LUNAR SOUTH POLE HYDROGEN & WATER ICE DEPOSITS: CONSTRAINTS FROM LUNAR PROSPECTOR MAGNETIC FIELD OBSERVATIONS. E. W. Schaler[1] , M. E. Purucker[2], [1]Magnet Program at Montgomery Blair H.S. (Silver Spring, MD), [2]Raytheon at Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, (Code 698, purucker@geomag.gsfc.nasa.gov).

Summary: The source of the anomalous hydrogen in the south polar region of the moon has long been puzzling. The conflicting interpretations of neutron spectrometers and long-wave radar suggest that other techniques should be brought to bear to address this question. Magnetic field measurements of internal origin, measured by Lunar Prospector's fluxgate magnetometer, were used to map the crustal magnetic field in the polar region. Magnetic fields originating from the moon can act to stand off the solar wind and prevent the implantation of solar wind hydrogen. We find a positive correlation between high hydrogen presence and an elevated magnetic field, suggesting that implanted hydrogen is not a significant hydrogen source. Six craters - Shoemaker, Nobile, and unnamed craters at (87.7 S, 99.8 W), (85.5 S, 48.1 E), (87.5 S, 4.0 W), and (88.5 S, 87.0 W) - have been isolated as likely targets for water ice deposits.

Introduction: Permanently shadowed craters near the lunar south pole have long attracted attention as a possible host for water ice deposits. Satellites, including Clementine in the early '90s, and Lunar Prospector in 1999, have given tantalizing hints that water ice may be present. Results of neutron spectrometer mapping from orbit [1] and long wavelength radar [2] have not yielded a consistent picture of the source of the anomalous hydrogen. The neutron spectrometer results suggest that 2.4E8 metric tons of water may be present, while analysis of long-wave radar data generates the conclusion that 'any ice… must be in the form of disseminated grains or thin interbedded layers'.

Magnetic data can provide insight into the geological composition of the region and identify major anomalies that influence the surrounding lunar system. For example, the presence of a strong magnetic field is capable of protecting the lunar regolith from external interference by standing off fields of non-lunar origin, such as the solar wind field.

Data: Spin averaged magnetometer data from Lunar Prospector were used after transformation from SEL coordinates into a local spherical system. Modelingof the south pole's magnetic field observation utilized observations collected on 35 of the 560 days during which the magnetometer was in operation – 27 days in the magnetotail of the Earth, 4 days in the magnetosheath, and 4 days in the solar wind. The data is evenly distributed throughout the examined region between 75 degrees latitude and the pole, and incorporates altitudes between 16 and 50 km.

Model:

External magnetic field. A simple model of the external field, that of a uniform field over each satellite half-orbit, was removed from the observations. We varied this parameterization by centering our half-orbital passes both on the pole and on the equator. The resulting vector fields are shown in Figure 1. Note that fields of internal origin appear on multiple passes because of the spacing of adjacent passes, and their altitude above the surface.

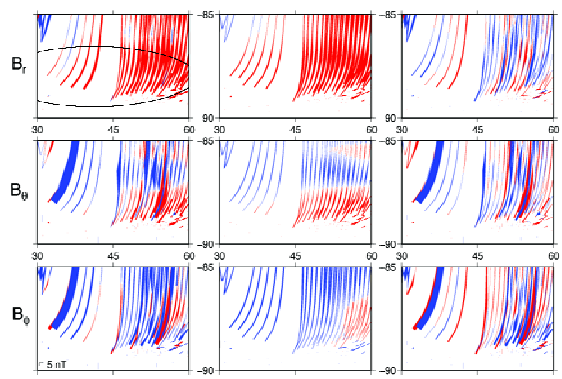
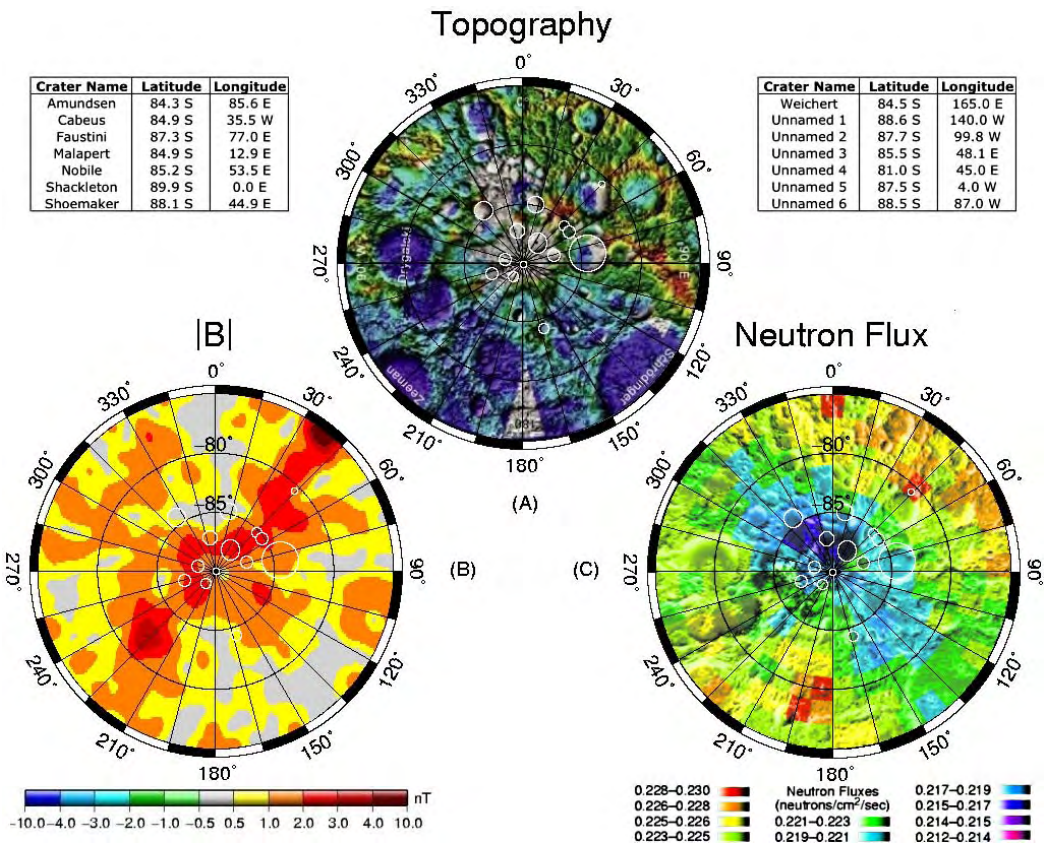


