

INTRODUCTION

Versatile monazite: Resolving geological records and solving challenges in materials science†

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Monazite is ubiquitous in the geological realm (Overstreet 1967). Its compositional and isotopic response to changes in intensive and extensive rock parameters has made it an increasingly important component of integrated pressure-temperature-deformation-composition-time (*P-T-D-X-t*) studies, particularly in complex poly-metamorphic terranes (Janots et al. 2012; Kelly et al. 2012; Langille et al. 2012). The utility of monazite also includes its role in understanding igneous, sedimentary, and hydrothermal systems (Dumond et al. 2008; Mahan et al. 2010; Aleinikoff et al. 2012), and more recently, as a means for examining repositories of radioactive waste (Oelkers and Montel 2008).

Since the broader potential applications of monazite as a geochronometer were described by Parrish (1990), several significant developments have since occurred that allow for the routine compositional and isotopic analysis of monazite by a variety of techniques. These include technological advances in electron-probe microanalysis (EPMA: Suzuki and Adachi 1991; Montel et al. 1996; Pyle et al. 2005; Williams et al. 2007; Jercinovic et al. 2008), secondary ion mass spectrometry (SIMS: Zhu et al. 1997; Bosch et al. 2002), laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS: Machado and Gauthier 1996; Košler 2001; Horstwood et al. 2003), isotope dilution-thermal ionization mass spectrometry (ID-TIMS: Hawkins and Bowring 1997; Crowley et al. 2009), and micro-XRF (Cheburkin et al. 1997; Engi et al. 2002). While U-(Th)-Pb dating of monazite is well established, in situ isotopic analytical techniques (SIMS, LA-ICP-MS) are now being applied to the Sm-Nd system in monazite (McFarlane and McCulloch 2007; Gregory et al. 2009; Fisher et al. 2011; Iizuka et al. 2011; Liu et al. 2012). Advances in laser and multi-collector detector technology also enable accurate measurement of isotopic abundances from exceptionally small sample volumes of monazite (Cottle et

al. 2012), while developments in chemical abrasion-TIMS techniques (without high-temperature annealing) may provide even more high-precision data for monazite (Peterman et al. 2012).

In addition to more traditional aspects of high-temperature geochronology and the integration of monazite into constraining deformation histories (e.g., Williams and Jercinovic 2012), new techniques are continually being developed that have expanded the numbers of geological problems to which monazite may be applied. These applications include: low temperature (U-Th)/He thermochronology for constraining cooling ages (Boyce et al. 2009), detrital monazite geochronology (Hietpas et al. 2011), understanding mechanisms for alteration via dissolution-reprecipitation (Harlov et al. 2011; Williams et al. 2011; Wawrzenitz et al. 2012), and incorporating monazite phase relations into thermodynamic phase equilibria (Kelsey et al. 2008; Spear 2010).

The value of monazite is not restricted to the Earth sciences. The ability of monazite to accommodate significant quantities of naturally occurring actinides (Th and U) makes it an attractive natural analog for studying the long-term effects of radioactive decay on the structural and crystallographic properties of phosphate-based materials that have been proposed for isolation and storage of radioactive waste (Oelkers and Montel 2008). Other applications in materials science include studying the proton-conductivity of rare earth element phosphates for applications in hydrogen-based clean energy technologies (Amezawa et al. 1998; Norby and Christiansen 1995). Last, monazite is mined or quarried at various localities around the world as a source of light rare earth elements that are increasingly important commodities for high-technology industries (Chakhmouradian and Wall 2012).

The papers assembled for the launch of this special issue result from presentations made at a special theme session convened at the 2011 Geological Society of America Annual Meeting in Minneapolis, entitled “Monazite: The ultimate geologic record.” Oral contributions and posters were presented in two well-attended sessions, and we thank all the participants for making them such a success. During the development of this special collection for *American Mineralogist*, the title was changed to reflect the diversity of contributions received, which covered a broad spectrum of mineralogy, geochronology, geochemistry, petrology, tectonics, as well as materials science. We thank the authors who have contributed manuscripts for the launch of this special collection and the reviewers for their careful and valued comments. We hope more contributions will be added as

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† Special Collection: Versatile Monazite: Resolving Geological Records and Solving Challenges in Materials Science is a thematic collection of papers based on a session at GSA in 2011. The special associate editors are Gregory Dumond and Callum Hetherington. Special collection papers can be found on GSW at <http://ammin.geoscienceworld.org/site/misc/specialissuelist.xhtml>. Additionally the GSW site has a classification tag found on the right-hand side of the article that is a link to all the collection papers. The MSA website has complete information at <http://www.minsocam.org/MSA/AmMin/AmMineral.html>

time goes by, and we sincerely thank the staff and the editors of *American Mineralogist* for the invitation to work with them in publishing a series of papers that truly demonstrate the diversity and versatility of monazite-related science.

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