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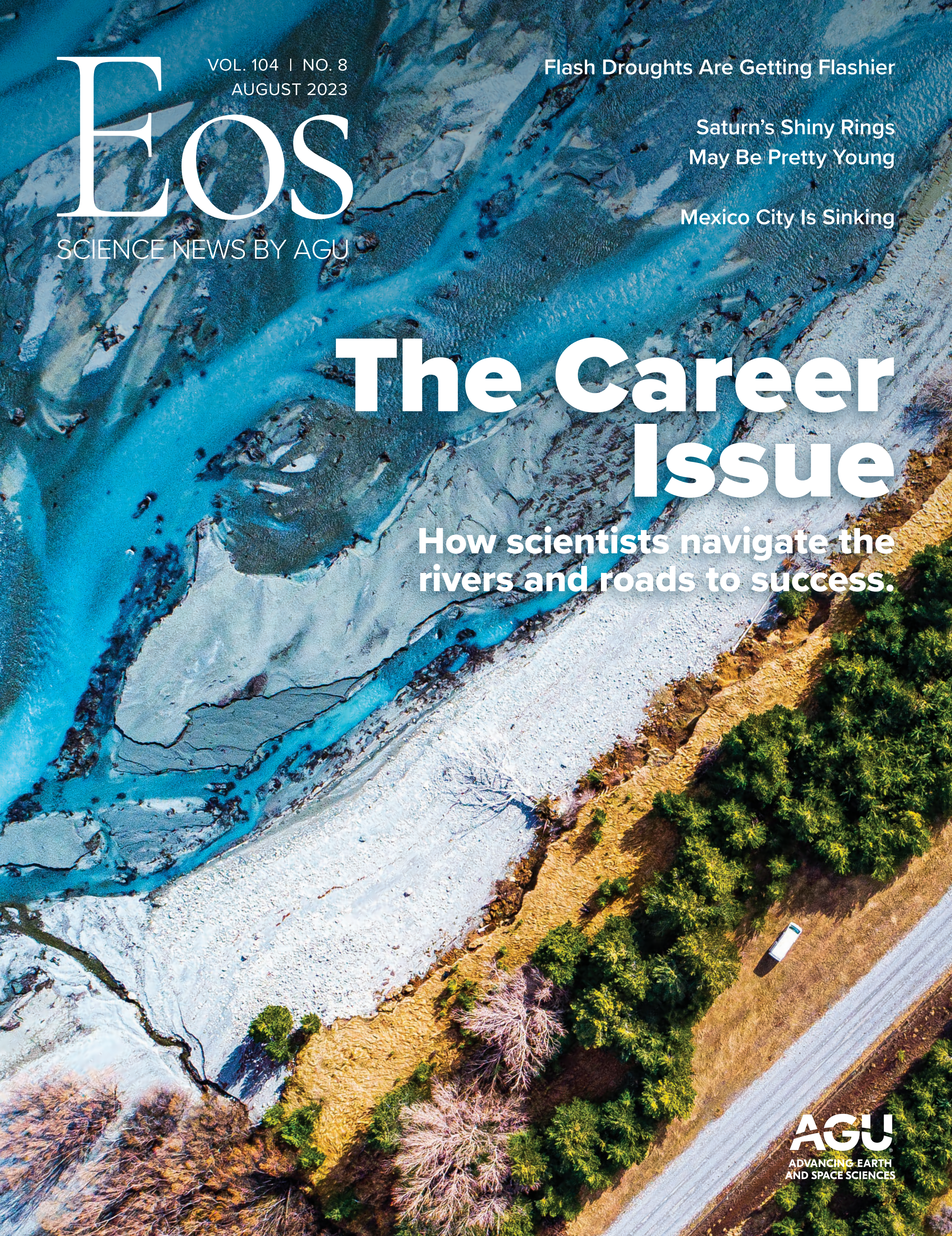

