



Scientists discover Moon caves Artists impression [5]

Moon: Back to the Cave? A Pathway to Lunar Settlement

Scientists have suspected for decades that there are subsurface caves on the Moon, just like there are on Earth. Pits that may lead to caves were suggested in images from NASA's lunar orbiters that mapped the Moon's surface before NASA's Apollo human landings. A pit was then confirmed in 2009 from images taken by JAXA's (Japan Aerospace Exploration Agency) Kaguya orbiter, and many have since been found across the Moon through images and thermal measurements of the surface taken by the Lunar Reconnaissance Orbiter (LRO).

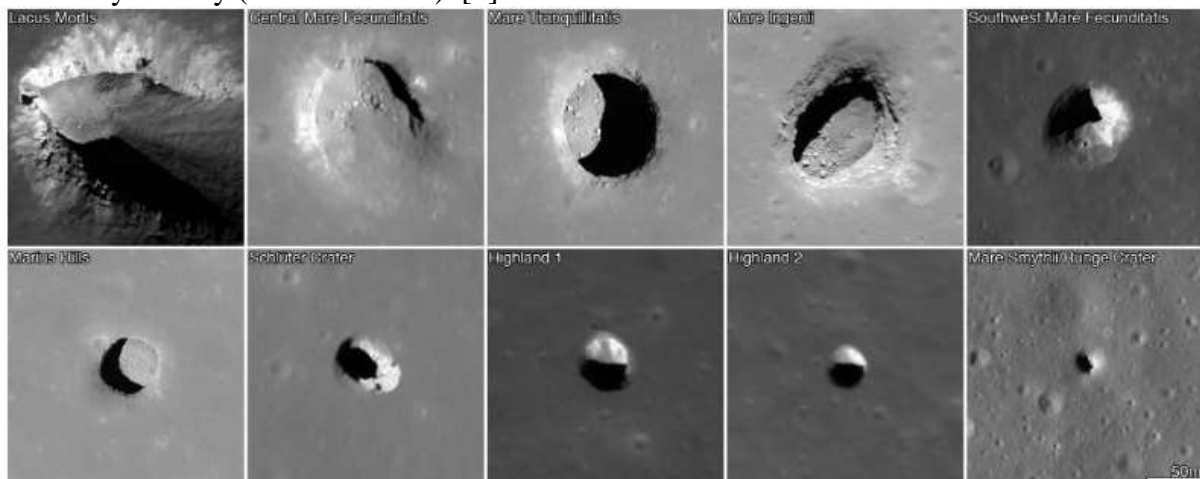
Lunar pits are formed by 'lava tubes' like here on Earth, scientists suspect that lunar caves formed when molten lava flowed beneath a field of cooled lava, or a crust formed over a river of lava, leaving a long, hollow tunnel. If the ceiling of a solidified lava tube collapses, it opens a pit, like a skylight, that can lead into the rest of the cave-like tube. [1]

A study published in 2024 on Nature Astronomy under the leadership of RSLab UniTrento, Italy, has proven for the first time the existence of an accessible conduit at the bottom of a lunar pit in the Tranquility Sea. This has been possible by re-analyzing a synthetic aperture radar image acquired in 2010 by the Lunar Reconnaissance Orbiter (LRO) of NASA with a new radar processing technique recently developed at RSLab UniTrento. The study has very important scientific implications and is very relevant for shaping future activities for the exploration on the Moon. [2]

In re-analyzing radar data collected by LRO's Mini-RF (Miniature Radio-Frequency) instrument in 2010, the team found evidence of a cave extending more than 200 feet from the base of a pit. The pit is located 230 miles northeast of the first Apollo human landing site on the Moon in Mare Tranquillitatis.

The full extent of the cave is unknown, but the new analysis shows that a gigantic shaft reaches approximately 130 m into the basalt rock. And according to Lorenzo Bruzzone, cave expert of the Uni Trento, it was confirmed that the shaft is the entrance into a cave system, the tunnel (lava tube) is a dozen meters long, possible much longer. [3]

The whole cave system must be further explored by robots. Planning for such machines is underway already (see also below). [1]



These images from NASA's LRO spacecraft show a collection of pits detected on the Moon. Each image covers an area about 728 feet wide. [3]

What Are Moon Caves?

Moon caves, or lunar lava tubes, are large, hollow tunnels beneath the lunar surface, believed to have formed billions of years ago during periods of volcanic activity. When molten lava flowed across the Moon's surface, it created channels. As the exterior of these channels cooled and solidified, the interior lava continued to flow, eventually draining away and leaving behind empty tubes.

These lunar lava tubes can vary greatly in size, with some potentially stretching for kilometers and boasting widths of several hundred meters. Such expansive underground networks present a wealth of possibilities for lunar exploration and habitation.

Why Are Moon Caves Important for Lunar Settlement?

