DEVOTED TO THE STUDY OF EARTH'S MOON
VOL. 29 NO. 1 SPRING 2010

SELENOLOGY

The Journal of The American Lunar Society

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The official journal of the American Lunar Society, an organization devoted to the observation and discovery of the earth's moon

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Lunokhod Rover model.
http://spacetoys.com/proddetail.php?prod=WSM10004

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Send manuscripts, general observations, photographs, drawings and other correspondence to:
Steve Boint, Pres. ALS, 1807 S. Spring Ave., Sioux Falls, SD 57105
E-mail: steveboint@earthlink.net
Send changes of address to Andrew Martin at sellallyouown@yahoo.com
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Lunar Toys
by Steve Boint

As a high school astronomy teacher, I am always looking for ways to bring the topic down to Earth, especially since my state's approach to No Child Left Behind has shifted astronomy into the midst of students less comfortable with abstract concepts. It was while surfing the Web in search of teaching aids that I discovered a world which I had forgotten—the world of space toys. Going way beyond mere tools for learning, these are FUN! And there are so many. I'd go broke buying all the lunar toys, not to mention the models.

My favorite is the lunar lander pencil sharpener. First, it isn't plastic but die-cast metal. Second, the return vessel is a different color from the landing gear, making it easy to understand the basic structure. Third, it has great detail. And fourth, it sharpens pencils—a great addition to my classroom since the district-supplied sharpener hooked to the wall breaks the tips off every pencil it sharpens (Fig. 1).

Runner-up is the Lunokhod 1 model which appears to be dwindling in supply. It was fun to snap together—no glue was needed—with the only difficulty being an arm which had to be trimmed with a knife before it would fit. It provides far more detail than I expected for the price (cover).

Figure 1: Antique version of the lunar lander pencil sharpener. http://www.pencilthings.com/lunar-lander-die-cast-miniature-antique-metal-pencil-sharpener.html

Figure 2: Pricey model of Apollo 11. http://www.warplanes.com/store/item.asp?department_id=38&item_id=1763

The Apollo 11 model of the command module and lander attached to each other is beautiful, even if a little pricey. It's a strong tool for understanding the machines which took us to the moon, but not something to lightly pass around the classroom (Fig. 2).

Staying with pricey models, the lunar lander model provides a far greater amount of detail than does the

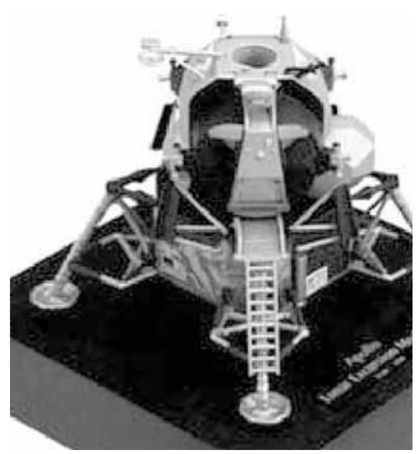


Figure 3: http://www.warplanes.com/store/item.asp?department_id=38&item_id=1144

Figure 4: Monogram model of Apollo command module. http://spacetoys.com/proddetail.php?prod=MAP14

pencil sharpener and is just plain beautiful (Fig. 3).

And as something which you probably won't find again, the plastic model of the Apollo command module is a steal at less than $100. I had a similar model of the lander when I was a kid, but could no longer find any available (Fig. 4).

I also had a lunar rover model in the 70's, but the closest I could find available was a remarkable toy which would be great for passing around the classroom or for playing with when the boss isn't looking (Fig. 5).

No model set of the Apollo missions could possibly be complete without the Saturn V. Although I

Figure 5: Lunar rover toy. http://spacetoys.com/proddetail.php?prod=LunarRoverKit

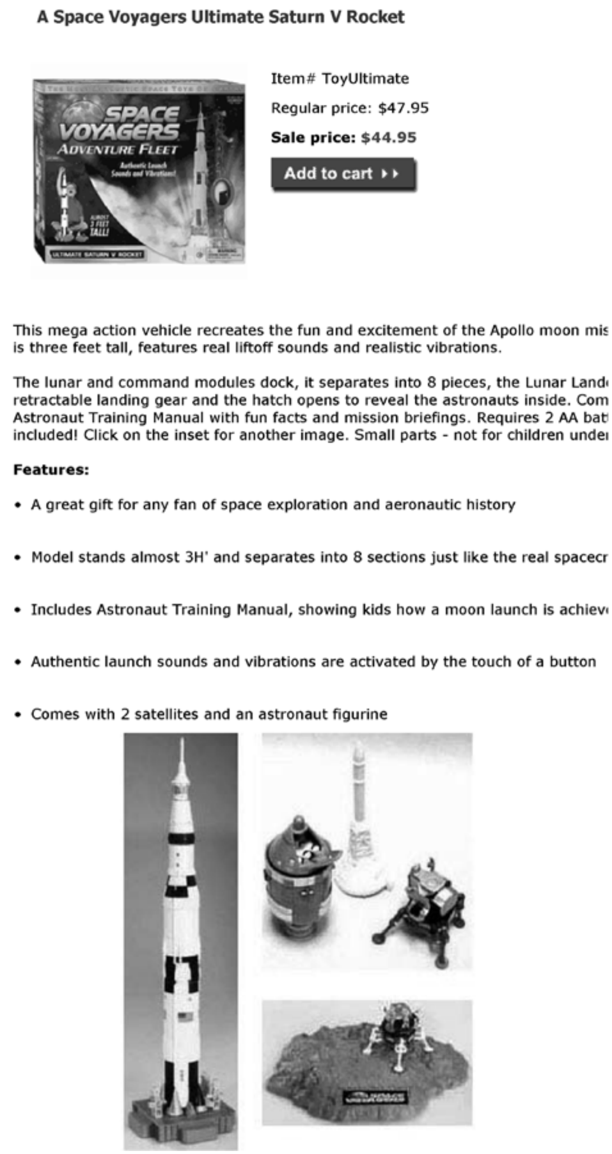


Figure 6: Your own Saturn V. http://www.thespacestore.com/spacvoyulsat.html

haven't bought this toy yet, I have bought others from this company and am very impressed with their handiwork. This has got to be about the coolest toy I've ever seen (Fig. 6).

