The three ages of Mars

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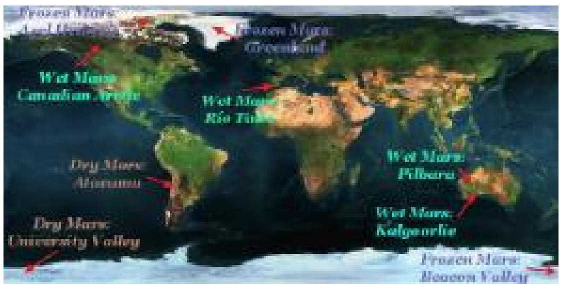


Map of Earth showing locations of the terrestrial martian analog sites the researchers analyzed. Credit: Alberto Fairen

There is no place on Earth that is a perfect copycat of Mars as it is now, or as it was at any specific point in the past. But scientists suggest Earth has little versions of Mars as it might have been over decades. These places could help scientists develop a timeline of the red planet's history.

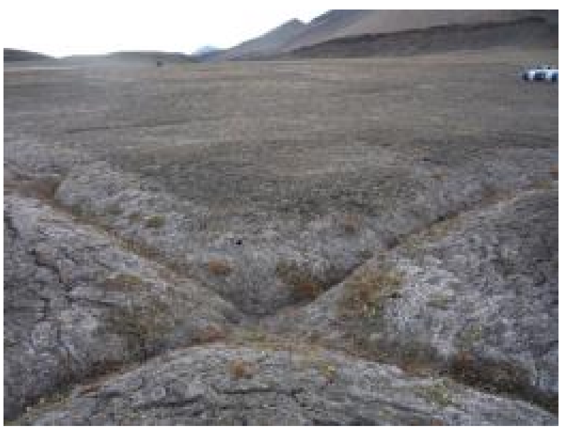
By providing insights on how Mars has changed over time, these terrestrial mimics could help us better understand the results of past and current missions to Mars. They also could help researchers plan future expeditions to look for signs of life on Mars. In addition, investigating these extreme sites on Earth could shed light on the limits of life.

Astrobiologist Alberto Fairen at the SETI Institute and NASA Ames Research Center and his colleagues identified three stages Mars went through. In the first, cold, wet age, enough liquid water and energy was present to make Mars potentially habitable. In the second "Snowball

Mars" age, conditions became extremely challenging, and the liquid water that could have made life possible became scarce. In the current hyper-arid age, conditions on the surface have become largely uninhabitable, save perhaps some isolated niches.

"We have tried to assign every analog to a specific time in Mars' geological history, so we can study the evolution of Mars in Earth environments," Fairen explained. "This will be the only way to ask ourselves the right questions." Their research was detailed in the November issue of the journal Astrobiology.

First Age of Mars — cold and wet



Close-up of the polygons in Axel Heiberg Island. Credit: Alberto Fairen

The first 700 million to 900 million years of the red planet are what the researchers dub the first age of Mars. Back then, although temperatures overall were cold, it appears liquid water was probably abundant on the surface. The planet also possessed a thicker atmosphere and a global magnetic field that could have protected against hostile radiation, helping provide the most hospitable conditions for life as we know it in the entire history of Mars.

Most of the water-linked features and mineral deposits seen to date on Mars stem from this first age. The largest part of the surface was composed of volcanic rocks and related soils, which the surface waters reacted with to generate a variety of minerals. These include phyllosilicates, which are typical products of the weathering of volcanic basalt, and evaporites, deposits that form after the upwelling and evaporation of groundwater.

Four sites on Earth mimic rocks from this age on Mars. They could yield insights not only into the chemistry that dominated the surface of the red planet back then, but also into the potential for both life and the preservation of traces of life.

The North Pole Dome area, which covers some 230 square miles (600 square km) in the 3.5-billion-year-old Pilbara region of Western Australia, is an excellent analog for martian phyllosilicate formation, the researchers noted. It also contains evidence of Earth's earliest biosphere in the form of stromatolites and possible microfossils more than 3 billion years old, and therefore could shed light on how any martian fossils might have been preserved or degraded over time.

When it comes to evaporites, acidic environments on Earth could serve as compelling analogs for acid sulfate-rich regions such as Meridiani Planum on Mars, including seasonally dry, acid lakes in Western Australia, the Rio Tinto basin in Spain and cold acid drainage systems in the Canadian Arctic. These acidic environments on Earth are either rich in microbes or possess evidence of microbial activity, and as such could shed light on Meridiani Planum, which is considered a prime target for the search for any organic material that life could potentially have left on Mars.

