3 A CONVERSATION WITH
Mike Bettwy and NOAA keep an eye out for threats from space weather.

3 PALEONTOLOGY
The genetic history of mammoths offers lessons for saving endangered species.



7 WELL
Attempting to untangle the link between stress and chronic disease.

ScienceTimes
The New York Times

Endless Possibilities

For 50 years, the Rubik's Cube has been, by turns, frustrating and exhilarating.

BY SIOBHAN ROBERTS | PAGE 5

AKOS STILLER FOR THE NEW YORK TIMES

China and the Far Side of the Moon

A mission's soil retrieval is a first and another win for the nation's lunar program.

By KATRINA MILLER

China brought a capsule full of lunar soil from the far side of the moon down to Earth, achieving the latest success in an ambitious schedule to explore the moon and other parts of the solar system.

The sample, retrieved last week by the China National Space Administration's Chang'e-6 lander after a 53-day mission, highlights China's growing capabilities in space and notches another win in a series of lunar missions that started in 2007 and have so far been executed almost without flaw.

"Chang'e-6 is the first mission in human history to return samples from the far side of the moon," Long Xiao, a planetary geologist at China University of Geosciences, wrote in an email. "This is a major event for scientists worldwide," he added, and "a cause for celebration for all humanity."



AGENCE FRANCE-PRESSE — GETTY IMAGES

Officials in Inner Mongolia prepared to recover the landing module of the Chang'e-6 moon probe and its contents.

Such sentiments and the prospects of international lunar sample exchanges highlighted the hope that China's robotic missions to the moon and Mars will serve to advance scientific understanding of the solar system. Those possibilities are contrasted by views in Washington and elsewhere that Tuesday's achievement is the latest milestone in a 21st-century space race with geopolitical overtones.

In February, a privately operated American spacecraft landed on the moon. NASA is also pursuing the Artemis campaign to return Americans to the lunar surface, although its next mission, a flight by astronauts around the moon, has been delayed because of technical issues.

China, too, is looking to expand its presence on the moon, landing more robots there, and eventually human astronauts, in

CONTINUED ON PAGE D4

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This Beer Has Been Millennia in the Making

A home brewer's concoction relies on rare ingredients and an ancient Egyptian recipe.

By ALEXANDER NAZARYAN







WALTRAUD GRUBITZSCH/PICTURE ALLIANCE, VIA GETTY IMAGES



PHOTOGRAPHS BY KIM RAFF FOR THE NEW YORK TIMES

Clockwise from top: the Ebers Papyrus, an Egyptian text of medical recipes from 1500 B.C., on view at the Albertina University Library in Leipzig, Germany; Dylan McDonnell, who believes his brew is the closest approximation yet to what Rameses the Great may well have enjoyed between battles; hojari frankincense; and desert dates.

The idea came to Dylan McDonnell early in the pandemic, when a sourdough-baking craze took over a nation under lockdown. Mr. McDonnell, an amateur brewer who lives outside Salt Lake City, saw Seamus Blackley, a video game designer, boasting on social media about baking bread with 4,500-year-old Egyptian yeast.

I wonder if I could do that with beer, Mr. McDonnell recalled thinking.

The answer recently arrived in the form of an amber brew that Mr. McDonnell believes is the closest approximation yet to what Rameses the Great may have been drinking between battles with the Hittites.

Recent years have seen attempts to recreate the beer of the Vikings, the Late Shang and Western Zhou dynasties of China, and the Sumerians, who are believed to have invented beer. "These beers can be all over the map," said Neil Witte, a beer expert at Craft Quality Solutions in Kansas City, Mo. "What was good 500 or 1,000 years ago is likely nothing like what we consider good today."

Still, the lure of connecting with bygone civilizations by reviving their potent potables appears to be surging.

Mr. McDonnell, who is the chief operations officer of a nonprofit organization that helps people with disabilities, has no desire to compete with professional brewers — or to commercialize his own concoction. But he does believe that he has gone further than others in seeking out the exact ingredients the ancient Egyptians would have used — and fermenting them with ancient yeast.

While wine is often associated with the Greco-Roman civilization, "beer was integral to ancient societies in the Levant and the ancient Near East," said Marie Hopwood, a scholar of ancient beer at Vancouver Island University, where she is the head of the anthropology department. "Everyone drank beer," she said, especially since water was often contaminated.

