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Microstructures, polygenetic minerals, fluids, retrogression: details or factors controlling the isotope record?

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Sixty years ago Hart [1,2] introduced the working hypothesis that all isotope variations in minerals (zircon, amphibole, micas, feldspars, etc) were to be explained by volume diffusion. Not all data in [1] were included in [2], Wetherill's U-Pb diffusion calculations [3] were disproved, but the dogma remained forever, according to which diffusion is the only factor controlling the isotope record, whereas retrogression reactions, recrystallization, metasomatism, and alteration rarely occurred and were minor disturbing details anyway.

The petrological community went on a diverging path by studying minerals and rock textures with increasing detail. The observations proved that at the sub-µm scale most if not all terrestrial minerals are not ideally monomineralic. Relict inclusions, retrograde reaction phases, and patchy textures due to fluid interactions are the rule rather than the exception, including especially the products of hydrothermal laboratory experiments. As each of these polygenetic mineral generations has an individual isotopic signature, the task for geochronologists is combining the petrological, microtextural and compositional observations with the isotopic data [4,5], ideally of several chronometric systems in the same rock. This work-intensive burden is not a nuisance but an opportunity to obtain a deeper understanding of geological histories.

A reassessment [6] of the alleged "mutidomain" archetype, the Chain of Ponds microcline, revealed that it actually records a multistage history comprising sericitization, adularia precipitation, and anorthite relicts in addition to K-feldspar, a vast improvement over oversimplified modelling. In the Western Alps, multichronometric (Lu-Hf, Sm-Nd, Ar-Ar) and microchemical analyses [7] disentangled the peak eclogitization from inheritance and greenschist-facies retrogression; phengite retained Ar above 550 °C. Relict inheritance, eclogitization, and retrogression (revealed by EPMA element maps to occur at a scale ≤1 µm) were all dated by Rb-Sr and Ar-Ar in Naxos [8]. Minerals favorable for petrochronology and hygrochronology are not just monazite and allanite, but also amphiboles and micas [9].

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