Some sets are available which combine more than one of the vehicles and look fairly detailed (Fig. 7, Fig. 8).

For those interested in models of astronauts, and if you really want to impress people with your model astronaut, it seems unlikely that anyone else in your astronomy club would have one of these (Fig. 9).

A replica of the apparently-never-

Figure 7: The whole kit-n-kaboodle for only $9. http://shopnasa.com/store/product/3403/EZ-Build-Lunar-Rvr-Scale-Model/

going-to-be-built Orion lunar craft is even available. It's priced a little high, but given the new plans to privatize spaceship building, not even NASA would be closer to having an actual spaceship (Fig. 10).

And a mini-globe fits perfectly where a full lunar globe can't go (Fig. 11).

As far as I can tell from the ad, this pen has a compartment containing lunar simulant. If true, what better way to showcase the cutting edge of

Figure 9: This set even has a chunk of the moon. http://spacetoys.com/proddetail.php?prod=TAP39

Figure 9: Maybe a little over-the-top. http://spacetoys.com/proddetail.hp?prod=Astronaut&cat=29

lunar chemistry—at least until we return (Fig. 12).

I even stumbled across this old game. I have no idea how it's played, but it does make me won-

Figure 10: http://www.thespacestore.com/1scorspamnem.html

Figure 11: http://shopnasa.com/store/product/4057/ Wonder-Globe-Moon/

der why no one has developed a lunar exploration video game (Fig. 13).

Finally, our own Marianne Dyson has written the award-winning book, *Home On The Moon*. Not only is it a great and informative read, but it's also an excellent opportunity for writing a book review and getting it published in Selenology—hint (Fig. 14).

Figure 12: http://www.thespacestore.com/moon-dustpen.html

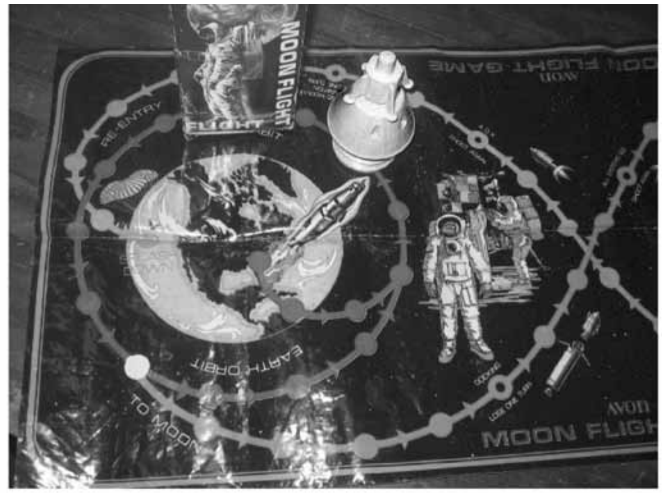


Figure 13: http://www.timewarptoys.com/mflight1.jpg

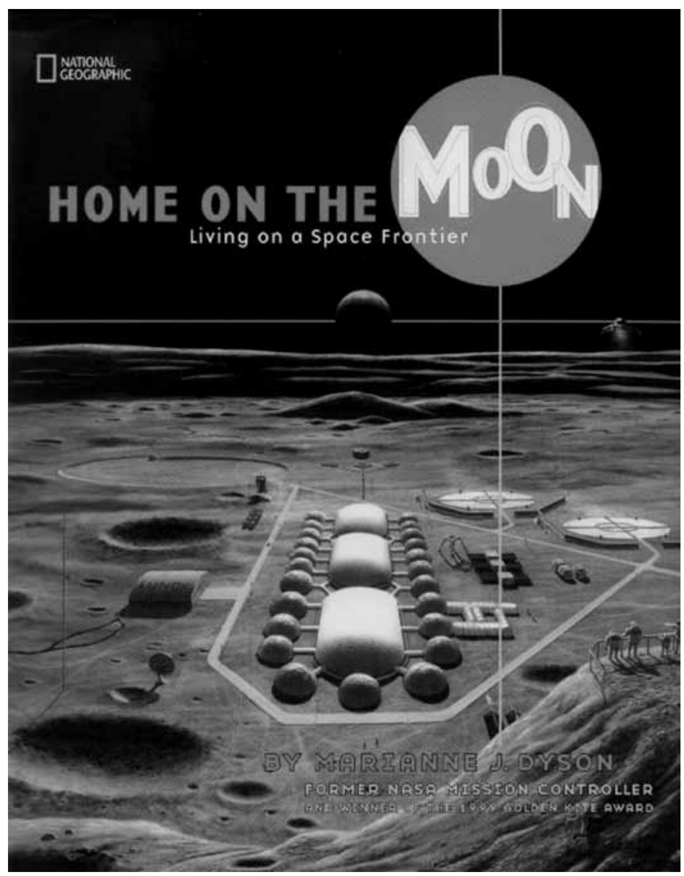
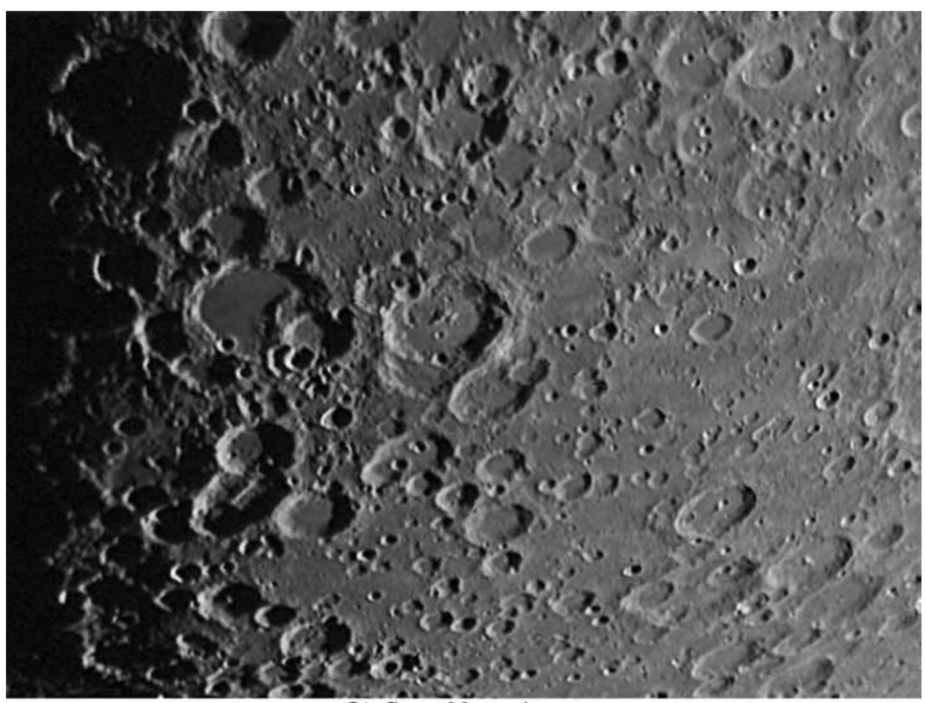


