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Dating faults, metamorphism, diagenesis, and surface processes by U-Pb small scale isochrons

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The uranium-lead (U-Pb) isotope system is widely applied for dating crystallization and re-crystallization of mineral assemblages during high temperature (HT) events in earth history. Alongside improvements on instrumentation over the last decades, considerable effort has been spent developing and refining methods for dating single crystals or even individual growth domains of high-U (>30 ppm) accessory phases.

Whereas in general these methods are very successful for dating magmatic and metamorphic events, there are rocks and processes that often cannot be dated as appropriate accessory minerals are absent and temperatures were below the closure temperature of common thermo-chronometers. Examples for such rocks can be found in many shear zones, e.g. mylonites and tectonic carbonates, but extend to high-P/low-T metamorphic rocks, ore mineralsation, diagenetic minerals / cement, and sedimentary rocks as well as to different alteration assemblages.

This study focuses on the application of in-situ U-Pb isotope analyses of low-U (e.g., 0.001 to 5 ppm) minerals in thin/thick sections by laser ablation inductive coupled plasma sector-field mass spectrometry (LA-ICP-SFMS). Such rock-forming minerals and mineral assemblages (re-) crystallised and equilibrated during an event with low and variable amounts of U and with low μ ($^{238}U/^{204}Pb$). Instead of dating domains of single accessory phases, multiple analyses with variable U/Pb within mm- to cm-areas of a rock section can form a linear array in $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ space; the lower intercept with the Concordia is interpreted as the crystallisation age and the intercept at the y-axis as the initial Pb isotope composition.

Over the last year this method has been applied at Goethe University to various rock types (e.g., mylonites, cataclasites, carbonatites, calcite slickenfibres, cherts, shales, calc-silicates, calcite veins, altered MORB and sulfate minerals) formed during Archean to Neogene time. Small scale isochron (SSI) ages generally agree surprisingly well with known ages, if available, for these rocks and geological processes and events recorded within them.