Unravelling chronological complexities in lunar materials with baddeleyite (ZrO_2)

TAIT, K.T[1], WHITE, L. F[1], MOSER, D. E[2], DARLING, J. R[3]

[1]Royal Ontatio Museum, Toronto, Canada
[2]University of Western Ontario, London, Canada
[3]University of Portsmouth, UK

The complex pressure-temperature history of many planetary materials resulting from ~4.5 Ga of brecciation, shock and crustal metamorphism, produces a muddled array of undisturbed, partially distrubed and fully reset radiogenic ages [1]. Dating of microstructurally characterised accessory phases, such as zircon ($ZrSiO_4$), can resolve crystallization and impact age domains [2], although zircon is not widely occuring in these mafic crustal lithologies. Baddeleyite (ZrO_2) is a robust chronometer in such materials, incoporating radiogenic U and Th and excluding common Pb during crystallization [3]. Here we apply a range of micro- to nano-scale structural and chemical techniques, such as electron backscatter diffraction (EBSD), atom probe tomoraphy (APT) and secondary ion mass spectrometry (SIMS) to microbaddeleyite grains in two lunar meteorites (NWA 3163 & NWA 2200) with complex and conflicting age data.

EBSD analysis of >20 baddeleyite grains within these two meteorites reveals a range of microstructures, including nanocrystallinity, crystal plastic deformation (< 18°), and orthoganlly related interlocking domains suggestive of reversion from a high symmetry ZrO_2 phase [4]. SIMS dating of baddeleyite in NWA 2200 yield a range of ^{207}Pb / ^{206}Pb ages between ~4.40 and ~3.84 Ga, spanning a greater age range than zircon in the sample (4.4 to 3.98 Ga). Baddeleyite in NWA 3163 records signifcant Pb loss at the length scale of SIMS analysis (micrometres), likely induced during granularization and shock deformation of the sample [5]. Nanoscale APT Th-Pb dating of domains with different microstructural characteristics yield new, robust ages for crystallization (~4.3 Ga) and shock deformation (~2.2 Ga) of the meteorite, allowing accurate age resolution of key geological events on the Moon. Linking nanostructural data with micro- to atomic-scale U-Th-Pb isotope analyses in baddeleyite can resolve chronological complexitites in even the most highly shocked and metamorphosed planetary samples, whilst also providing new insights into their impact and crustal histories.

[1] Darling et al. 2016. EPSL [2] Cavosie et al. 2015. Geology. [3] Heaman. 2009 Chem Geol. [4] Timms et al. 2017. EPSL. [5] McLeod et al. 2016. GCA.