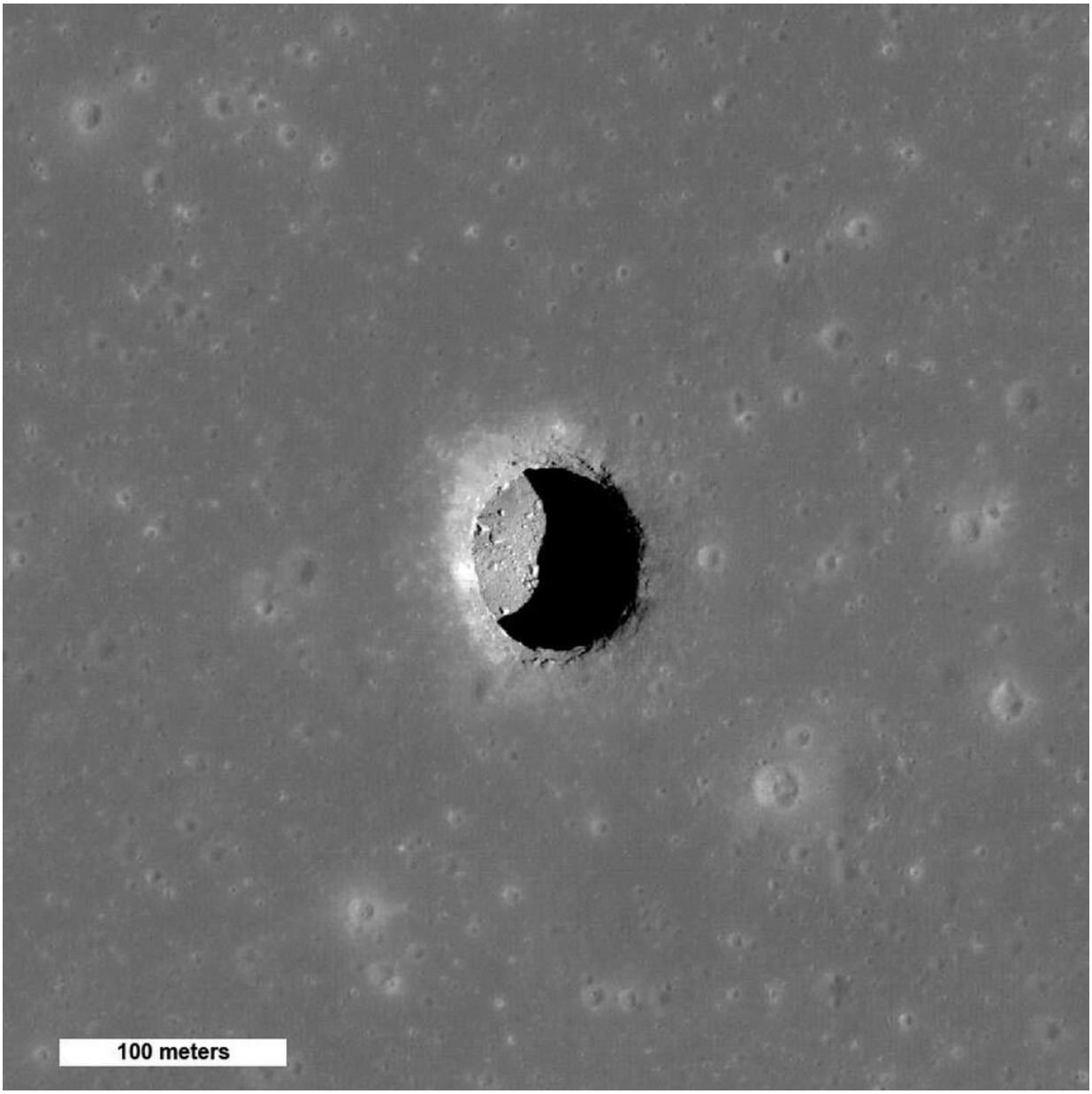
Why lava tubes should be our top exploration priority on other worlds

July 13 2020, by Evan Gough



Credit: NASA

When magma comes out of the Earth onto the surface, it flows as lava. Those lava flows are fascinating to watch, and they leave behind some unique landforms and rocks. But a lot of what's fascinating about these flows can be hidden underground as lava tubes.