And yet only recently, Dr. Hopwood added, has beer archaeology attained the respect long afforded to the study of wine, a discrepancy she attributed to modern biases. Many 20th-century archaeologists "grew up thinking of wine as elite and beer as low class," she said.

But with archaeologists now excavating brewing sites on Cyprus, and Archival Brewing, a brewpub in Belmont, Mich., focusing on historical recreations like 19th-century Mexican lager, both academia and the brewing industry appear to have expunged that longstanding favoritism.

Ancient beer would have been less alcoholic than ours, and served warm. Women typically brewed it, Dr. Hopwood said.

"We see evidence for this all over the world," she said, including in Viking and Inca cultures. "They would have been taught by their mothers, who had been taught by theirs."

Constrained by work and family, Mr. McDonnell took more than three years to carry out what he described as his "harebrained" idea. First, he consulted the Ebers Papyrus, an Egyptian text of medical recipes from 1500 B.C. One recipe calls for "fat from a fierce-looking lion" to cure male baldness, for example, while another suggests a concoction of salt, milk fat, sweet beer and honey "to be poured into the buttocks" of women experiencing gynecological pain.

Mr. McDonnell found about 75 recipes for beer and compiled the ingredients in a spreadsheet. Eventually, he settled on eight representing the most frequently mentioned: desert dates, Yemeni Sidr honey, sycamore figs, Israeli golden raisins, prickly juniper berries, carob fruit, black cumin and hojari frankincense.

Sycamore figs were especially hard to find. But as luck would have it, his friend Marika Dalley Snider, an architectural historian at the University of Memphis, was working at the time on a digital reconstruction of the Karnak Temple in Egypt. It turned out that the family of an archaeological foreman in Luxor had been tending to a grove of sycamore fig trees for generations. "We just celebrated," Mr. McDonnell said.

For base grains, he chose purple Egyptian barley and emmer wheat. Then he turned to the yeast. Much like Mr. Blackley, Mr. McDonnell wanted to use an ancient strain, not an ordinary commercial variety.

Here, he was fortunate again. In 2015, an Israeli team led by Itai Gutman, a veteran brewer living in Europe, had extracted yeast from an amphora found in Israel that had most likely been used by the Philistines for brewing around 850 B.C.

Yeast has a remarkable ability to lie dormant for exceptionally long periods of time. The billions of cells in a dormant colony "still talk to each other," Mr. Gutman said. "They still have all those chemical signals between them. And they just wait. They say, 'Now is not a good time to reproduce.'"

Mr. Gutman is the founder of Primer's Yeast, a company that sells ancient strains of the microorganism. He argues that the difference between ancient yeast and the yeast found on a supermarket shelf is the difference between a wolf and a golden retriever. Commercial yeast creates a more predictable taste profile, whereas wild yeast came to be associated with what are now called "off flavors."

"What they did is to take away a lot of the byproducts," Mr. Gutman said. Traditional European breweries — like those run by Belgian monks hewing to centuries-old methods — retain the fruity signature of yeast in its untamed, lupine form, he said.

Those were the very flavors Mr. McDonnell wanted to tease out. "It was by far the most important part of the process," he said, referring to Mr. Gutman's yeast. "To me, this would have just been another fun beer I made that isn't noteworthy if it didn't include the yeast."

Some in the industry are skeptical that ancient yeast is much of a game changer. "Modern science hasn't deprived anyone of anything," said Mr. Witte, the beer expert. Thanks to modern microbiology, brewers can use "pure cultures of a single yeast strain," he said. "This gives brewers more control over the finished beer than at any time in history."

Mr. McDonnell, though, is pleased with his historical blend, which is initially sour but then becomes increasingly complex, arriving at a rich, refreshing, cider-like quality. The flavor, like the color, suggests apricot. The carbonation, in keeping with history, is low.

Mr. McDonnell said he is often asked what the beer is called. Branding was not much of a consideration, he said, since he had no plans to sell his suds. But the question has been posed frequently enough that Mr. McDonnell has settled on a name, one that reflects both the beer's flavor profile and its distant origins near the desert peninsula where the ancient Egyptians mined turquoise: "Sinai Sour."

China's Ambition and the Far Side of the Moon

CONTINUED FROM PAGE D1

the years to come.