The idea of using moon caves for human habitation is gaining traction due to the numerous advantages they offer:

1. Protection from Radiation

The Moon lacks a significant atmosphere and a protective magnetic field, exposing its surface to high levels of cosmic radiation and solar wind. Long-term exposure to this radiation poses serious health risks to humans, including increased chances of cancer and other illnesses. The thick walls of lunar lava tubes provide natural shielding, significantly reducing radiation exposure and making them a safer environment for humans compared to the lunar surface.

2. Thermal Stability

The Moon experiences extreme temperature fluctuations, ranging from about 127°C (260°F) during the day to -173°C (-280°F) at night. These drastic changes pose a challenge for human survival and the stability of infrastructure. Moon caves, insulated by meters of rock, offer a more stable thermal environment, with temperatures likely remaining relatively constant. This thermal stability reduces the need for excessive heating or cooling, making it easier to maintain habitable conditions.

NASA's LRO finds lunar pits might harbor comfortable temperatures, with an average of +17⁰ Celsius, this compares with the average temperature of Rome, Italy. [4]

3. Protection from Micrometeoroids

The Moon is constantly bombarded by micrometeoroids, tiny space rocks that can cause significant damage to equipment and structures. On the lunar surface, there's no atmosphere to burn up these projectiles, making them a real threat. Moon caves provide natural protection against micrometeoroid impacts, safeguarding both human settlers and their equipment.

4. Potential for Resource Utilization

Moon caves could also be valuable in terms of in-situ resource utilization (ISRU), a key strategy for sustainable lunar exploration. Some lava tubes may contain deposits of ice or other volatile compounds, which can be harvested and used for life support systems, fuel production, and other essential functions. Additionally, the rock within and surrounding these caves may contain useful materials, such as aluminum, silicon, and oxygen, which can be extracted and utilized for building infrastructure and other purposes.

5. Structural Integrity for Habitats

Building habitats within moon caves could reduce the need for extensive surface construction, which requires materials to withstand the harsh conditions of the lunar surface. The natural caverns provide ready-made spaces that can be sealed and pressurized to create a livable environment. The structural integrity of these caves, combined with modern engineering techniques, could allow for the creation of large, interconnected habitats capable of supporting human life.

Challenges and Considerations

While moon caves offer many advantages, several challenges need to be addressed to make their use feasible for lunar settlement:

1. Access and Exploration

Identifying suitable lava tubes and gaining access to them is a significant challenge. Current observations rely on satellite imagery, which provides limited information about the interior of these tubes. Robotic missions equipped with advanced sensing technology could be deployed to map and assess the structural integrity and accessibility of these caves. Entry points, known as skylights, have been identified, but more detailed exploration is necessary to understand the layout and condition of the lava tubes.

2. Habitability Concerns

Creating a habitable environment inside moon caves will require careful engineering. Issues such as air quality, pressure maintenance, lighting, and waste management must be addressed. Life support systems will need to be robust and reliable to ensure the safety and well-being of lunar inhabitants. Additionally, measures to prevent the contamination of lunar environments, both inside and outside the caves, will be crucial to preserving the natural state of the Moon.

3. Psychological Impact

Living in a cave-like environment, away from natural sunlight and in confined spaces, could have psychological impacts on settlers. The design of habitats will need to consider factors such as artificial lighting, space layout, and recreation areas to mitigate the effects of isolation and confinement. Ensuring the mental health and well-being of lunar settlers will be as important as addressing physical health and safety.

The Future of Moon Caves in Lunar Settlement

The discovery and exploration of moon caves open up exciting possibilities for the future of lunar colonization. As space agencies like NASA, ESA, Japan, China, India and private companies like SpaceX and Blue Origin continue to advance their lunar exploration programs, moon caves could play a pivotal role in establishing a sustainable human presence on the Moon. The protection and stability offered by these natural structures provide a strong foundation for building the first lunar colonies, serving as stepping stones for humanity's expansion into the solar system.

In the coming decades, the exploration of these lunar lava tubes will likely become a priority for lunar missions.

ESA has developed a RoboCrane, a type of crane that could lower a spherical research robot called Daedalus into a lunar cave on an exploration mission from 2033 onwards. In the USA, a concept for the two-wheeled Moon Driver was developed - and at the German Aerospace Center, the Scout robot was built, which looks a bit like a multi-legged high-tech insect. [4]

Moon caves may well be the key to unlocking the next era of human space exploration, offering a safe haven for lunar pioneers as they take their first steps toward building a permanent outpost on our celestial neighbor.

The potential they hold for human settlement could transform our vision of life on the Moon from a distant dream into a reality.

References

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[2] <https://lnkd.in/dj2GgyJf>.

[3] NASA/GSFC/Arizona State University

[4] Der SPIEGEL Nr. 30, 20.July 2024

[5] <https://www.youtube.com/watch?app=desktop&v=YRtJLogP04Q>

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