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月の縦孔・地下空洞

Lunar vertical hole and subsurface cave

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1. Lunar Vertical Holes and Underground Caves

Three vertical holes, each several tens of meters in diameter and depth, were discovered in 2009 using data from the SELENE (Kaguya) mission¹⁻³: Marius Hills Hole (MHH) at 303.3°E, 14.2°N; Mare Tranquillitatis Hole (MTH) at 33.2°E, 8.3°N; and Mare Ingenii Hole (MIH) at 166.0°E, 35.6°S. These holes are believed to be skylights leading to likely volcanic caves beneath the lunar surface¹. These underground caves are expected to be suitable locations for establishing human bases due to their protection from cosmic rays and meteorites, as well as the stable temperature environment they offer^{e.g.3-5}. Such conditions make them favorable for both human habitation and equipment operation.

2. Scientific Importance of Lunar Vertical Holes and Associated Subsurface Caves

The walls of lunar vertical holes present excellent outcrops, which are highly valuable for geological and volcanological research. Remote sensing observations suggest that these outcrops exhibit more than 10 distinct layers⁶. If these layers are confirmed, they could provide insights into the following:

- The style and evolution of lunar volcanism, which would offer critical information about the Moon's internal activity.
- The process of regolith formation, shedding light on the history of meteorite impacts on the lunar surface.
- The history of lunar paleomagnetism and magnetic pole shifts, providing constraints on the Moon's thermal and material evolution.

Additionally, the interiors of lunar caves could serve as valuable repositories of lava rocks. Unlike surface samples, the rocks retrieved from these caves are likely unbrecciated, which means they may contain specific volatiles (such as water) and deep mantle materials. Therefore, lunar vertical holes and underground caves are critical exploration targets for advancing lunar science.

3. Martian Vertical Holes and Underground Caves

Numerous vertical holes have also been identified on Mars⁷, and we are particularly interested in ones located at the base of Elysium Mons. Considering the age of the mountain's formation^{e.g.8}, it is suggested that it was surrounded by the sea in ancient times, and the inside of the cave at its base must have alternated between wet and dry periods due to the tides. This environment could have been conducive to the origin of Martian life, and it may still harbor life forms, protected from ultraviolet radiation and surviving underground.

Martian vertical holes and underground caves are thus important targets for both scientific exploration and assessing the potential for human habitation on Mars.

4. UZUME Program

We are currently developing a series of programs called "Unprecedented Zipangu Underworld of the Moon/Mars Exploration (UZUME)" aimed at exploring underground caverns on the Moon and Mars. The first phase of the program will focus on the MTH, located within the scientifically significant Cauchy Shield volcano. The MTH is prioritized as the initial exploration target due to several advantages for establishing a lunar base^{3, 5}):

- The MTH is one of the largest vertical holes on the Moon, making it ideal for the potential development of a large-scale human activity base.

- There is a location at the floor of the MTH where the Earth can be seen at all times, so a means of communication with the Earth can be secured even underground.

- The regolith around the MTH contains over 10% oxidized titanium, which could be electrolyzed to produce metallic titanium and oxygen.

- Being near the lunar equatorial region, the area around the MTH is expected to be favorable for collecting solar-origin helium-3, a raw material for future nuclear fusion.

The UZUME program aims to address various technical challenges, gather information to solve key scientific questions related to the Moon and Mars, and ultimately contribute to humanity's expansion into space.

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