# Lava tubes may be havens for ancient alien life and future human explorers

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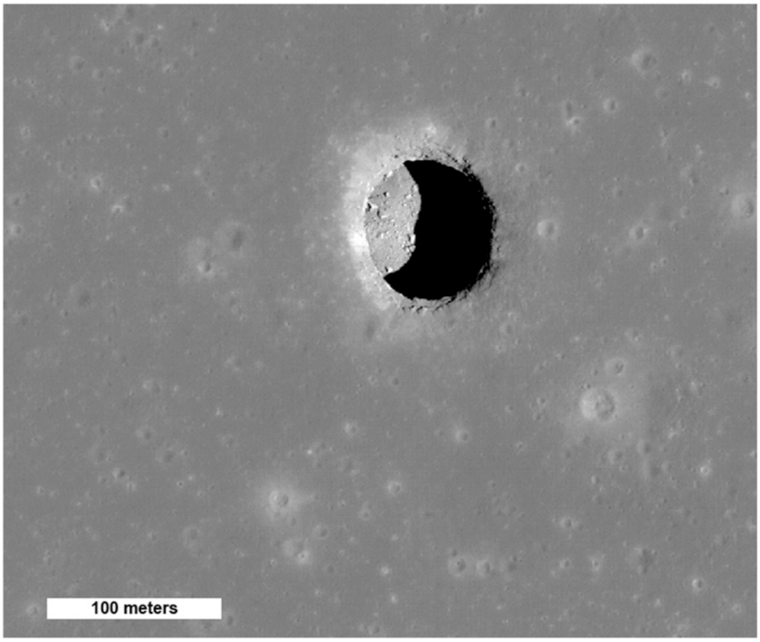
Sometimes, there's more to a lava flow than meets the eye. Beneath a fresh, sterile, and steaming hot surface, molten rock can still be chewing its way into the ground, carving caves that can stretch dozens of kilometers. On Earth, such lava tubes (once cooled) are a challenge for spelunkers. On the moon and Mars, these features are piquing the interest of planetary geologists, astrobiologists, and explorers.

Besides providing a window into geological history, lava tubes offer environmental conditions that are relatively stable and likely to be more hospitable than those found on a planet's surface. This may make the tubes appealing to life-forms of all sizes, from microbes to spacefaring colonists from Earth.

If Mars ever hosted life, it may have moved into such refugia as the planet evolved and surface conditions became increasingly harsh. Indeed, some researchers suggest that microbial life may yet hang on in the Red Planet's underground havens. "On Mars and other places, lava tubes have the potential to have made the difference between life and death," says Pascal Lee, a planetary researcher at NASA Ames Research Center in Mountain View, CA.

Wherever lava tubes are found, they'll be scientifically exotic, says Lee. And if a mission to another world is designed to explore such an underground feature as well as the surface, "it'll be like getting two planets for the price of one," he notes.

**Lava tubes on the moon and Mars—larger than this one in Iceland's Surtshellir-Stefanshellir lava tube system—could provide habitat for spacefaring colonists as well as opportunities for geological exploration. Image credit: Under Earth Images/Dave Bunnell.**




**The shadow cast by a skylight into a lava tube beneath the moon's Mare Tranquillitatis suggests the feature may be a little more than 100 meters deep. Image credit: NASA/Goddard/Arizona State University.**

### Grow With the Flow

Lava tubes can form almost anywhere molten rock streams from the ground. Steady flows of low-viscosity lava are the most likely to form lava tubes. They can form in a way akin to how rivers ice over during a cold spell. As flowing lava loses heat to the overlying air, its surface cools and solidifies—but it does so more quickly at the edges of the flow, where material moves slowly. Eventually, the molten flow freezes over from shore to shore, which insulates the underlying lava by robbing it of the ability to directly radiate heat upward or be cooled by winds, he explains. Then, when the source of lava begins to wane or as the molten flow chews or melts its way into the underlying rocks, or both, lava drains from the conduit and leaves behind a smooth-sided, steep-walled cavern.

Lava flows can melt their way into underlying rocks. If the flow is fast and turbulent, lava can erode downward as much as 1 meter each day, according to Alan Whittington, a geologist at University of Texas San Antonio, speaking at the Third International Planetary Caves Conference in San Antonio, TX, in February (1). So the tubes created by voluminous and long-lived flows can be huge. The longest known lava tube on Earth—65-kilometer-long Kazumura Cave, on the Big Island of Hawaii—stretches almost to the sea from the Kilauea volcano. In some spots, the tube measures 21 meters wide and 18 meters tall (2)—a profile big enough to hold a good-sized house.

But lava tubes on the moon and Mars are almost certainly bigger. Most of these features likely date from 3 to 4 billion years ago, when both bodies had frequent volcanic activity. Grooved features known as sinuous rilles have long been suspected to be collapsed lava tubes; and more recently, stronger evidence has emerged. Images snapped by orbiting probes show openings into underground voids. Often referred to as skylights, these openings probably formed when the roofs of lava tubes fell in. The first such feature on the moon—a hole 50 meters across and dozens of meters deep—was discovered more than a decade ago in an image captured by Japan's SELENE orbiter (3). Many more skylights have been found on the moon since then, and hundreds of possible skylights have been spotted on images snapped by Mars orbiters, the first of which were taken in the mid-1970s (4).

Earth's lava tubes range in age from a few years old, such as those on the slopes of Hawaii's Kilauea volcano, to a few hundred thousand years or more. The freshest tubes have yet to be mapped, but in some areas they're known to stretch dozens of kilometers. In California's Lava Beds National Monument, for example, more than 800 lava tubes together extend at least 350 kilometers.

