Recrystallization rims in zircon (Valle d’Arbedo, Switzerland): An integrated cathodoluminescence, LA-ICP-MS, SHRIMP, and TEM study

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ABSTRACT

Recrystallization rims are a common feature of zircon crystals that underwent metamorphism. We present a microstructural and microchemical study of partially recrystallized zircon grains collected in polymetamorphic migmatites (Valle d’Arbedo, Ticino, Switzerland). The rims are bright in cathodoluminescence (CL), with sharp and convex contacts characterized by inward-penetrating embayments transgressing igneous zircon cores. Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) data and transmission electron microscopy (TEM) imaging indicate that the rims are chemically and microstructurally different from the cores. The rims are strongly depleted in REE, with concentrations up to two orders of magnitude lower than in the cores, indicating a significant loss of REE during zircon recrystallization. Enrichment in non-formula elements, such as Ca, has not been observed in the rims. The microstructure of zircon cores shows a dappled intensity at and below the 100 nm scale, possibly due to radiation damage. Other defects such as pores and dislocations are absent in the core except at healed cracks. Zircon rims are mostly dapple-free, but contain nanoscale pores and strain centers, interpreted as fluid inclusions and chemical residues, respectively. Sensitive high-resolution ion microprobe (SHRIMP) U-Pb ages show that the recrystallization of the rims took place >200 Ma ago when the parent igneous zircon was not metamict. The chemical composition and the low-Ti content of the rims indicate that they form at sub-solidus temperatures (550–650 °C). Recrystallization rims in Valle d’Arbedo zircon are interpreted as the result of the migration of chemical reaction fronts in which fluid triggered in situ and contemporaneous interface-coupled dissolution-reprecipitation mechanisms. This study indicates that strong lattice strain resulting from the incorporation of a large amount of impurities and structural defects is not a necessary condition for zircon to recrystallize. Our observations suggest that the early formation of recrystallization rims played a major role in preserving zircon from the more recent Alpine metamorphic overprint.

Keywords: Alps, microstructure, recrystallization, trace elements, U-Pb geochronology, zircon

INTRODUCTION

Zircon (ZrSiO₄) is a widely studied mineral in Earth sciences, first because it contains a large spectrum of geochemically important trace elements, such as Y, P, Hf, U, Th, and the rare earth elements (REE), and second because it is known to be physically and chemically very robust. Those features make zircon a key mineral in various disciplines of geosciences, primary geochronology of magmatic, metamorphic, and sedimentary terranes, but also increasingly petrogenesis (e.g., Belousova et al. 2002; Hoskin and Schaltegger 2003) and geothermometry (Watson and Harrison 2005). Geological interpretation inferred from studies on zircon is not always straightforward, however, as zircon grains may contain a record of multiple geological events. Characterization of zircon-forming processes from zircon internal textures and chemistry is thus a prerequisite to validate and interpret compositional and isotopic measurements.

Rims of unzoned to weakly zoned zircon transgressing oscillatory zoned zircon cores have been reported abundantly over the last 25 yr. Van Breezen et al. (1987) attributed them to resorption by melt, followed by precipitation of new zircon. Other authors (Black et al. 1986;Claoué-Long et al. 1988; Schiotte et al. 1989) interpreted them as the result of recrystallization rather than new crystal growth. This interpretation was based on the preservation of primary zoning in the rims and deep embayments of the rims toward the inner parts of the grains. Similar rims were observed in metamict zircon from granitoid rocks (Pidgeon 1992; Nemchin and Pidgeon 1997; Pidgeon et al. 1998), granulites (Vavra et al. 1996, 1999) and eclogites (Rubatto and Gebauer 2000). For such zircon the idea of solid-state recrystallization triggered by migrating reaction fronts became predominant (Schaltegger et al. 1998; Schaltegger et al. 1999; Hoskin and Black 2000; Rubatto and Gebauer 2000). Tomaszek et al. (2003) reported that recrystallization rims could also form in fully non-metamict zircon, thus indicating that radiation damage is not a necessary condition for zircon to recrystallize. Geisler et al. (2007) proposed two models (further discussed at the end of this paper) to account for the formation of recrystallization rims in metamict and non-metamict zircon. Recently, Harlov et al. (2011) also provided significant insights into similar processes, although their study focused into the mineral monazite. They experimentally produced and then characterized replacement rims, revealing crystallographic continuity with pre-existing core crystals reacted with alkali-bearing fluids.

Although knowledge of recrystallization features is crucial for...