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Impact origin of 4.33 Ga old baddeleyite in a strongly shocked silica oversaturated lunar norite

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Absolute dating of the large lunar basins represents one of the most challenging objectives in unravelling the early lunar bombardment history. Recent studies provided hints that impact-related recrystallization of zircon occurred between 4.3 and 4.1 Ga (e.g. [1-3]). Baddeleyites in the highly shocked norite 78235,38 (Apollo 17) provide further evidence for multiple impact-related heating episodes between 4.2 and 4.33 Ga. The norite predominantly comprises orthopyroxene and plagioclase (ca. 10% maskelynite) with patches of SiO_2 glass. Glass and ophitic melt veins have a similar composition as the coarse-grained host rock, suggestive of in situ melting by shock heating and pressures > 50 GPa [4]. Most baddeleyites are reverse discordant with Pb-Pb ages (n = 10 on 9 grains) between 4.34 and 4.2 Ga. The baddeleyites preferentially occur in the melt veins, but also as inclusions or intergrown with coarse anorthite and orthopyroxene (4.2 and 4.34 Ga). The 4.34-4.33 ages are most common and match previous Pb-Pb and Sm-Nd ages from a different piece of 78235. [5] interpreted these ages to date igneous crystallization. However, the coarse-grained norite of section 78235,38 contains a large metal grain coexisting with plagioclase and SiO_2, hinting that the cumulate may have crystallized from a slowly cooling impact melt sheet. The 4.33 Ga ages are also identical within errors with Pb-Pb ages of zircon from breccia 73217 (Station 3) which were interpreted as impact-related [1]. Thus, the 4.33 Ga ages may reflect the age of a large impact. Pb-Pb ages of 4.22 and 4.30 Ga were obtained for baddeleyite embedded in a small patch of a SiO_2 phase (see figure), possibly representing decomposed zircon, which requires temperatures > 1600°C at low pressures [6]. Impact-related heating around 4.2 Ga may have partially disturbed the U-Pb system of 4.33 Ga old baddeleyite.

[1] Grange, M. L., et al. (2009) *GCA* 73.10, 3093-3107 [2] Crow et al. (2017) *GCA* 202, 264-284 [3] Vanderliek, D. M. et al (2019) *LPSC*, 2132 [4] Gibbons, R. V., et al. (1975) *LPSC* 6. [5] Edmunson, J., et al. (2009) *GCA* 73.2, 514-527 [6] Timms, N. E., et al. (2017) *Earth-Sci. Rev.* 165, 185-202.