Evidence for lunar true polar wander, and a past low-eccentricity, synchronous lunar orbit

James Tuttle Keane\(^1\) \& Isamu Matsuyama\(^1\)

\(^1\)Department of Planetary Science, University of Arizona, Tucson, AZ 85721
Contact: jkeane@lpl.arizona.edu

Abstract. For nearly 200 years, the nature of the Moon’s shape has remained a mystery. The observed lunar figure is significantly more deformed than it should be, given its present orbital and rotational state\(^1\). This excess deformation has long been ascribed to a “fossil figure,” frozen into place when the Moon was much closer to the Earth\(^2,3,4\). However, the observed figure requires an initially large eccentricity or non-synchronous spin-orbit state\(^5,6\), which seem at odds with our understanding of the Moon’s formation and evolution. In this work, we use GRAIL gravity data\(^7\) to investigate whether lunar impact basins and mascons have any contribution to the observed figure. We find that the South Pole-Aitken (SPA) basin and its associated global ejecta blanket account for a significant fraction of the observed lunar figure, while most other impact basins and mascons are negligible. Removing the contribution from SPA reveals a fossil figure that is misaligned with respect to the present-day rotational and tidal principal axes – suggesting a past episode of lunar true polar wander driven by the formation of SPA. Correcting for this reorientation reveals a lunar figure consistent with the Moon forming in a low-eccentricity, synchronous orbit. Constraining these past orbital and rotational states is important for improving our understanding of the formation, dynamical evolution of the Moon.

\(^1\) Laplace, P.-S. Oeuvres comptetes de Laplace. (Gauthiers-Villars, 1878).
\(^2\) Sedgwick, W. F. On the oscillations of a heterogeneous compressible liquid sphere and the genesis of the Moon; and the figure of the Moon. Messenger Math. 27, 159-173 (1898).
\(^3\) Jeffreys, H. Certain hypothesis as to the internal structure of the Earth and Moon. Mem. R. Astron. Soc. 60, 187-217 (1914).