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Dating faults by quantifying shear heating

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Dating brittle and brittle-ductile faults is crucial for developing seismic models and for understanding the geological evolution of a region. Improvement the geochronological approaches for absolute fault dating and its accuracy is, therefore, a key objective for the geological community. Direct dating of ancient faults may be attained by exploiting the thermal effects associated with deformation. Heat generated during faulting – i.e. the shear heating – is perhaps the best signal that provides a link between time and activity of a fault. However, other mechanisms not instantaneously related to fault motion can generate heating (advection, upwelling of hot fluids), resulting in a difficulty to determine if the thermal signal corresponds to the timing of fault movement. Recognizing the contribution of shear heating is a fundamental pre-requisite for dating the fault motion through thermochronometric techniques; therefore, a comprehensive thermal characterization of the fault zone is needed. Several methods have been proposed to assess radiometric ages of faulting from either newly grown crystals on fault gouges or surfaces (e.g. Ar/Ar dating), or thermochronometric reset of existing minerals (e.g. zircon and apatite fission tracks). In this contribution we show two cases of brittle and brittle-ductile faulting, one shallow thrust from the SW Alps and one HT, pseudotachylite-bearing fault zone in Sardinia. We applied, in both examples, a multidisciplinary approach that integrates field and micro-structural observations, petrographical characterization, geochemical and mineralogical analyses, fluid inclusion microthermometry and numerical modeling with thermochronometric dating of the two fault zones. We used the zircon (U-Th)/He thermochronometry to estimate the temperatures experienced by the shallow Alpine thrust. The ZHe thermochronometer has a closure temperature (Tc) of $\sim$180°C. Consequently, it is ideally suited to dating large heat-producing faults that were active at shallow depths (<6-7 km) where wall-rock temperature does not exceed Tc. On the other hand, the retrogressed pseudotachylites from the Variscan basement of Sardina developed in deeper crustal levels and produced considerably higher temperatures (>800 °C). They have been dated using laser ablation ICP-MS on monazites and zircons. This large dataset provides the necessary constraints to explore the potential causes of heating, its timing and how it is eventually related to fault motion.