

## Pb-Pb chronometry of lunar impact melt breccias

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Lunar impact breccias record the bombardment history of the Moon's surface. Recent findings of >4 Ga impact ages in Apollo 16 and 17 breccias [1-3] call into question whether the surface of the Moon was subjected to a spike in the impact rate ("lunar cataclysm") at ~3.9 Ga. As an alternative, it is possible that there was a steady decline in the impact rate, such that the earliest impact melts did not survive [4]. Application of multiple radiochronometers with different closure temperatures, such as Ar-Ar, Pb-Pb, and U-Pb in various minerals, can provide better constraints on the lunar impact history.

We investigated Apollo 16 and lunar meteorite impact melt and fragmental breccias to compare the impact records in different chemical groups of the central highlands as well as random sites sampled in feldspathic meteorite breccias. All of these breccias were either fully recrystallized or contain abundant impact melt with lithic clasts. We performed Pb-Pb dating (methods in [5]) of separated fragments of impact melt in MIL090034 and NWA6355, of bulk sample and/or mineral separates from crystalline breccias 65015, 62235, 67016 and Shisr 166, and of an individual clast from the polymict breccia 67016. We find impact ages of ~4.19 Ga for feldspathic 67016, and 3.92-3.93 Ga for KREEP-rich 65015 and 62235. Pb-Pb ages of the studied meteorites are 3.57 Ga (Shisr 166), 3.86 Ga for MIL09, and 3.96 Ga (NWA6355). So far, there are no impact Ar-Ar and Pb-Pb ages in lunar meteorites older than 4 Ga, and several younger events can be identified [6]. Ar-Ar ages of these breccias are, in all cases, younger than Pb-Pb ages [3]. These results indicate that Ar-Ar ages are susceptible to resetting by a subsequent strong impact shock event, while Pb-Pb and U-Pb in U-rich phases are disturbed to variable degrees. An early protracted period of high cratering flux that rapidly decayed with a half-life of 50-100 Ma, combined with a short period of cataclysm at ~3.9 Ga, could explain these impact records.

[1] Grange *et al* (2011) *GCA* **75**, 2213. [2] Fernandes *et al* (2013) *MAPS* **48**, 241. [3] Norman & Nemchin (2014) *EPSL* **388**, 387. [4] Hartmann (2003) *MAPS* **38**, 579. [5] Bouvier *et al* (2011) *GCA* **75**, 5310. [6] Cohen (2008) *Work. Early Sol. Syst. Impact Bomb.*, **27**.