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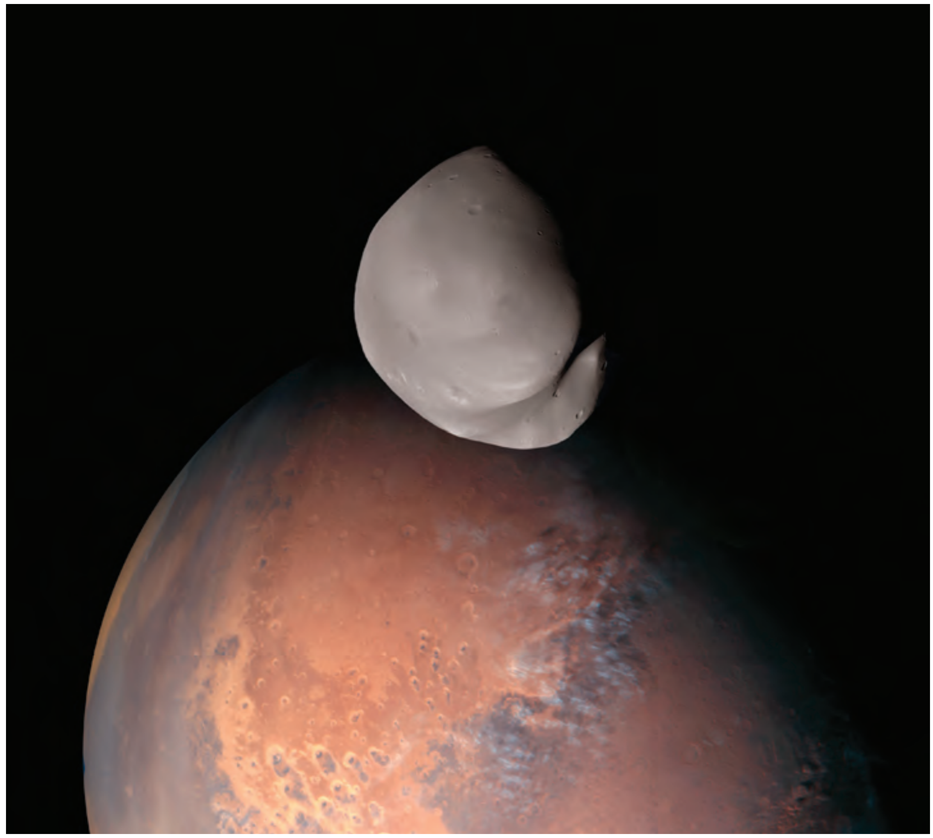
Tiny Martian Moon May Be a Chip Off the Old Block

The origin of Mars's moons, Phobos and Deimos, has puzzled scientists since their discovery in the 1870s. On the basis of the objects' small, irregular shapes and shade (among the darkest in the solar system), scientists have thought they could be asteroids captured by chance into Martian orbit.

Since the captured-asteroid theory took hold, however, new ideas have emerged to explain the origin of Phobos and Deimos—mostly variations of a giant impact scenario that launched enough Martian material into orbit to form the moons. One variation posits that the moons could have coalesced directly from material lifted by the impact. Another suggests that a single larger moon formed first but got too close to Mars and disintegrated, leaving Phobos and Deimos to form from its scraps.

New close-up images of the outer moon, Deimos, seem to support the impact theory. The images, obtained by the Emirates Mars Mission, show that Deimos lacks the expected signs of an asteroidal origin. Instead, chemical clues point to a makeup similar to that of Mars itself, suggesting that the moon could have been born of the Red Planet.



Deimos is seen by the Hope probe, with Mars in the background. Credit: Emirates Mars Mission

Long Time No See

Deimos is a hard target for space missions. It averages just 12 kilometers in diameter and orbits more than 20,000 kilometers from the surface of Mars—much farther away than most spacecraft around the planet. The Viking 2 lander achieved the last close-up in 1977 while en route to Mars.

