RELATIONSHIP BETWEEN LRO LEND NEUTRON FLUX AND LUNAR IMPACT CRATER AGES.
J.B. Garvin[1], I. Mitrofanov[2], A. Malakhov[2], and J. Frawley[1]. [1]NASA Goddard Space Flight Center, Greenbelt MD 20771 USA; [2]IKI at RAS, 117997 Moscow, Russia. (james.b.garvin@nasa.gov)

Introduction: The Lunar Reconnaissance Orbiter spacecraft (LRO) Lunar Exploration Neutron Detector (LEND) permits analysis of the neutron flux [1] for landforms with reasonably well-established surface ages, such as impact craters. In addition, thanks to LRO observations of crater geometric properties that are formation-age dependent, additional factors can be analyzed. Using LEND neutron counting statistics acquired between September 2009 and December 2010 from the primary LRO mapping orbit, we have analyzed the neutron flux signature of a population of fresh Copernican age craters in comparison with a set of “control” craters with greater formation ages (Eratosthenian). Best-available crater age data from published literature [2] has been utilized together with a set of crater geometric properties measured from released LOLA gridded data [3]. The primary objective is to test the hypothesis that neutron flux (and hence bulk Hydrogen content) signatures are related to crater formation ages, at least for impact events in some specific geological settings. Thanks to the high spatial resolving power of current LEND measurements (10-20 km), craters and their surrounding ejecta blankets can be assessed at scales not possible with Lunar Prospector LPNS data. A set of 24 impact crater targets was selected (Table 1) on the basis of crater age, morphology, and LEND sampling statistics. We fully recognize that continuously improving LEND counting statistics as well as calibrations will lead to a continual refinement of these preliminary results. Nonetheless, we believe that the basic trends established herein are noteworthy.

LRO LEND Observations: Table 1 illustrates the reference set of 24 impact features selected for analysis. It includes mostly fresh Copernican craters (FCC) with a few Eratosthenian craters as controls. Table 1 highlights the key parameters for each crater from LEND and those derived from geometric analysis of LOLA gridded data using methods developed by Garvin for Mars and Earth [4]. On the basis of the results in [1], LEND neutron flux values < 4.96 counts per second (cps) are associated with appreciable concentrations of hydrogen in the regolith, with values as high as 4 wt. % if a dry layer mantles the underlying H-bearing regolith. On the basis of preliminary analysis, there is no first-order statistical correlation of LEND neutron flux (or related H concentration) and first-order crater age. Young features such as Giordano Bruno and Aristarchus, for example, display neutron flux values that range from 4.98 cps to 5.10 cps, while much older (Eratosthenian) craters have values in a similar range. Thus, exposure of fresh regolith, whether in the mare or the highlands, does not appear to reflect local H concentration, at least in the regions sampled by the 24 craters evaluated in this study (Fig. 1). Some of the most recent but smaller complex craters evaluated, however, do show the greatest level of neutron suppression, suggesting the possibility of enhanced regolith hydrogen (e.g., Kepler, Godin).

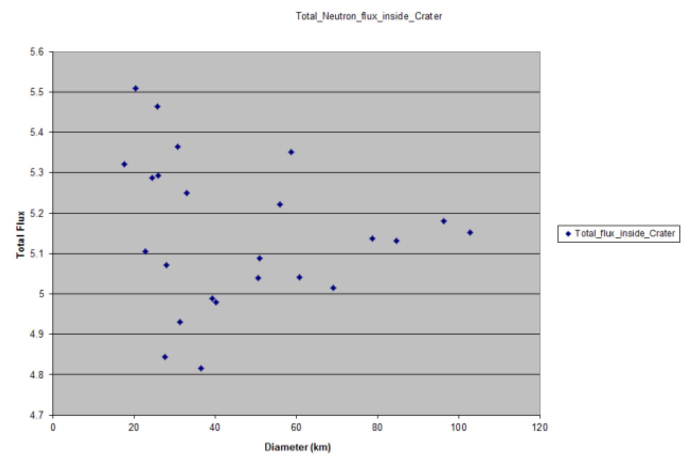

Figure 1: **Distribution of LEND neutron flux values versus crater diameter D. Note that flux values < 5.0 are correlated with smaller complex craters.**

Current LEND counting statistics limit studies to those craters larger than ~ 20km, with best results for craters with diameters D > 40km. By the end of the LRO Science mission in September 2012, the increase in LEND counting statistics should allow analysis of craters down to ~ 14 km, including a larger population of FCC’s.

