Geophysical Research Abstracts
Vol. 13, EGU2011-13443, 2011
EGU General Assembly 2011

Dating Brittle Deformation with the U-Pb method

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Fault planes and fractures are amongst the most commonly observed expressions of brittle deformation in the uppermost crust. With current methods, absolute ages of these structures are difficult to determine, since only few minerals grow at such low temperatures. We evaluate U-Pb dating of syndeformationally grown calcite slickenfibres, tension gashes and similar features (summarised as "tectonic carbonates") as a new tool to directly date brittle deformation.

Depending on lithology and fluid flow, tectonic carbonates occur in abundance on brittle faults and fractures, yet have so far proven difficult to date with radiogenic isotopes. Under favourable conditions, calcite incorporates uranium preferably over Pb, resulting in high U/Pb ratios, and preserves the isotopic system well enough to allow a precise age calculation. This has been successfully applied to calcite from sedimentary, chemogenic and biogenic environments. We developed and optimised the U/Pb analytical workflow for the low U and Pb concentrations typically observed in tectonic carbonates.

For this study, we sampled tectonic carbonates from various areas along the Alps, from localities spanning a wide range of host rock lithologies, tectonic settings and deformation styles, focussing on younger (Cretaceous to Miocene) fault systems. The sampling areas were chosen where ages of deformation are well established in the literature, to better evaluate the reliability of the new method.

The samples are screened by laser ablation inductively-coupled plasma mass spectrometry (LA-ICPMS) for their major and trace element concentrations and spatial distribution. A custom data processing software was developed to produce two-dimensional element maps of a sample. The best parts of a sample are chosen for further microsampling. U and Pb are separated from the microsamples with ion exchange chemistry followed by analysis of the isotopic composition on a multi-collector ICP-MS.

Alternatively, we measure isotopic ratios directly on the quadrupole ICPMS connected to the laser ablation system. Though instrumental limitations result in a lower precision, speed and simplicity make this approach very attractive.

The principles of the workflow are presented from a "user's point of view", including the main difficulties and our approaches to overcome them. We present initial results obtained with the new method and give an overview of its capabilities and limitations at the current state, as well as an outlook on likely future applications.