Re-Os isotopic disturbances at unconformities: Challenges and opportunities

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In the increasingly mature practice of Re-Os geochronology of black shales, we can now begin to predict which sections will provide robust geochronology and how to extract information from problematic sections. We present two case studies. In each case, we analyzed two sample suites, one near the base and one near the top of a shale unit. In each, we acquired precise isochrons for the lower suite, but scattered data for the top suite. In each, the scatter can be explained by oxidation that leaves little trace in the rocks.

In the Neoproterozoic Biri Formation, southern Norway, 80 meters of black shale are exposed in a steep bedrock stream channel. Samples from a 4-m stratigraphic interval mid-way through the section yield a robust Model 1 isochron age of 561 Ma (initial $^{187}Os/^{188}Os = 1.10$, MSWD = 0.5, n = 6). Data scatter, however, for samples taken within 3 m of the unconformable upper contact with a fluvial conglomerate. The disturbed section is not visibly altered and shares features with the undisturbed section; both contain fine pyrite framboids and total organic carbon (TOC) near 1%.

In the Middle Triassic Botneheia Formation, western Spitsbergen, 90 meters of black shale are exposed in sharp cliffs and incised gullies. Samples from a 70-cm stratigraphic interval near the base of the shale member yield a well-constrained Model 3 age of 241 Ma (initial $^{187}Os/^{188}Os = 0.83$, MSWD = 16, n = 8). Data scatter, however, for samples from a 1-m stratigraphic interval 4 m below the upper contact with a red pro-delta siltstone. Like the Biri section, the disturbed samples are not visibly altered. TOC contents of 2-8% are representative of the shale section.

In both cases, the tops of shale units were potentially oxidized prior to burial and/or during post-burial exchange of pore fluids across a redox boundary between contrasting sediment types. Oxidizing fluids mobilize Re and Os, decoupling radiogenic ^{187}Os from parent ^{187}Re. Over time, transport of Re and Os may exceed the sample size, resulting in variable $^{187}Os/^{188}Os$ within the sample suite. This violates a basic tenet of the isochron method. Isotopic disturbance may therefore mark the vertical extent of visually undetectable oxidation of shales underlying fluvio-deltaic systems.

Rb-Sr systematics of angrites

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Volatile depletion in many meteorite parent bodies as well as in the terrestrial planets resulted in a fractionation of volatile Rb from more refractory Sr, such that the initial $^{87}Sr/^{86}Sr$ of a volatile-depleted planetesimal can be used to estimate the time at which this planetesimal separated from the solar nebula or any other source reservoir with known Sr isotope evolution. The angrite parent body has the most extreme depletion in volatile elements and the ^{87}Rb-^{87}Sr systematics of angrites LEW 86010 and Angra dos Reis (AdoR) were used previously to determine the timeing of volatile depletion [1,2]. However, these samples formed ~10 Myr after CAIs and thus may not represent the initial $^{87}Sr/^{86}Sr$ of their parent body. We developed improved techniques for precise Sr isotope measurements (≈5 ppm, 2 σ external reproducibility for NBS 987) and present high-precision Sr isotope data for plagioclase separates from several angrites. These data are used to better determine the timing of volatile loss from the angrite parent body. The $^{87}Sr/^{86}Sr$ ratio of D'Orbigny plagioclase is among the lowest yet measured for angrites and provides the currently most precise estimate for the initial $^{87}Sr/^{86}Sr$ of the angrite parent body of 0.698955±0.000004. This value is in excellent agreement with the estimate based on AdoR and LEW 86010 of 0.698967±0.000015 [1,2]. D'Orbigny and LEW 86010/AdoR have crystallization ages of ~4 and ~10 Myr after CAI formation [3] and their initial $^{87}Sr/^{86}Sr$ ratios thus provide the Sr isotope composition of the angrite parent body at ~4 and ~10 Myr after CAI formation (assuming that both angrites sample the mantle of the their parent body). This allows estimating the Sr isotope evolution of the angrite parent body and calculation of the time at which the solar nebula had reached the initial $^{87}Sr/^{86}Sr$ of the angrite parent body. In this two-stage model volatile loss occurred within the first ~2 Myr of the solar system, a timescale similar to Hf-W ages for the accretion and differentiation of the angrite parent body [4].

[1] Lugmair and Galer (1992) *GCA* **56**, 1673–1694. [2] Nyquist *et al*. (1994) *Meteoritics* **29**, 872–885. [3] Amelin (2008) *GCA* **72**, 4874-4885. [4] Kleine *et al*. (2009) *LPSC* **XL**, 2403.