The Hope probe, as the Emirati spacecraft is called, arrived at Mars in February 2021 to observe variations in the Martian atmosphere over the seasons. To get a full view of the outer atmosphere, the satellite has a high elliptical orbit at 20,000–43,000 kilometers from the planet.

After a full Martian year of watching the planet, mission scientists took a unique opportunity to approach Deimos. Flight engineers maneuvered the spacecraft to synchronize its orbit with the moon, enabling a series of flybys. The nearest approach occurred on 10 March 2023, when it got to within 103 kilometers of the moon's surface.

During the flyby, Hope mapped almost the entire surface of Deimos, capturing the first view of its farside. The craft's visible-light camera took photos of the surface with a resolution of 10 meters per pixel. Two other instruments recorded the infrared and ultraviolet light radiating off the moon's surface, revealing details about its composition and temperature. The findings were reported at the European Geosciences Union General Assembly in April (bit.ly/Deimos-flybys).

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Visually, Deimos doesn't look like asteroids Ryugu or Bennu, visited by the Hayabusa2 and OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer) spacecraft, respectively. Those asteroids have a very coarse surface filled with loose boulders and rocks. Deimos, on the other hand, is covered by a fine powder called regolith, lending it a smooth look, similar to those of our own Moon and neighboring Phobos.

In the ultraviolet, the researchers didn't find signs of organic compounds or carbon-rich minerals, which are expected in D-type asteroids—those that look most like Deimos. These asteroids formed beyond Jupiter's orbit and are thought to be rich in water and other volatiles.

This is the first time either Martian moon has been successfully observed in the ultraviolet. "Previous missions had tried to look at Phobos at similar wavelengths and just failed to get any signal at all," explained Justin Deighan, a planetary scientist at the University of Colorado Boulder. The Emirates Mars Ultraviolet Spectrometer (EMUS) on board Hope is the most sensitive spectrometer that has ever orbited Mars, a capability that proved crucial to observing the dark Martian moon, he said.

In the infrared, the tiny moon doesn't match what scientists expect from an asteroid, either. Researchers compared Deimos's infrared signature with those of the carbon-rich Tagish Lake meteorite (which landed in British Columbia in 2000), the closest match to the expected composition of a D-type asteroid. Instead of seeing similarities with the meteorite, however, they found that Deimos's infrared spectral signature more closely resembled that of basalt, a volcanic rock that covers most of the Martian surface.

No More Asteroid Talk?

Given the new observations, the captured asteroid scenario looks less likely than the giant impact theory.

"This raises interesting questions, like, Why do some of the rocky bodies in our solar system have different moons?" said Christopher Edwards, a planetary scientist at Northern Arizona University and an instrument scientist for the Emirates Mars Infrared Spectrometer (EMIRS) on board Hope. Scientists question why Venus and Mercury don't have moons at all, he said, while Earth has one big moon and Mars has two small moons. "[A giant impact origin] tells us about the diversity of early planetary processes that may be going on in our solar system," he explained.

