

ACCESSORY MINERAL U-Th-Pb CHRONOLOGY OF LATE AMAZONIAN MAGMATISM RECORDED BY ENRICHED SHERGOTTITES

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Introduction: The chronology of martian meteorites offers unique insights into volcanism on Mars, and hence the geological and thermal evolution of the martian crust and mantle system. It is thought that depleted shergottites (derived from incompatible trace element-depleted mantle sources) formed from a long-lived volcanic centre over more than 2 billion years [1], and that nakhlite source volcano grew many orders of magnitude slower than comparable systems on Earth [2]. In potential contrast, existing estimates of enriched shergottite crystallization ages have a relatively narrow range from 165 to 225 Ma ([3], and references therein). However, alongside rapid growth in the number of classified samples, increasing petrological diversity of enriched shergottites has been recognized. This includes gabbroic samples interpreted as cumulates [4, 5]. New age data are needed to help test potential magmatic links between petrological types of enriched shergottites, and better understand volcanism at enriched shergottite launch site(s) for samples with linked cosmogenic ray exposure (CRE) ages.

Unambiguous interpretation of age data from shergottites has long proven challenging due to secondary processes that include intensive shock metamorphism. However recent advances in nanostructurally-guided U-Pb chronology of baddeleyite (e.g. [6, 7]) have overcome these challenges. Apatite and merrillite also have tremendous potential to record igneous, thermal and shock histories [8]. Here, we combine new U-Th-Pb isotope analyses of accessory minerals in enriched shergottites with recent results to further refine understanding of late Amazonian magmatism on Mars, and highlight the potential of apatite and merrillite to constrain the timing of magmatic emplacement.

Methodology: Our group have recently undertaken nanostructurally-guided baddeleyite U-Pb isotope analysis of enriched basaltic to microgabbroic shergottites Tindouf 002, Northwest Africa (NWA) 7257, NWA 8679, Jiddat al Harasis (JaH) 479, NWA 10299, and NWA 12919, along with gabbroic shergottite NWA 6963. The approach follows that of [7], combining SEM imaging and electron backscatter diffraction (EBSD) analysis at the University of Portsmouth, with SIMS U-Pb isotope analysis at the University of Heidelberg (following methods of [9]). Nanostructurally-constrained apatite and merrillite U-Th-Pb isotope analysis was undertaken by LA-ICP-MS at the University of Portsmouth, targeting three samples with a range of shock-metamorphic conditions: NWA 7257, NWA 5298 and Zagami.

Findings: EBSD analysis has revealed that all of the studied samples have a range of baddeleyite nanostructures, including evidence for widespread reversion from high P-T ZrO₂ polymorphs. Some samples also retain domains with preserved magmatic twin relationships. None of the baddeleyite analysed by SIMS contains evidence for widespread granularization or recrystallisation, which are the only processes known to lead to resolvable Pb-loss and age resetting in baddeleyite from shergottites [6, 7]. As such, the baddeleyite U-Pb Tera-Wasserburg discordia arrays are interpreted to record the timing of magmatic crystallization for each sample. The relatively narrow range of resulting ages (~185 to 220 Ma) from these samples, including an age of 189 ± 13 (95 % conf.) for gabbroic sample NWA 6963, underlines the close temporal linkage between enriched shergottites of varying petrology and geochemistry.

LA-ICP-MS U-Pb isotopic dates from apatite and merrillite in NWA 7257 (164 ± 37 Ma; all 2σ) and Zagami (199 ± 34 Ma) are within uncertainty of baddeleyite ages [7, 10]. Combining data with [10] results in an apatite and merrillite age of 194 ± 27 Ma for Zagami. Given the modest closure temperature of apatite to Pb-diffusion (350-570 °C [11]), the results imply a simple thermal history from shortly after formation at the martian surface, and insufficient post-shock heating to drive resolvable Pb mobility. This shows that Ca-phosphates can record the timing of primary magmatic processes in shergottites, despite complex shock histories.

In combination, the new results further strengthen interpretations that enriched shergottites formed within a relatively short period (~225 to 170 Ma) in the late Amazonian, and that their volcanic centre(s) was/were relatively complex. Additional CRE ages for enriched shergottites will enable analysis of individual launch sites, and testing of the hypothesis that they record a distinct style of martian volcanism from depleted shergottites and nakhlites.

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