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Petrochronology and hygrochronology of the U-Th-Pb, Rb-Sr and K-Ar systems

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U-Th-Pb petrochronology is based on the incontrovertible fact that Pb* diffusion is negligibly small relative to retrograde reaction rates. Multi-element maps [1, 4] demonstrate the tight correspon-dence between U-Th-Pb ages and patchy textures, requiring that fluid-induced dissolution/ reprecipitation is the principal cause of Pb* mobility. Attempts to model intracrystalline core-rim Pb zonations as diffusive transport are not legitimate unless genuine bell-shaped diffusion profiles in minerals can be documented, which happens ony exceptionally [2]. Monazite and zircon intra-grain age maps [3, 4, 7, 8] confirm that dissolution/reprecipitation and retrogression reactions assisted by fluids control U-Th-Pb ages, not temperature. The chemical zonations in monazite (allanite, xenotime, zircon) provide petrological constraints. Linking petrology with textures and the isotope record allows reconstructing entire segments of the P-T-A-X-d-t history of a rock and its geodynamic environment.

The dearth of mathematically sound diffusion profiles equally applies to micas and feldspars. The tight link between petrology, microtextures, chemical composition and geochronology also pertains to Rb-Sr and K-Ar. Overdetermined multi-mineral Rb-Sr isochrons with excess scatter, and spatially resolved/stepwise release 39Ar-40Ar results, demonstrate ubiquitous correspondence between relict phases and isotopic inheritance [5]. Many rock-forming minerals are highly retentive of Sr and Ar, unless they are obliterated by retrograde reactions. The rates of dissolution in fluid-controlled reactions are up to 7 orders of magnitude higher than diffusive reequilibration rates. Thus, as a rule Rb-Sr and K-Ar chronometers date their own formation. What Rb-Sr and K-Ar ages carry is hygrochronological information, just as do U-Th-Pb ages [6].

Accurately establishing pressure-temperature paths of monometamorphic rocks requires assessing petrologic equilibrium using multivariate thermodynamic software. Dating complex parageneses of polymetamorphic, unequilibrated rocks requires labor-intensive disentangling by: (i) qualitative identification of relicts, retrogression reactions, and chemically open systems by imaging techniques (e.g. cathodoluminescence, element maps, etc.); (ii) microchemical analyses at the μm-scale quantifying heterochemical disequilibrium phases and assigning them to a P-T-A-X segment; (iii) spatially resolved/stepwise release, relating the chemical signature of the analyzed mineral to its age. K-Ar and Rb-Sr usually provide a different perspective on the P-T evolution of a rock than does U-Th-Pb, as K-Rb-rich minerals (phyllosilicates and especially feldspars) mostly form later and react/dissolve faster in the retrograde path than U-rich accessory phases.

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