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Polyphase tectono-magmatic episodes as revealed by SHRIMP U–Pb geochronology and microanalysis of zircon and titanite from the central Okcheon belt, Korea

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ABSTRACT

The south central Okcheon belt of the southern Korean peninsula experienced polyphase granitic magmatism and deformation during the Mesozoic. This study presents integrated results of ion microprobe U–Pb geochronology and microtextural and microchemical analyses of zircon and titanite from pre-tectonic (Baegnok and Cheongsan) and post-tectonic (Boeun and Sokrisan) plutons with respect to the Cheongsan shear zone. The Baegnok granodiorite sample yielded coherent zircon and titanite $^{206}Pb/^{238}U$ ages of 225.6 ± 1.8 and 223.9 ± 4.4 Ma, indicating a rapid early cooling of the pluton. The Cheongsan K-feldspar megacryst-bearing biotite granite sample yielded a coeval zircon $^{206}Pb/^{238}U$ age of 224.7 ± 1.8 Ma. On the other hand, the titanite grains from this rock are categorized into two age populations corresponding to the late Triassic (214.3 ± 7.9 Ma) and the late Cretaceous (96.2 ± 8.2 Ma) growth. The older population is clearly of igneous origin, considering partly preserved oscillatory zoning in back scattered electron images. Therefore the age indicates contrasting early cooling paths of the two pre-tectonic plutons. The younger population is interpreted to be the product of superimposed metasomatic reactions involving plagioclase, ilmenite, rutile, epidote, and calcite. The two populations show different patterns in their atomic Al/Fe ratios. Zircons from the Boeun and Sokrisan plutons yielded $^{206}Pb/^{238}U$ ages of 172.2 ± 2.1 and 94.2 ± 2.1 Ma, respectively, with the latter being indistinguishable from the younger titanite age of the Cheongsan pluton. The SHRIMP U–Pb age of syn-deformational fine-grained titanite grains lying on sigmoidal foliations in a mylonite from the Cheongsan shear zone has a large error (165 ± 47 Ma) due to their low U/Pb ratios possibly affected by post-tectonic magmatic activities. This study highlights the importance of detailed microanalysis prior to the isotopic dating of samples that have experienced complex tectono-magmatic episodes.

1. Introduction

Zircon ($ZrSiO_4$) and titanite ($CaTiSiO_5$) are common accessory minerals in which the U concentrations are generally sufficient to use as geochronometers. Zircon usually retains the original U–Pb isotopic composition by virtue of its low solubility in crustal melts and sluggish diffusion of U and Pb (Cherniak, 2010). Titanite, on the other hand, is more readily produced through metamorphic reactions principally because many rock-forming minerals can provide Ca and Ti (Frost et al., 2000). Its U–Pb isotope system often renders the opportunity to directly date deformation (Getty and Gromet, 1992; Resor et al., 1996). The multifaceted isotopic behavior of zircon and titanite has been collectively used to decipher complex evolution histories of polymetamorphic terranes (Corfu and Grunsky, 1987; Corfu, 1988, 1996; Corfu et al., 1994; Aleinikoff et al., 2002; Gilotti et al., 2014). U–Pb dating of micron-scale subgrain domains has been feasible by developments of the secondary ion mass spectrometry and laser ablation-inductively coupled plasma-mass spectrometry (Williams, 1998; Williggers et al., 2002; Ireland and Williams, 2003; Jackson et al., 2004). When combined with microanalytical investigation, these *in situ* dating techniques provide more reliable time constraints for grains containing multiple age components (Aleinikoff et al., 2002; Corfu et al., 2003; Spencer et al., 2013).

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The south central part of the Okcheon belt in the southern Korean peninsula has experienced multiple igneous activities and intervening deformational episodes during the Mesozoic (Cheong and Chang, 1997; Ree et al., 2001), which possibly led to different responses of pre-existing minerals and the growth of new minerals. To investigate this in detail, we carried out U–Pb dating using a SHRIMP (Sensitive High-Resolution Ion Microprobe) and microtextural and microchemical analyses of zircon and titanite from Mesozoic granitoid plutons. Our study demonstrates the importance of such analytical combination in dating complex mineral populations.

2. Geological background and sample collection

The tectonic setting, geodynamic framework and metallogenic models of the Korean Peninsula have been debated in many recent studies (e.g., Yin and Nie, 1993; Ernst and Liou, 1995; Chang, 1996; Ree et al., 1996, 2001; Chough et al., 2000; Ishiwatari and Tsujimori, 2003; Zhai and Liu, 2005; Cho et al., 2007; Oh and Kusky, 2007; Zhai et al., 2007; Kwon et al., 2009a,b; Lee et al., 2011; Chang and Zhao, 2012; Kim et al., 2011, 2012, 2013; Park et al., 2013; Goldfarb et al., 2014) particularly with reference to the complex tectonic environments in relation to the superimposed multiple orogenies in space and time. The southern part of the peninsula is composed of two Paleoproterozoic massifs (Gyeonggi and Yeongnam massifs) consisting of high-grade schists and gneisses. An intervening NE-trending fold-thrust belt (*viz.* Okcheon belt) between the massifs is composed of Neoproterozoic to Paleozoic metasedimentary and metavolcanic rocks (Cho and Kim, 2005; Cho et al., 2013) extensively intruded by Mesozoic granitoid plutons. This polymetamorphic belt is often correlated with the Dabie-Sulu collisional belt in China (Ernst and Liou, 1995).

