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Zircon growth and recrystallization during progressive metamorphism, Barrovian zones, Scotland

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Abstract

The effects of progressive metamorphism (Grampian orogeny) and later tectonic activity on detrital zircon in the Barrovian zones of Scotland were studied using secondary ion mass spectrometry (SIMS) and backscattered electron imaging (BSE). Fifteen samples recording progressive metamorphism from the chlorite through the sillimanite–K-feldspar zones were investigated by: (1) SIMS U-Pb depth profiling into rims of unpolished zircon grains to analyze sub-micrometer-scale features, and (2) conventional spot analysis on sectioned and polished grains. Spot analyses of zircon interiors yield pre-metamorphic detrital ages for all metamorphic grades. Most are in the range ca. 600 to ca. 2000 Ma, but some stretch back to the Archean. Younger ages are recorded in zircon rims, but zircon rim alteration at lower metamorphic grades occurs over much shorter length scales (the outer ~80 nm to ~1 μm of the grain) than in the upper amphibolite to granulite facies (rims of 10 to 30 μm). For example, Grampian (~470 Ma) metamorphism from the garnet and kyanite zones affected only the outermost rims (<1 μm) of detrital zircon grains. Thicker, 10 to 30 μm rims that could be dated by conventional spot analysis developed only at high grades in the sillimanite and sillimanite–K-feldspar zones, probably in the presence of partial melt. The mean Grampian zircon age from spot and depth profile analyses is 472 ± 4 Ma (n = 19). In addition to Grampian ages, the zircon depth profiles reveal ages related to five main events that postdate the Grampian Orogeny: decompression melting at ca. 450 Ma; subduction and I-type granite intrusion at ca. 420 Ma; granite intrusion at ca. 384 Ma; extension-related volcanism and vein mineralization at ca. 335 Ma, and further rifting and basaltic magmatism at ca. 250 Ma. These events are recorded only in the very narrow rims (<1 μm) of zircons, and are thus undetectable with conventional spot analysis. We conclude that: (1) zircon interiors were able to retain detrital ages up to and including the highest grade of Barrovian metamorphism (sillimanite–K-feldspar zone), and (2) the <1 μm thick zircon rims may preserve a rich history of metamorphic and post-metamorphic events that can be dated using SIMS U-Pb depth profiling techniques.

Keywords: Barrovian, zircon, U-Pb geochronology, metamorphism, Dalradian