Combining U and Sr isotope tracers to evaluate water sources and mixing relations in freshwater and estuarine wetlands

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Understanding wetland water supplies is important for managing these resources and determining habitat impacts due to climate change or other anthropogenic activities. However, identifying multiple sources and contributions is often difficult due to complex hydrologic, biologic, and chemical processes. Combined $\delta^{87}Sr$ and $^{234}U/^{238}U$ data from wetlands in NV and CA identified 3-component mixing patterns that were not easily recognized by other chemical approaches. Isotopes of Sr and U are particularly useful because they are relatively abundant, can be analyzed with high precision, may have large differences between sources, and remain unchanged by geochemical processes such as evaporation and mineral precipitation or biological fractionation. Mixing models form distorted triangular nets that bound the data and allow contributions from each source to be estimated.

Sources of water in wetlands on the Pahranagat National Wildlife Refuge (PNWR), NV consist of surface flow from high-volume springs from the regional carbonate aquifer and groundwater from local volcanic aquifers. Major ions and H-O-S isotopes are affected by evapotranspiration, mineral precipitation, and sulfate reduction. However, $\delta^{87}Sr$ and $^{234}U/^{238}U$ are unaffected and indicate a 70:20:10 mixture for the irrigation source and a range of mixtures depending on location and water management practices (fig. 1A).

Variations in river water and tidal influence in the Sacramento-San Joaquin Delta, CA, over the last 6,000 years were recorded by $\delta^{87}Sr$ and $^{234}U/^{238}U$ in peat cores. Plants take up substantial dissolved Sr during growth, whereas redox reactions at the peat-water interface causes immobilization of U dissolved in the water column. Analyses of peat cores show coherent changes in space and time, reflecting evolving mixtures of fluvial and seawater sources (fig. 1B). Contributions from hydraulic mine sediment with $\delta^{87}Sr$ >0.0 and $^{234}U/^{238}U$ activities ~1.0 are also apparent in peat-poor samples deposited between 1850 and 1963.
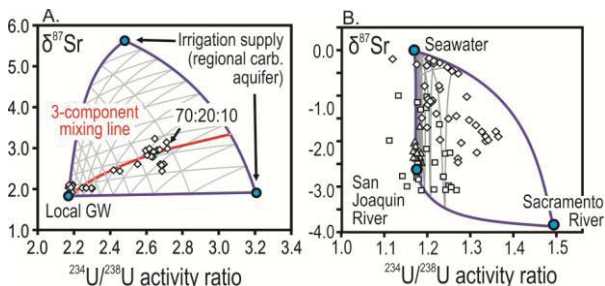

Figure 1: Three-component mixing models showing 10% intervals for water in the PNWR (A) and peat in the Sacramento-San Joaquin Delta (B).

Elucidating the complex thermal and fluid history of Austurhorn Intrusive Complex: zircon elemental and isotopic geochemistry

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The Austurhorn Intrusive Complex (AIC), comprising large bodies of granophyre, gabbro, and a mafic-felsic composite zone, is Iceland's best-studied intrusion (Blake 1966; Furman et al 1992a,b; Thorarinsson & Tegner 2009). However, despite widespread recognition of the value of zircon as a tracer of history and evolution of its parental magma(s), zircon studies are notably lacking for the AIC and other Icelandic plutons. Here, we present the first detailed chronologic, elemental, and isotopic Icelandic plutonic zircon study.

The elemental compositions of AIC zircons generally form a broad but coherent array which, for the most part, overlaps with that of zircons from Icelandic silicic volcanic rocks (Carley et al 2011). With some exceptions (see below), Ti concentrations range from 6-25 ppm (Ti_{zirc} temperatures ~ 730-870°C), and Hf concentrations are low (<10,000 ppm, typical of Icelandic zircon). Epsilon-Hf values are constrained to +13±1, falling between ϵ_{Hf} for Icelandic basalts from rift and off-rift settings. Similarly, $\delta^{18}O$ values are generally well-constrained at +3 to +4‰, consistent with Icelandic magmatic zircon (Bindeman et al 2012) and suggesting contributions from hydrothermally-altered crust to the petrogenesis of the parental silicic magmas. Zircons from a high-silica granophyre are notable exceptions to the trends described above: a large portion fall well outside of the AIC elemental array, distinguished primarily by extreme Hf concentrations ranging upward to 24,000 ppm (far higher than other analyzed Icelandic zircon), along with generally higher U and Th and lower Ti (down to 2 ppm [~630°C], lowest for Iceland). Their $\delta^{18}O$ values range from "normal" (+4) to extremely low (-6‰). Most of the elementally and isotopically unusual analyses are from CL-dark zones that display convolute and/or irregular zoning. We interpret these zones to reflect hydrothermal crystallization or recrystallization.

Zircon U-Pb geochronology reveals that the AIC was constructed by two distinct major intrusive events, the first at 6.45±0.04 Ma (MSWD=1.3) and a second at 5.99±0.06 Ma (MSWD=1.17). Most ages in the older population are from silicic rocks, while most ages in the younger populations are from a dominantly mafic zone. We interpret the younger age to represent the intrusion of voluminous basalt, which partially reactivated and remobilized the host silicic material ~500k.y. after initial emplacement of the AIC.