In the south central Okcheon belt, two pre-tectonic (Baegnok and Cheongsan) plutons are preserved (Fig. 1), where a quasi-plastic deformation zone (*viz.* Cheongsan shear zone) is developed along their western boundary (Kang, 1998; Ree et al., 2001). The Baegnok and Cheongsan plutons are bounded by an E–W trending fault. The two plutons intruded into the Carboniferous-Early Permian lower greenschist-facies metasedimentary sequences (Pyeongan Supergroup). The variations within a 100 m-thick zone that shows transitions from protomylonite to ultramylonite are best exposed along the northwestern margin of the Cheongsan pluton, where the ultramylonite (phyllonite) zone is developed close to the geologic boundary with the coal-bearing sandstone of the Pyeongan Supergroup (Kwon et al., 2009a,b).

The Baegnok pluton is typically a coarse- to medium-grained equigranular granodiorite consisting of plagioclase, quartz, K-feldspar, biotite and hornblende with minor apatite, allanite,

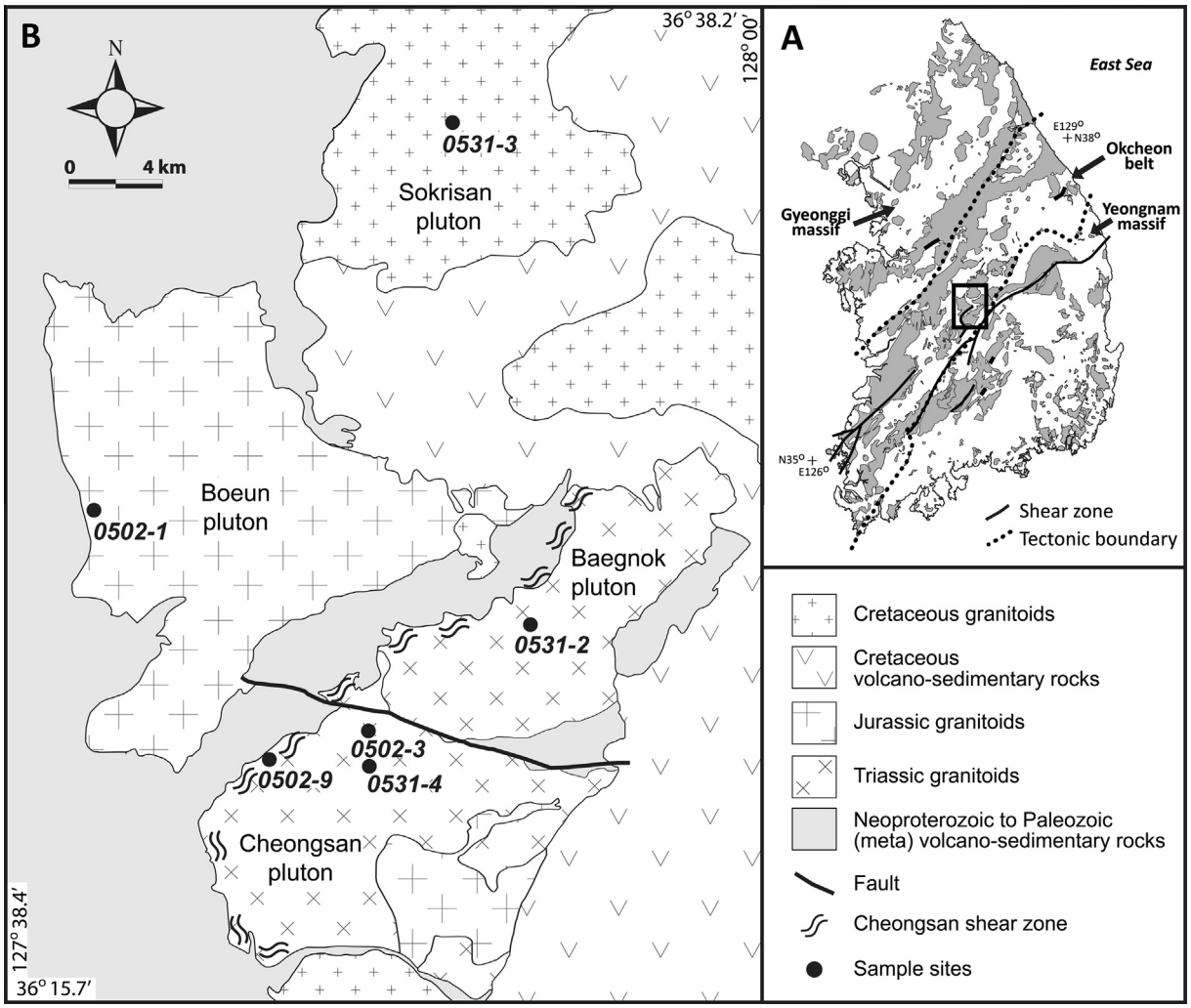

Fig. 1. (A) Distribution of Phanerozoic granitoids and ductile shear zones in the southern Korean Peninsula (modified after Sagong et al., 2005; Cheong and Kim, 2012) and (B) simplified geologic map of the study area with sample locations (after Ree et al., 2001).