# Precambrian Microbial Mats and its Astrobiological Implications

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**Abstract**

It is now understood that if life had ever erose on Mars, it might have been preserved in the simplest form. Therefore, studying the traces of simple life forms from the rock records of various Earth environments and climatic conditions perhaps helps to narrow down the region of interest while searching for life on the red planet. The Precambrian era covered almost 80% of Earth's geologic history, witnessed the appearance of life on Earth and experienced prolonged extreme climatic events that delayed biological evolution. During this extreme period, primitive lifeforms such as microbial mats had a strong influence on sedimentation, and they facilitated the formation of a variety of mat-induced sedimentary structures (MISS) in siliciclastic and carbonate sedimentary environments. In the last two decades MISS have been identified from several Precambrian successions of India for example, Vindhyan, Marwar, Chhattisgarh and, Cuddapah Supergroup. In this study we tried to provide an updated catalogue based on the chronologic, stratigraphic and paleoenvironmental occurrences of MISS from the Indian Precambrian successions. We further explore their potential in understanding extreme habitability, searching biomarkers and biosignatures on Mars and propose a few potential sites for astrobiological research.

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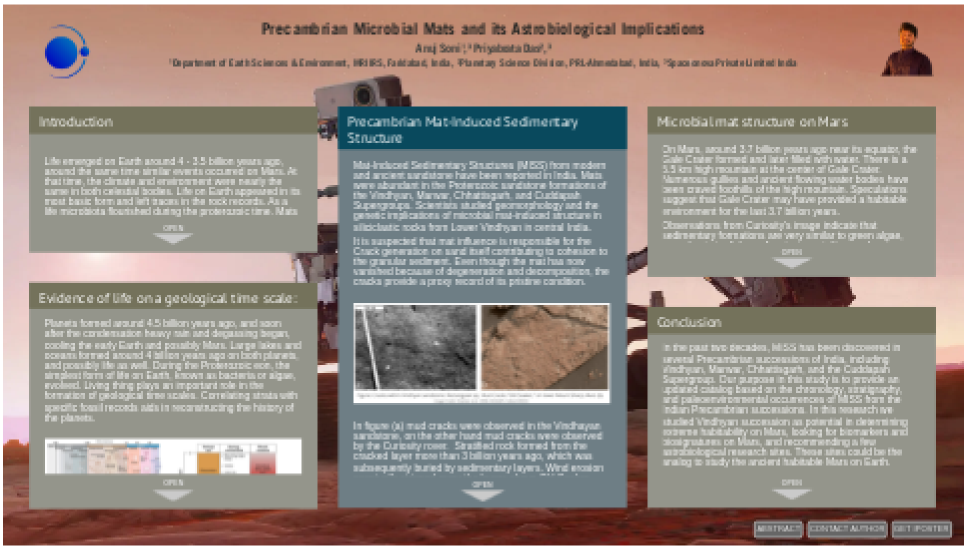
# Precambrian Microbial Mats and its Astrobiological Implications

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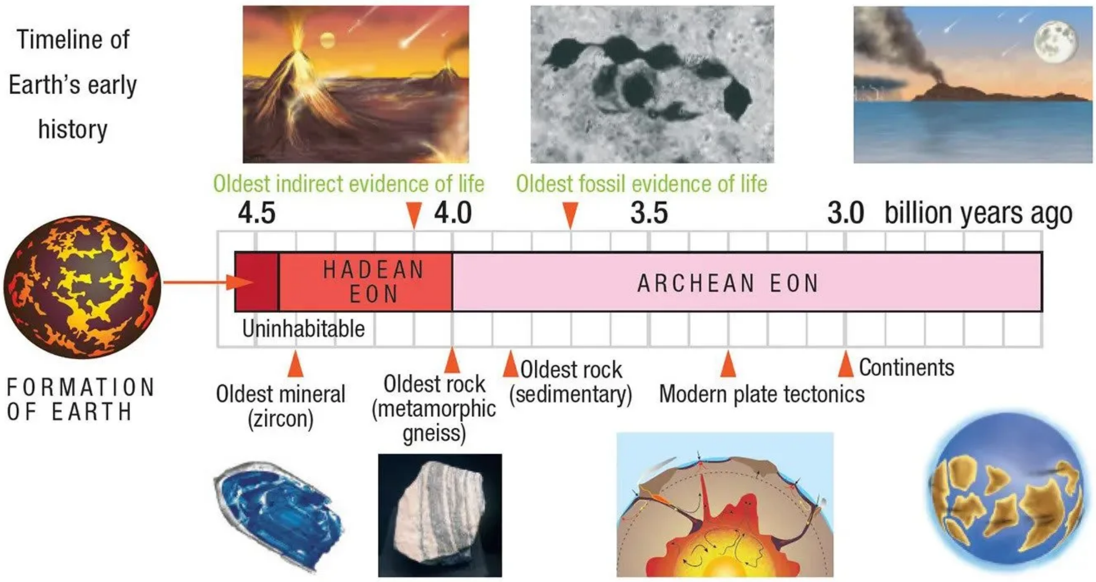
**PRESENTED AT:**