Figure 14: http://shopnasa.com/store/product/106/ Home-on-the-Moon/

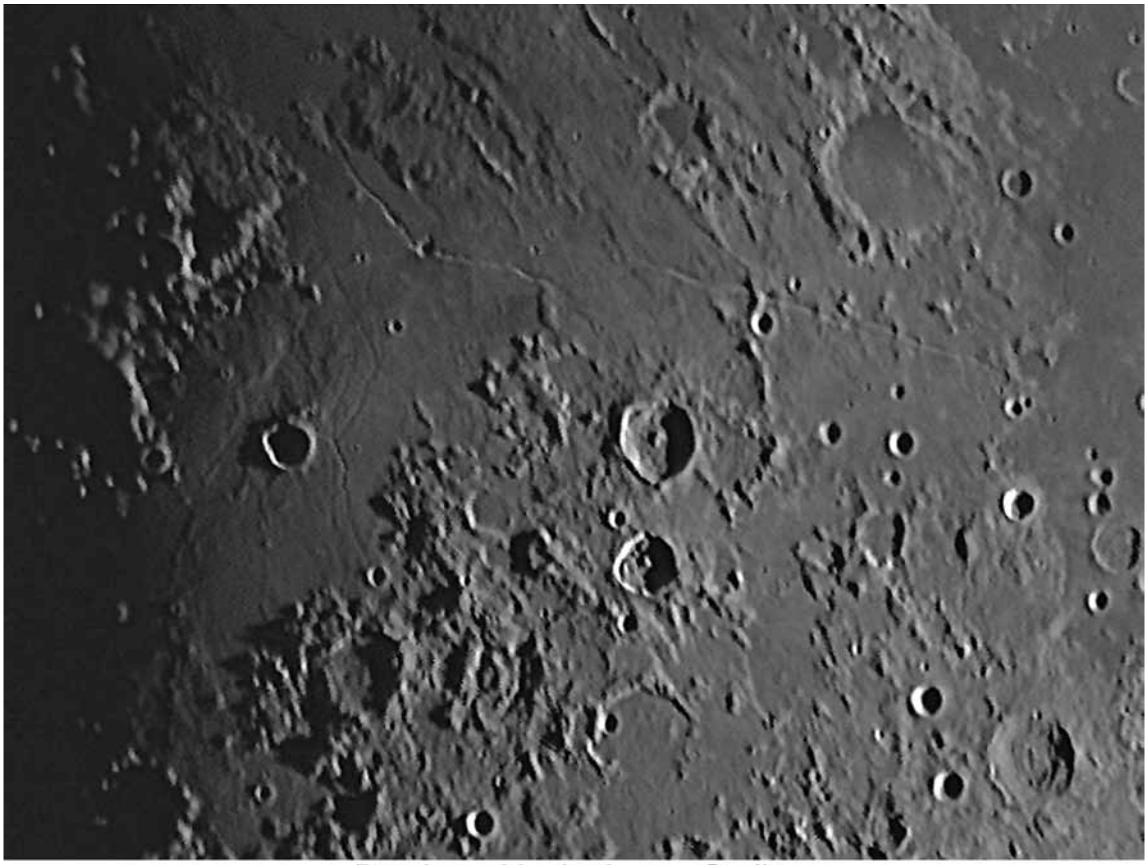
The Photography Of William M. Dembowski, FRAS

Janssen
William M. Dembowski, FRAS - Elton Moonshine Observatory
6 October 2009 - 01:14 UT - Colong: 116.4 - Seeing 5/10
Celestron 9.25 inch f/10 SCT - ImagingSource DMK41 - UV/IR Filter

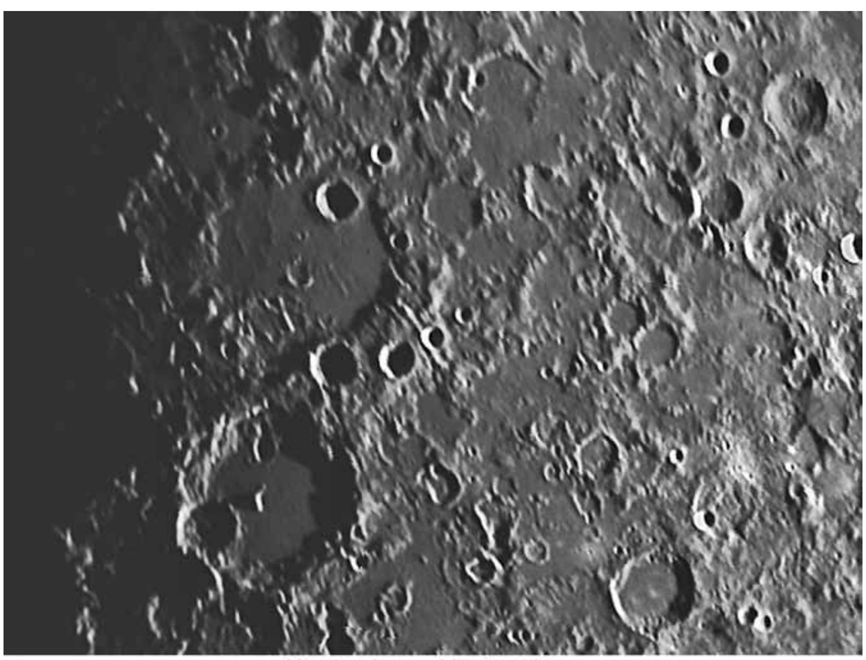
Aristoteles - Eudoxus - Montes Causasus
William M. Dembowski, FRAS - Elton Moonshine Observatory
25 October 2009 - 23:24 UT - Colong: 359.5 - Seeing 5/10
Celestron 9.25 f/10 SCT - ImagingSource DMK41 - UV/IR Filter