Figure 1. Magnetic profiles over the lunar south pole at crater Shoemaker, an outline of which appears in the top left box. Plots depict the observations of the magnetic field after external field model removal (left column), the modeled internal component (middle), and the remaining unfit field (right).

Internal magnetic field. The internal magnetic fields and sources within the lunar crust are modeled using an equivalent source technique, on an equal area grid of 2530 dipoles. The magnetic dipoles are expressed in a spherical coordinate system and defined as being radially-oriented with a half-degree latitude spacing and variable longitude spacing. The dipole magnitudes are constrained through the use of all three orthogonal magnetic field components (Figure 1, left). This allows for the generation of altitude-normalized maps of the magnetic field components, and the associated scalar (Figure 2), for comparison with the neutron flux, and topography.



Crater Name	Latitude	Longitude
Amundsen	84.3 S	85.6 E
Cabeus	84.9 S	35.5 W
Faustini	87.3 S	77.0 E
Malapert	84.9 S	12.9 E
Nobile	85.2 S	53.5 E
Shackleton	89.9 S	0.0 E
Shoemaker	88.1 S	44.9 E

Crater Name	Latitude	Longitude
Weichert	84.5 S	165.0 E
Unnamed 1	88.6 S	140.0 W
Unnamed 2	87.7 S	99.8 W
Unnamed 3	85.5 S	48.1 E
Unnamed 4	81.0 S	45.0 E
Unnamed 5	87.5 S	4.0 W
Unnamed 6	88.5 S	87.0 W

Figure 2. Comparison of three views of the south polar region (75 S to the pole). (A) a shaded relief topographic map of the lunar surface (modified from [3]. Craters highlighted in white represent regions found to exist in perpetual shadow [4] [1] [5]. (B) an altitude-normalized projection at 30 km of the scalar magnitude of the internal magnetic field, utilizing a parameterization of the external field that was centered at the pole and (C) a color-coded map of the crustal neutron flux, modified from [6].

Discussion: Six craters have been identified (Figure 2) which exhibit characteristics favorable for the presence, and retention of water ice deposits. For example, Crater Shoemaker is located almost directly over a relatively large magnetic feature (Figure 1) with a scalar field strength of approximately 3.2 nT at 30 km altitude, and is also in a region identified as having a low neutron flux. The relatively strong internal magnetic fields produce a mini-magnetosphere [7] that, in quiet times, prevents the implantation of solar wind hydrogen. The effectiveness and scope of this mini-magnetosphere can be documented by the data of Figure 1: sequential (adjacent) passes demonstrate a strong correlation, a characteristic demonstrating that the mini-magnetosphere's field of influence extends above the altitude of measurement (33+-17 km).

A relatively strong magnetic field, like the one observed over Crater Shoemaker and in several other areas near the south pole, is capable of standing off the solar wind during quiet times. The consequences are two-fold: magnetically-shielded regions would contain lower quantities of solar wind-implanted hydrogen (than those measured elsewhere on the moon), and would also be protected from solar radiation, thereby preserving any existing water ice deposits.

The results of this study further refine the potential location of water ice deposits at the lunar south pole. Six specific craters – Shoemaker, Nobile, and Unnamed 2,3,5, and 6 (Figure 2A) – have been isolated as likely targets for such deposits.

References: [1] Feldman W.D. et al (2000) *JGR*, 105, 4175-4195 [2] Campbell B. D. et al. (2003) *Nature*, 426, 137-138 [3] USGS Astrogeology Research Program (2006) [4] Margot J. D. et al. (1999) *Science*, 284, 1658-1660 [5] Berezhnoy A. E. et al. (2005) *LPSC XXXVI*, 1061 [6] Feldman W.D. et al (1998) *Science*, 281, 1496-1500.

Additional Information: Further information can be found at our web page: http://geodynamics.gsfc.nasa.gov/personal_pages/purucker/purucker.html