LCROSS: IMPLICATIONS FOR A LUNAR CATACLYSM. G. D. Bart[1], A. Colaprete[2], [1]*Dept. of Physics, Univ. of Idaho, Moscow, ID (USA), (gwen@barnesos.net)*, [2]*NASA Ames Research Center, M/S 245-3, Moffett Field, CA 94035.*

Introduction: The evolution of the early solar system was dominated by impacts. The rate at which these impacts occurred over the first billion years of solar system history is not yet entirely understood. One possibility is that the number of impacts simply tapered off slowly with time. However, evidence from both returned Apollo samples [1], and from found lunar meteorite samples [2] indicate that there was also a brief but intense period of bombardment about 3.9 billion years ago. Several unknowns remain regarding this lunar cataclysm. For instance, what was the source of the impactors? Were they asteroids or comets? What perturbed their orbits to produce this cataclysm? In this abstract we first introduce the LCROSS mission, and then discuss some ways that the LCROSS data may be able to help answer some questions about the lunar cataclysm.

LCROSS:

Lunar CRater Observation and Sensing Satellite (LCROSS), will be launched on the same rocket as the Lunar Reconnaissance Orbiter (LRO) later this year (http://lcross.arc .nasa.gov). The primary LCROSS objective is to confirm the presence or absence of water ice in a permanently shadowed region on the Moon. Other related objectives include identifying the form and state of hydrogen observed at the lunar poles; quantifying (if present) the amount of water in the lunar regolith, with respect to hydrogen concentrations; and characterizing the lunar regolith within a permanently shadowed crater on the Moon. The presence of the water ice is hypothesized [3, 4] and supported by data from the Lunar Prospector neutron spectrometer showing hydrogen in permanently shadowed regions at the poles [5].

The LCROSS spacecraft will set the rocket's Centaur Earth departure upper stage (EDUS) on an impact trajectory with the Moon. Once the trajectory is set, the spacecraft will release the EDUS, which will then impact the Moon in a permanently shadowed region characterized by high concentrations of hydrogen according to the Lunar Prospector neutron spectrometers. Following four minutes behind the EDUS, LCROSS will fly through the impact plume, using its 9 instruments to examine the impact ejecta. The LCROSS payload includes 5 cameras (1 visible, 2 Near IR, 2 Mid IR), three spectrometers (1 visible, 2 NIR) and one photometer.

Although the primary LCROSS objective is to look for water, its instruments will be taking data about the entire impact plume. It will be excavating to a depth of about 10 m, identifying subsurface composition at the pole.

Impact Site Candidates: Four regions are currently candidates for the LCROSS impact: Shoemaker crater (88.1°S, 44.9°E, 50.9 km diameter), Shackleton crater (89.9°S, 0.0°E, 19 km diameter), Faustini crater (87.3°S, 77.0°E, 39 km diameter), and Cabaeus (85°S, 35°E). These regions are labeled in Fig. 1.

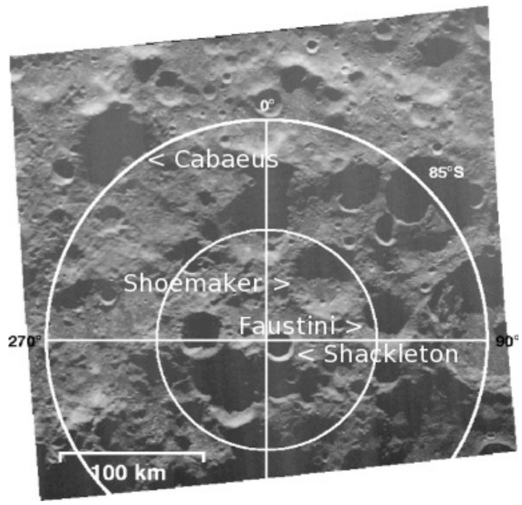

Figure 1: Illustration of the location of possible candidate impact locations for LCROSS, superimposed on a radar backscatter map of the lunar south pole from [6].