These lava tubes are turning out to be a very desirable target for exploration on other worlds, just as they are here on Earth.

Lava tubes are formed when the surface of flowing lava cools and hardens, but the lava underneath keeps flowing. It's kind of like a freezing river that forms an ice layer on top while the water underneath keeps flowing. The flowing lava can remain hot and drain out, leaving a cave. This happens on Earth, and can be both a delight and a challenge for spelunkers.

But it's also happened on the moon, and on Mars, and maybe anywhere else where there's been volcanic activity. Lava tubes are unique environments. They may provide a shelter for life, or evidence of microbial life in the past, and they may contain easily observed records of geological activity.

This is the main idea behind an article titled "Core Concept: Lava tubes may be havens for ancient alien life and future human explorers." The author of the article is Sid Perkins, a science journalist who specializes in Earth Sciences, and who also writes about planetary sciences. The article is published in the *Proceedings of the National Academy of Sciences* (*PNAS*) of the United States of America.

The Kazamura Cave is the longest lava tube on Earth. It features the tell-tale arched ceiling of lava tubes, and the floor was the crust of a former lava lake that collapsed inward as the lake drained. Credit: Dave Bunnell / Under Earth Images – Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=48891612

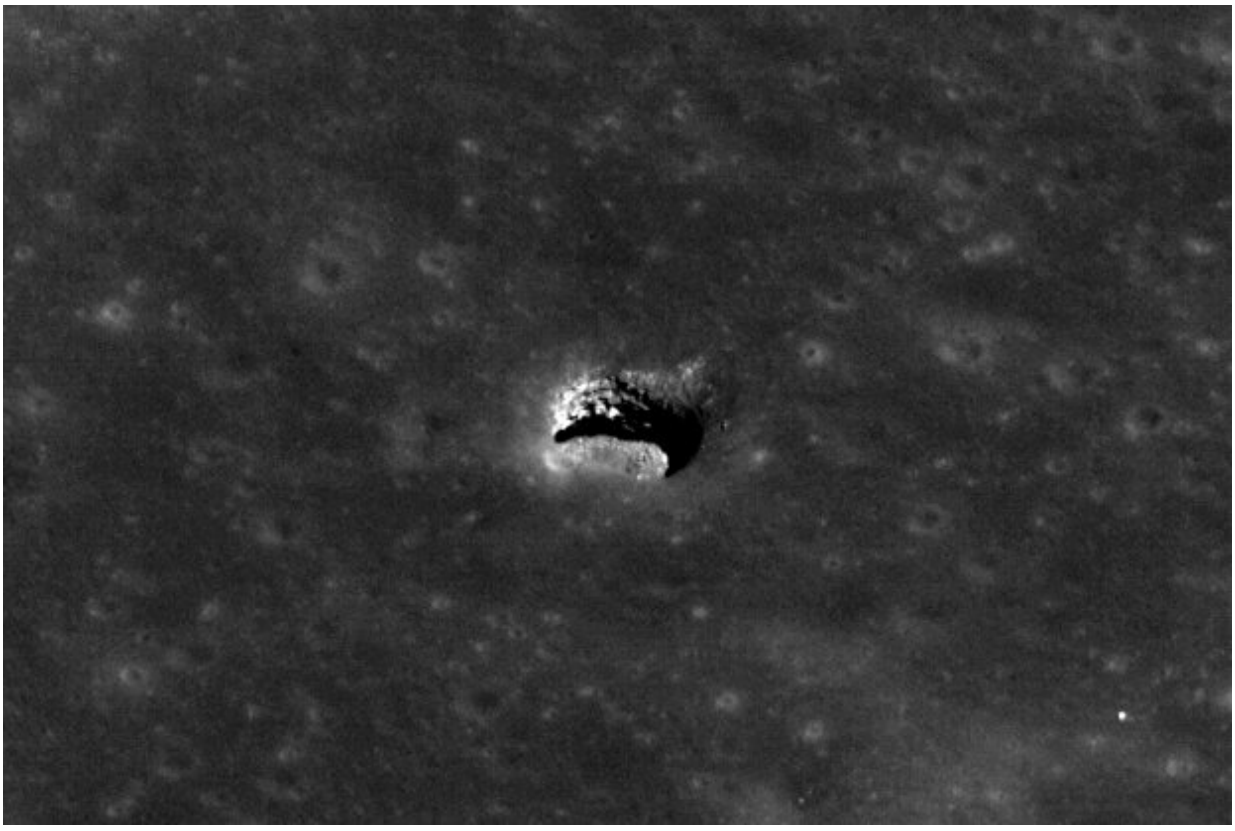
Lava tubes can be very large, sometimes many kilometers long. The longest one that we know of on Earth is the Kazamura Cave in Hawaii. It's 65.5 kilometers (40.7 mi) long. It's also the deepest.