Building toward that goal, it has taken a slow and steady approach, executing a robotic lunar exploration program — named after the Chinese moon goddess Chang'e (pronounced "chong-uh") — that it devised decades in advance. The program's first two missions orbited the moon to photograph and map its surface. Then came Chang'e-3, which landed on the lunar near side in 2013 and deployed a rover, Yutu-1. It was followed in 2019 by Chang'e-4, which became the first vehicle to visit the moon's far side and put the Yutu-2 rover on the surface.

One year later, it landed Chang'e-5, which sent nearly four pounds of near-side lunar regolith to the Earth. The achievement made China only the third country — after the United States and the Soviet Union — to achieve the complex orbital choreography of collecting a sample from the moon.

According to Yuqi Qian, a lunar geologist at the University of Hong Kong, the maneuvers of Chang'e-5 and Chang'e-6 are test runs for China's future crewed missions to the moon, which, like the Apollo missions of the 1960s and '70s, need to land and then launch humans from the lunar surface.

While it works toward putting astronauts on the moon, China's long-term strategy is paying scientific benefits for understanding the solar system.

The Chang'e-5 sample was more recent than the lunar material collected by the Americans or Soviets in the 1960s and '70s. It is made up mainly of basalts, or cooled lava from ancient volcanic eruptions.

Two Chinese-led research teams concluded that the basalts were about two billion years old, suggesting that volcanic activity on the moon extended at least a billion years beyond the time frame deduced from the U.S. Apollo and Soviet Luna samples.

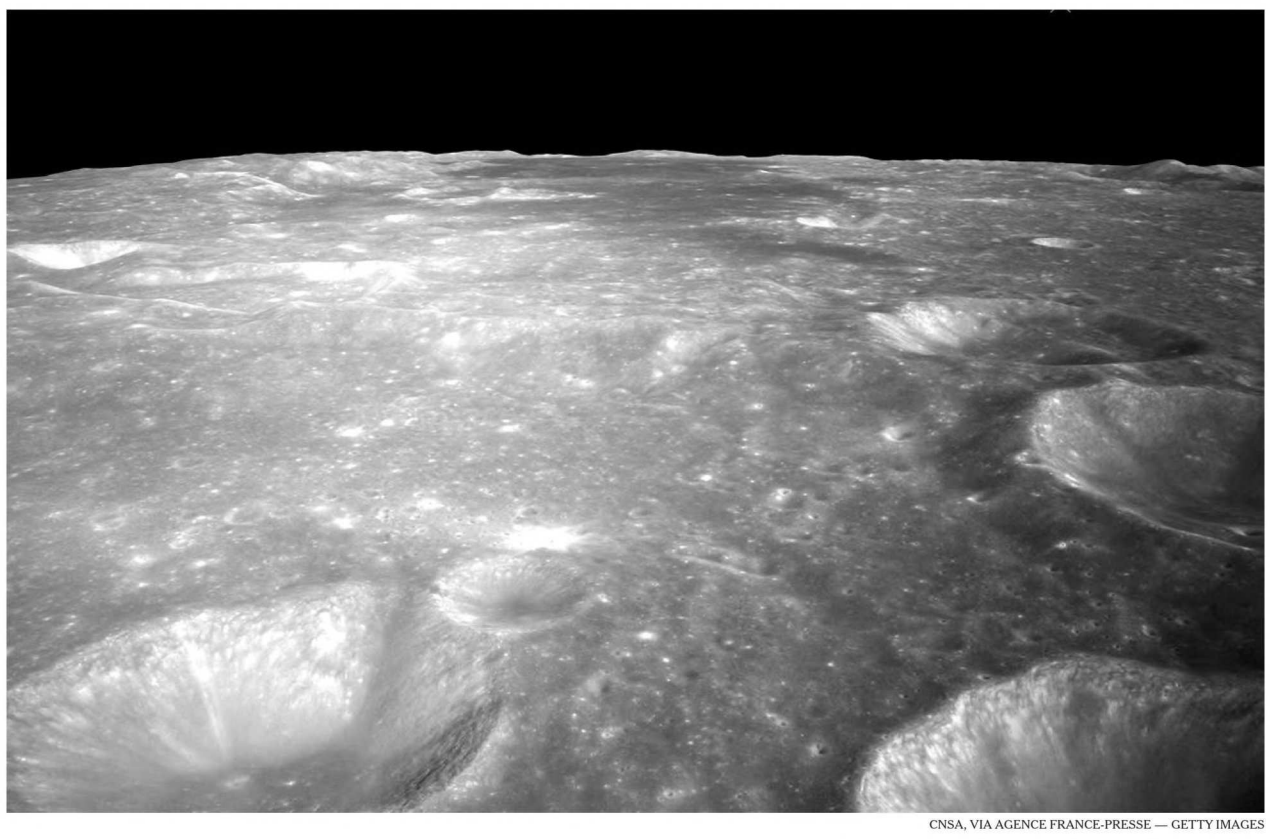
The latest achievement in a space race with geopolitical overtones.

