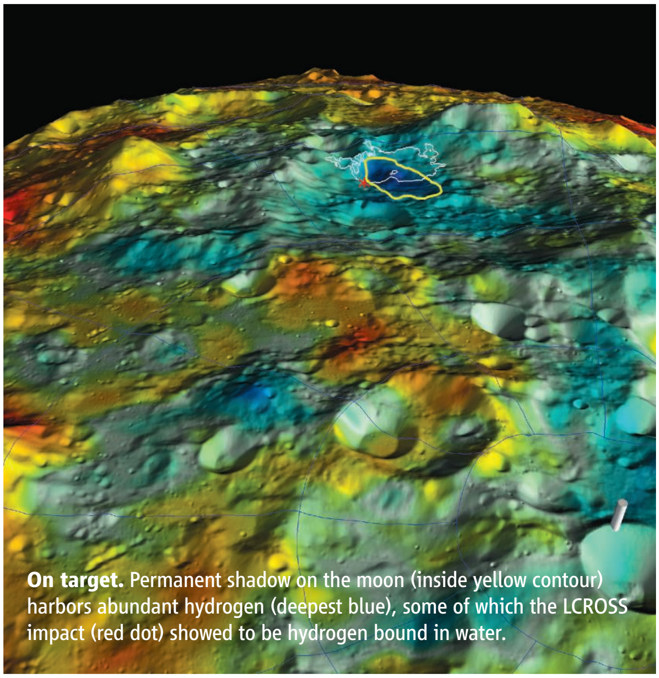
PLANETARY SCIENCE

How Wet the Moon? Just Damp Enough to Be Interesting



On target. Permanent shadow on the moon (inside yellow contour) harbors abundant hydrogen (deepest blue), some of which the LCROSS impact (red dot) showed to be hydrogen bound in water.

"The Moon Is Wet," read many a headline in the past year, at times with an exclamation point. That's an overstatement, with or without the exclamation point, says lunar scientist Paul Spudis of the Lunar and Planetary Institute in Houston, Texas. But "the old statement that the moon is 'bone-dry' is not correct either. What we have found is that the moon has a hydrosphere, it has a water cycle."

But the moon's hydrosphere is nothing like Earth's watery regime. None of the moon's water is ever liquid. Water in its reservoirs can be imperceptibly sparse, flows into its reservoirs may proceed a few molecules at a time, and none may ever leave. And, as seen in the five reports of new water-related results from the moon beginning on page 463, many enigmas remain.

A year ago, researchers found the first water on the moon, frozen water buried in Cabeus crater near the south pole. Blasted into view by a plunging spent rocket stage (*Science*, 19 March, p. 1448), this subsurface ice is now pegged at only about 6% by mass of the top meter or two of lunar soil, according to LCROSS (Lunar Crater Observation and Sensing Satellite) mission team members reporting on page 463. This LCROSS water was the prize in a decades-long search driven most recently by NASA's push to sustain astronauts returning to the moon. But since the LCROSS mission, the Obama Administration and now Congress have turned away from sending humans back to the moon (*Science*, 1 January, p. 18).

There's still plenty in recent results to intrigue researchers, however. For starters, the controversial radar probing of the subsurface that ignited the hunt for lunar water (*Science*, 13 March 1998, p. 1628) was misinterpreted, the LCROSS result shows. No radar could detect such sparse ice. And the remote probing for subsurface hydrogen that led LCROSS team members to Cabeus was misleading. The Lunar Exploration Neutron Detector (LEND) instrument flying on NASA's Lunar Reconnaissance Orbiter (LRO) (p. 483) picked up a strong hydrogen signal. But it wasn't mostly from water's hydrogen, as team members originally thought. LRO's Lyman Alpha Mapping Project found that at least as much hydrogen in the LCROSS impact plume took the form of molecular hydrogen, H_2, as was locked up in H_2O (p. 472). How the molecular hydrogen got there remains unclear.

Results from LCROSS, LRO, and other recent moon missions confound as well as illuminate. Radar probing from India's recently deceased Chandrayaan-1 orbiter picked up no reflections from LCROSS's Cabeus crater, consistent with sparse ice. But strong reflections from a couple of dozen craters around the lunar north pole suggest an icy bonanza: massive, nearly pure ice just beneath the crater floors. "How that would come about I haven't a clue," says Spudis, who is principal investigator of the Chandrayaan-1 radar.

The conventional explanation for ice in polar craters like Cabeus—whose floor is in permanent shadow and thus hovers near 40 degrees above absolute zero—is that icy asteroids or comets strike somewhere on the moon, and some of the resulting water vapor reaches a permanently shadowed crater's deep chill and freezes out there. But such cold trapping would only fill the empty space in the soil, not form nearly pure ice. No one really knows how nearly pure subsurface ice would form.

Adding further confusion, LEND team members also report that surprisingly high amounts of hydrogen lurk near the south pole in places that get at least some sunshine. It turns out that temperatures measured from LRO and reported on page 479 can be low enough to allow billion-year-old ice in sunlit areas as long as there are at least a few centimeters of overlying, insulating soil. More perplexing is LEND's failure to find abundant hydrogen in many permanently shadowed craters that are just as cold as Cabeus. "The data's not pointing to a single process for emplacing water," concludes Anthony Colaprete, LCROSS's principal investigator from NASA's Ames Research Center in Mountain View, California.

Even at its moistest, the lunar hydrosphere isn't very wet. Several teams of spectroscopists observing the moon from different space platforms have reported detecting water on the surface (http://scim.ag/whiff-of-water). But they are talking about layers just a few molecules thick.

One team reported a decrease in such surface water as the lunar day wore on, suggesting that heating frees water stuck to the surface to fly about the vanishingly thin lunar "atmosphere"—another water reservoir—until again hitting and sticking to the surface. This leapfrogging process might explain how water from impacting meteorites can bounce into a cold trap instead of escaping from the moon entirely.

Reports of wetness in rare minerals that Apollo astronauts brought home might also be overblown. From those analyses, some geochemists have inferred that the ancient moon's interior harbored a few tens of parts per million of water. But since those claims, a group analyzing chlorine isotopes in Apollo samples concluded that the lunar interior has always been bone-dry at less than 10 parts per billion (http://scim.ag/beneath-the-surface-of-the-moon). At stake, hydrologically speaking, is whether gas-emitting volcanoes on the moon ever contributed to the lunar hydrosphere.

As Colaprete notes, the question of lunar water "is complicated." Planetary scientist David Paige of the University of California, Los Angeles, thinks "we've done what we can remotely. My guess is the ultimate solution is in situ exploration." If the humans aren't game, bring on the robots.

–RICHARD A. KERR

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