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High resolution 40Ar/39Ar ages reveal intragrain fluid-assisted heterogeneities of magmatic micas

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The Phalaborwa carbonatite complex (NE Transvaal, South Africa) is a layered intracratonic alkali complex composed mainly of clinopyroxenites with minor carbonatites and phoscorites that intruded an Archean terrain (Eriksson, 1984). All layers of the intrusion have been dated by U-Pb (baddeleyite, zircon) at 2060±3Ma (Wu et al., 2011). The Rb-Sr age of phlogopite, 2059±5Ma, coincides with the U-Pb age (Naumenko-Dèzes et al., 2018). The K-Ar (40Ar/39Ar) age of phlogopite is expected to agree in any case with the Rb-Sr age (identical to the age of the complex). This makes Phalaborwa the best candidate for the geological intercalibration of the K-Ar geochronometer.

Phlogopite megacrysts were studied by optical microscope and electron microprobe (EPMA). Microscopic investigations of phlogopite showed mostly pristine mica sheets, with occasional slightly deformed grains. Despite the unaltered optical appearance of phlogopite, EPMA reveals patchy zonations, with resolvable compositional differences and negligible diffusional re-equilibration. Thin cracks propagate through the sample and show leaching of mobile cations and concomitant increase of Al, Fe(3+) and especially Ti, both inside the cleavage and at the tip. Age profiles through phlogopite sheets revealed irregular age variations from ca. 2060±10 to 1970±10Ma. Patchy intra-grain zonations are diagnostic of altered minerals (e.g. Villa and Hanchar, 2017, and references therein) and support the indication that late, post-magmatic fluid circulation disturbed both the magmatic chemical zonation and the K-Ar system. Even when chemical alteration patches deviate by less than 1% from stoichiometry, they escape detection by electron microprobe analysis, but can be detected by 40Ar/39Ar analyses, which can achieve a 0.1% precision. Based on this detailed case study, we propose that the significance of 40Ar/39Ar ages is mostly ascribed to the time and extent of hydrothermal events postdating the major phase of magmatic crystallization, and not to a simple temperature-driven diffusion history.

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