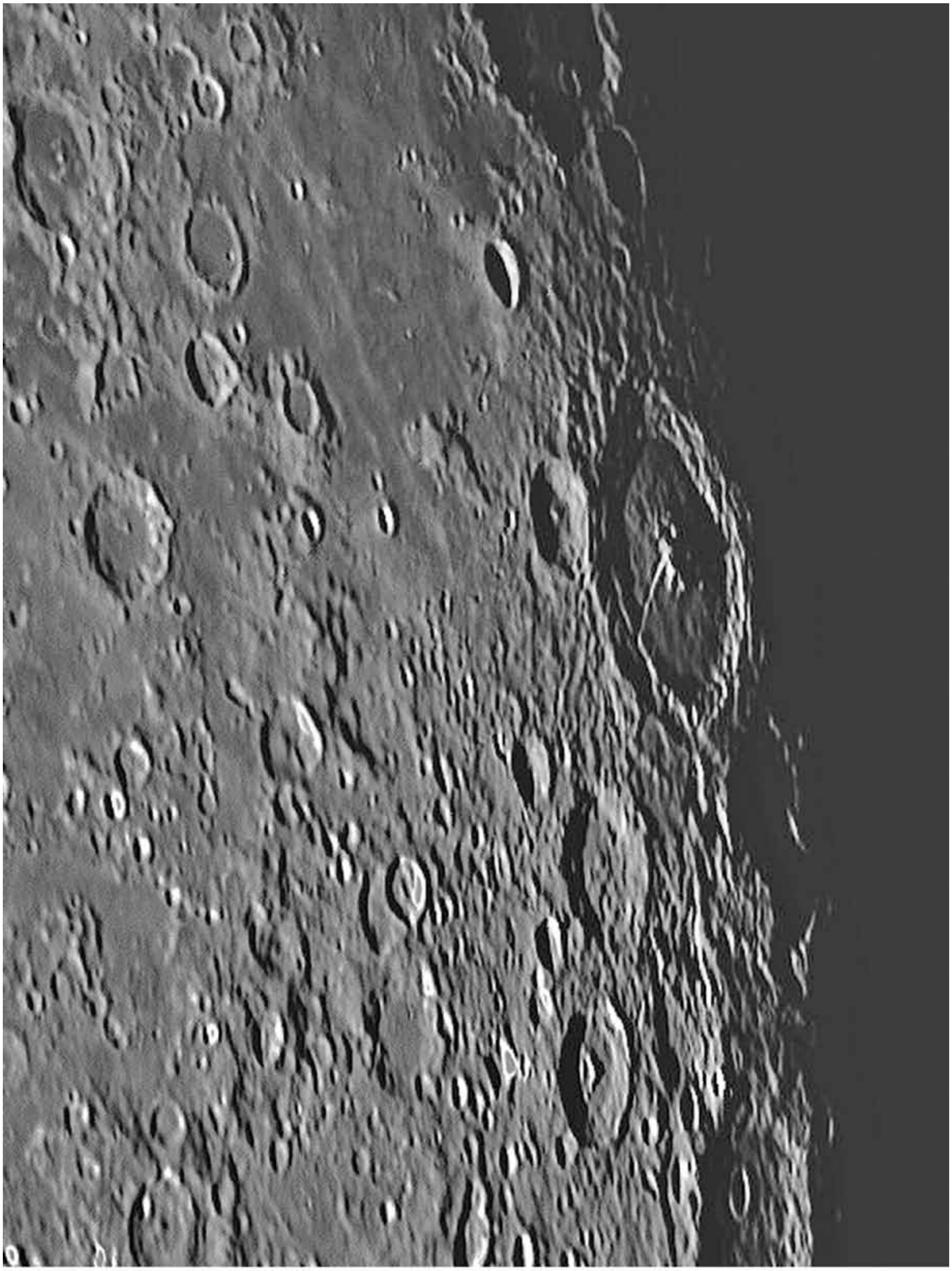
Stofler - Maurolycus
William M. Dembowski, FRAS - Elton Moonshine Observatory
25 October 2009 - 23:34 UT - Colong: 359.6 - Seeing 5/10
Celestron 9.25 f/10 SCT - ImagingSource DMK41 - UV/IR Filter



Dembowski - Agrippa - Godin
William M. Dembowski, FRAS - Elton Moonshine Observatory
26 October 2009 - 00:05 UT - Colong: 359.8 - Seeing 6/10
Celestron 9.25 f/10 SCT - ImagingSource DMK41 - UV/IR Filter



Hipparchus - Albategnius
William M. Dembowski, FRAS - Elton Moonshine Observatory
26 October 2009 - 00:16 UT - Colong: 359.9 - Seeing 6/10
Celestron 9.25 f/10 SCT - ImagingSource DMK41 - UV/IR Filter