# INTRODUCTION

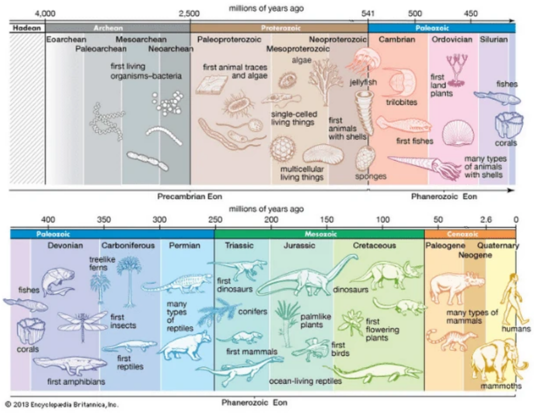
Life emerged on Earth around 4 - 3.5 billion years ago, around the same time similar events occurred on Mars. At that time, the climate and environment were nearly the same in both celestial bodies. Life on Earth appeared in its most basic form and left traces in the rock records. As a life microbiota flourished during the proterozoic time. Mats of microbes colonized most surfaces in Precambrian settings when predators and competitors were absent. Stromatolites and microbial laminites are very common evidence in Precambrian carbonate successions. On the other hand, the evidence for microbial activity in Precambrian siliciclastic successions is more subtle as mats, without cement, lose their characteristic structures.



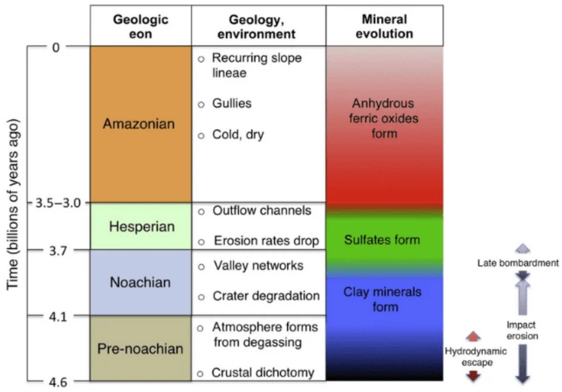

On Mars, there are substantial shreds of evidence of life that can be seen. Observations from the Opportunity rover in Eagle Crater have revealed mushroom-shaped colonies, lichen-like organisms, possibly engaged in photosynthesis. Moreover, it has been speculated that Gale Crater supports the growth and proliferation of a large variety of species, ever since the crater was formed and gradually filled with water billions of years ago. Gale Crater's watery environment may have contributed to stromatolite formation. Additionally, scientists found multiple pieces of evidence of microbial mat-like structures that resemble those found on Earth.

# EVIDENCE OF LIFE ON A GEOLOGICAL TIME SCALE:

Planets formed around 4.5 billion years ago, and soon after the condensation heavy rain and degassing began, cooling the early Earth and possibly Mars. Large lakes and oceans formed around 4 billion years ago on both planets, and possibly life as well. During the Proterozoic eon, the simplest form of life on Earth, known as bacteria or algae, evolved. Living thing plays an important role in the formation of geological time scales. Correlating strata with specific fossil records aids in reconstructing the history of the planets.




