Discordance in U-Pb and K-Ar

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In 1960, Tilton [JGR 65, 2933] calculated Pb diffusivity from discordant U-Pb zircon analyses. His estimated $D/a^2 = 8$ E-19 s^{-1} was long unquestioned as quantifying high-T Pb loss in zircon. Belief revision followed the coupling of imaging to in situ dating: cathodoluminescence (CL) [Gebauer et al, SMPM 68 (1988) 485] and back-scattered electrons (BSE) [Hanchar & Miller, Chem Geol 110 (1993) 1]. Discordant zircon (monazite, xenotime, etc) grains consist of young rims accreted onto/into older cores; age gradients are sharp, no Pb diffusion gradients are seen. As U-Pb discordance in crystalline non-radiation damaged grains is caused by diachronous, heterochemical mineral generations, strict diffusionism is superseded, and closure temperatures are irrelevant. Petrology controls U-Pb ages [Villa & Williams, in: Harlov & Austrheim, Metasomatism (Springer, 2013), Chap. 6].

Qualitative and quantitative maps (CL, BSE, EPMA) of K-feldspar and micas document patchy textures and mineral replacement reactions. It is important not to confuse causes and effects: heterochemical microstructures are not the *cause* of Ar loss, they are its *effect*. Ar loss occurs first, during dissolution of the older mineral generation; replacement textures form later, when the replacive assemblage recrystallizes. Heterochemical mineral generations are diagnosed and dated by their Ca/Cl/K systematics in ^{39}Ar-^{40}Ar (e.g. Ca/K vs Ar/K diagrams: young biotite intergrowing old amphibole, adularia replacing microcline, etc; Cl/K vs Ar/K: sericite overgrowing K-feldspar, muscovite retrograding phengite, etc). Mixed mineral generations are observed to be the cause of staircase-shaped age spectra [Villa & Hanchar, GCA 101 (2013) 24], while stepheating of crystals with age gradients gives plateaus [Hodges et al, Geology 22 (1994) 55]. Age gradients are unrelated to staircase age spectra.

There is a profound analogy between the U-Pb and K-Ar systems. No intra-grain bell-shaped Pb and Ar diffusion profiles have been observed. Pb and Ar diffusion are both slower than mineral replacement rates. Patchy retrogression textures are always associated with heterochemical signatures (U/Th ratio, REE patterns, Ca/Cl/K ratios). Single-generation minerals give concordant ages; discordance is caused by mixing heterochemical diachronous mineral generations. Dating concordant and discordant eclogites from the W Alps proves that the petrologic context is as essential as mass spectrometry for accurate geochronology [Villa et al, J Petrol 55 (2014) 803].