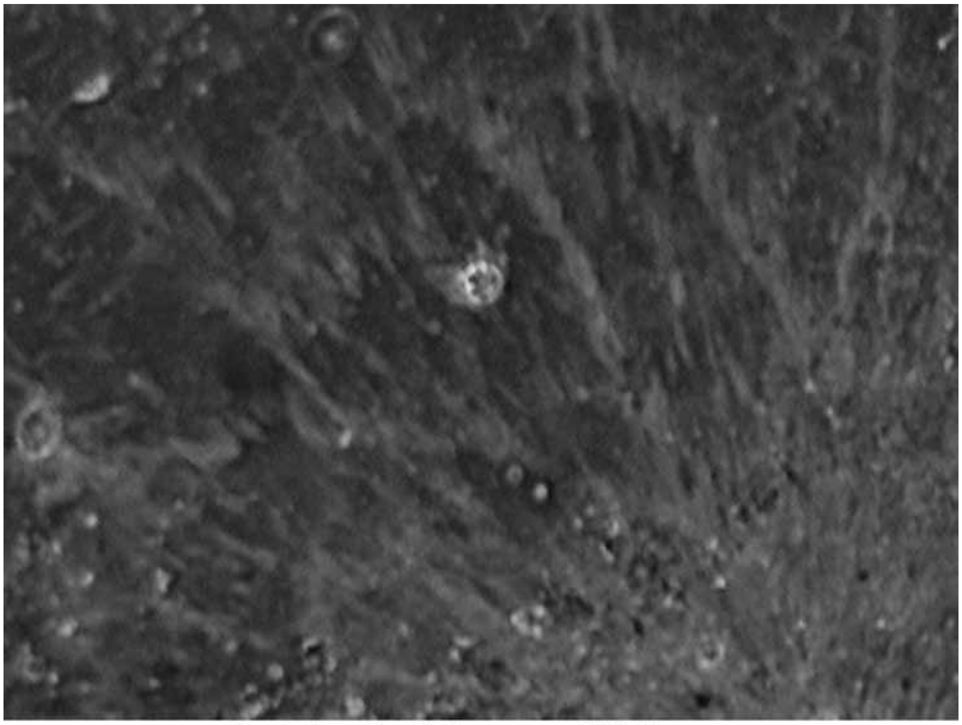


Petavius
William M. Dembowski, FRAS - Elton Moonshine Observatory
6 October 2009 - 02:06 UT - Colong: 116.9 - Seeing 5/10
Celestron 9.25 inch f/10 SCT - ImagingSource DMK-41 - UV/IR Filter

Schiller & Longomontanus
William M. Dembowski, FRAS - Elton Moonshine Observatory
1 September 2009 - 01:23 UT - Colong: 49.8 - Seeing 5/10
Celestron 9.25 inch f/10 SCT - ImagingSource DMK41 - UV/IR Filter

Southeast Quadrant
William M. Dembowski, FRAS - Elton Moonshine Observatory
25 October 2009 - 23:14 UT - Colong: 359.4 - Seeing 5/10
Celestron 9.25 f/10 SCT - ImagingSource DMK41 - UV/IR Filter

Plato - Goldschmidt - Anaxagoras
William M. Dembowski, FRAS - Elton Moonshine Observatory
1 September 2009 - 01:29 UT - Colong: 49.8 - Seeing 5/10
Celestron 9.25 inch f/10 SCT - ImagingSource DMK41 - UV/IR Filter



Banded crater Pytheas near Full Moon
William M. Dembowski, FRAS - Elton Moonshine Observatory
6 October 2009 - 02:10 UT - Colong: 116.9 - Seeing 5/10
Celestron 9.25 inch f/10 SCT - ImagingSource DMK41 - UV/IR Filter

Mare Humorum & Gassendi
William M. Dembowski, FRAS - Elton Moonshine Observatory
1 September 2009 - 01:21 UT - Colong: 49.8 - Seeing 5/10
Celestron 9.25 inch f/10 SCT - ImagingSource DMK41 - UV/IR Filter

Posidonius
William M. Dembowski, FRAS - Elton Moonshine Observatory
26 October 2009 - 00:09 UT - Colong: 359.9 - Seeing 6/10
Celestron 9.25 f/10 SCT - ImagingSource DMK41 - UV/IR Filter

FROM THE PAPERS…

By Eric Douglass

In this quarterly column, we will explore recent papers from the Lunar and Planetary Conferences. Our focus in on presenting topics of interest to the broader lunar community. The summaries presented here contain not only the results of the paper, but also background information that connects the results to broader lunar topics and background information.

Review: M. Wieczorek and M. Le Feuvre; "**Did a Large Impact Reorient the Moon**"; Lunar and Planetary Science Conference XL; 3/2009; #1554.

One of the most interesting events to happen in our solar system, in my opinion, are those massive impacts that occurred on planets and moons. We who study the moon are well familiar with these: the lunar basins (Imbrium Basin, Nectaris Basin, etc.) were formed when large impactors struck the moon. The largest of these is the South Pole-Aitken basin, which is a mammoth 2500 km in diameter! The most complete basin, due to its relative youth, is the Orientale Basin (figure 1), while one of the older basins is the Nectaris Basin (figure 2). These massive impacts resurfaced the moon with their ejecta blankets, creating a megaregoloith that is kilometers deep. However, what does the location of these basins tell us about the moon?

That question sounds odd. How can the location of the known basins tell us anything about the moon? The answer comes from realizing that the moon is not a static body, sitting "out there" in space. It is in motion around the earth, traveling just over 1 km/second. This means that the most forward region of the moon—the leading area (called the apex)—should have accumulated more impacts than the trailing area (called the antapex). However, the same thing could then be said about the earth in its rotation about the sun! Earth's leading area should have accumulated more impacts than the trailing areas. This is clearly not the case, which points to some differences between the systems.

