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Supplementary Information for

Deep-Seated Mantle Plumes Detected Beneath the Moon's Earth-Facing Hemisphere

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The PDF file includes:

Supplementary Text

S1 Detectability Test for Events Within Seismicity Gaps

To assess whether the two seismicity gaps identified in **Fig. 1b** (outlined in red in the main text) represent true seismicity deficits or artifacts of station geometry, we performed a synthetic test. We placed two hypothetical deep moonquake sources within the two gap regions (10° N, 20° W, 900 km depth; and 10° S, 6° W, 900 km depth), and evaluated whether their locations could be accurately inverted using arrival times from various Apollo stations.

Supplementary Table 1 lists the theoretical arrival times of direct *P* and *S* waves from the two preset seismic sources at the four Apollo stations, calculated using the very preliminary reference Moon model[1]. For the localization of deep moonquakes, only the differential arrival times ($Ts - Tp$) at each station can be used as input for the inversion, as the absolute travel times of direct waves cannot be determined in the absence of the origin time.

We then applied the least-squares inversion to invert the preset hypocenter locations. The input consisted of combinations of differential arrival times ($Ts - Tp$) from different station pairs. The optimal source location was identified via a grid search spanning latitudes from 40°S to 40°N and longitudes from 60°W to 60°E, both at 2° intervals, and depths from 700 km to 1,200 km at 20 km intervals. We inverted the event location by minimizing the following misfit function:

$$min\ \ Err = \sum_{i=1}^{n} \left(T_{dif}^{o} - T_{dif}^{p}\right)_{i}^{2}, n \geq 2,$$

where i denotes the Apollo station index, T_{dif}^{o} is the observed differential arrival time ($Ts - Tp$) at the corresponding station i, and T_{dif}^{p} is the corresponding predicted value. The number of stations n used in the inversion is at least two. The solution corresponds to the location that minimizes the total prediction error.

These tests (**Supplementary Table 2**) shows that even with arrival time differences from only two stations, the preset source locations can be accurately inverted, demonstrating that the observed seismicity gaps are not artifacts of station geometry.

Supplementary Table 1 | Theoretical arrival times of direct *P* and *S* waves from the two preset source locations to the four Apollo stations, calculated using the very preliminary reference Moon model[1]. The values are given in seconds.

Preset Position (Longitude, Latitude, Depth)	Apollo 12 (*Tp*)	Apollo 12 (*Ts*)	Apollo 14 (*Tp*)	Apollo 14 (*Ts*)	Apollo 15 (*Tp*)	Apollo 15 (*Ts*)	Apollo 16 (*Tp*)	Apollo 16 (*Ts*)
(10° N, 20° W, 900 km)	123.9	216.9	124.2	217.5	139.7	244.5	159.1	278.6
(10° S, 6° W, 900 km)	129.7	227.0	124.3	217.5	154.2	269.8	130.4	228.3

Supplementary Table 2 | The inverted locations of the two preset earthquake sources. They are determined using combinations of arrival time differences (*Ts – Tp*) from various station pairs.

Inverted Postion (Longitude, Latitude, Depth)	Apollo 12 (*Ts - Tp*)	Apollo 14 (*Ts - Tp*)	Apollo 15 (*Ts - Tp*)	Apollo 16 (*Ts - Tp*)
(10° N, 20° W, 900 km)	√	√	√	√
(10° N, 20° W, 900 km)	×	√	√	√
(10° N, 20° W, 900 km)	√	×	√	√
(10° N, 20° W, 900 km)	√	√	×	√
(10° N, 20° W, 900 km)	√	√	√	×
(10° N, 20° W, 900 km)	√	√	×	×
(10° N, 20° W, 900 km)	√	×	√	×
(10° N, 20° W, 900 km)	√	×	×	√
(10° N, 20° W, 900 km)	×	√	√	×
(10° N, 20° W, 900 km)	×	√	×	√
(10° N, 20° W, 900 km)	×	×	√	√
(10° S, 6° W, 900 km)	√	√	√	√
(10° S, 6° W, 900 km)	×	√	√	√
(10° S, 6° W, 900 km)	√	×	√	√
(10° S, 6° W, 900 km)	√	√	×	√
(10° S, 6° W, 900 km)	√	√	√	×
(10° S, 6° W, 900 km)	√	√	×	×
(10° S, 6° W, 900 km)	√	×	√	×

(10° S, 6° W, 900 km)	√	×	×	√
(10° S, 6° W, 900 km)	×	√	√	×
(10° S, 6° W, 900 km)	×	√	×	√
(10° S, 6° W, 900 km)	×	×	√	√

References in the Supplementary Materials

1. Garcia, R. F., Gagnepain-Beyneix, J., Chevrot, S. & Lognonné, P. Very preliminary reference Moon model. *Physics of the Earth and Planetary Interiors* **188**, 96–113 (2011).