(a) Geological Time Scale of Earth




(b) Geological Time Scale of Mars

Image Credit: Encyclopedia (a), Catling, D.C.(2014), in T Spohn, D. Breur & T. V. Johnson (Eds), Encyclopedia of the Solar System, Elsevier, 343-357

The presence of clay minerals on Mars is unequivocal evidence of water. This mineralization event occurred during the Early Noachian eon, and valley networks have been formed around 3.7 billion years ago on Mars. Sulfates were formed in the Late Noachian, and by interacting with water, hydrous sulfates were formed. Hydrous sulfates are one of two major types of secondary minerals found in large quantities and widely distributed on Mars' surface (the other type is phyllosilicates). The degree of hydration of these sulfates on Mars' surface is influenced by environmental conditions, which are determined by diurnal and seasonal cycles, as well as, in the long term, by Mars' obliquity cycles. Sulfate-Reducing Bacteria (SRB) that live in an anaerobic environment also support to form microbial mats on Earth and maybe on Mars.

# PRECAMBRIAN MAT-INDUCED SEDIMENTARY STRUCTURE

Mat-Induced Sedimentary Structures (MISS) from modern and ancient sandstone have been reported in India. Mats were abundant in the Proterozoic sandstone formations of the Vindhyan, Marwar, Chhattisgarh, and Cuddapah Supergroups. Scientists studied geomorphology and the genetic implications of microbial mat-induced structure in siliciclastic rocks from Lower Vindhyan in central India.

It is suspected that mat influence is responsible for the Crack generation on sand itself contributing to cohesion to the granular sediment. Even though the mat has now vanished because of degeneration and decomposition, the cracks provide a proxy record of its pristine condition.

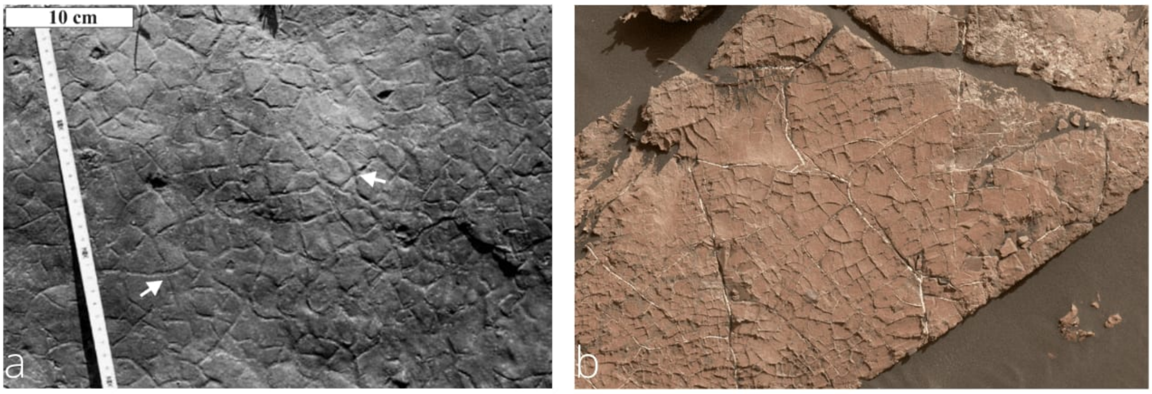



Figure: Cracks within Vindhyan sandstone: Rectangular (a), Mud Cracks "Old Soaker," on lower Mount Sharp, Mars (b).
Image Credit: Shankar et al. 2006, NASA/JPL-Caltech/MSSS

In figure (a) mud cracks were observed in the Vindhayan sandstone, on the other hand mud cracks were observed by the Curiosity rover. Stratified rock formed from the cracked layer more than 3 billion years ago, which was subsequently buried by sedimentary layers. Wind erosion eventually stripped away the layers above Old Soaker. Since the material that filled the cracks prevented erosion better than the mudstone around it, the crack pattern now appears as raised ridges.