Second Age of Mars — Snowball Mars

As Mars became increasingly dry and cold some 3 billion to 3.6 billion years ago, its water froze, leaving its surface nearly or entirely frozen. The disappearance of the planet's magnetic field and the surface's increasing cold and aridity probably made it dramatically less habitable overall. Still, there was massive volcanism, leading to episodic inundations of large parts of the lowlands, which might have provided favorable conditions for the preservation and evolution of life. The prevailing conditions on the surface then were probably similar to ones seen at polar regions on Earth, including large ice sheets and glaciers.

Astrobiologists looking for lessons on Mars are especially interested in how microbes and signs of life on Earth are preserved for long spans of time in ice, and how microorganisms deal with the rigors of arctic conditions and impact their environment. Ice and permafrost on Earth are known to hold a large number of viable microbes up to 8 million years old, with permafrost bacteria showing measurable activity down to at least minus 4 degrees F (minus 20 degrees C), and that survival could even extend to at least minus 40 degrees F (minus 40 degrees C).

Three analogs on Earth for "Snowball Mars" include Axel Heiberg Island in the extreme northern regions of the Canadian High Arctic, Beacon Valley in Antarctica, and the North Greenland Eemian Ice Drilling Project site. The permafrost at Axel Heiberg island is analogous to martian permafrost; Greenland is a good analog to the martian north polar layered deposits, exhibiting similar patterns when it comes to accumulations of material, and the up to 10-million-year-old ice of Beacon Valley might be the oldest known ice on Earth, and as such could shed light on anything preserved for long times on Mars.

Third Age of Mars — Hyper-Arid Mars

Filamentous algae at Berrocal, Rıo Tinto. Credit: Ricardo Amils

The last age of Mars that has persisted for the past 3 billion years has seen an extremely dry and cold red planet with a surface bathed by hostile solar ultraviolet radiation. The cold, coupled with an extraordinarily thin atmosphere, means that liquid water cannot survive long on the surface, which is probably the most serious constraint for life there.

Although there are no places on Earth today akin to the arid and cold conditions seen on Mars today, there are two areas where liquid water is extremely fleeting. In the Atacama Desert in Chile, the heat makes water vaporize, while in University Valley in Antarctica, the water freezes.

In the Atacama Desert the soils are very old, up to 2 million years in age, as well as extremely dry and enriched in soluble salts similar to those found on Mars. The soils also possess very low levels of bacteria and organic materials, providing a way to study the rigors any martian microbes might face. Another way the soils in the Atacama Desert mimic martian ones lies in how they possess levels of perchlorates nearly as high as those seen by the Phoenix lander on Mars. These were likely created by sunlight-induced chemical reactions in the atmosphere.

A Contentious Past

There have been decades of debate over how warm, cold, wet or dry Mars has been in the past, and not everyone agrees with the timeline that Fairen and his colleagues set forth.

For instance, during the earliest age of Mars, which Fairen and his colleagues set forward as cold and wet, "I don't think you can create the kinds of features that they see without a much warmer climate than they propose," said planetary scientist James Kasting at Pennsylvania State University, who did not participate in this study. "I don't believe in a cold, wet Mars — I think it was warm and wet in the distant past, and I think climate models for Mars bear that out. That doesn't mean that it was as warm as the Earth is today, but that mean annual temperatures were above the freezing point of water."

Yungay, Atacama Desert. Halite rocks sculpted by winds. Rocks are some tens of centimeters in size. Credit: Jacek Wierzchos

Fairen noted that it was "difficult is to know if the planet was warm or cold. Atmospheric models are unable to raise the temperatures on the surface over zero degrees C (the freezing point of water) whatever the concentration of carbon dioxide assumed, so additional gases must have contributed to warm early Mars. Which gases did this, and what their concentrations were, is something that still needs to be determined, so the 'warm' model for early Mars lacks solid evidence. Alternatively, salty solutions could have kept liquid on Mars at temperatures somewhat under the freezing point of pure water, for a cold and wet Mars."

Regardless of the arguments over how warm or wet Mars was in the past, planetary scientist Victor Baker at the University of Arizona, who did not take part on this study, felt the timeline would help motivate research. "It can help us understand particular periods in martian history and formulate strategies on where to go and search for life," he said. "They're presenting the idea that we have to think of Mars as a whole planet evolving through time, and as something that we can look at on Earth."

"If people don't like the timeline, that's a positive thing, too — they can go out and find hard data that the timeline is wrong, and then create a better one, and then science can move forward," Baker added. "This framework they propose is not absolute — it's a working idea. They're not saying this is absolutely the way Mars is, but that this is a way we can think of it as a strategy to learn more about the planet, and it's something we can revise as we move along."

Source: Astrobio.net