Other studies of the material ruled out theories about how the moon's insides had warmed enough to generate volcanic activity. One research group found that the amounts of radioactive elements in the lunar interior, which could decay and produce heat, were not high enough to cause the eruptions. Another result ruled out water in the mantle as a potential source of the interior melting that led to volcanism.

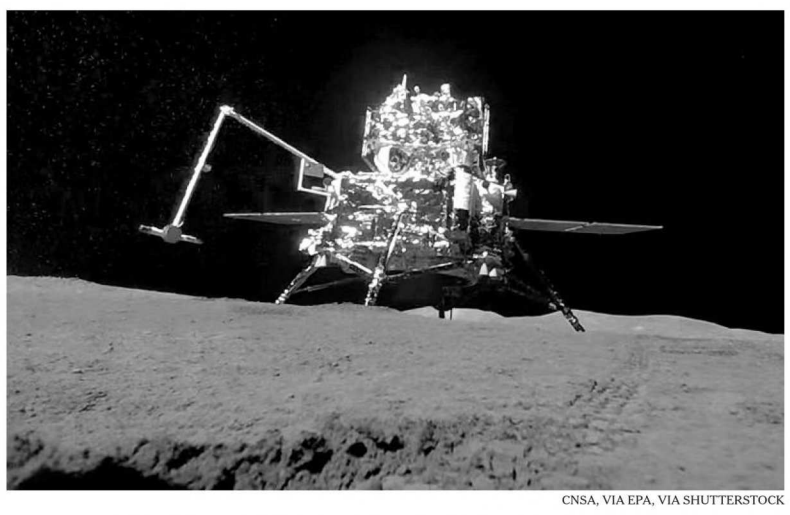
Chang'e-6 launched on May 3 with even grander scientific ambitions: bringing back material from the far side of the moon. The near side of the moon is dominated by wide, dark plains where ancient lava once flowed. But the far side has fewer of those plains. It also has more craters and a thicker crust.

And because that half never faces Earth, it is impossible to directly communicate with landers on the lunar far side, making it difficult to reach. The Chinese space agency relied on two satellites it previously launched into orbit around the moon, Queqiao and Queqiao-2, to remain in touch with Chang'e-6 during its visit.

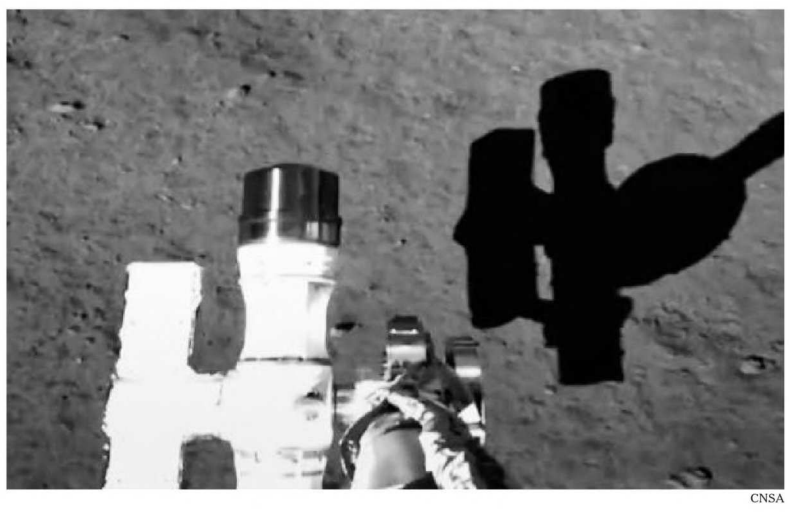
The spacecraft used the same technique as Chang'e-5 to reach the moon and then return its sample to Earth.



