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Assessing isotope mobility in the beta-decay system

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Understanding the mechanisms that govern the mobility of elements in minerals is critical to unravelling the tectonothermal evolution of orogenic belts. Under dry, static conditions, elemental redistribution by diffusion is generally considered to be extremely slow, such that reequilibration may not occur even when temperatures significantly exceed commonly assumed closure temperatures for prolonged periods. Here, we investigate the behaviour of the beta-decay isotopic system in both deformed and undeformed rocks.

The Musgrave Province is a Mesoproterozoic granulite- to amphibolite-facies terrane, central Australia that was heterogeneously overprinted by high-strain deformation during the Petermann Orogeny (ca. 630–520 Ma). Two study areas were selected to evaluate how beta-decay isotopic systematics in micas from pegmatites respond to a thermal pulse Kulgera (eastern Musgraves) and deformation and metamorphism Kelly Hills (central Musgraves).

In the Kulgera area, undeformed pegmatite form steeply dipping dykes up to 7 km long and were intruded at ca. 1070 Ma by shallow dipping, undeformed dolerites. The pegmatite include quartz, K-feldspar, plagioclase, muscovite, biotite and magnetite. Beryl, garnet and tourmaline occur randomly within the dykes in thick pockets of quartz. Zircon U-Pb dating indicates crystallisation at ca. 1135 Ma. Garnet Lu-Hf (ca. 1130 Ma) also records crystallization, unaffected by the thermal overprint associated with the later dolerite intrusion. Coarse muscovite and biotite are partially or completely reset: in situ Rb/Sr dates are ca. 1080 and 1057 Ma, and Ar/Ar are ca. 1102 and 1088 Ma, respectively. The K/Ca date of muscovite is ca. 1077.

In the Kelly Hills, pegmatites are relatively undeformed in low-strain zones to strongly deformed in high-strain zones. The argon system was completely reset to ~550 Ma (during the Petermann Orogeny), irrespective of strain intensity. In contrast, the Rb–Sr system is partially to completely equilibrated, which is different to the Kulgera area.

The isotopic results suggest that deformation and metamorphism at amphibolite facies conditions will not necessarily equilibrate the different isotopic systems to give a consistent age. In addition, we show that Ar is mobile in rocks that are relatively dry and undeformed, which has implications for diffusion rates and for determining the duration of thermal events.