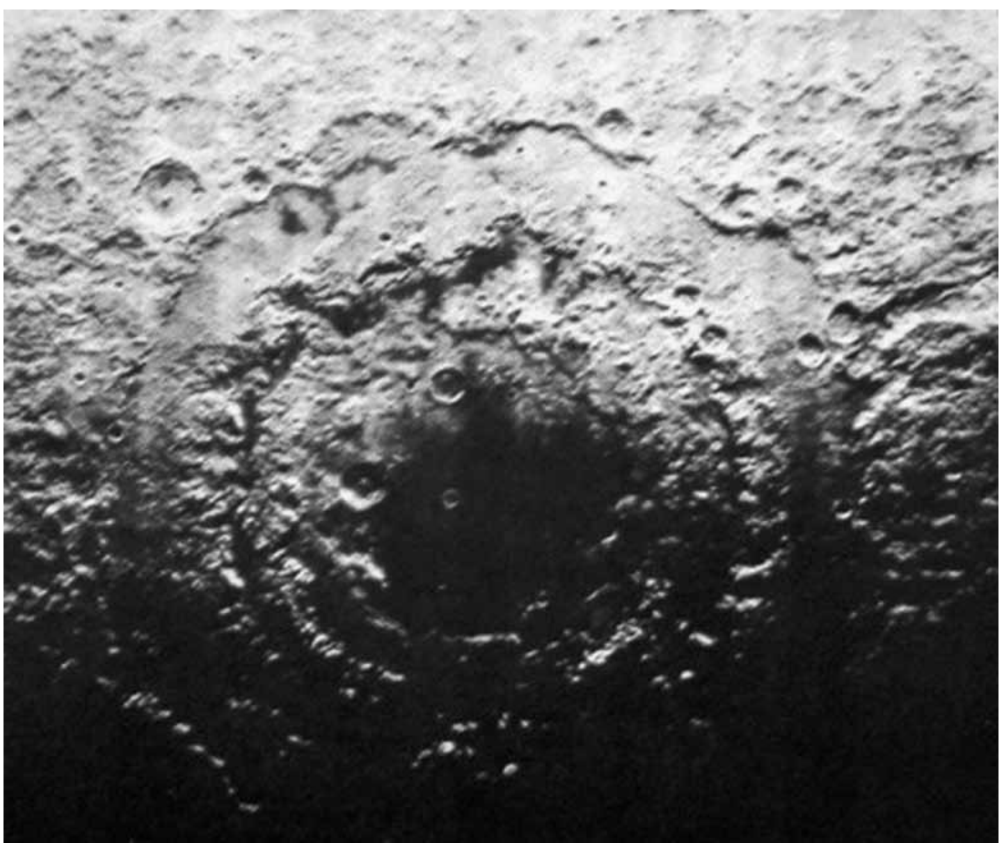


Fig 1: Kosofsky, L. and El-Baz, F.; The Moon as Viewed by Lunar Orbiter: NASA SP-200*; Washington, USGPO: 1970; 19.*

The earth is rotating on its axis as it moves about the sun, and so has no fixed "leading" area. The moon, on the other hand, is in a locked, synchronous rotation about earth, so that the same "face" of the moon always points towards earth. This means that as the moon circles the earth

Fig 2: Wilhelms, D; The Geologic History of the Moon: US Geological Survey Professional Paper, 1348*; Washington, USGPO: 1987; 62.*

the same area is always “leading” in its movement. This was not the moon’s original orientation. The moon originally rotated in a non-locked way about the earth just as the earth does about the sun. But earth’s gravity created tidal friction, slowing the moon’s rotation. Eventually sufficient angular momentum was lost that the moon became fixed in its rotation so that the same side faced earth and the same “area” (though in a different location) leads in its rotation about earth.

This leading area (apex, 0^{0}N, 90^{0}W) should collect more impacts than the trailing area (antapex, 0^{0}N, 90^{0}E). The apex is more likely to encounter meteriods than the antapex. Indeed, meteoroids traveling slower than the moon’s orbital velocity never impact on the antapex (though this would be a very small number, as most meteoroids travel at much higher velocities). This difference in impact rates means that one can look *at the distribution of impacts on the moon* for new information.

This gets us to the work of Wieczorek and Le Feuvre. They looked at the distribution of the largest impacts (basins) and noted a problem: when looking at the distribution of the older basins, they are preferentially distributed about the antapex (the trailing region). On the other hand, the newer basins are preferentially distributed about the apex. How can this be explained?

The authors offer the following tantalizing possibility: perhaps the moon’s orientation was different in the past. The moon has a tidal buldge, created by the effects of earth’s gravity on the moon, so that the moon has two possible stable orientations: the near side facing earth and the far side facing earth…each 180 degrees different in orientation. The authors hypothesize that one of the basin-sized impacts imparted sufficient energy to the moon so that it flipped from the far side facing the earth (the original “locked” orientation) to the near side facing earth (the present “locked” orientation).

Next the authors calculate the size of an impact required to create such an effect. Unfortunately, these calculations require estimations for velocity, density, earth-moon separation, and the like. Nevertheless, they suggest that at the current earth-moon distance, a meteoroid capable of creating a crater of 300 km in diameter would have been sufficient. It need only strike at the right place. A number of the current basins could have easily done this.

Thus, these authors suggest that sometime during the late heavy bombardment (the period in which most of the observable basins formed), one of the basin-sized impacts caused the moon to temporarily “unlock” in its rotation, and turn 180 degrees…so that the prior far-side become our present near-side. It is of interest that other researchers have applied a similar method to studying the assymetrical distribution of rayed craters (cf. T. Ito and R. Malhotra, “Asymmetric Impacts of Near-Earth Asteroids on the Moon”, Astronomy & Astrophysics, July 17, 2009).

Recent Lunar Probe News

By Steve Boint

LCROSS Update

Not so long ago, the news brief that LCROSS found buckets of water on the moon promised at least a short span of interesting news about our nearest neighbor. Unfortunately, not much information has come out since then. The short papers summarizing presentations at the 41st Lunar and Planetary Science Conference (2010) promise details to those who can attend, but provide little new information for the vast majority of selenophiles. LCROSS was designed to study the hyrdrogen atoms in the regolith of Cabeus crater (one of the permanently shadowed, south-polar craters previous missions had identified as possibly containing frozen water). On October 9, 2009, a 2300kg Atlas V Centaur rocket upper stage crashed into the floor of Cabeus. The Shepherding Spacecraft followed 4 minutes behind and made observations of the ejecta plume. The spectra of the plume revealed volatiles besides but including[1] water. Spectral analysis of multiple compounds is complex and the details are still being worked out.[2]

Spectral analysis of the plume revealed a hydroxyl component which increased over time. Absorption lines for water and other hydrogen-bearing compounds lasted for the duration of observation. Visual observations showed an ejecta plume which expanded and then disappeared, but the plume remained visible at other wavelengths. During the observation, it remained a diffuse cloud. Sodium was detected, but the spectrometers were not able to detect other individual atoms. The absence of an ejecta ring around the crater suggests a high angle of impact for the Centaur rocket.[3]

