Electron probe (Ultrachron) microchronometry of metamorphic monazite: Unraveling the timing of polyphase thermotectonism in the easternmost Wyoming Craton (Black Hills, South Dakota)

PETER S. DAHL,†* MICHAEL P. TERRY, MICHAEL J. JERCINOVIC, MICHAEL L. WILLIAMS, MICHAEL A. HAMILTON,‡ KENNETH A. FOLAND, SUSANNE M. CLEMENT,§ AND LAVERNE M. FRIBERG

ABSTRACT

A metapelite from the easternmost Wyoming craton (Black Hills, South Dakota) has been analyzed by microstructural methods to unravel polyphase deformational history associated with 1800–1700 Ma assembly of southern Laurentia. Three deformational fabrics are recognized in oriented thin sections: an ENE-trending S1 fabric, preserved as oblique inclusion trails in garnet porphyroblasts; a NNW-trending S2 fabric, preserved as microlithons in the rock matrix; and a flattening fabric, S3, which transposed S1-S2 and dominates the matrix. A complex monazite porphyroblast has been analyzed in situ with the electron microprobe (Ultrachron) to constrain the timing of S1-S3 fabric formation associated with monazite growth. The core of this grain uniquely preserves the S1-S2 fabrics as sigmoidal inclusion trails. The mean total-Pb age of this domain is 1750 ± 10 Ma (all dates reported at 95% confidence; n = 39 spots), which is equivalent to the published 207Pb/206Pb age for the same domain. These results validate the total-Pb dating method in general and the Ultrachron in particular, for reliable age determination in low-Th monazite, and are interpreted as 1750 Ma minimum ages for the S1-S2 fabrics and sequential, D1-D2 collisional events that imposed them (~N-directed arc accretion and ~E-W continental collision, respectively). A higher-Th,Y rim of this same “Rosetta” grain truncates the S1-S2 sigmoid, and is associated with resorption textures in garnet porphyroblasts, coupled release of Y, and an S3 fabric that pervasively overprinted S1-S2 in the rock matrix. The mean Ultrachron date of this domain is 1692 ± 5 Ma (n = 17 spots), which is slightly younger than the published isotopic age for all monazite rims combined. These results support a ~1715–1690 Ma timeframe for localized doming (D3) related to granite magmatism, the onset of which has been dated independently at 1715 ± 3 Ma. The timing of post-D3 cooling through 350 and 300 °C is constrained by 40Ar/39Ar dates of ~1610 and ~1480 Ma obtained for separates of D3 matrix muscovite and biotite, respectively, which are interpreted as closure ages.

This study shows that fabrics in poly-deformed rocks can be dated by linking monazite spot ages to key microtextures. Further, the results of this micrometer-scale study enhance previous knowledge of local thermotectonism (Black Hills) and regional terrane assembly (Laurentia).

INTRODUCTION

Monazite is a widespread phosphate mineral that occurs as an accessory in diverse crystalline rocks. In poly-deformed rocks, it commonly preserves discrete age-composition domains within single thin sections, individual grains, and/or specific microtextural environments. As such, occurrences of polygenetic monazite are utilized increasingly for deciphering complex histories of grain growth, recrystallization, dissolution, and regrowth (e.g., Lanzirrotri and Hanson 1996; Vry et al. 1996; Ayers et al. 1999; Williams et al. 1999; Pyle and Spear 1999; Vavra and Schaltegger 1999; Wing et al. 2003). Moreover, the record of such grain-scale processes in monazite can be linked to regional thermotectonic histories when integrated with a full complement of petrofabric, petrologic, and geochronologic data (e.g., Zhu and O’Nions 1999a, 1999b; Montel et al. 2000; Terry et al. 2000a, 2000b; Pyle and Spear 2003; Williams and Jercinovic 2002; Foster and Parrish 2003; Shaw et al. 2001; Gibson et al. 2004). For constraining absolute ages of monazite at the micrometer scale, chemical (henceforth, total-Pb) dating with the electron microprobe has matured into a viable complement to isotopic

* E-mail: pdahl@kent.edu
† Current address: Jack Satterly Geochronology Laboratory, Department of Geology, Earth Sciences Centre, University of Toronto, Toronto, Ontario, Canada MSS 3B1.
‡ Current address: Department of Geology, Kent State University, Kent, OH 44242.