Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 1019

The Effect of Chemical Exchange on Mica Rb-Sr Ages in Slowly Cooled Rocks: Theory and Results

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Determination of cooling and exhumation rates of metamorphic terranes depends on knowing closure temperatures for different geochronological systems. Ages measured for geochronological systems are plotted against their closure temperatures to produce cooling curves. However, at present, models for closure temperature are simplistic and it cannot be accurately predicted.

Closure temperatures have conventionally been assumed to relate to the effective cessation of isotopic exchange (for example, Sr isotopes in the Rb-Sr system) during cooling. However, we suggest that the down-temperature chemical exchange of elements involved in dating schemes (for example, Rb with K, or Sr with Ca) may be equally important in controlling closure temperatures of radiometric systems.

Jenkin et al. (1995) have suggested down-temperature exchange of Sr isotopes among minerals. However, in slowly cooled rocks there is the additional potential for down temperature exchange of elements. For example, the chemical exchange of Mg and Fe between biotite and garnet to produce a geo-thermometer (Ferry and Spear, 1978). In geochronological systems there is, therefore, potential for both isotopic (^{87}Sr with ^{86}Sr) and chemical (Rb with K) exchange as the rock cools that will cause variations in measured ages, see presentation by Jenkin et al for further discussion. A more thorough understanding of closure temperature ages is required before they can be used with confidence to construct cooling curves.

Experimental partition coefficients between phlogopite and sanidine (Beswick, 1973) and muscovite and sanidine (Volfinger, 1976) suggest the partitioning of Rb and K changes so that, in cooling closed systems, Rb concentration in feldspar should decrease, and Rb concentration in mica increase. Assuming a phlogopite-sanidine system approximates a biotite-orthoclase system, the exchange during cooling of a metamorphic rock can be predicted.

The total amount of down-temperature exchange is limited by the inter-diffusion coefficient of Rb and K between the two minerals. Increasing Rb in biotite will decrease the age measured and lower closure temperature compared to that calculated assuming exchange of Sr isotopes only. The increase in Rb in the biotite increases with the K-feldspar/biotite ratio, so that the decrease in closure temperature and measured age will be greatest in feldspar rich rocks, enhancing the mode effect described by Jenkin et al. (1995).

These theoretical results have been tested by examination of mica-bearing meta-carbonate samples from the amphibolite facies Lepontine Dome (Central Swiss Alps). Ion microprobe analyses of core to rim element concentration profiles in grains show varying results. Adjacent mica and K-feldspar grains (profile HT15-97) show that towards the grain boundary there is a Rb increase in both mineral grains. However, non-adjacent biotite and K-feldspar grains from the same sample, profile HT15-76) show that towards the grain boundaries there is an increase in Rb in the mica and a decrease in the feldspar. Other profiles, from different samples, show similar characteristics irrespective of whether the grains are adjacent or non-adjacent. The increase of Rb in both feldspar and mica (HT15-97) suggests that another phase is the source of Rb with both biotite and K-feldspar being sinks. A different area of the same sample (HT15-76) shows a profile approaching that predicted by the theoretical work. These profiles indicate that chemical re-equilibration is taking place as the rock cools. When we understand the effects of chemical exchange we can produce better models of closure temperatures and, therefore, the uplift rates of mountain belts.

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