Lunar Prospector's measurements of epithermal neutrons showed that the lunar soil in permanently shadowed polar craters had a hydrogen content, by weight, of between 0.2 and 40 percent. However, SELENE's terrain camera found no evidence of exposed water ice on the floor of Shackleton crater (near the south pole). LCROSS was designed to determine if water was indeed located in the regolith of permanently shadowed craters. Calculations assuming a 1 percent water abundance suggested that about 200 kg of water would be vaporized by the impact and be able to form a plume reaching above the 2 km crater rim of Cabeus crater. This should be visible from Earth-based telescopes which would provide the added bonus of another angle of observation compared to the downward view of a lunar orbiter. Researchers at the Subaru telescope in Hawaii observed the LCROSS event with an infrared spectrometer. Their results showed a negligible amount of water, probably due to a smaller-than-predicted amount of the plume rising above the crater wall. The data suggest that the amount of ejecta reaching above the crater rim was only one twentieth of what had been predicted.[4] The most likely cause was that the Centaur either did not produce as big a bang as

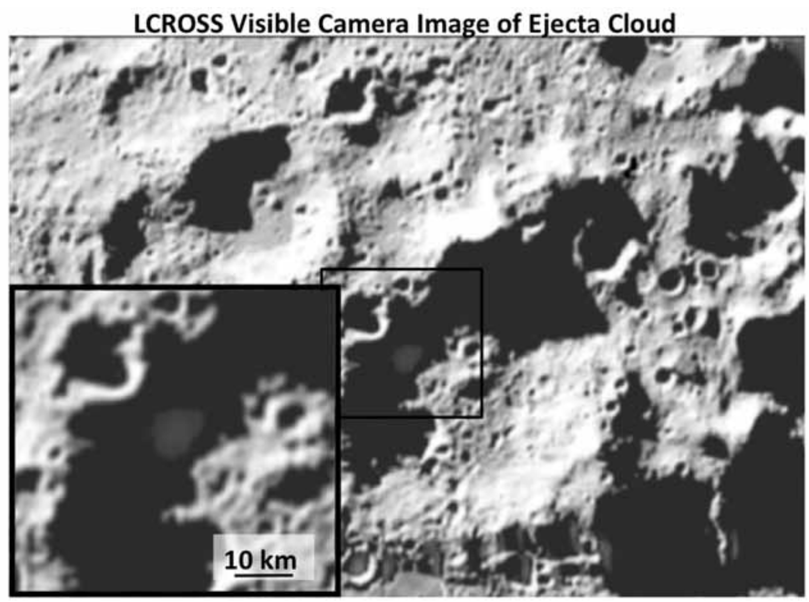


Figure 1: Image of the LCROSS impact ejecta cloud as seen in the visible context camera. Inset shows the ejecta cloud expanding to fill the shadowed region targeted at the bottom of the crater Cabeus. From Water and More: An Overview of LCROSS Imapct Results.

expected or else hit at more of an angle than predicted.[5]

Raffaello Lena, Jim Phillips and Ed Crandall made photometric observations of the impact from Earth. The resulting light curve showed a possible minor brightening due to ejecta from the impact, suggesting that most of the event was masked by the surrounding raised terrain.[6]

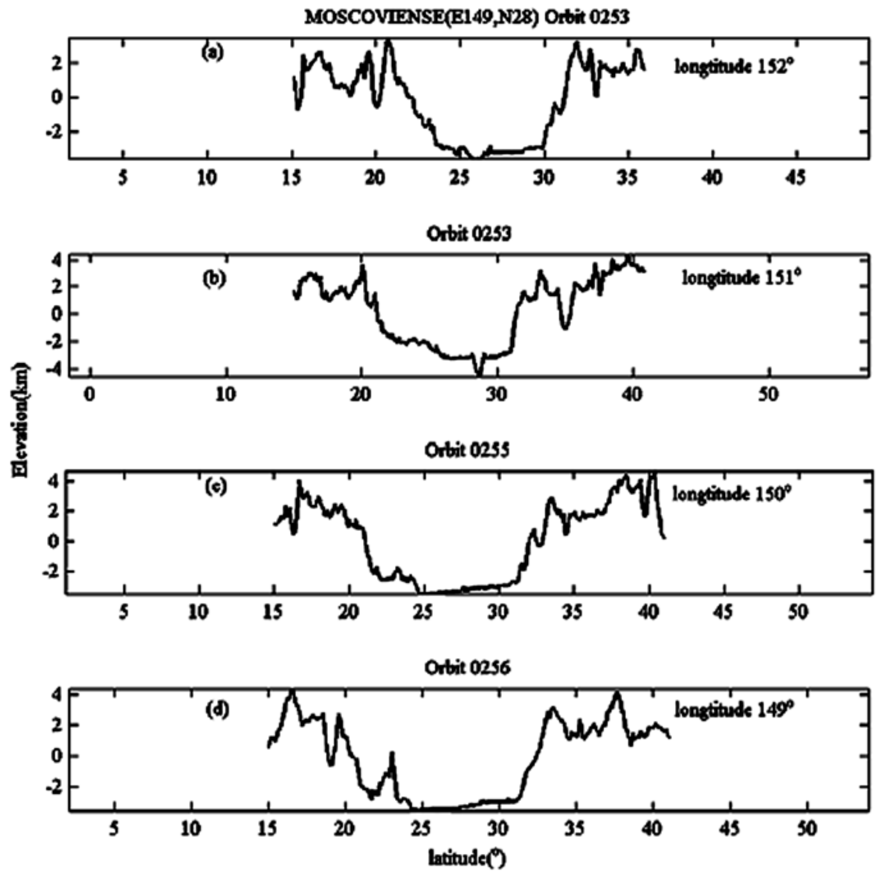


Figure 1. *Topographic profiles across the Moscoviense impact basin (149^{o} E, 28^{o} N), illustrating the multiple ring structure of this impact structure. The horizontal axis is lunar latitude, where one degree corresponds to about 30 km. The height is referenced to a sphere with a radius of 1738 km. From:* Improved Global Lunar Topographic Model By Chang'E-1 Laser Altimetry Data.

