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^{40}Ar/^{39}Ar geochronology by stepwise crushing

Jan Wijbrans, Huaning Qiu, Rongguo Hu, and Fraukje Brouwer
FALW-VU, Isotope Geochemistry, Amsterdam, Netherlands (Jan.Wijbrans@falw.vu.nl)

Crustal fluid flow occurs at all levels of the continental crust. Fluid flow is assumed to be episodic, resulting from protracted events in the crust such as diagenesis, ore genesis, prograde metamorphism and hydrothermal circulation following magma emplacement, and commonly leads to the deposition of secondary minerals in veins in the rock. Vein minerals contain fluid inclusions that were encapsulated by the mineral during first growth, and during later stages by crack-seal mechanisms. Primary fluid inclusion composition reflects the composition of the fluids attending diagenesis and the early stages of metamorphism, commonly aqueous fluids with varying levels of salinity. Most vein minerals contain secondary fluid inclusions incorporated after original mineral growth. Such secondary inclusions are introduced when cracks develop that are subsequently sealed by deposition of minerals. Secondary fluid inclusions have been used with success to decipher quite intricately changing physical conditions during metamorphism.

We have developed a method for ^{40}Ar/^{39}Ar analysis of fluid inclusions by stepwise crushing and we have applied this method to diagenitic quartz veins, ore deposits and metamorphic veins. Although from fluid inclusion petrology it is known that fluid inclusion patterns in most minerals are mixed, from our work on veins in many different settings we note that argon release shows common features. In crushing experiment, the reservoir that first contributes to fluid release quite consistently shows the highest amounts of excess ^{40}Ar. This reservoir is gradually exhausted, to be followed by argon from other reservoirs in the mineral. The parameters that are most easily monitored are apparent age (^{40}Ar/^{39}Ar ratio), Ca and Cl derived isotopes of argon such as ^{37}Ar and ^{38}Ar, and air argon monitored by the ^{36}Ar content. We have developed a first order model by which we can explain the fluid inclusion content of vein minerals as a three reservoir system: excess argon – radiogenic argon and air-argon. We use calcium derived ^{37}Ar, chlorine derived ^{38}Ar and potassium derived ^{39}Ar to obtain additional information on the chemistry of the postulated reservoirs. In favorable cases age information on the formation of such inclusions can be obtained, because radiogenic argon formed from the in situ decay of ^{40}K in solution in the fluid inclusions is an end-member of our mixing model. The diffusion rate of argon in the mineral hosting the fluid inclusion determines the closure temperature associated with the argon age obtained.