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U-Pb age dating of brittle deformation via LA-ICP-MS imaging on calcite veins

U-Pb dating of carbonates can be applied to a variety of geological themes including constraining the time of a brittle deformation/faulting (i.e., tectonic processes of the upper, rigid part of the crust). However, absolute age dating of brittle deformation is challenging mainly due to a lack of robust chronometers that meet isotopic prerequisites. To tackle these challenges, the combined use of U-Pb geochronology and Laser Inductively Coupled Plasma Mass Spectrometer (LA-ICP-MS) of carbonate minerals have been utilized since a near decade. Carbonates, and especially calcite, are prime targets because they are typical fracture-filling minerals, and they can incorporate sufficient amounts of U during formation. Nonetheless, the challenges remained as the U incorporated to carbonates is low (typically below ca. 10 ppm) while the amount of initial Pb is significant. Additionally, carbonates are susceptible to a secondary alteration process that involves mobility of U and Pb. The LA-ICP-MS imaging U-Pb method circumvent many challenges via increasing surface scan of analytical areas, thereby allowing usage of 2-D elemental and isotope map characterization as well as petrographic interpretations of analyzed areas.

The goal of this thesis project was to test and apply the LA-ICP-MS imaging U-Pb method on tectonic carbonate/fracture-filling calcites using the Bruker Aurora Elite single collector ICP-MS at the Department of Geology, Lund University. Samples were collected in the Skrylle and Dalby quarries along the Sorgenfrei Tornquist Zone (STZ) of Scania region, southernmost Sweden. STZ represents a 20-50 km wide, NW-SE trending major tectonic system of fault zones within the gneissic basement, which also affects overlaying Phanerozoic sediments in southern Sweden.

In situ sampling was done on thin section surfaces via successive linear scans of rectangular areas aimed to obtain the largest possible spread in U-Pb to constrain a lower intercept age in the Tera-Wasserburg diagram. Age dating calculations were done based on selection of data points through sorting and pooling using certain criteria.

U-Pb dating of calcite in the Skrylle quarry yielded dates of 222 ± 46 and 213 ± 29 Ma. Dated calcite from the Dalby quarry yielded 495 ± 29, 553 ± 10, and 505 ± 9 Ma. Results have shown that despite overall low U and high initial Pb in calcites, analyses of large analytical areas enable to obtain realistic U-Pb dates. On the assumption that the dates are analytically accurate, and the dated calcite is formed at the instant of fracturing, the U-Pb ages are the first that directly dates brittle deformation along the STZ. Existing terrestrial common Pb model was used for initial Pb assessment and the U-Pb dates were assessed using known age of reference samples that were concurrently analyzed with the unknown samples. Petrographic characterizations were used for interpretation of the tectonic significance of the U-Pb dating results.

This study has shown that combining petrography and LA-ICP-MS imaging U-Pb analysis is a promising approach to acquire plausible absolute ages of tectonic carbonates and hence brittle deformation. Given that fracturing at both localities are located within the STZ, the age results indicate that the STZ is not a result of single tectonic event of brittle deformation but has a prolonged tectonic history, presumably involving several discrete events.

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