

Caltech Team Finds Evidence of Water in Moon Minerals

That dry, dusty moon overhead? Seems it isn't quite as dry as it's long been thought to be. Although you won't find oceans, lakes, or even a shallow puddle on its surface, a team of geologists at the California Institute of Technology (Caltech), working with colleagues at the University of Tennessee, has found structurally bound hydroxyl groups (i.e., water) in a mineral in a lunar rock returned to Earth by the Apollo program.

Their findings are detailed in this week's issue of the journal *Nature*. "The moon, which has generally been thought to be devoid of hydrous materials, has water," says John Eiler, the Robert P. Sharp Professor of Geology and professor of geochemistry at Caltech, and a coauthor on the paper.

"The fact that we were able to quantitatively measure significant amounts of water in a lunar mineral is truly surprising," adds lead author Jeremy Boyce, a visitor in geochemistry at Caltech, and a research scientist at the University of California, Los Angeles.

The team found the water in a calcium phosphate mineral, apatite, within a basalt collected from the moon's surface by the Apollo 14 astronauts.

To be precise, they didn't find "water"-the molecule H₂O. Rather, they found hydrogen in the form of a hydroxyl anion, OH⁻, bound in the apatite mineral lattice.

"Hydroxide is a close chemical relative of water," explains coauthor George Rossman, Caltech's Eleanor and John R. McMillan Professor of Mineralogy. "If you heat up the apatite, the hydroxyl ions will 'decompose' and come out as water."

The lunar basalt sample in which the hydrogen was found had been col-

lected by the Apollo 14 moon mission in 1971; the idea to focus the search for water on this particular sample was promoted by Larry Taylor, a professor at the University of Tennessee in Knoxville, who sent the samples to the Caltech scientists last year.

"The moon has been considered to be bone dry ever since the return of the first Apollo rocks," Taylor notes. However, there are lunar volcanic deposits interpreted as having been erupted by expanding vapor. Although carbon dioxide and sulfur gases have generally been thought to dominate the expanding vapor, recent evidence from the study of the these deposits has suggested that water could also play a role in powering lunar volcanic eruptions. The discovery of hydroxyl in apatite from lunar volcanic rocks is consistent with this suggestion.

The idea of looking for water in lunar apatite isn't new, Boyce notes. "Charles B. Sclar and Jon F. Bauer, geoscientists at Lehigh University, first noted that something was missing from the results of chemical analyses of apatite in 1975," he says. "Now, 35 years later, we have quantitative measurements-and it turns out, they were right. The missing piece was OH."

The Caltech team analyzed the lunar apatite for hydrogen, sulfur, and chlorine using an ion microprobe, which is capable of analyzing mineral grains with sizes much smaller than the width of a human hair. This instrument fires a focused beam of high-energy ions at the sample surface, sputtering away target atoms that are collected and then analyzed in a mass spectrometer. Ion microprobe measurements demonstrated that in terms of its hydrogen, sulfur, and chlorine contents, the lunar apatite in this sample is indistinguishable from apa-

tites from terrestrial volcanic rocks.

"We realized that the moon and the earth were able to make the same kind of apatite, relatively rich in hydrogen, sulfur and chlorine," Boyce says.

Does that mean the moon is as awash in water as our planet? Almost certainly not, say the scientists. In fact, the amount of water the moon must contain to be capable of generating hydroxyl-rich apatite remains an open question. After all, it's hard to scale up the amount of water found in the apatite-1600 parts per million or 0.16 percent by weight-to determine just how much water there is on the lunar landscape. The apatite that was studied is not abundant, and is formed by processes that tend to concentrate hydrogen to much higher levels than are present in its host rocks or the moon as a whole.

"There's more water on the moon than people suspected," says Eiler, "but there's still likely orders of magnitude less than there is on the earth."

Nonetheless, the finding is significant for what it implies about our moon's composition and its history. "These findings tell us that the geological processes on the moon are capable of creating at least one hydrous mineral," Eiler says. "Recent spectroscopic observations of the moon showed that hydrogen is present on its surface, maybe even as water ice. But that could be a thin veneer, possibly hydrogen brought to the moon's surface by comets or solar wind. Our findings show that hydrogen is also part of the rock record of the moon, and has been since early in its history."

Beyond that, Eiler continues, "it's all a great big question mark. We don't know whether these were igneous processes,"-in which rocks are formed by solidification of molten lava-"or metamorphic"-in which minerals re-crystallize or change in change in chemistry without melting. "They're both on the table as possible players."

A plane that lands like a bird

An innovative control system allows a foam glider to touch down on a perch or a wire like a pet parakeet.

