

***IN-SITU* GEOCHRONOLOGY OF ENRICHED BASALTIC SHERGOTTITES JIDDAT AL HARASIS (JaH) 479, NORTHWEST AFRICA (NWA) 10299, AND NWA 12919: THE RELATIONSHIP BETWEEN BADDELEYITE MICROSTRUCTURES AND U–Pb ISOTOPE SYSTEMATICS.**

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Introduction: The crystallization ages of shergottites are essential to our current knowledge of the absolute time scale of Mars, pointing to long-lived magmatism in the late Amazonian (582–157 Ma) within limits of the sampling bias inherent in the martian meteorite suite [1]. Advances in secondary ion mass spectrometry (SIMS) U–Pb analysis of baddeleyite (monoclinic ZrO₂, *m*-ZrO₂) have enabled *in-situ* geochronology of shergottites with the advantage of preserving the sample and its petrographic context compared to bulk mineral separation and dissolution methods [e.g., 2,3,4]. As a result of shock metamorphism during shergottite ejection from the surface of Mars, baddeleyite microstructures reflect varying degrees of phase transformation to metastable high-pressure orthorhombic (*o*-ZrO₂) and tetragonal (*t*-ZrO₂) polymorphs followed by reversion [5,6]. While some baddeleyite grains in the highly shocked Northwest Africa (NWA) 5298 show resolvable Pb loss, those in three less shocked shergottites display no link between baddeleyite microstructures and U–Pb isotope systematics [4,5]. To further constrain how U–Pb isotope systematics in baddeleyite responds to shock metamorphism, this study examines a suite of shergottites with estimated bulk shock pressures intermediate to those investigated by [4] and [5].

Methodology: We examined the enriched basaltic shergottites Jiddat al Harasis (JaH) 479, NWA 10299, and NWA 12919. Baddeleyite microstructures were analyzed by electron backscatter diffraction (EBSD) using a Zeiss EVO MA10 LaB₆ SEM with an Oxford Instruments Symmetry S2 detector at the University of Portsmouth. Samples were analyzed uncoated at 20 kV and 1.5–2 nA, with step sizes of 30–80 nm. SIMS U–Pb baddeleyite analyses were conducted using a Cameca IMS-1280HR ion microprobe at Heidelberg University following methods outlined in [7], with ~1 nA primary O₂⁺ beam current and 10 kV acceleration voltage for extracting secondary ions. Sampling pits were imaged following SIMS analysis and measured to be ~8–10 µm in diameter.

Results & Implications: Baddeleyite microstructures in the studied samples are dominantly quasi-amorphous (n=56), characterized by low band contrast (BC) values across the whole grain with localized areas of indexing or complete lack thereof. Strong diffraction from surrounding phases rules out sample polishing as a cause of the quasi-amorphous appearance of these baddeleyite grains. This suggests that reversion from high-pressure polymorphs occurred at temperatures that were insufficient for the nucleation of reverted *m*-ZrO₂ domains large enough to be detected at the EBSD length-scales (a few 10's of nm in this study). More extensive nucleation of reverted *m*-ZrO₂ is present only in a small population of baddeleyite (n=4), manifesting as localized domains with strong BC values and which are related by orthogonal orientation relationships (ORs). Additional grains (n=9) display preserved single orientation and magmatic twinning, sometimes with subgrains of reverted *m*-ZrO₂, indicating partial to no phase transformation during impact shock. The quasi-amorphous microstructure characterizes nearly all surveyed grains in NWA 10299 and 12919, but is less dominant in JaH 479. The larger diversity of baddeleyite microstructures in JaH 479 suggests relatively lower shock pressures which allowed more preservation of magmatic crystal orientations.

SIMS U–Pb baddeleyite analyses uncorrected for common Pb yield Tera-Wasserburg ²³⁸U–²⁰⁶Pb discordia ages of 209.7±9.1 Ma for JaH 479 (n=14), 196±11 Ma for NWA 10299 (n=14) and 188±11 Ma for NWA 12919 (n=9). We find no resolvable linkage between baddeleyite microstructures and the observed scatter in U–Pb data, which can instead be attributed to 1) crystal orientation effects, 2) topographic effects on measured ²³⁸U/²⁰⁶Pb ratios of closely adjacent analysis spots, and 3) sampling of surrounding phases which causes U/Pb fractionation to deviate from standard calibration. Our findings suggest that the diffusion of Pb isotopes across baddeleyite grain boundaries was minimal due to insufficient post-shock temperature gradients, reflected in the prevalence of the quasi-amorphous microstructure. The three new U–Pb ages are consistent with the range of known igneous ages of enriched shergottites (223–157 Ma). Combined with petrography, mineralogy, and geochemistry, results of this study provide additional constraints on potential petrogenetic links among the inventory of enriched shergottites.

References: [1] Walton E. L. et al. (2008) *Geochimica et Cosmochimica Acta* 72:5819–5837. [2] Moser D. E. et al. (2013) *Nature* 499:454–457. [3] Zhou Q. et al. (2013) *Earth and Planetary Science Letters* 374:156–163. [4] Staddon L. G. et al. (2021) *Geochimica et Cosmochimica Acta* 315:73–88. [5] Darling J. R. et al. (2016) *Earth and Planetary Science Letters* 444:1–12. [6] Takagi S. et al. (2020) *Geophysical Research Letters* 47:e2020GL089592. [7] Schmitt A. K. et al. (2010) *Chemical Geology* 269: 386–395.