NEW INSIGHTS INTO LUNAR TRUE POLAR WANDER. J. T. Keane[1], I. Matsuyama[1], and M. A. Siegler[2,3]; [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721, USA; [2]Planetary Science Institute, Tucson, Arizona 85721, USA; [3]Southern Methodist University, Dallas, Texas 75275, USA; Correspondence: J. T. Keane (jkeane@lpl.arizona.edu).

Introduction: True polar wander (TPW) is the re-orientation of a planetary body with respect to its spin axis due to the redistribution of mass the object. As mass is redistributed (e.g. due to an impact, mantle plume, etc.) the planet reorients in order to remain in a minimum energy rotation state (with the maximum principal axis of inertia aligned with the spin vector). Thus, the study of TPW and the associated paleopoles is intricately related to large-scale geophysical processes, including impact basin formation [1], mantle convection [2], tidal heating [3], etc. In this paper, we summarize recent developments in understanding the polar wander history of the Moon, including: the first accurate measurements of the Moon's fossil figure (and the primordial spin pole of the Moon), and the observation of a new class of lunar paleopole recorded in polar volatiles.

The Moon's Fossil Figure: As first recognized by Laplace [4], the Moon's rotational and tidal bulges are much larger than expected from hydrostatic equilibrium assuming the Moon's present orbital and rotational state. This excess deformation has been ascribed to a "fossil figure"—an elastically supported lithosphere preserving an epoch of lunar history when the Moon was closer to the Earth and was subject to larger tidal/rotational potentials. While the presence of a fossil figure can explain the Moon's observed figure (quantified by the Moon's inertia tensor or degree-2 gravity), early attempts necessitated the formation of the lithosphere during a period of high eccentricity and/or higher-order spin-orbit resonance [5,6], which is problematic for the formation of an elastic lithosphere [7].

Keane & Matsuyama [1] and Garrick-Bethell et al. [3] independently explained this anomalous lunar figure by removing the contribution of impact basins from the lunar figure. Impact basins have some power in degree-2 topography and gravity and obscure the true underlying fossil figure. Keane & Matsuyama showed that South Pole-Aitken (and the other large basins to a much smaller extent) resulted in ~20° of polar wander. Furthermore, removing impact basins and TPW also results in a figure consistent with an early low-eccentricity, synchronous lunar orbit. Using a different technique, Garrick-Bethell et al. also found a small amount of polar wander due to basins, although they did not fully address the nature of the fossil figure. A detailed comparison of these two methodologies will be presented.

A Paleopole Recorded in Ice: Siegler et al. [2] recently identified an off-polar, antipodal polar hydrogen enhancements as candidate "volatile" paleopoles. Dynamical analysis indicates that this paleopole resulted from TPW due to the formation and evolution of the Procellarum KREEP Terrane (PKT). As polar volatile stability requires extremely low obliquities (<12°), the epithermal neutron paleopole likely tracks TPW in the last 3 Gyr, after the Cassini-state transition. This paleopole also provides a new window into the geologic history of the PKT, as the TPW is strongly dependent on the heating and uplift history of the PKT.

A Unified Chronology of Lunar Polar Wander: Although there is significant scatter in the observed lunar paleopoles (Fig. 1), there is promise in unifying these paleopoles into a cohesive TPW chronology. The fossil figure [1,3] provides the "initial" spin pole of the Moon. Paleomagnetic poles likely trace the lunar pole during the first Gyr of lunar history when the core dynamo was active. Finally, the strong sensitivity of polar volatiles to spin geometry means that the volatile paleopole [2] are particularly sensitive to small amounts of polar wander, late in lunar history.

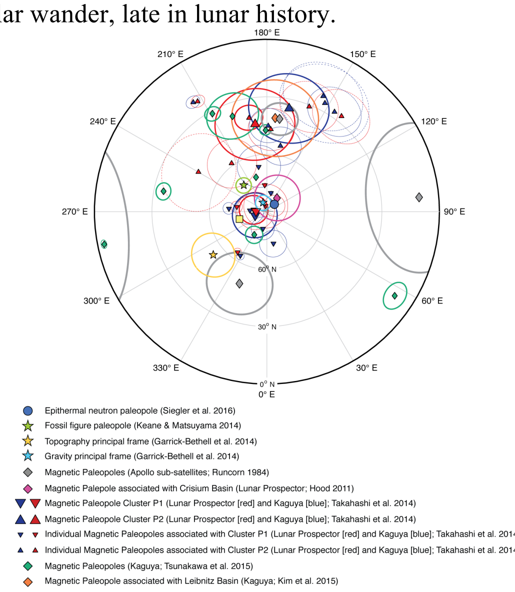

Fig. 1: The many proposed lunar paleopoles.

References: [1] Keane J. T. and Matsuyama I. (2014) *GRL, 41,* 6610–6619. [2] Siegler M. A. et al. (2016) *Nature,* in press. [3] Garrick-Bethell, I. et al. (2014) *Nature,* 512, 181-184. [4] Laplace P.-S. (1878) *Oeuvres comptetes de Laplace*, Gauthiers-Villars. [5] Garrick-Bethell, I. et al. (2006) *Science*, 313, 652-655. [6] Matsuyama, I (2013) *Icarus*, 222, 411-414. [7] Meyer, J. L. et al. (2010) *Icarus*, 208, 1-10.