2. Salar De Pajonales – Places in News

A recent study at Salar de Pajonales in Chile's Atacama Desert examined gypsum-based stromatolites, identifying protective microhabitats that could guide future life-detection missions on Mars. The Salar, located at 3.5 km altitude, experiences extreme aridity, freezing temperatures, and intense ultraviolet radiation, making it a near-perfect Mars analogue environment.

1. Discovery of Microbial Life Beneath Gypsum in the Atacama Desert- Implications for Mars Exploration

Recent scientific investigations in the Salar de Pajonales region of the Atacama Desert (Chile) have revealed microbial life and preserved biosignatures embedded within gypsum deposits associated with stromatolites. The discovery has significant implications for astrobiology and the search for extraterrestrial life, particularly on Mars.

2. The Atacama Desert as a Mars Analogue

The Atacama Desert is widely regarded as one of the best natural analogues on Earth for studying Martian environmental conditions.

A. Extreme Aridity

1. The Atacama is among the driest regions on Earth, with certain hyper-arid zones receiving virtually no rainfall for decades.
2. This extreme dryness closely resembles Martian surface conditions, where liquid water is largely absent today.

B. High Ultraviolet Radiation

1. The desert lies at high altitudes in the Andes region, where thinner atmospheric protection allows intense UV radiation exposure.
2. Mars similarly lacks a dense atmosphere and protective ozone layer, resulting in strong ultraviolet radiation at the surface.

C. Mineralogical Similarity

1. The Atacama contains extensive saline flats (salars) rich in evaporite minerals such as-
    1. Gypsum
    2. Halite
    3. Nitrates
2. Similar minerals have been detected on Mars by orbiters and rovers, indicating ancient water-driven geological processes.
3. Because of these similarities, the Atacama serves as an Earth-based laboratory to test life-detection strategies for Mars missions.

3. Gypsum- Mineralogical and Astrobiological Importance

A. Chemical Composition

1. Gypsum is a hydrated calcium sulphate mineral with the chemical formula $CaSO_4 \cdot 2H_2O$.
2. The presence of water molecules within its crystal structure makes it an important indicator of past aqueous environments.

B. Evidence on Mars

1. Space missions have identified extensive gypsum deposits on Mars through orbital spectroscopy and rover analysis.

2. These deposits suggest that liquid water once existed on the Martian surface, making certain regions potentially habitable in the past.

C. Radiation Filtering and Light Transmission

1. Gypsum crystals are translucent, allowing sunlight to penetrate while filtering harmful UV radiation.
2. This property creates microhabitats beneath the mineral surface where microorganisms can survive despite hostile external conditions.

4. Stromatolites- Biological Structures and Biosignatures

A. Nature of Stromatolites

1. Stromatolites are layered sedimentary structures formed by microbial communities, especially cyanobacteria.
2. These microorganisms trap and bind sediment particles while producing layered mineral deposits over long periods.

B. Evidence of Ancient Life

1. Stromatolites represent some of the oldest evidence of life on Earth, dating back more than 3.5 billion years.
2. Because of their distinctive layered morphology and chemical signatures, they are considered important biosignatures in astrobiology.

C. Stromatolites in Salar de Pajonales

1. In the Atacama Desert, stromatolites embedded within gypsum deposits provide-
    1. Refuge for living microbial communities
    2. Preserved fossil evidence of ancient microbes
2. This dual presence makes the site particularly valuable for studying life in extreme environments.

5. Dual Protective Role of Gypsum

The study revealed that gypsum provides two key protective functions for microbial life.

A. Shelter for Living Microorganisms

1. Living microbes were discovered a few millimetres beneath the gypsum surface.
2. The mineral acts as a natural shield against intense UV radiation, which would otherwise destroy microbial DNA.
3. At the same time, gypsum allows enough sunlight to penetrate for photosynthesis by microbial communities.

B. Moisture Retention

1. Gypsum crystals trap microscopic pockets of water, enabling microbial survival even in extremely dry conditions.
2. This micro-scale water retention helps organisms survive temperature fluctuations and prolonged drought.

C. Preservation of Fossilised Biosignatures

1. Deeper stromatolite layers contained fossilised microbial remains and chemical biosignatures.
2. As gypsum crystals grow and recrystallize, they seal and protect organic material, preventing degradation.
3. This process allows gypsum deposits to function as long-term geological archives of biological activity.

6. Implications for Mars Exploration

The findings have important consequences for future Mars exploration strategies.

A. Gypsum Deposits on Mars

1. Mars hosts widespread gypsum deposits identified by missions such as those of NASA and other international agencies.
2. If gypsum can shelter and preserve microbes in Earth's harshest desert, it may perform a similar role on Mars.

B. Potential Preservation of Ancient Life

1. Even if life no longer exists on Mars today, gypsum deposits may contain fossilised microbial evidence from ancient Martian environments.

C. Target Selection for Future Missions

1. Future Mars missions may prioritize gypsum-rich terrains for-
    1. Drilling operations
    2. Sample collection
    3. Biosignature detection.

7. Science and Technology Implications

A. Improved Landing Site Selection

1. Mineralogical studies help identify locations where biosignatures are most likely to be preserved.

B. Analytical Technologies

1. Instruments such as Raman spectroscopy and organic molecule detectors are crucial for analysing gypsum samples.

C. Mars Sample Return Missions

1. Planned missions aiming to return Martian samples to Earth may target evaporite minerals like gypsum.
2. These minerals have a higher probability of preserving organic molecules.

8. Broader Astro biological Insights

A. Micro-Niche Survival

1. Life does not necessarily survive in open environments but may persist in micro-niches protected by mineral matrices.

B. Definition of Habitability

1. Planetary habitability may include subsurface or mineral-protected habitats rather than only surface environments with liquid water.

C. Role of Earth Analogues

1. Studying extreme Earth environments helps scientists design better life-detection strategies for other planets.

9. Conclusion

1. The discovery of microbial life and fossil biosignatures beneath gypsum in the Atacama Desert strengthens the hypothesis that mineral shelters can preserve traces of life in extreme environments.
2. For Mars exploration, gypsum deposits may act as natural time capsules preserving evidence of ancient biological activity.
3. By integrating geology, microbiology, and planetary science, such analogue studies significantly improve the prospects of answering one of humanity's most profound scientific questions—whether life ever existed beyond Earth.

Source- https-//www.thehindu.com/sci-tech/science/why-are-scientists-looking-for-gypsum-in-the-salar-de-pajonales/article70687753.ece