There's plenty of evidence that lava tubes have formed on the moon and on Mars.

In 2009, NASA's Lunar Reconnaissance Orbiter took pictures of a

skylight opening into a lava tube in the Marius Hills region. A couple years later, the Indian Chandrayaan-1 lunar orbiter spotted more lava tubes. Pretty quickly, people started to wonder about exploring these unique landforms. There was also some conjecture about their suitability for habitation.

The first evidence of lava tubes on Mars came from NASA's Viking Orbiter. At the volcano Alba Mons, in the Tharsus region of Mars, Viking's camera captured an image of a long tube shape extruded above the surface of the volcano's flank. This is almost undeniably a lava tube.



The collapsed sklyight on a lava tube in the Moon’s Marius Hills region, as imaged by NASA’s Lunar Reconnaissance Orbiter. Credit: ASA/GSFC

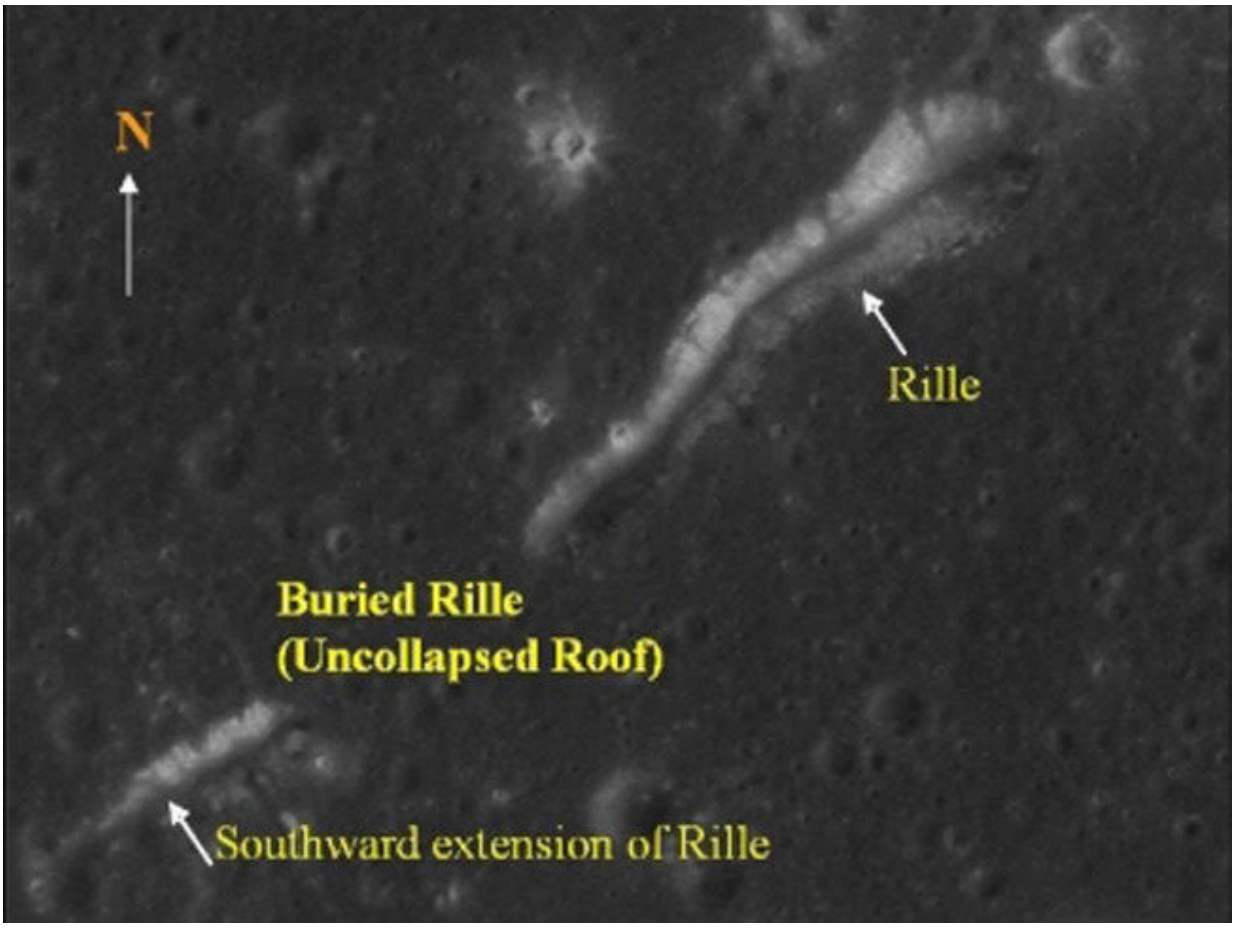
Mars, at one time in its past, was wet and warm, and may have hosted life. Over time, it was stripped of its atmosphere and its water, and became frigid. But if there was life there, it may have had time to "migrate" to the only remaining niches where it could survive. On Mars, that might mean lava tubes.

That's what makes them such desirable exploration targets.

"If Mars ever hosted life, it may have moved into such refugia as the planet evolved and surface conditions became increasingly harsh," Perkins wrote in his article. 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," said Pascal Lee, a planetary researcher at NASA Ames Research Center in Mountain View, California.

But the task of exploring those tubes is onerous. It would have to be done by robot, at least initially. What astronaut would want to climb into a lava tube on Mars without knowing how stable and safe it might be? Anyone willing to take that risk without understanding what they're venturing into probably wouldn't make it through astronaut training, anyway.



