data set is interpreted geologically as reflecting multiple episodes of monazite growth that are provisionally related to known metamorphic events in the Black Hills. Taking the most precise EMP data at face value, it is possible to resolve the timing of the two older events at ≤1784 ± 4 Ma (or ≤1786 ± 6 Ma) and 1756 ± 3 Ma (or 1753 ± 4 Ma), with 95% confidence. These events are considered to be related to sequential episodes of N-directed thrusting and ~E-W compression associated with Paleoproterozoic crustal assembly in the mid-continent. A younger metamorphism, related to granite intrusion known to have occurred at 1715 ± 3 Ma, is dated independently at 1717 ± 2 Ma from the EMP monazite ages.