Peter ridges in the supratidal flats, spherical, elliptical, or elongated forms can be seen on the mat surface. A variety of petee ridges are the result of gas and sediment moving upward through cracks in the mat cover.[Figure a]

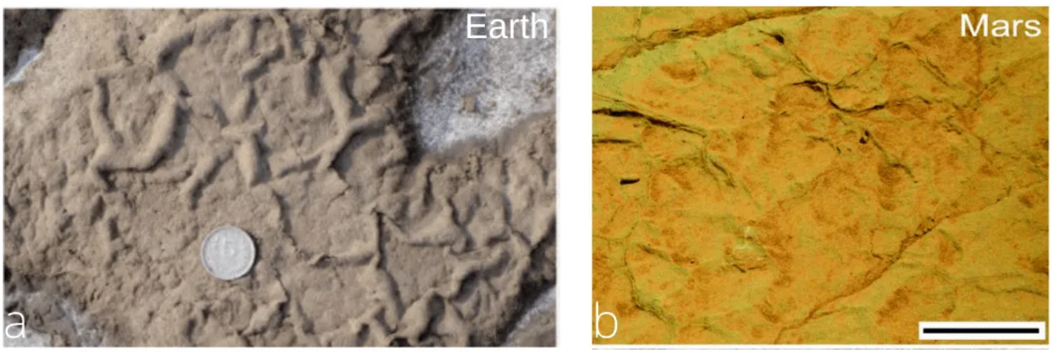



Figure: Mat structure on Petee ridges of Vindhyan supergroup (a), MISS on Gillespie Lake Member outcrop (b).
Image Credit: SantanuBanerjee et al. 2014, NASA / Nora Noffke.

[Figure b] Observations made by Curiosity's Mastcam photographs of the Gillespie Lake Member outcrop have led to the following hypothesis: the sedimentary structures in the Gillespie Lake Member are ancient MISS produced by microbial mats interacting with their environment maybe gas and upward moving sediments.

# MICROBIAL MAT STRUCTURE ON MARS

On Mars, around 3.7 billion years ago near its equator, the Gale Crater formed and later filled with water. There is a 5.5 km high mountain at the center of Gale Crater. Numerous gullies and ancient flowing water bodies have been craved foothills of the high mountain. Speculations suggest that Gale Crater may have provided a habitable environment for the last 3.7 billion years.

Observations from Curiosity's image indicate that sedimentary formations are very similar to green algae, cyanobacteria, lichens, fungi, stromatolites, and mat-forming organisms, including those that appear to be fossilized or trace fossils of various organisms including metazoans (R. G. Joseph et al. 2020).

Scientists identified algal-like formations that often accompanied or were adjacent to specimens such as ooids, lichens, fungi, microbial mats, and stromatolites.

Figure: Sol 309 Layers resembling microbial mats that have become fossilized and scoured with algae.
Image Credit: Curiosity (MSL) Analyst's Notebook

Sol 309 image showing the microbial mat-like features that lately become fossilized over time, algae might be helped to form such layered structure.


Figure: Sol 322 Mark indicates degassing from microbial activity.
Image Credit: Curiosity (MSL) Analyst's Notebook

Sol 322 image that showing at its top left corner marked by an arrow is might be the result of degassing by microbial activity. A similar type of feature can easily be noticed in the rocks of vindhyan supergroup formed by microbial action.

Figure: Sol 322 suspected microbial action.
Image Credit: Curiosity (MSL) Analyst's Notebook

In Sol 322 image Curiosity's rover consider to be a suspected microbial action due to its usual pattern of brown color microbial activity forms a mat.

# CONCLUSION

In the past two decades, MISS has been discovered in several Precambrian successions of India, including Vindhyan, Marwar, Chhattisgarh, and the Cuddapah Supergroup. Our purpose in this study is to provide an updated catalog based on the chronology, stratigraphy, and paleoenvironmental occurrences of MISS from the Indian Precambrian successions. In this research we studied Vindhyan succession as potential in determining extreme habitability on Mars, looking for biomarkers and biosignatures on Mars, and recommending a few astrobiological research sites. These sites could be the analog to study the ancient habitable Mars on Earth.

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