Everyone knows what it's like for an airplane to land: the slow maneuvering into an approach pattern, the long descent, and the brakes slamming on as soon as the plane touches down, which seems to just barely bring it to a rest a mile later. Birds, however, can switch from barreling forward at full speed to lightly touching down on a target as narrow as a telephone wire. Why can't an airplane be more like a bird?



MIT researchers from the Computer Science and Artificial Intelligence Laboratory have developed a control system that lets a foam glider land on a perch like a pet parakeet.

The smooth airflow over the wings of a normally operating plane is well-understood mathematically; as a consequence, engineers are highly confident that a commercial airliner will respond to the pilot's commands as intended. But stall is a much more complicated phenomenon: Even the best descriptions of it are time-consuming to compute.

Reap the whirlwind To design their control system, MIT Associate Professor Russ Tedrake, a member of the Computer Science and Artificial Intelligence Laboratory, and Rick Cory, a PhD student in Tedrake's lab who defended his dissertation this spring, first developed their own mathematical model of a glider in stall. For a range of launch conditions, they used the model to calculate sequences of instructions intended to guide the glider to its perch. "It gets this nomi-

nal trajectory," Cory explains. "It says, 'If this is a perfect model, this is how it should fly.'" But, he adds, "because the model is not perfect, if you play out that same solution, it completely misses."

So Cory and Tedrake also developed a set of error-correction controls that could nudge the glider back onto its trajectory when location sensors determined that it had deviated from it. By using innovative techniques developed at MIT's Laboratory for Information and Decision Systems, they were able to precisely calculate the degree of deviation that the controls could compensate for. The addition of the error-correction controls makes a trajectory look like a tube snaking through space: The center of the tube is the trajectory calculated using Cory and Tedrake's model; the radius of the tube describes the tolerance of the error-correction controls.

The control system ends up being, effectively, a bunch of tubes pressed together like a fistful of straws. If the glider goes so far off course that it leaves one tube, it will still find itself in another. Once the glider is launched, it just keeps checking its position and executing the command that corresponds to the tube in which it finds itself. The design of the system earned Cory Boeing's 2010 Engineering Student of the Year Award.

The measure of air resistance against a body in flight is known as the "drag coefficient." A cruising plane tries to minimize its drag coefficient, but when it's trying to slow down, it tilts its wings back in order to increase drag. Ordinarily, it can't tilt back too far, for fear of stall. But because Cory and Tedrake's control system takes advantage of stall, the glider, when it's landing, has a drag coefficient that's four to five times that of other aerial vehicles.

portion as evidence that the evolutionary pressure to develop an external means of storing and transmitting information -- symbolic language -- came primarily from the animal connection.

Shipman concludes that detailed information about animals became so advantageous that our ancestors began to nurture wild animals -- a practice that led to the domestication of the dog about 32,000 years ago. She argues that, if insuring a steady supply of meat was the point of domesticating animals, as traditionally has been assumed, then dogs would be a very poor choice as an early domesticated species.

"Why would you take a ferocious animal like a wolf, bring it into your family and home, and think this was advantageous?" Shipman asks. "Wolves eat so much meat themselves that raising them for food would be a losing proposition."

Shipman suggests, instead, that the primary impetus for domestication was to transform animals we had been observing intently for millennia into living tools during their peak years, then only later using their meat as food.

"As living tools, different domestic animals offer immense renewable resources for tasks such as tracking game, destroying rodents, protecting kin and goods, providing wool for warmth, moving humans and goods over long distances, and providing milk to human infants" she said.

"The animal connection is an ancient and fundamentally human characteristic that has brought our lineage huge benefits over time," Shipman said. "Our connection with animals has been intimately involved with the evolution of two key human attributes -- tool making and language -- and with constructing the powerful ecological niche now held by modern humans."

New hypothesis for human evolution and human nature



"No other mammal routinely adopts other species in the wild -- no gazelles take in baby cheetahs, no mountain lions raise baby deer," Shipman said. "Every mouthful you feed to another species is one that your own children do not eat. On the face of it, caring for another species is maladaptive, so why do we humans do this?"

Shipman suggests that the animal connection was prompted by the invention of stone tools 2.6-million years ago. "Having sharp tools transformed wimpy human ancestors into effective predators who left many cut marks on the fossilized bones of their prey," Shipman said. Becoming a predator also put our ancestors into direct competition with other carnivores for carcasses and prey. As Shipman explains, the human ancestors who learned to observe and understand the behavior of potential prey obtained more meat.

"Those who also focused on the behavior of potential competitors reaped a double evolutionary advantage for natural selection," she said.

