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## U-Pb dates measured in fracture-filling calcites from the SE Pyrenees: syn- or post-kinematic mineral growth?

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Recently, U-Pb dating of fracture-filling carbonates has revealed as a powerful tool to constrain the absolute timing of deformation in fold and thrust belts. However, geochronological studies of these minerals have to be combined with petrological observations and geochemical analyses to decipher if measured dates document fluid flow synchronously to deformation or post-kinematic events.

The Pyrenean compressional belt formed from Late Cretaceous to Oligocene due to the stacking of three thrust sheets and a deformed foreland basin. From top-and-older to bottom-and-younger, these consist of the Bóixols-Upper Pedraforca, Lower Pedraforca and Cadí thrust sheets and the Ebro foreland basin. Here, we quantify the duration of thrust sheet emplacement and shortening rates in the SE Pyrenees using U-Pb dating of 43 calcites filling fractures and interparticle porosity.

Four fracture sets related to compressional tectonics and one set related to extension are identified. The compressive sets include: 1) N-S, NNW-SSE and NNE-SSW trending veins; 2) E-W trending folding-related veins; 3) E-W trending reverse faults; and 4) NW-SE and NE-SW trending strike-slip faults. Fractures related to extension are NNW-SSE and NW-SE trending normal faults.

Elongated blocky, blocky and bladed calcite textures of the dated cements are observed. Elongated textures are observed in reverse, strike-slip and normal faults and occasionally in N-S, NNW-SSE and NNE-SSW and E-W veins. In these fractures, calcite crystals are arranged parallel, oblique, or perpendicular to fracture walls and provide evidence for syn-kinematic growth. Blocky and bladed textures have been identified in N-S, NNW-SSE and NNE-SSW veins, E-W folding-related veins, reverse and strike-slip faults and in calcite precipitated between sedimentary breccia clasts. Although these textures indicate precipitation after vein opening or at lower rates than vein opening, their presence in crack-seal veins and in stepped slickensides also indicates syn-kinematic growth. Moreover, clumped isotope temperatures measured in several blocky and bladed calcites precipitated in veins and faults indicate that most of them precipitated from fluids in thermal disequilibrium with host rocks, revealing rapid fluid flow and precipitation just after fracturing. Contrarily, low temperatures measured in blocky and bladed calcite precipitated in the

interparticle porosity of sedimentary breccias indicate late fluid migration.

U-Pb dating applied to fracture-filling calcites in the SE Pyrenean fold and thrust belt yielded 46 ages from  $70.6 \pm 0.9$  Ma to  $2.8 \pm 1.8$  Ma (Cruset et al., 2020). The results reveal minimum durations for the emplacement of each thrust sheet (18.7 Myr for the Bóixols-Upper Pedraforca, 11.6 Myr for the Lower Pedraforca and 14.3 Myr for the Cadí), and that piggy-back thrusting was accompanied by post-emplacement deformation of upper thrust units above the lower ones during tectonic transport. These estimated durations, combined with the minimum shortening established for the Bóixols-Upper Pedraforca, Lower Pedraforca and Cadí thrust sheets by other methods, allows calculating shortening rates of 0.6 mm/yr, 3.1 mm/yr and 1.1 mm/yr, respectively. Finally, the results also reveal the development of local normal faults at late Oligocene times during the final stages of compression and exhumation.

#### **References:**

**Cruset et al. (2020).** Geological Society of London. 177, 1186-1196.