Summary: The LRO LEND experiment, in combination with geometric property measurements from LOLA gridded data [3] and from published crater age estimates [2] has facilitated an initial analysis of crater age versus neutron flux, with the following general observations:

1. There is no statistically-robust global trend that links observed neutron flux with age (but this may be a limitation of the initial population of 24 craters).
2. A sub-population of the younger Copernican age craters (Kepler, Godin, Aristarchus, etc.) with diameters < 50 km display some of the lowest neutron flux values, potentially linking their regolith expo-

sure ages to hydrogen enrichment by processes as yet unknown.

3. A separate sub-population of the younger impact craters also display some of the highest neutron flux values observed, with values as high as 5.3 to 5.5 cps. These craters include Lichtenberg, Taruntius, Mosting, and Dionysius. Such values would suggest the regolith in such regions is depleted in H.
4. Geometric properties that are potentially tied to crater age, including d/D, cavity shape, ejecta thickness, and normalized cavity volume (V/SA/d) do not display any definitive trends when correlated with LEND neutron flux values, with one possible exception.
5. A potential age-related correlation between LEND neutron flux and V/SA/d can be identified if several of the older craters in the tested population are removed, but further refinement of this trend is required (on the basis of additional measurements).

Next Steps: We are currently increasing the LEND counting statistics for a population of 35 impact features by including the entire annular region associated with each crater's continuous ejecta blanket. This increases the lunar surface area counted and includes all of the ejecta within two crater radii of the rim crest. As LEND counting statistics improve with observation time, we will continue to expand the population of craters tested to produce a set of transfer functions that link crater age, geometric properties, and neutron flux. {We gratefully acknowledge the support of R. Vondrak, M. Wargo, J. Green, and N. White}.

References: [1] Mitrofanov I. et al. (2010) *Science 330*, p. 483-486. [2] Wilhelms D. (1987) *USGS Prof. Paper 1348*. [3] Zuber M. et al. (2010) *Space Sci. Rev. 150*, p. 63-87. [4] Garvin J. B. et al. (2000) *Icarus 144*, p. 329-352.

Name	Diam (km)	Age (Ga)*	LEND Neutron flux	d/D	Cav Shape n	ETF exp	slope	V/SA/d
Copernicus	96.398	0.85	5.1808522	0.044	2.399	-2.214	9.4	0.626
Petavius B	33	1	5.2491825	0.025	2.865	-0.1	2.344	0.599
Lichtenberg	20.409	1	5.5097331	0.13	1.493	-1.673	16.128	0.974
Proclus	28.111	0.5	5.0706631	0.159	1.958	3.988	22.943	0.515
Anaxagoras	50.683	1	5.038689	0.094	2.377	3.272	9.796	0.608
King	78.801	1	5.1369388	0.069	2.836	5.588	51.849	0.622
Eudoxus	69.132	1	5.0147364	0.074	2.543	-1.711	13.372	0.665
Aristarchus	40.326	0.5	4.9789294	0.092	2.12	4.245	15.878	0.551
Kepler	31.462	0.5	4.9310122	0.098	2.059	-2.258	15.639	0.534
Tycho	84.722	0.109	5.1315224	0.063	2.391	4.405	12.455	0.624
Giordano Bruno	22.855	0.01	5.10487	0.175	2.343	-34.61	21.632	0.501
Eratosthenes	60.731	3.2	5.0416526	0.09	2.413	-3.115	10.982	0.698
Autolycus	39.32	1.29	4.9886632	0.103	2.088	-2.318	16.423	0.726
Dionysius	17.749	1	5.3210539	0.168	1.537	0.944	26.967	0.440
Mosting	25.795	1	5.4645746	0.13	1.529	-2.0	14.779	0.487
Triesnecker	25.919	1	5.2921434	0.11	1.813	-3.924	13.603	0.528
Godin	36.519	1	4.8157687	0.113	2.141	-3.436	14.725	0.473
Crookes	51.089	1	5.0884662	0.098	2.298	3.381	14.563	0.973
Aristillis	55.973	1	5.2209159	0.071	2.667	-3.092	14.661	0.816
Taruntius	58.871	1	5.350566	0.046	3.054	-8.719	11.367	0.862
Picard	24.572	2	5.2875885	0.103	1.606	-3.117	13.258	1.67
Euler	27.748	2	4.8432766	0.091	1.697	-2.213	11.64	0.67
Lambert	30.766	3.2	5.3634741	0.088	2.238	-1.459	14.125	0.931
Theophillius	102.924	3.2	5.1511992	0.059	2.868	-3.086	11.816	0.709

Table 1: *Population of 24 craters tested in terms of LEND neutron flux, best-estimate of age, and specific crater geometric properties (from LOLA-based measurements). Crater ages* derived from published literature [2].*