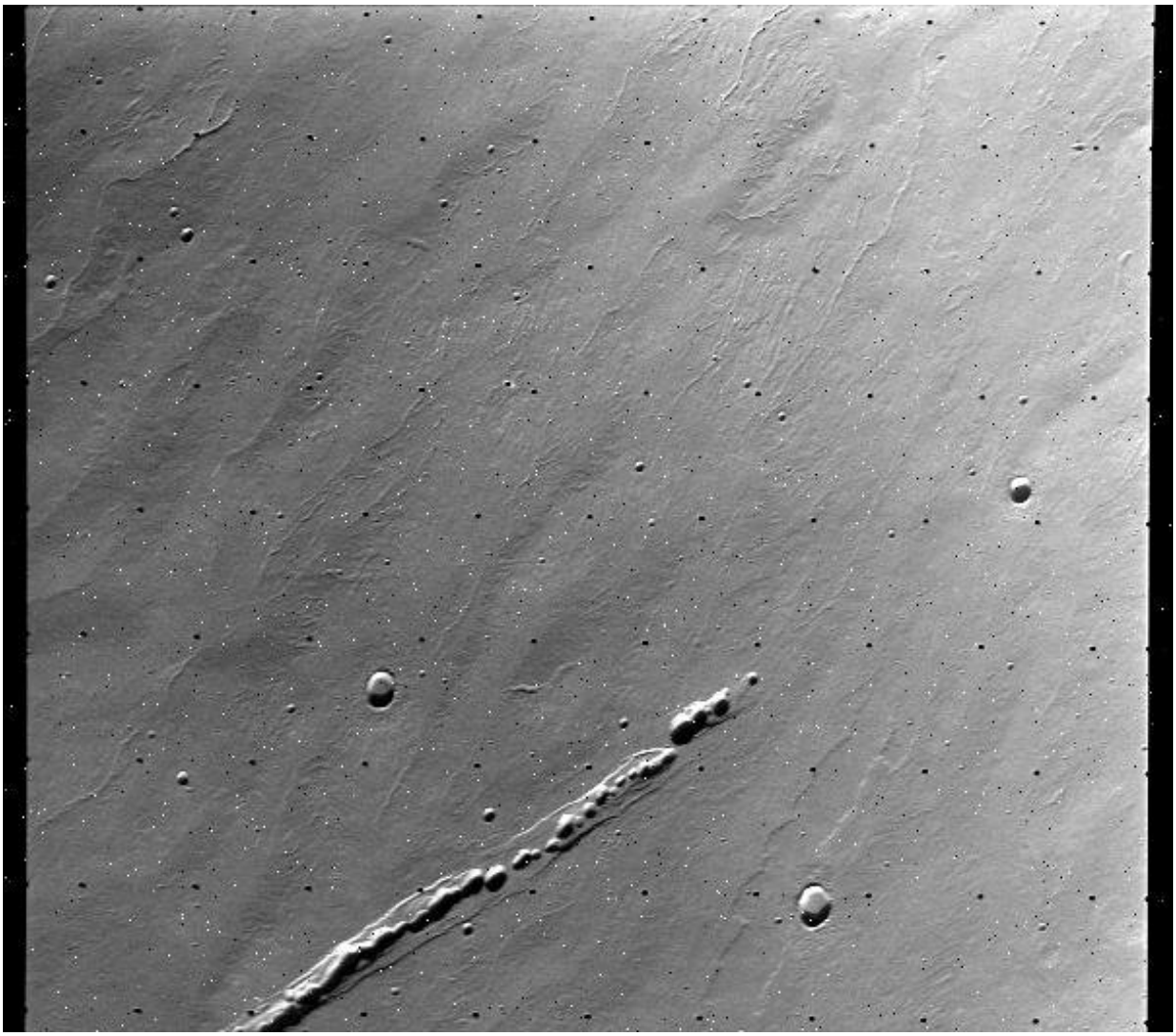
An image of a partially collapsed lava tube near the lunar equator, captured by India's Chandrayaan-1 lunar orbiter. Image Credit: Indian Space Applications Centre

Even on Earth, caves are dangerous. Exploring them takes a specialized skill set. Risking an astronaut's life is probably out of the question.

But what kind of robot could do it? The best way to access these lava tubes is through so-called "skylights." That's an opening in the top of the tube where the ceiling has collapsed. That grants access to the tube without any problematic, complicated drilling maneuver.

Laura Kerber is a geologist at NASA's Jet Propulsion Laboratory in Pasadena, California. Kerber and her colleagues proposed using a rappelling robot to explore the lava tubes on the moon, and the same thing could work on Mars. The robotic explorer is called the Moon Diver.

The Moon Diver is a great concept. It consists of both a rover and a lander. A precision landing system would get the craft to the surface, close to its target. The rover is tethered to the lander, and as the rover rolled towards the skylight, it would play out its tether. Once at the skylight, the rover would slowly lower itself into the hole and onto the floor of the lava tube.



