The New Fa
of the Moon

BY MARIANNE J. DYSON

Imagine the Moon without its familiar dark seas for eyes and sporting a gigantic dark "mouth" in its southern hemisphere instead. If it weren't for an impact about four billion years ago, that is the face that some lunar scientists now think we'd see.

IMAGE CREDIT: © NASA

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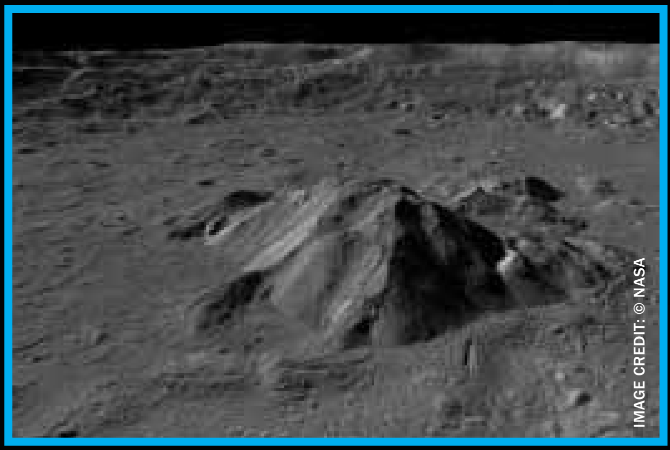
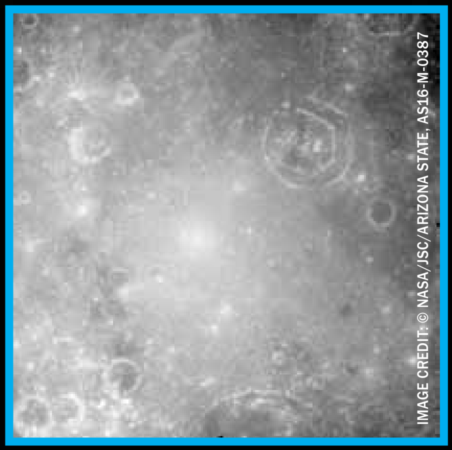
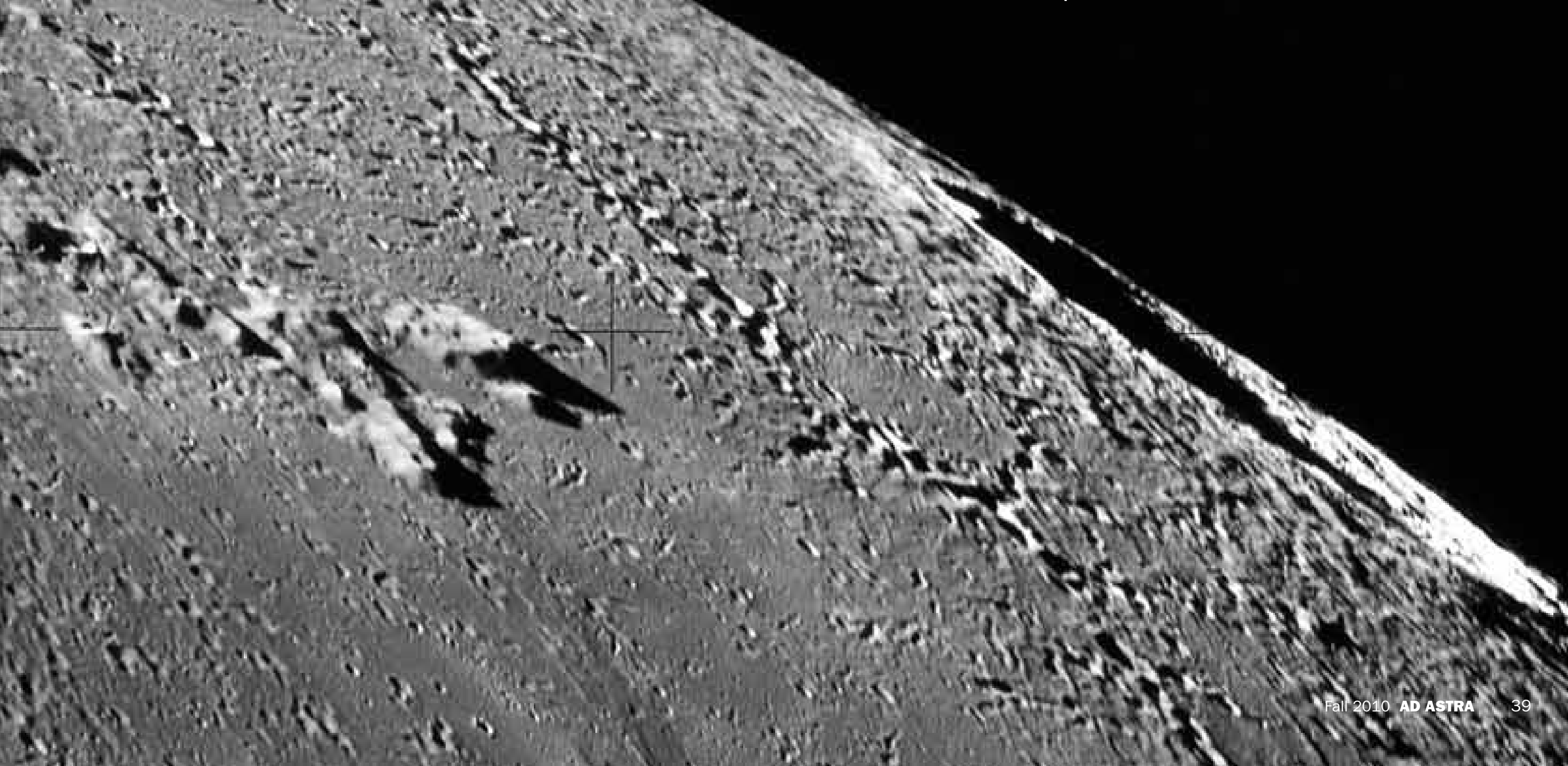
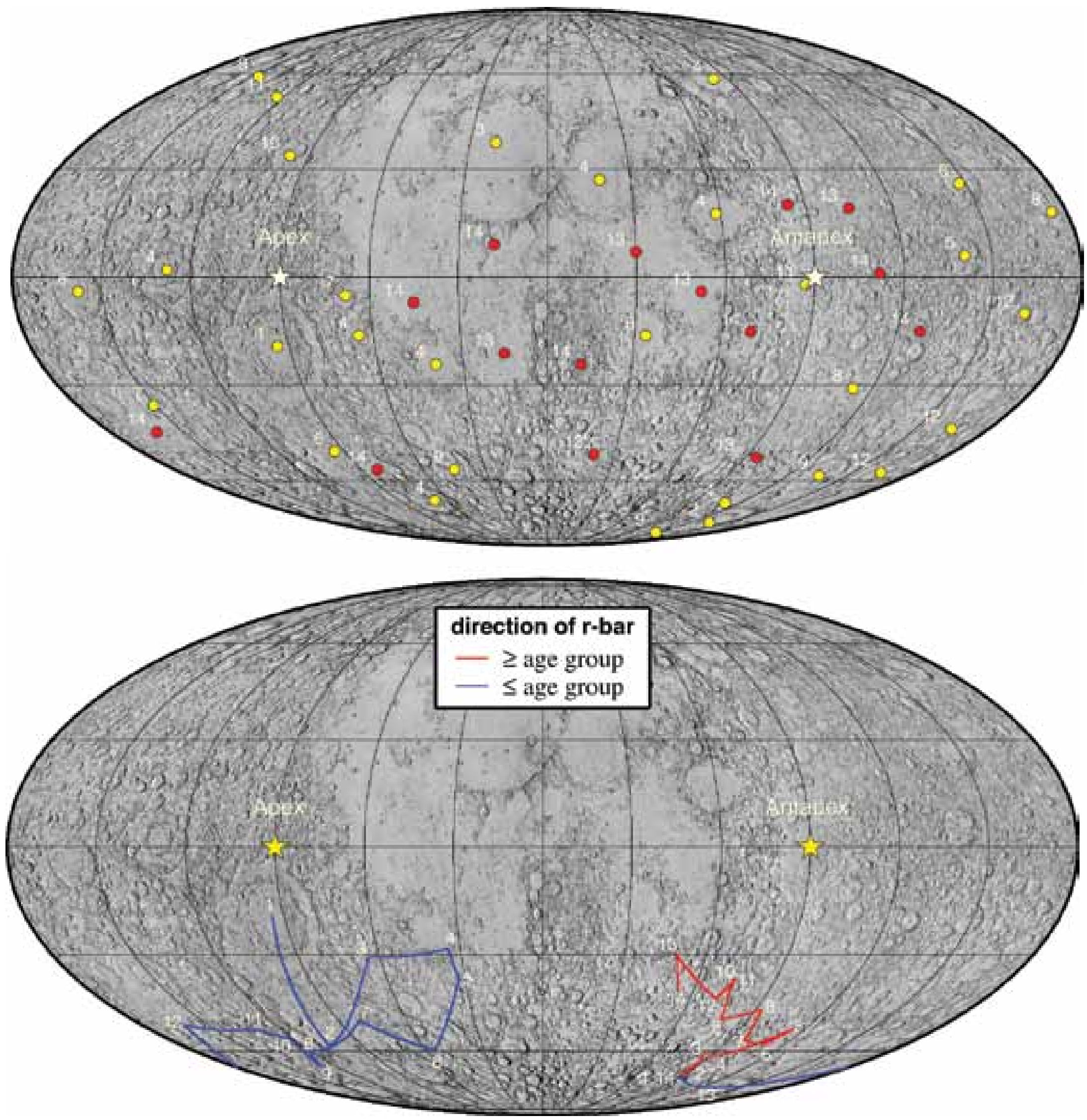