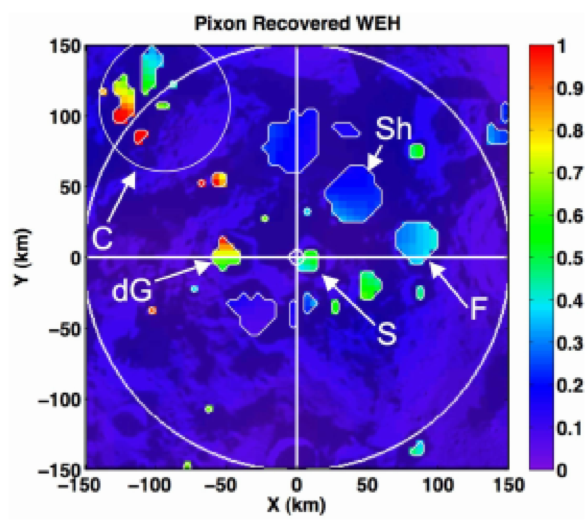

Figure 2: Water-equivalent hydrogen (WEH) in wt% corresponding to the epithermal count rates. Large circle denotes 85S. *C* = Cabaeus, *Sh* = Shoemaker, *dG* = de Gerlache, *S* = Shackleton, *F* = Faustini. From [7].

Target Selection Criteria:

In order to meet its primary science objectives, LCROSS has several required criteria for target selection. One criteria is that the site must be observable from ground based observatories. There are a variety of ground-based and orbital observations planned that will observe the dust and water plumes caused by the LCROSS impacts. The impacts are currently planned to occur with most favorable viewing geometry from Hawaii and North and South America.

Another criteria is that the ejecta plume be illuminated by sunlight. Since the LCROSS instruments primarily measure reflected light, instrument sensitivity will be greatest when the maximum amount of ejecta is exposed to sunlight.

Target properties are also important. Slopes should not exceed 10 degrees; lower slopes are preferred. Surface roughness must also be considered; a smoother surface is preferred. Low slopes and low surface roughness will will provide the best ejecta plume for detecting water.

The final criteria is that the location have an observed concentration of increased hydrogen, which could indicate the presence of water (Fig. 2).

Impact Site Characterization:

In order to meet these criteria we first must characterize the potential impact sites. Characterizing the terrain within the crater is difficult because the target impact site must be permanently shadowed. Because of lack of high resolution visible imaging at the poles, we would like to use high resolution ground based radar data [8]. Because the radar illuminated the Moon from the Earth, some of the observations were made in the permanently shadowed regions. Using this data we would like to characterize, if possible, the crater age, slope steepness, crater density, boulder density, and regolith depth.

Once the observable target parameters are established, we can conduct comparison studies of similar craters elsewhere on the Moon. We can obtain high resolution images of such craters and study their interior topographic profiles to better constrain the LCROSS impact site. Furthermore, once the tools and analysis methods are established, we will be ready to quickly assess new data provided by the instruments on LRO, which will begin taking data 2-3 months prior to the LCROSS impact.

Implications for the Lunar Cataclysm:

There are two main ways that LCROSS can contribute to understanding the lunar cataclysm. One is by simply carrying out its primary objective: detecting water (or the lack thereof.) One of the questions regarding the lunar cataclysm is the source of the impactors. It has been proposed that as the orbits of the giant planets migrated in the early solar system, disruptive resonances arose that should scatter small, icy, outer solar system bodies and send them into the inner solar system.

If LCROSS finds water, it may support such a model. There are several sources for water trapped in permanently shadowed regions of the Moon [4]: one is delivery of water by water rich meteorites (comets). Recent studies [9] used hydrocode models to simulate lunar water retention from cometary impacts. They show that 2% of the impactor mass will be retained at impact velocities of 15 km/s. The discovery of water on the Moon would support the model of a cometary-impact-dominated lunar cataclysm.

In addition to detecting water, the LCROSS instruments will determine the composition of the impact site, providing a data point for validation of orbital compositional data [10, 11, 12], assisting in determination of the variability of the lunar crustal composition.

Conclusion:

Characterizing potential impact sites will be critical to providing the best scientific return from the LCROSS mission. Understanding the target as well as possible will both optimize the quality of data return and improve the analysis of the data.

The detection of water by LCROSS would support the model of a lunar cataclysm dominated by cometary impacts. Furthermore, LCROSS will determine the composition of the lunar crust at the impact location.

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