Clumped isotope measurements to reveal diagenetic histories

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Clumped isotope geochemistry is a growing field, and more particularly the 'carbonate clumped isotope paleothermometer' is becoming more widely applied. Isotopologues are molecules that are identical except for their isotopic composition. Clumped isotopes are isotopologues where two or more heavy isotopes are clumped together; the effects of clumping are enhanced with decreasing temperatures, the zero point energy of the system being lowered. However, calibrating clumped isotopes is still a novel and challenging field of research, and more importantly measuring isotopologues requires skills and high sensitivity mass spectrometry.

So far, clumped isotopes have been used mainly in paleoclimate research. Here, we intend to calibrate the carbonate clumped isotope paleothermometer for diagenetic material. Carbonates are reactive minerals that can easily be modified during burial and exhumation. Post-depositional diagenetic processes such as dissolution and re-precipitation of new minerals are common and result in modified mineralogical and petro-physical characteristics of the initial carbonate rock. Temperature at which those transformations occur is a fundamental parameter in diagenesis: given a known geothermal gradient and burial history, the temperature of precipitation of carbonate cements can be translated into depth and timing of the event, assuming a thermal equilibrium between the fluids and the rock. Because it is thermodynamically based, the clumped isotope paleo-thermometer is independent of the isotopic composition of the diagenetic fluid and therefore can be applied with greater confidence.

We are currently implementing the technique at Imperial College London, both in a manual and in an automatic manner. Our aim is to improve the technique in order to be able to measure smaller sample sizes of diagenetic material (such as cement and crack infills) and to lower the associated error down to ± 1°C. We are therefore running a wide range of calibrations, on calcite and dolomite, and from different synthetically precipitated carbonate materials.

Ultimately, we aim to constrain the depositional and diagenetic environments of selected outcrops in Oman in the context of a wider study on Carbon Capture and Storage.

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A ~3.63 Ga major impact recorded by the Bunburra Rockhole anomalous basaltic achondrite

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The Bunburra Rockhole (BR) meteorite is an anomalous basaltic achondrite recovered in Western Australia [1]. BR mineralogy, petrology [1] and mineral composition [2] resemble classical brecciated basaltic eucrites, generally associated with asteroid 4 Vesta. However, BR oxygen isotopic composition is distinct from the general HED fractionation line, suggesting that BR, along with 3 other anomalous eucrites, belongs to a distinct differentiated parent asteroid. Previous chronology studies indicate a reset of the ^{26}Al-^{26}Mg system and a ~4.1 Ga ^{207}Pb-^{206}Pb whole-rock reequilibration age for BR [2].

The $^{40}Ar/^{39}Ar$ chronometer has typical low closure temperature of few hundred °C and has the potential to record heating events such as large collisions between asteroids. We have analyzed 4 groundmass (fine-grained) and 5 breccia (medium- to coarse-grained) single-grain aliquots of BR using the $^{40}Ar/^{39}Ar$ laser step-heating technique. All samples yielded well-defined plateau ages. 7 grains yielded a weighted mean age of 3634±18 Ma (P=0.53) suggesting that BR recorded a major impact event on its parent body at this time. 2 breccia grains suggest a secondary minor heating event at 3538±24 Ma (P=0.54).

Generally, eucrites $^{40}Ar/^{39}Ar$ analyses yield complex age spectra with ambiguous apparent ages between 3.4 and 4.1 Ga [3]. Here, a unique well-defined age at 3.63±0.02 Ga based on several flat age spectra indicate that BR had a simpler history than eucrites from Vesta 4 and may suggest that BR belongs to a different parent asteroid.

[1] Bland *et al*. (2009) *Science* **325**, 1525-1527 [2] Spivak-Birndorf *et al*. (2010) 41th LPSC [3] Bogard & Garrison (2009) 40th LPSC.