Unlocking the secrets to Mars by simulating the planet's geology and hydrology

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Mars is known as the Red Planet because iron minerals in the soil oxidize, giving it and the atmosphere the distinctive colour. Credit: NASA/JPL-Caltech

Humans have been fascinated by Mars probably since the first of the species turned their gaze to the night sky. Space exploration today attests to that continuing fascination.

Since the 1960s, more than 40 missions have tried to reach the red planet . As a result, there are currently three rovers active on the Martian surface, plus one lander and one helicopter, while eight orbiters circle the planet.

Simulating the red planet's geology and hydrology can reveal how the landscape has changed, helping the search for landing sites for future missions.

Special interest

"Many of the planets and moons in our solar system are very interesting, but Mars is a little special," said François Forget, an atmospheric scientist at Sorbonne University in France. "Nowadays, Mars is quite similar to Earth, but in the past—3 to 4 billion years ago—it was even more similar."

While the extensive exploration to date has produced a wealth of geological data, plenty remains unknown about the fourth planet from the sun.

Signs exist of a once vast ocean covering Mars's northern hemisphere, while elsewhere lie scars carved out by rivers and glaciers.

Yet the climatic processes that shaped the planet observed today remain a mystery.

As far back as 4 billion years ago, when life started to appear on Earth, Mars had rivers and lakes of liquid water. This raises the possibility that life also developed on Mars.

But scientists are also interested in the processes that created the dry, desert planet seen today and what they could reveal about Earth's climate.

Areas of Mars's surface are more than 3 billion years old. Such records are unavailable on Earth as it has been fundamentally altered by life, which has erased much of the planet's early history.

Something else also makes Mars special: it's a place where astronauts are hoping to go at some point.

The European Space Agency, or ESA, and the US National Aeronautics and Space Administration—NASA—are working towards sending astronauts to Mars.

Time test

Forget is the lead researcher on an EU-funded project developing a model of how Mars evolved in a bid to answer some of the questions about the planet's history.

Called Mars through time, the project began in late 2019 and is due to last into most of 2025.

Current climate models for Mars cover only short periods—several years—of its history and simulating the impact of features such as glaciers, rivers and lakes is tricky, particularly over long timeframes, according to Forget.

The project's model is designed to run for thousands, or even millions, of years, simulating the past evolution of geological features along with the changing atmosphere.

While current climate models require assumptions about where water sat on the planet's surface, the evolution one for Mars is designed to work out where water would have naturally developed and reached a stable equilibrium, says Forget.

This is done by incorporating more detail into the model such as the effect of microclimates.

For instance, slopes that face a pole on a planet are usually cooler, potentially leading to the formation of ice and glaciers. On warmer slopes facing the equator, liquid water might be more likely.

"If you wanted to simulate the Earth but you didn't know anything about it, you would put water in the oceans and then slowly Earth's evolution model would, for instance, build the Antarctic ice sheets," Forget said. "You want to be able to do the same on Mars, and of course, the model will create lakes, seas and rivers."

It also incorporates large-scale changes that occur on longer geological timescales. The tilt of Mars rotational axis, known as obliquity, typically changes every 50,000 years and brings with it large scale climatic changes.

Carbon-dioxide glaciers

To use the model, the scientists rely on known data from Mars's past such as geology and topography, the location of rivers, lakes and glaciers and atmospheric composition. They also make some assumptions around missing data.

When the simulation runs, the scientists adjust their assumptions and parameters until the evolution of the model Mars fits with the existing knowledge of the planet in the past and the present.

Once a model matches the geological records, it provides information on the environment, chemistry and atmosphere of the planet and how they changed, according to Forget.

So far, the model has confirmed that some strange-looking moraines—debris left behind by glaciers—are likely from ones made of frozen carbon dioxide.

The simulations have also suggested how these CO_2 glaciers could have formed and shown that they would have caused dramatic changes in the composition of Mars's atmosphere.

To test one theory of how liquid water might have existed on the Martian surface, scientists plugged a hydrogen-rich parameter into their model to get a possible hint of how Mars's climate might have become warm enough to sustain liquid lakes and rivers.

The model showed that, if Mars had had a hydrogen-rich atmosphere in the past, it could have produced a significant greenhouse effect and boosted the planet's temperature.

Frozen reservoirs

At the other end of the temperature spectrum, a better understanding of the formation of glaciers and where frozen water might exist today could help with manned missions to Mars.

"Having access, without too much difficulty, to water ice on Mars will be very helpful, according to NASA," Forget said. "They have set up project teams looking at where water ice can be found and the Mars through time project can really contribute."

The EU research could also provide information on where liquid water might be found. As it happens, these are areas where astronauts don't want to land.

That's because of a concept known as planetary protection. The last thing astronauts want to do is contaminate Mars with microorganisms from Earth, particularly in liquid water where they could thrive.

More information:

- Mars through time