An image of a lava tube on Mars' Alba Mons, from NASA's Viking Orbiter. Credit: NASA

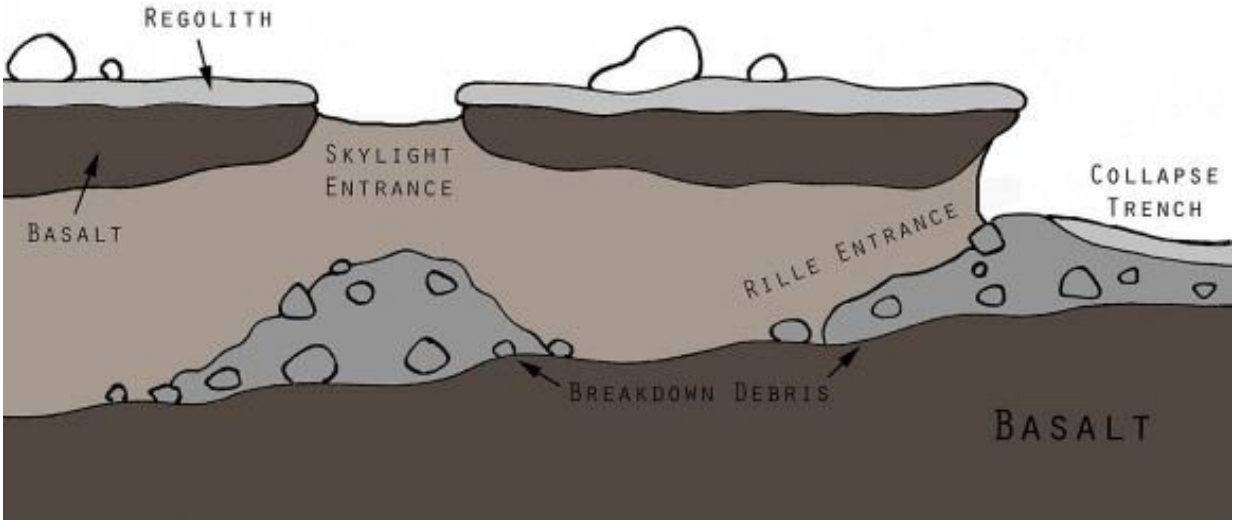
But whether it's the Moon Diver, a Mars Diver, or some similar concept, the key thing is what it'll see once it's inside.

The walls of lava tubes might hold all kinds of evidence of the history of the world they're on that's simply unattainable any other way.

When the Apollo astronauts visited the moon, they never drilled deeper than about 2.9 meters (9.5 feet). But the walls of skylights and tubes on the moon can be tens of meters thick. Mars will be similar, maybe even more exposed.

Distinct geological layers will be exposed to easy study. The walls of lava tubes could show evidence of periods of lava flow, evidence of periods of intense meteor impacts, and more. Examining these walls can shed light on Earth's history, too.

Earth is a very active planet, and lots of ancient evidence is simply erased by all the geological activity and erosion. If lava tube walls on the moon show evidence of sustained periods of meteor impacts—like a well defined layer of pulverized rock—that layer can be dated. With that evidence, we can conclude the same thing happened on Earth, at the same time.



An illustration of a longitudinal cross-section of a Martian lava pit. These are potentially hazardous environments, better explored by robot than by humans.

