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Illite polytype quantification for accurate K-Ar age determination

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ABSTRACT

PolyQuant, a new method to quantify illite polytypes in physical mixtures, has been coupled with Illite Age Analysis (IAA, Pevear 1992) to determine accurate K-Ar ages of the individual polytypes. K-Ar radioisotope dates from illite in shales and sandstones are typically meaningless because these rocks are mixtures of diagenetic and detrital components in unknown proportions. IAA uses linear extrapolation to unmix measured K-Ar ages and establish the end-member ages. This procedure requires samples to have a diagenetic Illite-Smectite (I-S) component mixed with a detrital discrete illite component because they are separable and quantifiable using X-ray diffraction (XRD) of oriented aggregate samples. We extend IAA for use in mixtures of diagenetic and detrital illite with no I-S component by coupling a genetic algorithm (GA) with the WILDFIRE programs (1993) of Reynolds in a new computer program, PolyQuant, which quantifies illite polytypes in a natural sample.

Based on first principles of XRD, WILDFIRE is a forward model that calculates *hkl* reflections by varying parameters such as rotational disorder, octahedral cation occupancy (i.e., *cis*- and *trans*-vacancies), chemical substitutions (K and Fe), orientation, and crystallite thickness. PolyQuant executes several forward models, using the GA to vary the parameters and weight percents of each polytype to automatically achieve a "best fit" with an experimental XRD pattern. Sensitivity tests reveal that changes in the weight percent of an illite polytype, disorder (P_0, P_{cv}), and the orientation function affect the pattern more than other parameters. In addition, PolyQuant successfully quantified illite components in prepared mixtures of $1M$ illite and $2M_1$ muscovite and $1M_d$ illite and $2M_1$ muscovite.

We show examples to validate IAA from prepared mixtures of end-members with known ages and also to obtain end-member ages of highly illitic clay fault gouge. Using K-Ar ages and PolyQuant to quantify the $1M$ and $2M_1$ components from mixtures of RM-30 (25 ± 1 Ma) and a $2M_1$ muscovite from Wards (428 ± 9 Ma), IAA determined end-member ages of 19.9 Ma (0–44 Ma) and 429 Ma (408–459 Ma)—in reasonable agreement with the measured results. In addition, we use clay gouge from the Canadian Rockies to date movement along thrust faults. Regional geologic data indicate movement along these faults occurred between 73 and 48 Ma. IAA determined the ages of faulting to be from 79.2 to 53.5 Ma, in good agreement with the known range of fault dates. Our results indicate that neoformation of illite in the fault zone must have modified the ages to younger dates.