Over time, Shipman explained, the volume of information about animals increased, the evolutionary benefits of communicating this knowledge to others increased, and language evolved as an external means of handling and communicating information through symbols. "Though we cannot discover the earliest use of language itself, we can learn something from the earliest prehistoric art with unambiguous content. Nearly all of these artworks depict animals. Other potentially vital topics -- edible plants, water, tools or weapons, or relationships among humans -- are rarely if ever shown," Shipman said. She sees this dispro-

Domestic animals, such as this water buffalo in Vietnam, live intimately with humans and provide renewable resources to humans that communicate well with them.

It's no secret to any dog- or cat-lover that humans have a special connection with animals, but in a new journal article and forthcoming book, paleoanthropologist Pat Shipman of Penn State argues that this human-animal connection goes well beyond simple affection. Shipman proposes that the interdependency of ancestral humans with other animal species -- "the animal connection" -- played a crucial and beneficial role in human evolution over the last 2.6 million years.

"Establishing an intimate connection to other animals is unique and universal to our species," said Shipman, a professor of biological anthropology. Her paper describing the new hypothesis for human evolution based on the tendency to nurture members of other species will be published in the August 2010 issue of the journal *Current Anthropology*.

In addition to describing her theory in the scientific paper, Shipman has authored a book for the general public, now in press with W. W. Norton, titled "The Animal Connection."

LEGAL NOTICE - DIVORCE

IN THE CIRCUIT COURT OF THE 17TH JUDICIAL CIRCUIT, IN AND FOR BROWARD COUNTY, FLORIDA FAMILY DIVISION Case No. 10-4851 Division: 44/93

IN RE: THE MARRIAGE OF: CHERYL DOREEN WILLIAMS, Petitioner/WIFE And CLARENCE JOHN KEITH WILLIAMS, Respondent/HUSBAND

AMENDED NOTICE OF ACTION FOR DISSOLUTION OF MARRIAGE

TO: CLARENCE JOHN KEITH WILLIAMS

Last Known Address: Grand Turk, Turks & Caicos Island, British West Indies

YOU ARE HEREBY NOTIFIED that an action for dissolution of marriage has been filed against you and you are required to serve a copy of your written defenses, if any, to it on CHERYL DOREEN WILLIAMS, whose address is 2730 SOMERSET DRIVE, APT. V317, LAUDERDALE LAKES, FLORIDA 33311, on or before September 10, 2010, and file the original with the clerk of this Court at Broward County Courthouse, Clerk, Family Division, Room 230, 201 S.E. 6th St. Fort Lauderdale, FL 33301, before service on Petitioner or immediately thereafter; if you fail to do so, a default may be entered against you for the relief demanded in the petition. WARNING: Rule 12.285, Florida Family Law Rules of Procedure, requires certain automatic disclosure of documents and information. Failure to comply can result in sanctions, including dismissal or striking of pleadings. WITNESS my hand and the seal of said Court on July 27, 2010

HOWARD C. FORMAN CLERK OF THE CIRCUIT COURT By: Desiree Walters Deputy Clerk A TRUE COPY Circuit Court Seal

I, Terry Gardner, a nonlawyer, located at 4699 N. State Road 7, Suite R, Tamarac, FL 33319, (954) 739-6662, helped CHERYL DOREEN WILLIAMS who is the petitioner fill out this form. Publish July 29, August 5, 12, 19, 2010

LEGAL NOTICE - DIVORCE

IN THE CIRCUIT COURT OF THE 17TH JUDICIAL CIRCUIT, IN AND FOR BROWARD COUNTY, FLORIDA FAMILY DIVISION Case No. 10-009389 Division: 35

IN RE: THE MARRIAGE OF: ALEJANDRO R. ROSENFRIED, Petitioner And YENIFFER M. FERNANDEZS, Respondent

NOTICE OF ACTION FOR DISSOLUTION OF MARRIAGE

TO: YENIFFER M. FERNANDEZS Last Known Address: Somewhere in Baranquilla, Columbia

YOU ARE NOTIFIED that an action has been filed against you and you are required to serve a copy of your written defenses, if any, to it on ALEJANDRO R. ROSENFRIED, whose address is 4960 NW 92 Terrace, Coral Springs, FL 33067, on or before September 6, 2010, and file the original with the clerk of this Court at Broward County Courthouse, Clerk, Family Division, Room 230, 201 S.E. 6th St. Fort Lauderdale, FL 33301, before service on Petitioner or immediately thereafter; if you fail to do so, a default may be entered against you for the relief demanded in the petition. Copies of all court documents in this case, including orders, are available at the Clerk of the Circuit Court's office. You may review these documents upon request. You must keep the Clerk of the Circuit Court's office notified of your current address. (You may file Notice of Current Address, Florida Supreme Court Approved Family Law Form 12.915.) Future papers in this lawsuit will be mailed to the address on record at the clerk's office. WARNING: Rule 12.285, Florida Family Law Rules of Procedure, requires certain automatic disclosure of documents and information. Failure to comply can result in sanctions, including dismissal or striking of pleadings.

