Linking thermobarometry with ^{39}Ar-^{40}Ar and U-Th-Pb ages from the northern Central Alps: implications for Rb-Sr and K-Ar data

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The Barrovian metamorphism observed in the Alps results from the collision of Europe and Africa and reaches its thermal maximum in the Central Alps (upper amphibolite facies). Age data for this orogenic cycle remain controversial, despite a multitude of studies: Based on the resetting of Rb-Sr ages in muscovite from polymetamorphic gneisses, Hunziker (1969) and Jäger (1973) had proposed an age of 38±2 Ma for this metamorphism. Also based on isotopic data in the Alps, a field-calibration for the “closure-temperature” (Dodson, 1972) was then obtained by Purdy & Jäger (1976) , based on their K-Ar data for muscovite and earlier data for biotite (Armstrong et al., 1966). However, a uniform age (near 38 Ma) for ***the*** metamorphism in the Central Alps was in conflict already with early U-Pb data of monazite and xenotime from the same area (e.g. Köppel & Grünenfelder, 1975), which indicated an age near 30 Ma in the southern Lepontine, but ~20 Ma in the northern part of the amphibolite facies dome. A study by Janots et al. (2008) not only confirmed the young monazite age in the north (SHRIMP U-Pb of 18-19 Ma at Lucomagno, near T_{max} ~570 °C); it furthermore demonstrated that at ~30 Ma this part of the belt was still heating up (prograde formation of allanite near 440 °C). These recent results reopen questions about the interpretation of K-Ar and Rb-Sr data and the “closure-temperature” of each system, as well as effects of inheritance on age data in medium-pressure metamorphic rocks.

The present study makes an effort to interpret Ar-ages for mica based on thermobarometry and multi-chronometry. Based on select samples taken in the northern Central Alps, we used well equilibrated, homogeneous metasediments; exclusively Mesozoic protoliths were considered to avoid inheritance problems. ^{39}Ar-^{40}Ar ages for mica (separates) yield ages between 18.93±0.83 (Lucomagno Pass) and 15.79±0.11 Ma (Val Piora) for muscovite, and between 17.65±0.33 and 14.84±0.23 Ma for biotite (same localities). The muscovite Ar-ages pertain to conditions near the documented P-T equilibria (7-9 kbar, 550-570 °C). When compared to the monazite ages of 18-19 Ma from the same area, the Ar-loss owing to diffusion upon cooling from these conditions is minor for muscovite. Ar-loss is slightly more evident in white mica from a second area (Pizzo Molare), where slightly higher temperatures (580-600 °C) were reached.

Muscovite is chemically homogeneous in each of the samples dated; thermobarometry indicates equilibration at peak of metamorphic conditions and (stable!) preservation of muscovite along the retrogression path. This leaves diffusion as effectively the dominant resetting factor, hence the Dodson-type closure-temperatures for Ar-Ar in muscovite must be high, ~500°C. By contrast, biotite probably was also affected chemically on retrogression, due to minor chloritization. Where such retrogression reactions occur, their effect may overwhelm (thermally activated) diffusion, and age data are more difficult or impossible to interpret. In the samples dated here, Ar-loss in biotite yields Ar-Ar ages 1-2 Ma lower than muscovite. As retrogression of biotite in these samples is very limited, an approximate closure temperature of 450 °C is inferred for such biotites (grain diameter ~200 µm).

This study indicates that detailed micro-textural and micro-chemical investigations are a necessary (though not sufficient) prerequisite to yield meaningful geological ^{39}Ar-^{40}Ar ages. Such a characterisation is necessary to identify possible problems of inheritance or late re-equilibration, which plague many age interpretations. Moreover, the purity of mineral separates must be ascertained; at least possible impurities, even in traces, need to be accounted for. Together with diffusion, all of these factors affect isotopic systems. The art of geochronology implies identification of the dominant influences, such that an isotopic age may be correctly interpreted as (1) a crystallization age or (2) cooling stage (each corresponding to well defined tectono-metamorphic conditions), as distinguished from (3) meaningless “ages” (owing to inheritance or partial chemical retrogression).

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