### Habitat for Humanity?

Researchers have for decades speculated that lava tubes on the moon and elsewhere could offer prime space for setting up living quarters for colonists (5). The tubes are appealing for many reasons, as Laura Kerber, a geologist at NASA's Jet Propulsion Laboratory in Pasadena, CA, explained at the caves conference (6). First, the environment is protected from radiation such as cosmic rays, solar energetic particles, and ultraviolet light. Second, the rock roof would be a shield against micrometeorites that could otherwise puncture spacesuits and buildings. And as on Earth, the underground environment would be buffered from temperature swings. On the moon, those variations are extreme. Data gathered by the Lunar Reconnaissance Orbiter between 2009 and 2013 reveal that temperatures near the lunar equator can reach 120 °C in the daytime and plunge to –130 °C during the two-week-long night.

Whether colonists could actually take advantage of those benefits is another question. Considering the likely instability of material around the edges of skylights, as well as the limited mobility of existing spacesuits, it would be a big challenge to lower people into a hole in the ground and then get them back out, says Whittington. Then there's the question of whether lava tubes are safe, says NASA's Lee. Despite what he describes as the romantic idea of making a home in these features, "the truth about caves is that they're dangerous," he says. That's especially likely to be true near skylights, where the roof has already demonstrated the propensity to collapse. Human activity could well destabilize them even further, or cause avalanches of material around the edges of the skylights. "Lava tubes may be exciting to explore but not that safe to live in," Lee says.

### Holes without Drilling

Whether or not lava tubes provide homes for pioneering lunar colonists, they'll provide plenty of opportunities for geological research. As Charity Phillips-Lander, an astrobiologist at Southwest Research Institute in San Antonio, TX, remarked at the Planetary Caves conference, "caves provide access to the subsurface without the added weight of a drilling payload."

Apollo astronauts, as part of their rock- and soil-collecting activities on the lunar surface, never drilled more than 2.9 meters into the surface. In contrast, the walls of lunar skylights can measure tens of meters thick and show distinct layers. Some of those layers may be ancient lava flows that could be dated to show when and how often volcanic activity occurred, Kerber notes. Sandwiched between those strata may be layers of regolith, or pulverized rock, formed by the incessant pounding of meteorite impacts. The thickness of such layers may help researchers estimate the rates at which such impacts occurred in the past. The rates and timing of such impacts would be roughly the same as those Earth experienced, so they may shed light on the planet's environment as life emerged—and whether it was snuffed out before emerging again. Moreover, detailed chemical analyses of those materials may reveal information about past variations in the solar wind, whose charged particles become trapped in the regolith. Tracing the history of the solar wind could also shed light on variations in Earth's ancient climate. For one thing, a more active sun may have emitted more planet-warming radiation along with torrents of charged particles.

Kerber and her colleagues have come up with an idea for how to reach those skylight strata: a lunar rover that deploys a rappelling robot whose wheels are chock full of instruments and sensors (7, 8). After approaching the skylight as close as researchers dare—slopes near the hole consist of loose material and can be as steep as 20°—the rover pays out the yo-yo-bot on a 300-meter-long tether that carries power and communications. As currently conceived, those instruments include a trio of high-resolution cameras, a microscope that gathers images at various wavelengths, and a spectrometer to chemically analyze minerals. Other tools include a small grinder to remove surface patina and expose bare rock.

One big constraint on such a mission would be time, Kerber notes. The lander would need to set down on the moon, deploy its rover, and conduct its analyses all within the span of about 14 days, the length of time between lunar sunrise and sunset. That's because the exceptionally frigid conditions of the lunar night could wreak havoc on fragile electronics, sensors, and batteries, making it unknown whether the equipment would "wake up" when the next dawn arrived.

### Martian Haven

The discovery of minerals formed by water, along with other data gathered by orbiting probes, landers, and rovers, suggest that billions of years ago Mars was warmer, wetter, and had a thicker atmosphere than it does today. If life ever evolved on the Red Planet, and if it was anything like life on Earth, it wouldn't be living on the Mars surface today, says Lee. Besides being cold and arid, the surface is exposed to high amounts of ultraviolet radiation. The lack of a strong magnetic field means that cosmic rays and energetic particles from the sun are free to stream down, adding to the radiation hazard. Static electricity in the planet's fierce dust storms helps create reactive chemicals called perchlorates that are toxic to any Earthlike life.

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**—Charity Phillips-Lander**

"But when you look at the subsurface, all of a sudden a lot of these problems go away," Lee notes. Phillips-Lander agrees: "If life exists there, or existed there in the past, it probably will be best maintained in the subsurface, away from harsh surface conditions and processes."

Just as they do on the moon and Earth, lava tubes on Mars could provide a relatively stable environment. And even if that environment isn't amenable for life today, it could have been life's last holdout on a dying planet. At a time when large extraterrestrial impacts were more common, lava tubes could also have sheltered life from many of their devastating effects (9).

So, one of NASA's goals should be to determine whether there are any bioindicators—signs of past or present life—in Martian lava tubes (10), Phillips-Lander proposed at the caves conference. Such signs could include organic chemicals, which might fluoresce under certain wavelengths of light. Or they could be visible remnants of biofilms created by communities of microbes. Or if such obvious signs of life are absent, other signs of past life— such as fossilized microbial filaments or even fossil cells—could show up within minerals that formed on cave walls and were then preserved (11), says Michael Spilde, a mineralogist at the University of New Mexico in Albuquerque.

Exploring lava tubes on the moon and Mars might yield information not only about those bodies and their impact histories but also about the Earth and the Sun. These features, says Kerber, would be "like a time capsule for early solar system history."

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