A THREE-BILLION-YEAR HISTORY FOR THE LUNAR DYNAMO. S. M. Tikoo[1-4], B. P. Weiss[2], D. L. Shuster[3,4], C. Suavet[2], H. Wang[2], and T. L. Grove[2], [1]Department of Earth and Planetary Sciences, Rutgers University, Piscatwaway Township, NJ 08854 (sonia.tikoo@rutgers.edu), [2]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, [3]Department of Earth and Planetary Science, University of California, Berkeley, CA 94720, [4]Berkeley Geochronology Center, Berkeley, CA 94709.

Introduction: Lunar paleomagnetic studies indicate that the Moon generated a core dynamo with surface field intensities of ~20-110 μT between at least 4.25 and 3.56 billion years ago (Ga) [1-4]. The field subsequently declined to <~4 μT by 3.19 Ga [5], but it has been unclear whether the dynamo had ceased by this time or just greatly weakened in intensity. To investigate whether the lunar dynamo was still active after 3.56 Ga, we conducted a new analysis of regolith breccia 15498, a young rock that is capable of providing exceptionally high-fidelity paleomagnetic records.

Sample Description and Age: 15498 consists of clasts mainly derived from mare basalt fragments that are welded with basaltic composition melt glass [6-7]. We determined a 3.310 ± 0.024 Ga $^{40}Ar/^{39}Ar$ plateau age for one mare basalt clast, which places an upper limit on the lithification age of the breccia. Our thermochronometry modeling of the clast's thermal history suggests that 15498 formed between ~1-2.5 Ga. This range is consistent with trapped Ar data that indicate a ~1.3 Ga lithification age for the rock [8]. Our rock magnetic studies indicate that FeNi grains within the melt glass matrix are, on average, superparamagnetic to pseudosingle domain and are therefore excellent magnetic recorders.

Natural Remanent Magnetization (NRM): 12 mutually oriented melt glass matrix subsamples were collected from the interior of the breccia and were stepwise demagnetized using either alternating field (AF) or thermal methods. After removal of secondary magnetization components by AF levels of ~50 mT or temperatures of ~200°C, all subsamples exhibited a unidirectional, high coercivity (HC) and high temperature (HT) component blocked up to AF levels of at least 290-420 mT and temperatures up to 660-750°C (**Fig. 1**).

Paleointensity: We conducted Thellier-Thellier [9] paleointensity experiments on 6 out of the 12 matrix glass subsamples following the in-field, zero-field, zero-field, in-field (IZZI) protocol [10], including periodic checks for sample alteration. We obtained high-quality paleointensity values of 5 ± 2 μT (mean ± 1 σ) from the HT components.

Discussion: The highly stable, unidirectional nature of the HC/HT components and our paleointensity results collectively indicate that the melt glass matrix of 15498 records a primarily thermoremanent magnetization acquired during initial cooling in an ambient paleofield of

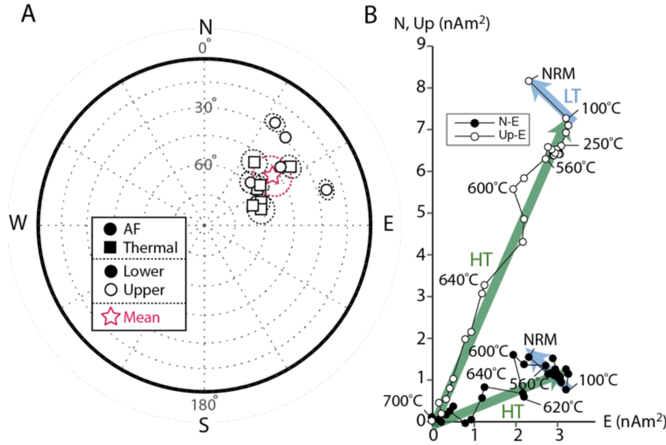

Fig. 1. (A) Equal area plot of HC/HT directions for 15498 subsamples. (B) Vector endpoint diagram showing thermal demagnetization steps for subsample 313e. LT and HT components are denoted with blue and green arrows, respectively.

~5 μT. This paleointensity is at least an order of magnitude stronger than lunar crustal fields at any Apollo landing site and external field sources like the Earth, Sun, and galactic magnetic fields [11].

The most likely mechanisms capable of generating ~5 μT fields at the lunar surface at ~1-2.5 Ga are impact fields and a core dynamo. Because the slow (several hours) primary cooling timescale of 15948 excludes a transient (<1 s) impact field origin for the observed TRM, our data strongly indicate that the glass matrix portion of 15498 preserves a dynamo record. No single dynamo mechanism proposed thus far (convective or mechanical) can explain the strong fields inferred for the period before 3.56 Ga while also allowing the dynamo to persist in such a weakened state beyond ~2.5 Ga [4]. Therefore, our results suggest that the dynamo was powered by at least two distinct mechanisms operating during early and late lunar history.

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