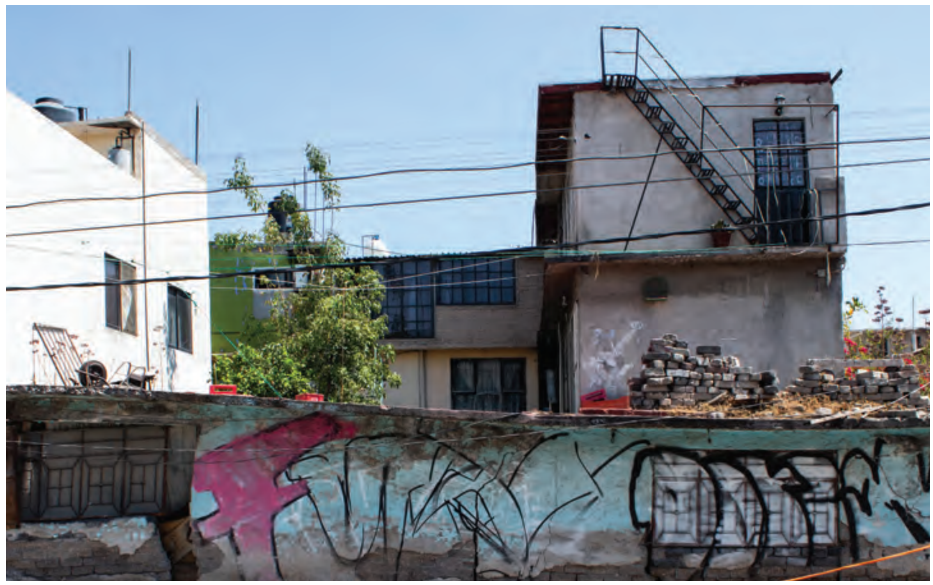
The new data don't entirely rule out Phobos and Deimos as captured asteroids—in part because researchers don't know for sure what a D-type asteroid looks like up close. "If we were to somehow magically take Deimos out of its orbit and put it on its own in the asteroid belt, we would call it a D-class asteroid based on its visible and near-infrared spectrum," said Andrew Rivkin, a planetary scientist at the Johns Hopkins University Applied Physics Laboratory who isn't involved with the Emirates Mars Mission. Still, "it's great to get [these] data for the first time ever," Rivkin said.

Rivkin said he thinks that a definitive answer about the origin of Mars's moons will likely have to wait for the Japan Aerospace Exploration Agency's Martian Moons Exploration (MMX) mission—scheduled to launch in 2024—which will orbit Phobos and return a piece of it to Earth.

"I think the impact hypothesis is putting itself in a good position here," Rivkin said, "but MMX will absolutely clinch it."

By **Javier Barbuzano** (@javibarbuzano), Science Writer

Groundwater Pumping Is Causing Mexico City to Sink



In the Ampliación Santa Martha neighborhood of Mexico City, land subsidence has contributed to hundreds of leaning fences, fractured walls, and cracked streets. Credit: Rodrigo Botello

Gerardo Medina's plumbing has never worked well. Most of the time, water arrives at his home on the outskirts of Mexico City dirty…or it doesn't come at all. And although the Mexico City Water System (SACMEX) repeatedly sends people to fix the pipes, the lines always fail again, Medina said. "It's a never-ending story."

In Medina's neighborhood, Ampliación Santa Martha, broken pipes, cracked streets, and curved windows warn of a (not so) hidden problem: Mexico City is sinking.

Scientists have agreed that groundwater extraction is a contributing factor to this subsidence, although estimates of the extraction rate vary. Authors of a new study published in *Geophysical Research Letters* used satellite data to narrow these estimates (bit.ly/Mexico-City-groundwater). They found that 1–13 cubic kilometers (0.2–3 cubic miles) of groundwater have been pumped each year since 2014 to serve the 22 million residents of the Mexico City Basin. (For reference, that's enough water to fill nearly 5 million Olympic-sized swimming pools.)

Perfectly Disastrous

The Mexico City Basin is like a wet sponge. It is composed of lava flows, ashes, clays, and sands. Water flows in the pore spaces between these sediments. Though pumping has caused the surface to sink by about 35 centimeters (14 inches) per year, subsidence is not uniform, according to the study's authors.

When water is removed, the sediment compacts, causing subsidence in some areas and cracks in others, explained Dora Carreón Freyre, a geological engineer at the National Autonomous University of Mexico (UNAM) and a member of the United Nations Educational, Scientific and Cultural Organization's Land Subsidence International Initiative (LASII) who was not involved in the new research.

Mexico City's growth also blocks precipitation from reaching the spongy sediments by increasing the amount of land covered by impervious surfaces like roads and parking lots. These impervious surfaces prevent increasingly scarce rains from recharging underground aquifers. "It's a perfectly disastrous formula," Carreón Freyre said.

Although previous studies did consider pumping to be a factor causing subsidence in Mexico City, some researchers have argued that the main trigger is long-term compaction of an ancient lake bed. The city was built on Lake Texcoco, which filled with silt in the