ENHANCED HYDROGEN ABUNDANCES NEAR BOTH LUNAR POLES. W.C. Feldman[1], S. Maurice[2], D.J. Lawrence[1], I. Getenay[2], R.C. Elphic[1], B.L. Barraclough[1], and A.B. Binder[3], Los Alamos National Laboratory, Los Alamos, NM 87545, wfeldman@lanl.gov, [2]Observatoire Midi-Pyrènèes, Toulouse, France, [3]Lunar Research Institute, Gilroy, CA 95020

Chemical analyses of all samples of the Moon returned to Earth show that the lunar surface is highly depleted in volatiles [1]. Specifically, the hydrogen content of lunar soils averages only 50 ppm, which can be explained in terms of surface implantation of solar wind hydrogen. We note that all returned samples come from near-equatorial latitudes where day time temperatures are sufficiently high that water is not stable to evaporation, photo dissociation, ionization, and eventual loss to space through pickup by the solar wind. However, it has long been postulated that a significant fraction of water delivered to the Moon by comets, meteoroids, and interplanetary dust, can be stably trapped within the permanently shaded floors of polar craters where temperatures are sufficiently low that sublimation times can be longer than several billion years [2,3].

Recent results from analysis of the high-altitude (100±20 km) portion of the Lunar Prospector Neutron Spectrometer (LPNS) data set [4] have revealed that hydrogen abundances near both lunar poles are enhanced relative to that which exist at equatorial latitudes. Because this average enhancement is not much larger than the near-equatorial average of 50 ppm, it is reasonable to ask how much of the polar H enhancement comes from the solar wind and how much comes from lunar impacts by solid interplanetary materials. Perhaps the low temperatures at polar latitudes could reduce loss rates of solar wind implanted hydrogen sufficiently to account for the inferred difference between average polar and equatorial hydrogen abundances.

Although the foregoing suggestion is plausible, neither laboratory simulations on returned soil samples, nor numerical simulations of hydrogen loss rates from the radiation-damaged surfaces of soil grains, have been performed to prove its feasibility. We try to address this question by analyzing the low-altitude (30±15 km) portion of LPNS data to search for relatively small spatial-scale enhancements in hydrogen abundances at both lunar poles. Maps were constructed of epithermal-neutrons corrected for elemental abundance variations by subtracting 7% of measured thermal-neutron counting rates. Although the spatial resolution of the LPNS at 30 km altitude is about 55 km FWHM, we binned all the data in 0.5^o x 0.5^o spatial pixels and then applied a 30 km FWHM Gaussian smoothing algorithm. Resultant polar maps of corrected epithermal counting rates are shown in Figure 1. Inspection reveals discrete depressions in counting rates that are superimposed on more generally distributed depressions that surround both poles. Comparison with the radar-measured polar topography shows that the areas of most depressed epithermal counts rates in the south overly craters that have floors in permanent shade. Furthermore, these depressions are neither cylindrically symmetric about either pole nor do they minimize at the poles. Similar maps of fast neutrons (not shown here) reveal a single, statistically-significant depression centered on the maximum depression of the epithermal neutrons at about (88^o S, 20^o E). Comparison between high-altitude and low-altitude epithermal maps reveals a larger depression at low altitudes in the south but the same magnitude of depression in the north. Hydrogen enhancements in the south must therefore have spatial scales comparable to the spatial resolution of LPNS, 55 km FWHM, yet consist of smaller clumps more uniformly distributed over the LPNS field of view in the north. A quantitative comparison between measured epithermal counting rates and numerical simulations using the measured polar topography [5] yields the following: 1) hydrogen abundances within the permanently shaded craters near the south pole are equivalent to a water-ice mass fraction of 1.5±0.8%, 2) the enhanced hydrogen within these craters must not be buried beneath the surface by more than about 10 g cm^{-2} (5 cm at a density of 2 g cm^{-3}), 3) the hydrogen abundance near both poles averages 100 ppm above that known from near-equatorial returned soil samples (50 ppm, [1]), and 4) the total mass content of hydrogen poleward of -75^o is about $200x10^6$ metric tons, and that poleward of $+75^o$ is about $150x10^6$ metric tons. If the enhanced hydrogen within all regions of permanent shade near both poles is in the form of water ice, then use of the area estimates given by Margot et al. [5] yields estimates of 135 (240) $x10^6$ metric tons in the 2250 (4000) km^2 of shaded areas poleward of -87.5^o, and $62x10^6$ metric tons in the 1030 km^2 of shaded areas poleward of $+87.5^o$.

We note, however, that neutron observations by themselves cannot uniquely identify the chemical form of hydrogen in lunar regolith. That is, LPNS data cannot discriminate solar wind implanted hydrogen from OH, H_2O, etc. In the absence of a temperature map of the lunar poles and a knowledge of the retentivity of hydrogen by lunar soil grains as a function of temperature, sufficient information is not yet available to uniquely identify water ice deposits at the lunar poles. Nevertheless, the floors of permanently shaded polar craters are predicted to have temperatures sufficiently low that water ice should be stable for billions of years, yet uncratered surfaces near the polar cap are too high in temperature to retain water ice [6]. This suggests that at least some of the enhanced deposits of hydrogen identified by LPNS are in the form of water ice.

References: [1] Haskin and Warren, in 'Lunar Sourcebook, a User's Guide to the Moon', G.H. Heiken, D.T. Vaniman, and B.M. French, eds., Cambridge U. Press, p. 357, 1991; [2] Watson, K., et al., JGR, 66, 1598, 1961; [3] Arnold, J., JGR, 84, 5659, 1979; [4] Feldman et al., Science, 281, 1496, 1998; [5] Margot et al., Science, 284, 1658, 1999; [6] Vasavada, A. R., et al., Icarus, submitted 1998.

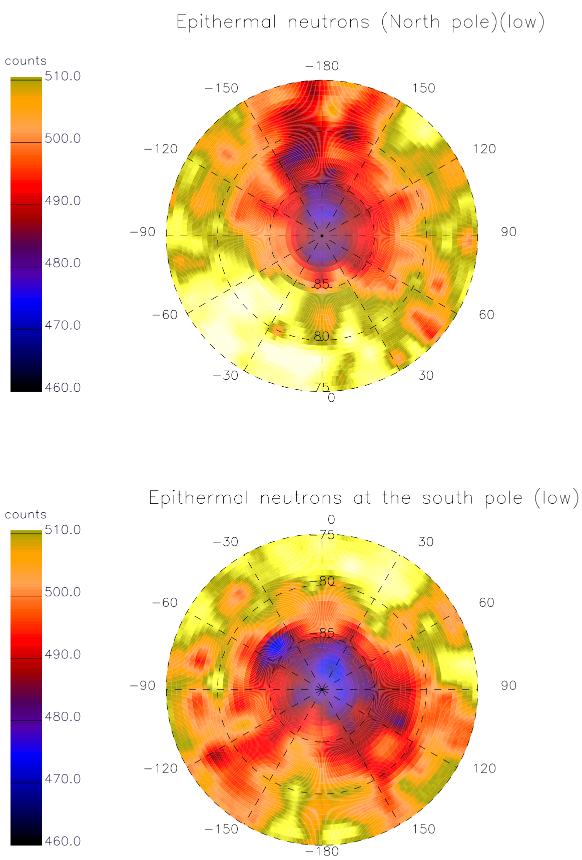

Figure 1: Counting rates of (epithermal - 0.07 x thermal) neutrons poleward of ±75° latitude.