References:

[1]*Water and More: An Overview of LCROSS Imapct Results***.** A. Colaprete, K. Ennico, D. Wooden, M. Shirley, J. Heldmann, W. Marshall, L. Sollitt, E. Asphaug, D. Korycansky, P. Schultz, B. Hermalyn, K. Galal, G. D. Bart, D. Goldstein, D. Summy, and the LCROSS Team. 41st Lunar and Planetary Science Convention (2010). Abstract.

[2]*Lunar Crater Observation And Sinsing Satellite (LCROSS) Mission: Results From The Nadir Near-Infrared Spectrometer Aboard The Shepherding Spacecraft.* D.H. Wooden, A. Colaprete, K. Ennico, M.H. Shirley, J.L. Heldmann, and the LCROSS Science Team. 41st Lunar and Planetary Science Convention (2010). Abstract.

[3]*Interpreting The LCROSS-EDUS Impact***.** P.H. Schultz1, B., Hermalyn, A. Colaprete, K. Ennico, M.Shirley, and the LCROSS Science Team. 41st Lunar and Planetary Science Convention (2010). Abstract.

[4]*The Estimate Of The Amount Of Ejecta In LCROSS Mission***.** N. Okamura, S. Sugita,P. K. Hong, H. Kawakita,Y. Sekine, H. Terada, N. Takatoh, Y. Hayano, T. Fuse, D. H. Wooden, E. F. Young, P. G. Lucey, R. Furusho, J. Watanabe, J. Haruyama, R. Nakamura, K. Kurosawa, T. Hamura, and T. Kadono. 41st Lunar and Planetary Science Convention (2010). Abstract.

[5]*Hot Bands Observation Of Water In Ejecta Plume Of LCROSS Impact Using THE Subaru Telescope***.** P. K. Hong, S. Sugita, N. Okamura, Y. Sekine, H. Terada, N. Takatoh, Y. Hayano, T. Fuse, H. Kawakita, D. H. Wooden, E. F. Young, P. G. Lucey, R. Furusho, J. Watanabe, J. Haruyama, R. Nakamura, K. Kurosawa, T. Hamura, and T. Kadono. 41st Lunar and Planetary Science Convention (2010). Abstract.

[6]Raffaello Lena, Jim Phillips and Ed Crandall (GLR Group). *Photometric observation of LCROSS Impact on the Moon*. *Selenology Today* 17.

Chang'E-1 Update

Results from the Chinese lunar probe are starting to be made public. New impact basins (Sternfeld-Lewis, Fitzgerald-Jackson), one new crater on the far side (Wugang crater), and one volcanic deposit on the near side (Yutu highland) were discovered. The Aitken basin was deemed the largest mascon on the terrestrial planets. Comparison of the lunar Apennines with the terrestrial Himalayas suggested a fault line and calls into question the idea of no interior lunar movement.[1]

Enhanced radioactivity was found to be limited to section of KREEP in Oceanus Procellarum. Radioactivity in this region was found to be significantly higher than any other place on the lunar surface. The Aitken basin was the next highest area of radioactivity.[2]

Investigation of microwave emission by lunar soil found the farside generally significantly lower than the nearside, suggesting a lower temperature on the farside during lunar formation and a different evolution of farside and nearside soils. Chang'E-1 was able to determine helium-3 content to a higher precision than was before possible. It shows the moon's surface contains only 1 million tons instead of the previously determined 5 million. The regolith was found to be much thinner, on average, than was previously thought, having a depth of only 5-6 m.[3]

Chang-E-1's laser altimeter provided over 3 million usable measurements of vertical displacement. Referenced to a mean radius of 1738km. these provide a vertical accuracy of 31m and a horizontal resolution of 0.25 degrees (7.5 km). A low-resolution global map has been generated and made available on the web. As the Clementine probe discovered earlier, the center of mass of the moon is displaced 22 degrees from the geometric center and toward the western limb. The Chinese probe determined this offset with greater precision: (~-1.777, -0.730, 0.237) km in the *x*, *y*, and *z* directions, respectively. The polar flattening of the moon due to rotation was found to be 1/963.7526 with respect to the equatorial diameter.[4]

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[1] *Chang'E-1 has blazed a new trail in China's deep space exploration.* December 1, 2009. Science in China Press.

[2] *Chang'e-1 Gamma-ray Spectrometer And Its Preliminary Radioactive Results.* M. H. Zhu, J. Chang, T. Ma, A. A. Xu. 41st Lunar and Planetary Science Conference (2010). Abstract.

[3] *China Probe CE-1 Unveils the World First Moon-globe Microwave Emission Map — The Microwave Moon ---Some Exploration Results of Chang'E-1 Microwave Sounder.* J. S. Jiang, Z. Z. Wang, X. H. Zhang, D. H. Zhang, J. Wu, Y. Li, L. Q. Lei, W. G.Zhang, H. Y. Cui, W. Guo, D. H. Li, X. L. Dong, H. G. Liu. 41st Lunar and Planetary Science Conference (2010). Abstract.

[4] *Improved Global Lunar Topographic Model By Chang'e-1 Laser Altimetry Data*. Q. Huang, J. S. Ping , M. A. Wieczorek, J. G. Yan, X. L. Su. 41st Lunar and Planetary Science Conference (2010). Abstract.

Chandrayaan-1 Update

Along with data from the Kaguya mission, the global magma ocean hypothesis was given support by Chandrayaan-1's confirmation of large amounts of crystalline feldspar on the lunar farside. New spinel-rich rock types were discovered on the farside. Chandrayaan-1 also detected hydrogen reflected from the surface in an amount up to twenty percent of the incident solar wind hydrogen ions. Chandrayaan-1 detected both water and hydroxide, with an increased abundance near the poles. [1]

Evidence of a minimum of 600 million metric tons of water ice located in the northern polar region of the moon was discovered. This ice is located in more than 40 permanently-shadowed craters ranging in size from 1 to 9 miles in diameter.[2]

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[1] ***An Overview Of The Chandrayaan-1 Mission.*** J. N. Goswami. 41st Lunar and Planetary Science Convention (2010). Abstract.

[2] *Tons Of Water Ice Found On The Moon's North Pole.* Tariq Malik. *Space.com.* March 1, 2010.

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