The Moscow Sea is one of the basins in the "yellow" group that came after the proposed reorientation of the Moon. It is the location of the thinnest crust on the Moon, with Orientale, the youngest of the large basins, a close second.



Could Smythii be the scar of an impact that flipped the Moon around? This image is from Apollo 16, taken from an altitude of 123 km. Mare Smythii fills the entire frame that is centered on longitude 83 degrees at the lunar equator.





Both maps are of the entire Moon with the near side in the center and the two "halves" of the far side "flattened out" on either side of it. The upper map shows basins older than Orientale and younger than South Pole-Aitken divided into two groups by age. The younger basins, shown in yellow in the upper image and grouped in blue on the lower image, are preferentially located on the western hemisphere near the current apex. The older basins, shown in red in both images, appear preferentially on the eastern hemisphere. R-bar is a unit vector pointing from each crater to the center of its group. If the basins were randomly distributed, r-bar would be zero. Credit: M.A. Wieczorek, M. Le Feuvre/Icarus 200 (2009) 358-366.

The Moon is currently locked in what is called synchronous rotation, spinning one time for every one revolution of Earth. The result is that, somewhat like a dance partner, what we call the near side with Mares Imbrium and Serenitatis (the eyes) in the northern hemisphere is always facing Earth as it swings around. The far side, with the large dark bruise of the South Pole Aitken basin in its southern hemisphere, is perpetually facing away from Earth.

This rotation is very stable. An impact might rock the Moon back and forth, but scientists estimate that motion would damp out within in a year. If the jolt is enough to "rock" the Moon more than 90 degrees, the Moon would show both faces to Earth for that year, then tidal torques would bring it back into locked rotation. But which face is then directed toward Earth is a matter of chance. Both orientations are equally stable.

Lunar scientists Mark Wieczorek and Mathieu Le Feuvre of the Institut de Physique du Globe de Paris in France have been researching the Moon's topography. Combining older topographic data with new geophysical data from recent lunar orbiters allowed them to discover that the oldest lunar impact basins are not randomly distributed, but clustered near what is now the trailing edge, or antapex, of the Moon. Because the leading edge, or apex (like the windshield of a car) gets more strikes than the trailing edge, they hypothesized that the Moon was once rotated 180 degrees, and the current far side once faced the Earth.

In their paper, "Did a large impact reorient the Moon?" published in Icarus in April 2009 and presented at the Lunar and Planetary Science Conference in Texas this March, they provide strong evidence for this amazing cosmic "about face."

First, they determined how much energy would be necessary to spin the Moon more than 90 degrees. At the Moon's current distance of 60 Earth radii, they calculated that an object would require a velocity of about 19 km/sec (42,500 mph) and be larger than 50 km (80 mi) in diameter to unlock the Moon from its synchronous rotation. The size of the resulting crater would be about 300 km (480 mi) in diameter.

They then took into account that the Moon is assumed to have formed (as a result of a giant impact) at what is called the Roche limit, around 3 Earth radii, and then because of tidal effects, moved outward to at least 25 Earth radii within about a hundred million years. When the Moon was at this distance, the Earth's gravitational pull was correspondingly greater, requiring even more energy to knock the Moon around. The scientists calculated that an impact with that much energy would create a crater of 350-500 km (560-800 mi) in diameter.

