Chemical lattice expansion of natural zircon during the magmatic-hydrothermal evolution of A-type granite

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ABSTRACT

Although thermal lattice expansion is a well-documented nature of crystals, including zircon and zircon-type minerals, chemical lattice expansion of natural mineral is rarely reported. Here we present a comprehensive investigation on three types of natural zircon that records the evolution of the granitic system in Xiangshan, North China, and shows expanding crystallographic parameters induced by chemical incorporation instead of thermal expansion. Prismatic and oscillatory-zoned zircon grains (Type-1A), crystallized early in the granitic magma at high temperatures in a volatile-undersaturated environment, have the smallest lattice parameters ($a = 6.603$ Å, $c = 5.971$ Å). Prismatic and altered zircon grains (Type-1B), formed under volatile-saturated conditions and in the presence of F-rich fluid with numerous thorite and xenotime inclusions, have intermediate lattice parameters ($a = 6.649$ Å, $c = 6.020$ Å). Pyramidal zircon grains (Type-2), formed in a subsolvus granitic system at relatively low temperatures and coexisted with fluid inclusions, have the biggest lattice parameters ($a = 6.677$ Å, $c = 6.010$ Å). Trace elements, including Hf, Th, Ti, Y, and REE, and volatiles content, increase in the structure of zircon from the early to late magmatic origin, which is consistent with the expansion of the lattice parameters. The occurrence of the three zircon types in the Xiangshan arfvedsonite granites is interpreted to reflect the progressive fractionation of granitic melt from hypersolvus to subsolvus conditions. Therefore, we conclude that the lattice expansion of zircon in this study results from chemical incorporation of trace element and volatile components during the magmatic to hydrothermal evolution of granitic magma. Besides, the textural and compositional evolution of zircon can be used as efficient indices for the fractionation and evolution of A-type granitic system.

Keywords: Chemical lattice expansion, zircon, fractionation crystallization, magmatic-hydrothermal evolution, A-type granite

INTRODUCTION

Zircon is a common accessory mineral in granitic rocks. It is chemically resistant, relatively insoluble and refractory, and can withstand weathering and recycling, as well as high-temperature metamorphism and anatexis (El-Bialy and Ali 2013). It is widely accepted that zircon can provide reliable and robust estimates of age, compositions of coexisting minerals and melts, and constraints on the petrogenesis of host rocks (Valley 2003). In spite of its apparently simple chemical composition (ZrSiO$_4$), zircon is able to accept substantial amounts of other minor and trace elements into its crystal lattice (e.g., Hf, Th, U, Ti, Nb, Ta, P, Y, and REE) (Breiter et al. 2014). Zircon crystals that are not affected by intense metamictization could provide information about the chemical composition of the melt from which they crystallized. In contrast, the metamict crystals may accumulate substantial amounts of non-formula elements, re-equilibrated with the hydrothermal and low-temperature fluids (Geisler et al. 2007; Yang et al. 2014).

In granitic systems, zircon is generally considered to form early in the crystallization history (Valley 2003). However, in some A-type granites it can crystallize during the whole process of magmatic crystallization, with significant distinction in both texture and composition (Belousova et al. 2006; Breiter and Škoda 2012; Pupin 1980). Although geologically complicated, the behavior of trace elements in zircon depends on physical-chemical conditions and partition coefficients between zircon and melt (Belousova et al. 2006). Presently, there are several speculations have been proposed regarding zircon texture and composition, which include that zircon can record the processes of: (1) magmatic and hydrothermal crystallization (Van Lith-tervelde et al. 2009; Yang et al. 2013); (2) hydrothermal alteration (Zheng et al. 2007); (3) country-rock assimilation; (4) magma mixing (Griffin et al. 2002); or even (5) tectonic setting (Grimes et al. 2007, 2009).

This study reports analyses of textures and compositions of three types of zircon from an A-type granite in north China. The purposes of this article are: (1) to determine the variation of zircon in both structure and composition that may influence the lattice expansion and (2) to test the speculation that zircon could record the processes of magmatic and hydrothermal evolution of the host granite. All samples come from the Xiangshan.