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How can K-Ar geochronology of clay-size mica/illite help constrain reactivation histories of brittle faults? An example from a Paleozoic thrust fault in Northern Norway

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By combining K-Ar age dating of clay-size mica/illite with the detailed structural and kinematic analysis of a complex brittle fault, we show that it is possible to recognize and date several generations of authigenic, synkinematic mica/illite grown during brittle deformation, and relate them to distinct episodes of fault movement. This multi-disciplinary approach provides a valuable tool for assessing potential reactivations of brittle faults that would otherwise remain very difficult to unfold.

The study area is within the Repparfjord Tectonic Window, Northern Norway, which is a culmination of lower greenschist facies Paleoproterozoic metasupracrustal rocks within the Caledonian Nappe System. In the western part of the window, NW-SE-directed compression during the Silurian Caledonian Orogeny caused the formation of an imbricated stack of Precambrian basement slivers. The studied fault, the Kvenklubben thrust fault, is part of this imbricate and juxtaposes metabasalts in the hanging wall against primary dolomites. Kinematic indicators within the footwall-derived phyllonites indicate early top-to-the SE thrusting, which is consistent with the regional Caledonian transport kinematics. In contrast, structures from the uppermost fault rocks, formed at the expense of the hanging wall, indicate later top-to-the NW normal reactivation. Quartz microstructures show that brittle faulting pre-dated shearing under ductile conditions at temperatures up to c. 350-380°C.

Fine- to clay-size mica/illite concentrates were separated from two phyllonitic samples collected from the two lithologically and kinematically distinct parts of the fault core. The samples were characterised in detail through petrographic, SEM, TEM and XRD studies and dated by K-Ar geochronology on multiple grain-size fractions (<0.1 to 6-10 μm). The obtained apparent ages are statistically different and define a pre- and a post-Caledonian age group for the lower and upper sample, respectively. Ages show invariably a strong correlation with grain-size, wherein the finer the grain size, the younger the age. We interpret the ages of the finest fractions as representing the actual time of faulting.

The finest grain-size fraction in the sample from the upper, extensionally-reactivated part of the fault records a Cretaceous age (c. 130 Ma), while the coarser micas have significantly older ages (c. 420 Ma). We interpret the ages of intermediate size fractions and the c. 300 Ma age spread to be the result of physical mixing between the two end-member generations of mica/illite: the younger neoformed, reflecting the Cretaceous fault reactivation, and the older inherited Caledonian component. Although lower greenschist facies conditions were reached within the fault during its Caledonian main activity and probably also the Mesozoic reactivation, mica/illite ages from the lower sample were not reset, and vary between c. 790 to 530 Ma. The age of the finest fraction suggests that the fault's first brittle top-to-the-SE thrust faulting occurred before the peak ductile Caledonian deformation, which is consistent with the documented microstructural evidence. This age is interpreted as reflecting faulting during an early Cambrian "Finnmarkian" compressional phase in Northern Norway.

Our new results show that fault reactivation in the brittle regime can be better understood and constrained by the combined approach documented by this study. By establishing the isotopic age of multiple faulting episodes accommodated within the same fault zone, the method provides the backbone toward the development of robust, well-constrained tectonic models.