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Imaging of trace element distribution in zircon by LA-ICP-MS: Insights into ultrahigh-pressure anatexis

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Zircon is a key accessory mineral in Ultra High Pressure (UHP) metamorphic rocks as it is stable during the entire metamorphic evolution and it remains as a restite phase after melt extraction. Zircon contains significant amounts of REE, Th and U, elements which, at the bulk-rock scale, are strongly affected by melting at UHP conditions. Due to its refractory nature, zircon can preserve pre-melting concentrations of such elements. Moreover, zircon growth zones can be precisely dated and the Ti-in-zircon thermometer can provide a temperature record.

A LA-ICP-MS imaging technique has been developed at the CODES analytical facilities at the University of Tasmania. The technique uses a set of parallel lines with spacing equaling the laser beam size. Pre-ablation of each line is essential for removing surface deposition from previous ablations. Regular measurements of the background and calibration standards are required for controlling memory effects and instrumental drift. Use of square rather than round beam shape is preferred for this application. LA-ICP-MS imaging provides spatial resolution of about 10 microns and detection limits below 1 ppm. High errors on individual measurements are compensated by large overall statistics.

Here we report the successful application of this imaging technique to zircons from the Kokchetav metamorphic complex (Kazakhstan). The UHP metamorphic rocks of the Kokchetav complex experienced partial melting and melt loss at extreme conditions of 45-60 kbar and 950-1000°C. Metamorphism of metasediments produced a specific bulk rock trace element signature with depletion in LREE, Th and U. LA-ICP-MS spots analysis and LA-ICP-MS imaging reveal at least four different compositional types of zircon. Type-1 zircon cores have low Th contents and Th/U ratios and steep REE patterns. The low Th content is attributed to formation in equilibrium with monazite, which hosted a large fraction of the bulk Th. Type-2 zircons are seen as mantles with Th/U ratios are not fractionated with respect to the bulk rock, indicating that monazite disappeared. This can be explained by complete dissolution of monazite in a melt formed at peak metamorphic conditions. Ti content is very high at 100-300 ppm. Type-3 zircons have mantles and rims characterized by high, but variable, Th/U ratios and low-flat HREE patterns. These domains formed during slightly cooler conditions than type-2 as they have lower Ti concentrations. The low U content and Sm/Nd ratio of this zircon type reflects formation after depletion of the rock in LREE, Th and U. Type-4 zircon occurs as rims with higher Th and U contents. The Ti content is as low as 10 ppm, corresponding to zircon formation during exhumation of the rock.