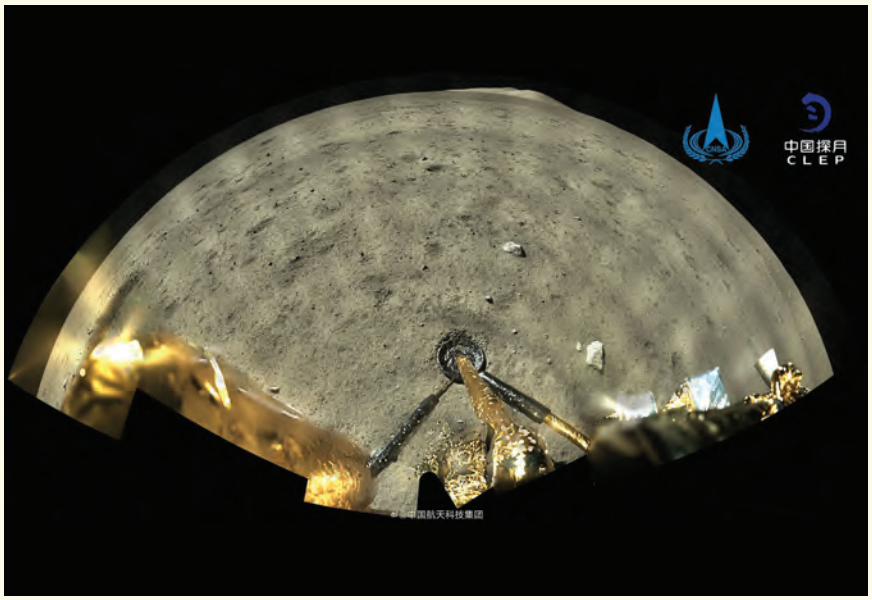
Two new minerals found on the Moon

A glass bead containing an impact crater just 9 μm across is the source of otherworldly titanium oxide compounds.

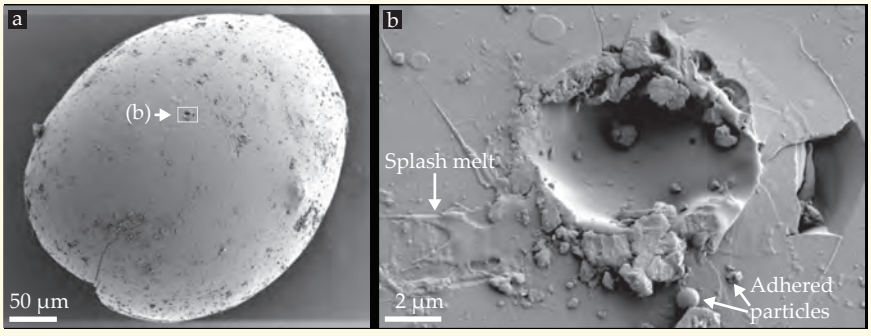
China's *Chang'e 5* lander returned to Earth on 16 December 2020 with the first sample brought back from the Moon since 1976. Within the roughly 1.7 kg sample, researchers found a glass bead with a pit about 9 μm across, formed by the impact of a piece of fast-traveling space dust known as a micrometeorite. On the rim of the tiny crater they found two titanium-based minerals—trigonal and triclinic Ti_2O—that had not been found on the Moon before and do not occur naturally on Earth. Those are now the seventh and eighth new minerals discovered on the Moon to date, as described in a recent *Nature Astronomy* paper by Xiaojia Zeng, Yanxue Wu, and colleagues.

Above Earth, the friction generated by meteors moving through the atmosphere slows them down and can burn them up, depending on their incoming size and speed. Above the Moon and other airless bodies, though, there is no atmospheric buffer between the debris of space and the rocky surface. The Moon is thus bombarded not only with the large meteors and asteroids that have given rise to its iconic cratered surface but also with tiny dust-sized meteors that travel at high speeds—as fast as 20 km/s, about 30 times as fast as an F-16 jet. Those micrometeorite impacts are crucial to the weathering of the lunar surface.



A PANORAMIC PHOTO of the lunar surface captured by China's *Chang'e 5* as it landed on the Moon in 2020. (Image from the China National Space Administration.)

The cratered glass bead, according to Zeng, Wu, and colleagues, is rich in iron and was likely formed from a larger meteorite collision in the lunar maria—vast, dark basaltic plains that fill ancient impact basins. Using scanning electron microscopy, the researchers identified the minerals ilmenite, troilite, and apatite on the surface of the bead. Ilmenite, which is common in the lunar mare regions, is a titanium iron oxide mineral and the likely source of the titanium that formed the two new minerals. To shed light on the chemical and physical reactions at play during the micrometeorite impact, the researchers homed in on the impact crater on the bead's surface.



A GLASS BEAD (a) from the surface of the Moon contains a micrometeorite crater **(b)** produced by a high-speed impact of micron-scale space debris. The impact produced titanium minerals that do not occur naturally on Earth. (Adapted from X. Zeng et al., *Nat. Astron.*, 2024, doi:10.1038/s41550-024-02229-4.)

Zeng, Wu, and colleagues used transmission electron microscopy to look at the tiny (100–300 nm) titanium oxide deposits on the crater rim and observe the lattice structures that define their mineral phases. The researchers believe that the minerals were formed by the vaporizing of ilmenite during impact, which ripped apart its constituent elements. Titanium and oxygen plasma then rapidly recombined and deposited onto the glass bead's surface. Such minerals have been artificially created in laboratories using pulsed-laser deposition, a similar process.

Zeng says there are two reasons for why we likely don't see the minerals occurring naturally on Earth: the lack of high-speed micrometeorites and the presence of water and oxygen in the atmosphere, which might alter the reactions that lead to deposition of the minerals postimpact. Given the abundance of both ilmenite and micrometeorite impacts on the lunar surface, the researchers expect that those products of space weathering should be present across the mare regions. But because the deposits are so small—only a few hundred nanometers—it's possible that they have been overlooked in previous samples taken from the Moon. (X. Zeng et al., *Nat. Astron.*, 2024, doi:10.1038/s41550-024-02229-4.)

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