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Meteoric water-rock interaction and clay-gouge formation during higher temperature brittle faulting on the Silltal-Brenner Fault Zone, Eastern Alps (Austria)

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The Silltal Fault is the northern brittle continuation of the Brenner Fault Zone, with a normal, down-to-west sense of movement. It is marked by a narrow zone of cataclasis and, in three sampled locations, clay-rich fault gouges. The clay mineral composition of these gouges is dominated by higher temperature $2M_1$ polytype illite/muscovite, with no $1M/1M_d$ illite or mixed layer illite/smectite detected. Smectite is limited to the northern samples from the Stephansbrücke location, whereas chlorite is present in all samples. New growth of $2M_1$ polytype illite in the finest size fractions indicates temperatures $>$ 200-250°C and therefore fault gouge development at depths and temperatures close to the ductile-brittle transition in quartz rich rocks ($\sim$280-300°C). Hydrogen stable isotope (δD) analyses show that gouge formation was associated with the influx of meteoric water, which was strongly focused within the fault zone itself, without significant interchange with the adjacent footwall and hanging wall rocks. K-Ar ages from the different sample grain size fractions ($<$ 0.1 to 6-10 μm and "whole rock gouge") show a wide spread, from ca. 115 to 12 Ma, with ages consistently decreasing with grain size. Although the ranges overlap, ages from the northern Stephansbrücke samples are generally older (115-36 Ma) than those from the south near Matrei (55-12 Ma), possibly reflecting increasing regional metamorphic temperatures to the south. The well-defined linear relationship between apparent age and hydrogen stable isotope (δD) values establishes a direct correlation between rejuvenation of the K-Ar system and increased interaction with meteoric water. The dependence of both apparent age and δD on grain size also indicates that radiogenic and stable isotope exchange was controlled by grain size, reflecting new $2M_1$ illite growth, mechanical grinding of protolith muscovite during cataclastic faulting, or both. The results demonstrate the advantages of combining radiogenic and stable isotope analysis in interpretation of K-Ar ages from clay fault gouges. The combined approach was necessary to establish the crucial influence on apparent K-Ar ages of meteoric water influx focused on the fault zone and its interaction with the clay-size-fraction grains localized within the fault core.