Dated: July 21, 2010

HOWARD C. FORMAN CLERK OF THE CIRCUIT COURT By: Desiree Walters Deputy Clerk A TRUE COPY Circuit Court Seal

I Claudia Solano, Document Solutioners a nonlawyer located at 8436 W. Oakland Park Boulevard, Sunrise, Florida 33321, 954-726-5656 helped Aylaiaire Aalcime, who is the petitioner, fill out this form. Publish July 29, August 5, 12, 19, 2010

LEGAL NOTICE - DIVORCE

IN THE CIRCUIT COURT OF THE 17TH JUDICIAL CIRCUIT, IN AND FOR BROWARD COUNTY, FLORIDA FAMILY DIVISION Case No. 10-009557 Division: 40/90

IN RE: THE MARRIAGE OF: LEONETA DAVY, Petitioner And HOSEA ANTONIO AUGUSTO SMALL, Respondent

NOTICE OF ACTION FOR DISSOLUTION OF MARRIAGE

TO: HOSEA ANTONIO AUGUSTO SMALL Last Known Address: 1700 EGLINTON STREET, TORONTO, CANADA

YOU ARE NOTIFIED that an action has been filed against you and you are required to serve a copy of your written defenses, if any, to it on LEONETA DAVY, whose address is 1175 WEEPING WILLOW WAY HOLLYWOOD, FLORIDA 33019, on or before September 3, 2010, and file the original with the clerk of this Court at Broward County Courthouse, Clerk, Family Division, Room 230, 201 S.E. 6th St. Fort Lauderdale, FL 33301, before service on Petitioner or immediately thereafter; if you fail to do so, a default may be entered against you for the relief demanded in the petition. Copies of all court documents in this case, including orders, are available at the Clerk of the Circuit Court's office. You may review these documents upon request. You must keep the Clerk of the Circuit Court's office notified of your current address. (You may file Notice of Current Address, Florida Supreme Court Approved Family Law Form 12.915.) Future papers in this lawsuit will be mailed to the address on record at the clerk's office. WARNING: Rule 12.285, Florida Family Law Rules of Procedure, requires certain automatic disclosure of documents and information. Failure to comply can result in sanctions, including dismissal or striking of pleadings.

Dated: July 20, 2010

HOWARD C. FORMAN CLERK OF THE CIRCUIT COURT By: Desiree Walters Deputy Clerk A TRUE COPY Circuit Court Seal

I, Rosemary Rivas of DOCUMENT EXPRESS, a nonlawyer, located at 6289 W. Sunrise Blvd., #120, Sunrise, FL 33313 (954) 581-9660, helped the petitioner fill out this form. Publish July 29, August 5, 12, 19, 2010

LEGAL NOTICE - DIVORCE

IN THE CIRCUIT COURT OF THE 17TH JUDICIAL CIRCUIT, IN AND FOR BROWARD COUNTY, FLORIDA FAMILY DIVISION Case No. 10009405 Division: 37/90

IN RE: THE MARRIAGE OF: MICHAEL LEWIN, Petitioner/Husband VS ROSA LEE GREEN, Respondent/Wife

NOTICE OF ACTION FOR DISSOLUTION OF MARRIAGE

TO: ROSA LEE GREEN Last Known Address: Unknown

YOU ARE NOTIFIED that an action has been filed against you and you are required to serve a copy of your written defenses, if any, to it on Gareth Bullock, Esq. Attorney for the Petitioner, whose address is 5220 University Drive, Ste. 106C, Davie, Florida 33328, on or before August 30, 2010, and file the original with the clerk of this Court at Broward County Courthouse, Clerk, Family Division, Room 230, 201 S.E. 6th St. Fort Lauderdale, FL 33301, before service on Petitioner or immediately thereafter; if you fail to do so, a default may be entered against you for the relief demanded in the petition. This notice shall be published once each week for four consecutive weeks in THE SENTRY. WITNESS my hand and the seal of said Court on July 16, 2010

HOWARD C. FORMAN CLERK OF THE CIRCUIT COURT By: Michael Corsaro Deputy Clerk A TRUE COPY Circuit Court Seal

Publish July 29, August 5, 12, 19, 2010

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