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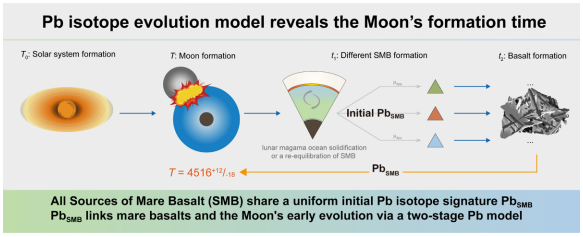

The life of the Moon

QIU-LI LI[1,2], QIAN W.L. ZHANG[1], MU-HAN YANG[1], BI-WEN WANG[1], RICHARD W. CARLSON[3], YUYANG HE[4] AND XIAN-HUA LI[1,5]

[1]Institute of Geology and Geophysics, Chinese Academy of Sciences

[2]University of Chinese Academy of Sciences

[3]Carnegie Institution for Science

[4]Insitute of Geology and Geophysics, CAS

[5]College of Earth and Planetary Sciences, University of Chinese Academy of Sciences

The fundamental questions of when the Moon formed and how long its internal geological activity persisted remain central to planetary science. Recent analyses of returned lunar samples and lunar meteorites have dramatically extended the record of lunar volcanism. Key findings include young mare basalts on the lunar nearside (~2.0 Ga)[1], farside basalts (~2.8 Ga)[2], a ~2.2 Ga KREEP-enriched basaltic lunar meteorite[3], and crucially, volcanic glass beads indicative of volcanic activity as recent as ~120 Ma[4]. These discoveries collectively point to a Moon with sustained endogenic geological vigor far longer than previously recognized.

To constrain the earliest lunar history, we employ a two-stage Pb isotope evolution model on four precisely dated mare basalt samples with well-defined initial Pb isotopic compositions. Our modeling calculates the timing of mantle source homogenization for these mare basalts to be ~4377 +57/-27 Ma. Extrapolating this model further back in time allows us to estimate the age of the Moon's primary differentiation, which we interpret as the lunar formation time, at ~4516 +21/-18 Ma[5].

This study provides chronological constraints from the Moon's late-stage volcanic products to its very origin. The results reconcile a formation time of the Moon within the context of the Giant Impact hypothesis with newly recognized evidence for its extraordinarily prolonged volcanic history.

[1] Qiu-Li Li, Qin Zhou, Yu Liu et al. 2021. Two-billion-year-old volcanism on the Moon from Chang'E-5 basalts. Nature 600, 54-58.

[2] Qian W.L. Zhang, Mu-Han Yang, Qiu-Li Li* et al., 2025. Lunar farside volcanism 2.8 billion years ago from Chang'e-6 basalts. Nature, 643:356-360.

[3] Muhan Yang, Qian W.L. Zhang, Qiu-Li Li* et al. 2025. 2.2-billion-year-old KREEP-rich volcanism on the Moon. Science Bulletin, 70: 3265-3271

[4] Biwen Wang, Qian W.L. Zhang... Qiu-Li Li*. 2024. Returned samples indicate volcanism on the Moon 120 million years ago. Science 385, 1077-1080.

[5] Muhan Yang, Qian W.L. Zhang...Qiu-Li Li*, 2026. The Moon's formation time recorded in lunar mare basalts. Icarus, 447: 116889.