CNSA, VIA AGENCE FRANCE-PRESSE — GETTY IMAGES



CNSA, VIA EPA, VIA SHUTTERSTOCK



CNSA

Above, craters on the far side of the moon's surface captured in an image from the Chang'e-6 lunar probe. Left, the probe after it raised a small Chinese flag. Below left, the probe observed collecting samples.

After a few weeks in lunar orbit, Chang'e-6 descended to a site at the edge of the South Pole-Aitken basin, the oldest, deepest impact crater on the moon. Equipped with a mechanical scoop and a drill, the lander spent two days gathering lunar rock and dust from its surroundings and the moon's subsurface.

It then stashed the material away. The mission deployed a miniature rover that snapped a picture of the lander with a small Chinese flag raised. Then, on June 3, a rocket flung the sample canister back into lunar orbit. The materials then reunited on June 6 with a spacecraft that had remained in orbit and prepared to begin the journey back to Earth.

The sample container re-entered Earth's atmosphere moving at around 25,000 miles per hour, according to Xinhua, a Chinese state news agency. Its parachute opened about six miles above the ground.

The capsule, scorched from its passage through the atmosphere, landed in the Siziwang Banner area of Inner Mongolia. A Chinese flag planted near the pod flapped in the wind as ground crews worked to recover the material.

The sample weighed more than four pounds, based on preliminary measurements. A spokesperson for the mission told Xinhua on Friday that the soil appeared more viscous and clumpy, compared with material retrieved in the past from the moon's near side.

Qiong Wang, the China National Space Administration's deputy chief designer of Chang'e-6, told Xinhua that part of the sample will be permanently stored. The rest will be distributed to researchers in China and abroad, he said.

When scientists take possession of the far-side soils, they will compare the composition of the newly recovered basalts with those from the lunar near side. That may help them deduce how the moon's volcanic activity caused its two halves to evolve differently.

"New samples will inevitably lead to new discoveries," Wei Yang, a researcher at the Chinese Academy of Sciences, told Xinhua. "Chinese scientists are eagerly anticipating the opportunity to contribute to lunar science."

The mission team will also be looking for material from surrounding regions, blasted away from their original sites by impacts with comets and asteroids. If strong enough, these collisions may have excavated material from the lower crust of the moon and its upper mantle, Dr. Qian said.

Melted rock from those impacts could also yield clues about the age of the South Pole-Aitken basin and the era in which it formed, during which scientists believe a barrage of asteroids and comets bombarded the inner solar system.

This period "totally changed the geological history of the moon," Dr. Qian said, and was "a critical time for the evolution of the Earth."

Clive Neal, a planetary geologist at the University of Notre Dame, called the goals lofty. Referring to China's streak of lunar success, "it's excellent," he said. "More power to them."

Strained political relations, however, will make it challenging for American scientists to collaborate with Chinese researchers on studying the far-side samples.

The Wolf Amendment, enacted in 2011, prohibits NASA from using federal funds for bilateral cooperation with the Chinese government. Federal officials recently granted the space agency an exemption, which allowed NASA-funded researchers to apply for access to the near-side sample retrieved by Chang'e-5. But another bill passed by the U.S. House of Representatives in June would bar universities with research ties to Chinese institutions from receiving funding from the U.S. Department of Defense.

For the future, China has its eyes set on the lunar south pole, where Chang'e-7 and 8 will explore the environment and search for water and other resources. It hopes to send crewed missions to the moon by 2030. Eventually, China plans to build an international base at the south pole.

NASA's Artemis campaign is also shooting for the lunar south pole. Bill Nelson, the space agency's administrator, has previously referred to the parallel programs as a race between the United States and China.

Many scientists reject that framing. Resources for studying the moon plunged after U.S. astronauts beat the Soviets to the lunar surface in 1969, Dr. Neal said. "I don't like international space races, because they're not sustainable," he said. "A race is to be won. Once you win it, then what?"

He added, "I think it's important to look at space as something that can bring us together, rather than tear us apart."

Several countries, including France and Pakistan, contributed payloads that flew with the Chang'e-6 mission. Chinese researchers took this as a good sign.

"Lunar exploration is a shared endeavor for all humanity," Dr. Xiao said, adding that he hopes for increased international collaboration, "particularly between major spacefaring nations like China and the United States."

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