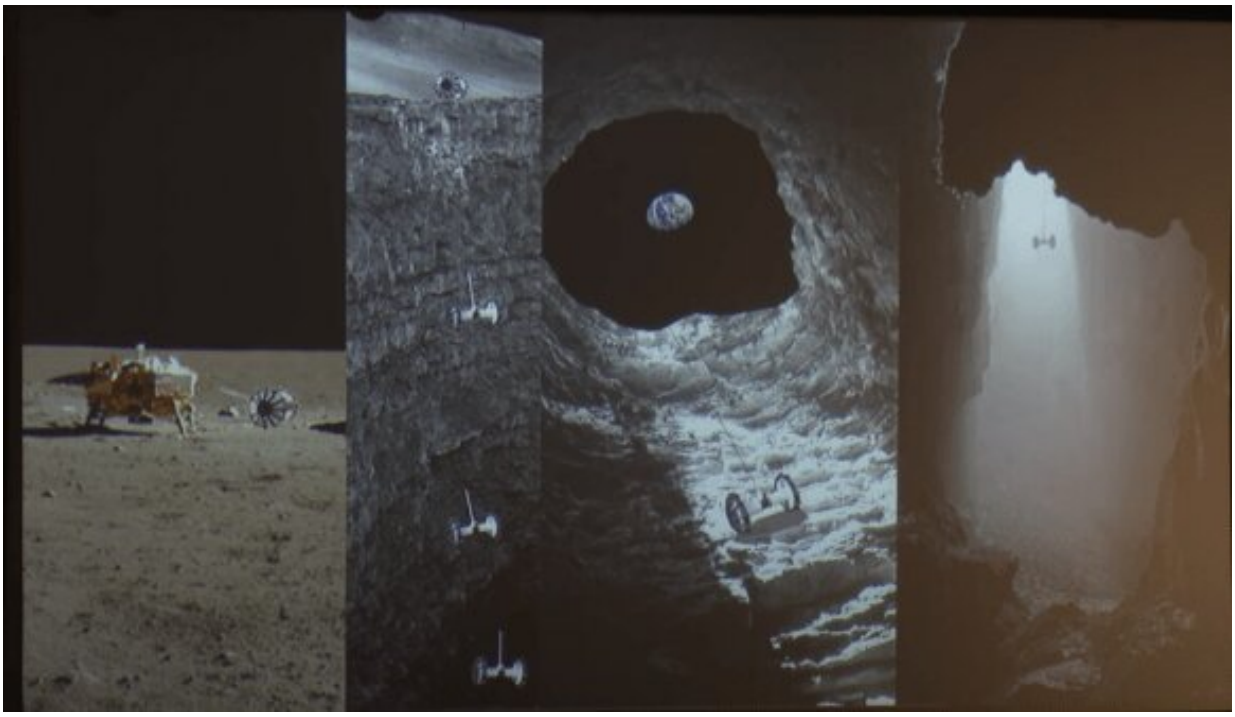
Credit: Melissausburn – Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=31385296

If we ever do send a robotic mission to Mars to explore lava tubes, there'll be no shortage of targets. The United States Geological Survey's Astrogeological Center has collected the locations of over 1,000 candidate cave entrances on Mars, many of which are lava tube skylights. It's called the Mars Global Cave Candidate Catalog.