The Moon sports quite a few craters from impacts this large, but none younger than Orientale (3.8 Ga) that are big enough to have done the deed. After ruling out some craters because detailed geophysical data (and thus ages) for them is not yet available, the scientists examined a list of 46 basins between 4.4 and 3.8 Ga old. They hypothesized that the oldest basins formed when the Moon had the far side towards Earth, and the more recent basins formed with the near side towards Earth. Because most impacts occur at the apex, if the Moon did indeed flip around, the oldest basins should cluster on one side, and the youngest on the other. The oldest basin, South Pole-Aitken, was excluded from the data set because it is assumed that impact was so enormous that it accounted for the "original" orientation of the Moon.

A plot of the basins clearly shows that they do indeed cluster on opposite sides of the Moon, supporting the hypothesis that the Moon experienced an "about face" between 4.4. and 3.8 billion years ago.

Objects are 29 percent more likely to strike on the apex. So the basin most likely formed by this Moon-flipping culprit is one that formed after most of the oldest ones, and before most of the youngest ones. Six basins fall into this category. The scientists consider Smythii as the most likely because of its size and location near the equator.

Data from Kaguya, Change'e-1, Chandrayaan-1, and the Lunar Reconnaissance Orbiter will refine the age data for about fifty more basins that can be used to further confirm the hypothesis and identification of the face-changing impact scar. Also, gravity data from the Gravity Recovery and Interior Laboratory (GRAIL) mission slated for launch in 2011 will improve the analysis of far-side basins.

What effects this reorientation may have had, if any, on lunar volcanism, magnetism, crustal composition, and distribution of resources is not yet clear. But as we plan the location of future human settlements on the Moon, we might want to avoid the apex!

Marianne Dyson is an award-winning author and former NASA flight controller. She is on the NSS Board of Advisors, chairman of the NSS Space Book (Reviews) Committee, an NSS blogger, a member of the NSS Policy Committee, and Treasurer of the Clear Lake Area/Houston NSS chapter. http://www.mdyson.com.

THICK LUNAR ICE

The Japanese Kaguya orbiter took this image of the lunar north pole on October 13, 2007. The Indian Chandrayaan-1 orbiter found water ice tucked into more than 40 craters in the area.

In 2009, The Indian Chandrayaan-1 spacecraft spent eight months mapping the surface of the Moon. Paul Spudis was the principal investigator of an instrument called the Mini-SAR imaging radar whose purpose was to characterize the composition of the lunar surface. At the Lunar and Planetary Science Conference in Texas in March, Spudis reported the good news: "What we think we have here is a clear indication of water ice — crystalline water ice."

The Mini-SAR transmitted pulses of left-circularly polarized radar. For most places on the Moon, the radar was reversed and reflected back as right-circularly polarized echoes, similar to the way an image is reversed from left to right by a mirror. If the surface is rough or transparent to radar (such as ice), the signal will be scattered multiple times and return to the spacecraft left circularly polarized.

The Mini-SAR instrument measured the ratio of left to right polarization, called the circular polarization ratio, or CPR. A low CPR value indicates that the surface has few rocks to scatter the radar's wavelength, 12.6 cm (7 in), that is, few that are 12.6 cm (7 in) in size. A high CPR value can either mean that large rocks are on the surface or that ice is present. To distinguish between the two causes, Spudis examined the geology of the high CPR areas.

Some 40 permanently shadowed craters near the lunar north pole had high CPR values inside, but not outside their rims. As Spudis wrote on his blog, "This relation suggests that the high CPR is not caused by roughness, but by some material that is restricted within the interiors of these craters. The craters that show this enhancement are all permanently cold and dark, where ice is stable. We thus interpret this high CPR to mean that water ice is present in those craters."

Spudis estimates the ice is at least two meters (6.5 feet) thick and relatively pure. At the north pole alone, there are at least 600 metric tons (1.3 million lbs) of water, or, as Spudis said, "the equivalent of one space shuttle (735mT of propellant) per day for 2,000 years."

He added, "Everything we find out about the Moon shows that it is more interesting, more complicated, and richer in both process and history than we had thought. We can now say with a fair degree of confidence that a sustainable human presence on the Moon is possible."

—Marianne J. Dyson