

Evidence for Water Ice Near the Lunar Poles. W.C. Feldman¹, S. Maurice², D.J. Lawrence¹, R.C. Little¹, S.L. Lawson¹, O. Gasnault¹, R.C. Wiens¹, B.L. Barraclough¹, R.C. Elphic¹, T.H. Prettyman¹, J.T. Steinberg¹, and A.B. Binder³. ¹Los Alamos National Laboratory, Los Alamos, New Mexico; ²Observatoire Midi-Pyrénées, Toulouse, France; ³Lunar Research Institute, Tucson Arizona.

Lunar Prospector epithermal neutron data were studied to evaluate the probable chemical state of enhanced hydrogen, [H], reported previously to be near both lunar poles [1,2]. Improved versions of thermal and epithermal neutron data were developed for this purpose. Most important is the improved spatial resolution obtained by using shortened integration times. A new data set was created, $Epi^* = [Epithermal - 0.057 \times Thermal]$, to reduce effects of composition variations other than those due to hydrogen.

The Epi^* counting rates are generally low near both lunar poles and high over terrane near recent impact events such as Tycho and Jackson. However, other lunar features are also associated with high Epi^* rates, which represent a wide range of terrane types that seem to have little in common. If we postulate that one property all bright Epi^* features do have in common is low [H], then measured Epi^* counting rates appear to be quantitatively self consistent. If we assume that $[H]=0$ above the top 98th percentile of Epi^* counting rates at $2^\circ \times 2^\circ$ spatial resolution, then $[H]_{ave} = 55$ ppm for latitudes equatorward of $|75^\circ|$. This value is close to the average found in returned lunar soil samples, $[H]_{ave} \sim 50$ ppm [3].

Using the foregoing physical interpretation of Epi^* counting rates, we find that the Epi^* counts within most of the large craters poleward of $\pm 70^\circ$ are higher, and therefore [H] is lower, than that in neighboring inter-crater plains, as shown in Figure 1. Fourteen of these craters that have areas larger than the LP epithermal spatial resolution (55 km diameter at 30 km altitude), were singled out for study. [H] is generally found to increase with decreasing distance from the poles (hence decreasing temperature). However, quantitative estimates of the diffusivity of hydrogen at low temperature show that diffusion can not be an important factor in explaining the difference between the relatively low [H] observed within the large sunlit polar craters and the relatively high [H] in neighboring inter-crater plains.

A closer look at the 'inter-crater' plains near the poles, shows that they are covered by many small craters that harbor permanent shade [4].

The temperatures within many of these craters are low enough [5] that they can disable sublimation as a viable loss process of $[H_2O]$. It is therefore tempting to postulate that the enhanced hydrogen within most regions of permanent shade is in the form of water molecules. This postulate is certainly viable within the bottoms of several large, permanently shaded craters near the south pole. Predicted temperatures within them [5] fall well below the 100 K temperature that is needed to stabilize water ice for aeons.

The picture is different near the north pole. Here, there are relatively few permanently-shaded craters that are large enough to harbor temperatures that are sufficiently low to stabilize water ice indefinitely against sublimation [5]. Instead, the 'inter-crater' polar plains are a jumble of many permanently-shaded craters that have diameters less than 10 km [4]. Although simulations of temperatures within this class of craters show they are only marginally cold enough to indefinitely stabilize water ice [5], this terrane appears to have the highest [H]. Nevertheless, predicted temperatures are close enough to that needed to permanently stabilize $[H_2O]$ to suggest that sublimation is indeed the process that discriminates between polar terrane that contains enhanced [H] and those that do not (see, e.g., the temperature estimates for doubly-shaded craters [6]). If correct, then an important fraction of the hydrogen near the north pole must be in the form of H_2O , which then resides within these small craters.

Estimates using our improved data set of [H] within craters near the south pole remain unchanged from those derived from our previous analysis [2], $[H] = 1700 \pm 900$ ppm. This translates to $[H_2O] = 1.5 \pm 0.8\%$. If all of the enhanced hydrogen in the north is in the form of H_2O and is confined to the jumble of small permanently-shaded craters identified by radar [4], then we can estimate their water-ice fraction, $[H_2O]$, using Figure 1a in [2]. We chose two regions near the north pole for this purpose. They each have areas just larger than the surface foot-print of the LP epithermal neutron

spectrometer. The first was an inter-crater region nestled between Rozhdestvenskiy and Plaskett, and the second covered the southeast corner of Peary. Using Figure 3 of [4], the first area contains 232 km² of measured permanent shade, and the second contains 129 km². Adopting the prescription used in Table 1 of [4] for estimating actual from sampled shaded areas, multiplication of sampled areas by 1.5 yields permanently shaded areas that amount to 350 km² in region 1, and 200 km² in the southeast corner of Peary. Comparison of the Epi* counts for both regions with the curves in Figure 1a of [2] yields an estimate for [H₂O] that is greater than 10%. Although this estimate is very uncertain (reflecting our large uncertainty in area of permanent shade), if correct, the resultant [H]

content is significantly higher than what can be delivered from the solar wind to, and retained by, the lunar polar terrane. Such a large value for [H] by itself, rules in favor of the existence of significant water ice deposits at both lunar poles.