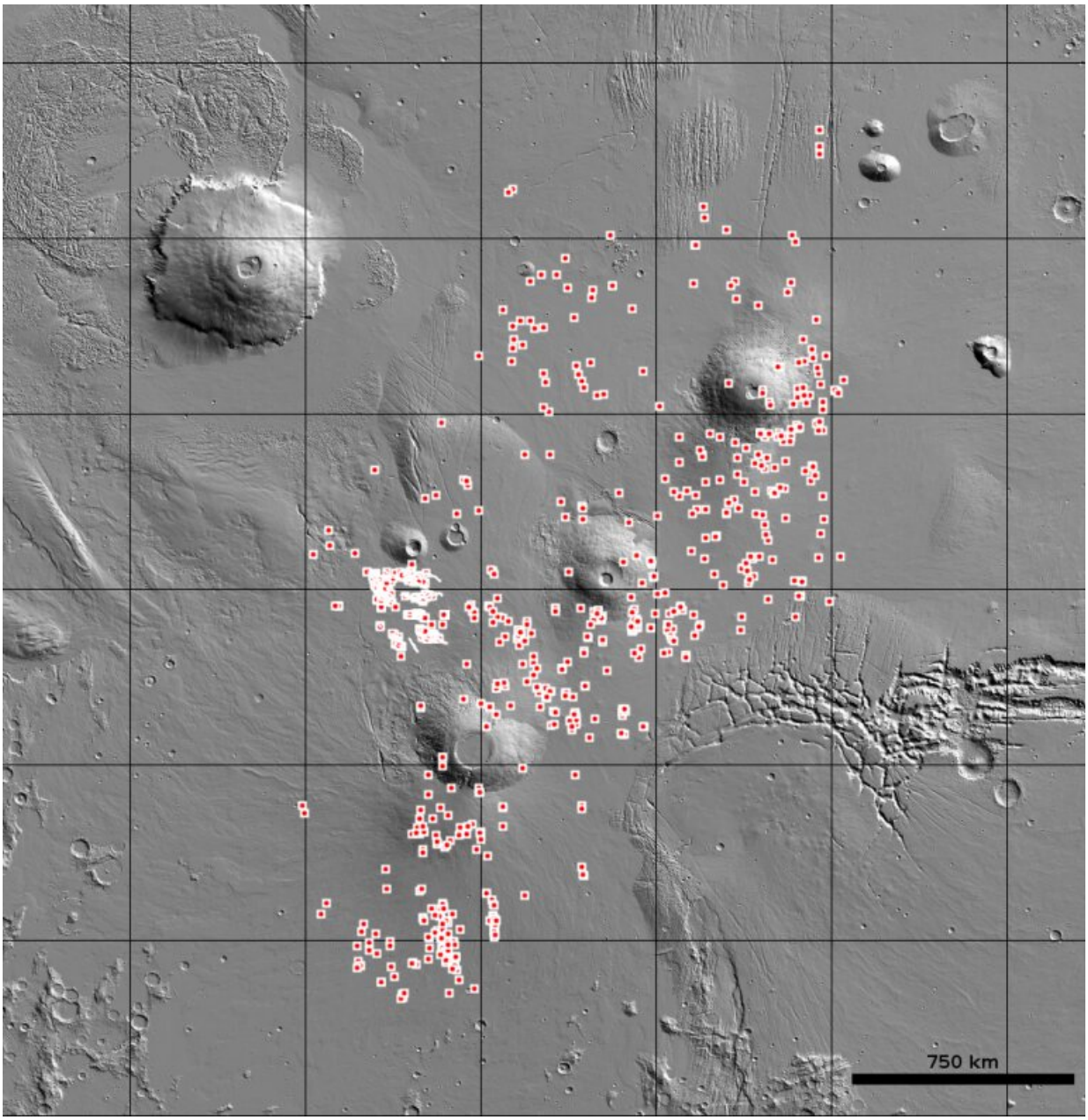
If modern Mars holds clues to its ancient habitability, the most promising place to search for it might be these lava tubes. Deep under the planet's subsurface, ancient simple Martian life may have made its last stand. Down there, it would have been protected from cosmic rays and damaging particles from the Sun, which streamed down on the planet, unimpeded by a protective atmosphere.

The young solar system was a much more chaotic place when ancient Mars was warm and wet. Large meteor impacts were more common, and lava caves might have provided refuge from those, too.

Protected cave walls might be the best pace to find evidence of past life on Mars. As Perkins writes in his article, "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."



Four panels from a video presentation on the Moon Diver concept. From left to right: Rover is deployed from the lander, rover rappels down the hole, with Earth in the background, the rover hanging free as it's lowered to the floor. Though the concept was developed to explore the Moon, something similar would likely work on Mars. Credit: KISSCaltech



Many of the cave openings and lava tube skylights the USGS has identified on Mars is in the post-volcanic Tharsis Region. In this image, each red dot is a candidate entrance. Credit: USGS/Mars Global Cave Candidate Catalog

With each succeeding robotic mission to Mars, our mission designs are

more refined. As our understanding of Mars grows, we get better at selecting specific areas and designing missions to explore specific questions. NASA's next Mars rover, Perseverance, is heading to Jezero Crater to look for signs of ancient life. That location was chosen after a rigorous selection process.

Is it only a matter of time before a mission is sent to explore lava tubes? Probably. And as usual, it'll be fascinating to watch the conversation start to gain momentum. It'll be fascinating to see what kind of vehicle and technologies innovative minds come up with for the mission.

And it'll be fascinating to see what they uncover in what might have been the last redoubt for ancient Martian life.

More information: Sid Perkins. Core Concept: Lava tubes may be havens for ancient alien life and future human explorers, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.2012176117

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