

Spatial resolution, stepwise release: connecting the multi-isotope record with microchemistry and petrology

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Most metamorphic reactions require dissolution/precipitation, i.e. water activity controls petrology in metamorphic minerals, and also the isotope record, as radiogenic isotopes (except ⁴He) do not diffuse faster than major elements forming the mineral structure [1]. Isotopic inheritance in relicts (i.e. slow diffusion) was observed in zircon, monazite, amphibole, K-feldspar, and micas. However, a priori there could be causes of isotope loss/exchange other than recrystallization. Temperature was proposed to play a role by changing diffusivity in geochronometers [2]. If diffusion has been the factor limiting isotopic (or chemical) closure, the concentration profile is bell-shaped. To ascertain if isotope transport in a sample was controlled by diffusion or recrystallization, spatial information is needed: only bell-shaped gradients are compatible with volume diffusion. So far, in-situ dating *never* described bell-shaped isotope gradients in patchily zoned minerals. On the contrary, patches are certain evidence of fluid-mediated local recrystallization, i.e. a guarantee of petrological, and therefore isotopic, disequilibrium.

The geochronology of mixed diachronous phases is managed by two complementary "SR techniques": spatially resolved analyses and stepwise release. SR techniques have shaped a better understanding of geochronology, as they reveal the elemental & isotopic compositions on the subgrain scale, and allow the recognition and the chemical/ isotopic characterization of relicts and retrogression. In SR techniques, the chemical signature is also measured in the same analysis as the age. Electron microprobe "chemical" geochronology [3] offers the most complete microchemical characterization of intra-crystalline zonations. ³⁹Ar-⁴⁰Ar analyses yield the concentrations of three elements (K, Ca, Cl) and their ratios to radiogenic ⁴⁰Ar. Why worry about the Ca/Cl ratio in a mineral, if the age is calculated from the Ar/K ratio? So as to unravel polyphase mixtures by comparing Cl/Ca/K signatures with independent microchemical data. When K-Ar ages of metamorphic minerals are older than we expect, they are brushed off as "excess Ar". Much confusion can arise if we mix up "excess Ar" (⁴⁰Ar gain) with "inherited Ar" (⁴⁰Ar loss). Inherited Ar often correlates with Ca/Cl. In addition to just K-Ar, multi-isotope geochronology (Rb-Sr, Lu-Hf, etc) should be used. If Ar and Sr correlate, it's due to Ar and Sr inheritance, not to excess Ar [4]. Overdetermined Rb-Sr isochrons [5] also can reveal inheritance.

Thanks to submicroscopic petrology, isotopic inheritance can be put into context with petrogenetic disequilibria. Analytical advances allow dating of each mineral generation. This opened up a wealth of data on the P-T-A-X-d history of rocks. In the long run, this will improve our ability to develop credible numeric models.

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Selenate reduction rates in littoral sediments of a hypersaline lake, the Salton Sea, CA

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The Salton Sea is California's largest lake and is located in the Salton Basin of the Colorado Desert. It supports one of the most productive fisheries of the Western hemisphere and more than 400 species of birds, including endangered migratory populations. The Alamo and New Rivers collect agricultural runoff from a 2,250 Km² area, and deliver 80% of the annual water inflow along with selenium (Se) and salts to the Salton Sea. Today, Se concentrations reach 10 mg Kg⁻¹ in the sediments of the lake, and salinity is expected to further increase from its current value of 48. Such high selenium concentrations and increasing salinity pose a serious threat to the unique avian diversity of the Salton Sea [1]. Selenium naturally occurs in Western U.S. bedrock and can be mobilized through irrigation water as selenate (SeO₄²⁻) and/or selenite (SeO₃²⁻). Upon reaching anaerobic sediments in the Salton Sea, Se is microbially reduced to Se(0) and immobilized. Reduced selenium species are expected to remain sequestered in sediments as long as anaerobic conditions persist.

To identify the environmental factors that control selenate reduction rates in the Salton Sea, we measured these rates at salinity 45, along with porosity, bulk density, C:N, and the abundance of selenate-reducing bacteria (SeRB) in littoral sediment samples collected from seven sites. We also measured pH and salinity in water overlying sampling sites.

Higher selenate reduction rates (45.42 nmol h⁻¹cm⁻³) and a higher abundance of SeRB (4×10³ cells cm⁻³) occurred at the site with the lowest C_{org}:N (2.7). Frequent and massive fish die-offs are commonly reported in the Salton Sea and lead to an accumulation of fish carcasses in the littoral potentially explaining such low C_{org}:N. Without nitrogen limitations, and given that selenate was the only terminal electron acceptor provided, SeRB can thus achieve higher abundances and higher selenate reduction rates.

Salinity averaged 48.41 in six out of seven sites; however, it was only 2.97 in a site mapped to the Alamo River delta. Selenate reduction rates and the abundance of SeRB were maximal in this site (223.3 nmol h⁻¹cm⁻³ and 3.5×10³ cells cm⁻³, respectively). The low salinity measured in this site may result from the mix between river freshwater and Salton Sea water. Interestingly, salinity is reported to negatively correlate with microbial diversity [2]; also, salinity imposes significant energetic requirements to microbial cells, especially under anaerobic conditions [3]. Finally, higher diversity results in communities more resistant to salinity stress [4]. Consequently, we hypothesize that the sediment exposed to salinity 2.97 supports a more diverse community of SeRB, and this higher diversity may facilitate a better response to salinity stress in experimental anaerobic slurries at salinity 45, detected as higher SeRB numbers and higher selenate reduction rates.

Our preliminary results show that water salinity and sediment C_{org}:N are important factors controlling selenate reduction in littoral sediments of the Salton Sea.

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