References: [1] Feldman, W.C., et al. (1998) *Science*, 281, 1496-1500. [2] Feldman, W.C., et al. (2000) *J. Geophys. Res.*, 105, 4175-4195. [3] Haskin, L., and P. Warren (1991) in *Lunar Sourcebook, a User's Guide to the Moon*, G. Heiken, D. Vaniman, B.M. French, eds., pp 357-474. [4] Margot, J.L., et al. (1999) *Science*, 284, 1658-1660. [5] Vasavada, A.R., et al. (1999) *Icarus*, 141, 179-193. [6] Carruba, V., A. Coradini (1999) *Icarus*, 142, 402-413.

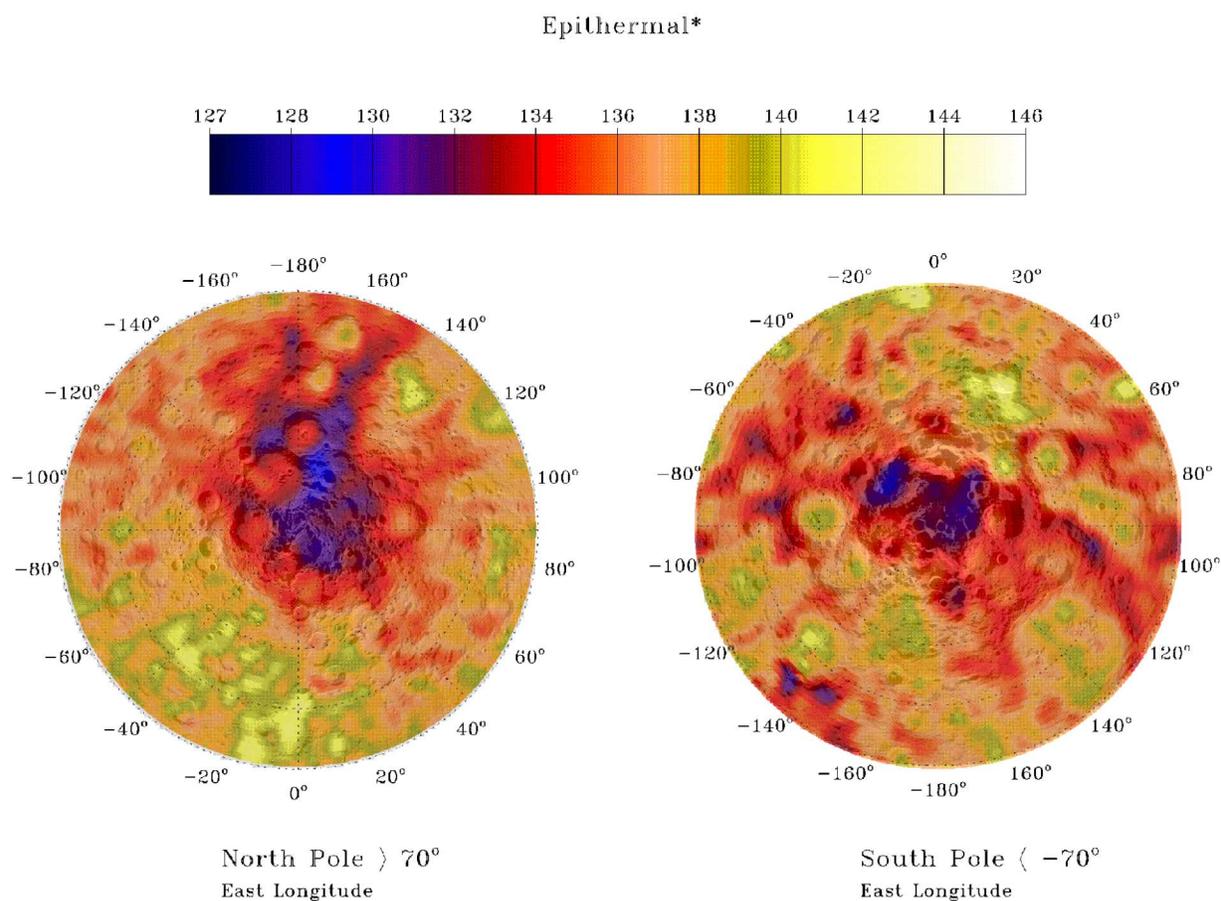


Figure 1. Overlays of stereographic projections of the Epi* neutron flux and Clementine 750 nm intensity poleward of +70° (left) and -70° (right) latitudes.