Precise U-Pb dating of incremental calcite slickenfiber growth by LA-ICP-MS imaging: Evidence for far-field Eocene fold reactivation in Ireland

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LA-ICP-MS mapping produces spatially resolved, quantitative trace element and isotopic analyses in geo-materials at the ppm level across nearly the entire mass range of the periodic table. Dating calcite by the U-Pb method is challenging as it contains very low U and/or high amounts of initial Pb, but opens up many exciting avenues in geochronology, including dating calcite veins in orogens, fossil-free ancient limestones in the geological record and ore-bearing vein systems. A U-Pb image mapping approach (Drost et al. 2018) can circumvent limitations of the U-Pb calcite system, as pixels on a U-Pb age map can be pooled into "analyses" based on elemental or isotopic ratio distributions to produce a spread in $^{238}U/^{204}Pb$ ratio (μ) on concordia. Simultaneous imaging of diagnostic trace elements allows identification and exclusion of zones representing chemically different generations of carbonate or detrital components. Rapid data acquisition is possible using a combination of high-repetition rates (>100Hz) and low-dispersion LA cells.

Our image mapping approach to U-Pb carbonate dating is illustrated with a case study from the Variscan Orogen in Ireland (Monchal et al. 2023). The field locality (Carboniferous North Dublin Basin) exhibits spectacular tight chevron folds and kinematically-linked en-échelon vein sets and bedding-parallel veins with slickenfibers clearly associated with N-S compression (flexural slip). Deformation is conventionally assumed to be Varsican, despite lying c. 150 km north of the Variscan 'front'. LA-ICP-MS U-Pb dating of these calcite vein samples shows relict Variscan U-Pb ages are very poorly preserved. Instead, many calcite veins yield late Eocene ages, including fold-hinge breccias and bedding-parallel slickenfiber veins. U-Pb ages from one bedding-parallel vein indicate protracted (5 myr) late Eocene flexural slip. Detecting several age-homogenous growth domains within this vein was facilitated by integrating spatial U-Pb isotopic information with maps of petrogenetically-diagnostic major and trace elements. The late Eocene folding phase is hitherto undetected on the Irish mainland due to the lack of post-Variscan markers (dykes or Mesozoic-Cenozoic cover sequences), which we link to far-field Pyrenean or Alpine compression (Monchal et al. 2023). Carbonate U-Pb geochronology is often the only feasible approach to detecting compressional reactivation of basement units when younger markers are absent.

References

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