

The Olympic Dam giant ore deposit – a fossil nuclear reactor?

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The Olympic Dam (OD) supergiant Cu-U-Au-Ag deposit in the Gawler Craton of South Australia occurs within tectonic-hydrothermal breccia hosted by 1.59 Ga granite of the Gawler silicic large igneous province. With probable reserves of ~200000 t of U, OD is one of the world's largest U deposits. The high uranium content and a possible Proterozoic age of mineralization raises the possibility of Oklo-style fossil nuclear reactor activity, although a much smaller degree of burn-up, similar to that documented in many other Proterozoic and Phanerozoic U deposits, is more likely, given the low average U concentration (450 ppm) at OD. We explore this possibility using U-Sm-Nd isotope data.

High-precision U isotope data for 43 samples with U concentrations up to 10.5% were obtained by MC-ICPMS at Cologne/Bonn, employing both double spiking and standard-sample bracketing to correct for instrumental mass bias. $\delta^{238}\text{U}$ (relative to a $^{238}\text{U}/^{235}\text{U}$ of 137.856 for REIMEP 18a) ranges from -0.5‰ to +0.2‰ (average $\delta^{238}\text{U} = -0.2‰$). Only four samples yield the positive $\delta^{238}\text{U}$ expected from consumption of ^{235}U in sustained nuclear fission, well below $\delta^{238}\text{U}$ found at Oklo (up to 560‰), but consistent with the minute isotopic effects reported for other old U deposits. Depletion of ^{149}Sm by slow neutron capture, observed in many U deposits, reaches 1.5 ϵ -units and only occurs in the few samples with positive $\delta^{238}\text{U}$. Isotope ratios of Nd are indistinguishable from normal. We conclude that OD contains U with a near-natural abundance of ^{235}U , but some U-rich domains appear to have experienced a small degree of induced ^{235}U fission with associated neutron capture effects in other elements.

The vast majority of our samples (10-8000 ppm U) exhibit slightly negative $\delta^{238}\text{U}$. Consistently negative $\delta^{238}\text{U}$ (-0.3 to -0.7‰) was previously found for 'magmatic' U deposits, defined to include hydrothermal (200-400°C) deposits [1]. ^{238}U depletion in such deposits is thought to reflect natural isotope fractionation during U deposition.

[1] Bopp *et al.* (2009) *Geology* **37**, 611-614

Calibration of the Δ_{47} (clumped isotope) thermometer for biogenic and inorganic carbonate using the MIRA IRMS.

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Using a suite of brachiopod samples collected from natural marine environments (5-22°C) and inorganic hydrothermal calcites collected from springs precipitated at up to 56°C we have determined a new calibration for the Δ_{47} isotope thermometer. This is the first reported calibration using the MIRA IRMS. All other previous determinations have been made using the Thermo-Finnegan 253 IRMS.

For all samples, 10mg of homogenised powder were reacted with ca. 2mL of 102% orthophosphoric acid for 12 hours at 25°C. CO_2 was collected by cryo-distillation after passing through sequential cold traps at -100 and -120°C to ensure complete removal of water vapour. Yields were determined barometrically before transferring the CO_2 , via a short packed column to remove any hydrocarbons, into gas tubes for mass spectrometric analysis. The MIRA mass spectrometer was operated at 8kV energy with an ionising electron current of 750 μA and $m/z = 44$ signal strengths of $4 \times 10^{-8}\text{A}$. Reported measurements are the average of 9 runs of 20 samples-reference cycles, with a 10 second integration per cycle. The measurement precision for δ^{47} approaches the shot-noise limit of ca. 0.01‰. All results are presented on the absolute reference frame outlined by Dennis *et al.* [1].

Between 5 and 56°C the Δ_{47} Vs. T relationship for both biogenic and inorganic calcite can be described by a single equation:

$$\Delta_{47} = 0.0368 (\pm 0.0037) \times 10^6 \cdot T^{-2} + 0.2345 (\pm 0.042) \\ (r^2 = 0.92)$$

The gradient of the response, within measurement error, is the same as recently reported studies [1, 2] and similar to the theoretical response [3]. There are, however, significant differences in the intercept that may result from different sample reaction conditions and procedures.

[1] Dennis *et al.* (2011) *Geochim.Cosmochim.Acta*, **75**, 7117-7131. [2] Henkes *et al.* (2013) *Geochim.Cosmochim.Acta*, **106**, 307-325. [3] Guo *et al.* (2009) *Geochim. Cosmochim. Acta*, **73**, 7203-7225.