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How to search for water on Mars

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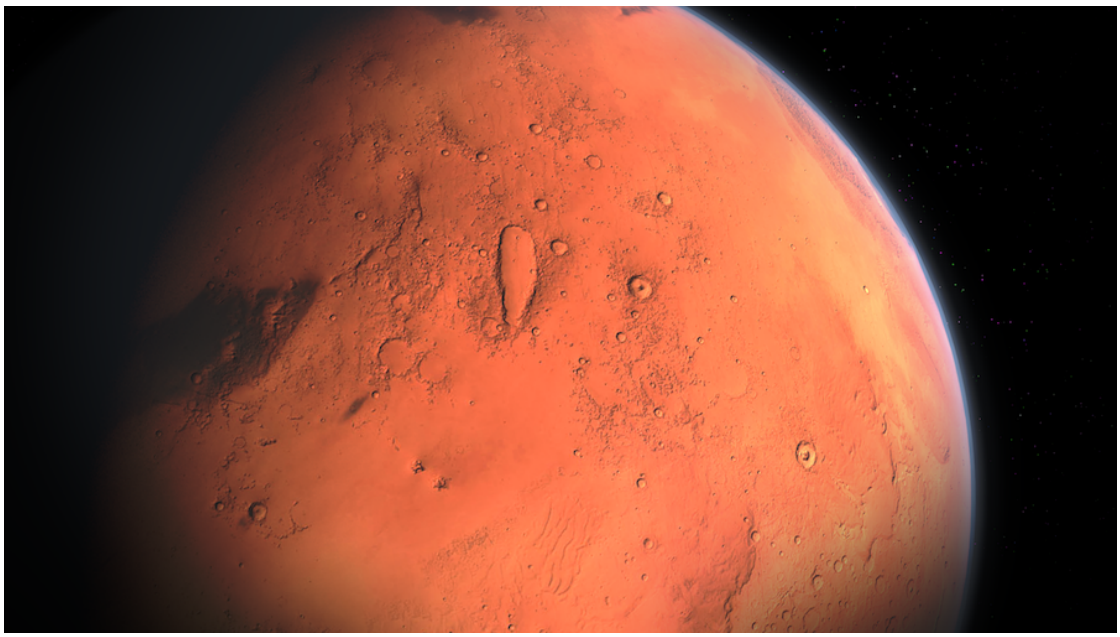
ABSTRACT

A body of liquid water about 20 km across was detected by radar under 1.5 km of ice in the Martian southern polar cap. This water is likely saturated with salts and below 0°C, but it could still be inhabitable by terrestrial extremophiles.



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The presence of water is considered a necessary condition for the existence of life as we know it. Even if Mars is today a cold and arid place, there is ample evidence that things were different in the past, and that rivers, lakes and perhaps seas existed for the first several hundred million years of its history. Such time span was sufficient for the emergence of life on Earth, and thus many have wondered if the same could have happened on our neighbor planet. The next question is then if life could have survived the dramatic changes in Martian climate and still be existing today, and where it could be found. The answer is summarized by the name NASA gave to its strategy for the exploration of the Red Planet: "follow the water".

A fraction of Mars' water was probably lost in space together with most of the planet's atmosphere, which the weak gravity could not retain over the ages. More water is present as ice in the polar caps and in the ground. At some depth below the surface, ground ice would melt as temperature increases due to the heat coming from the molten interior of the planet, similarly to what happens on Earth. Here, temperature rises by about 3°C every hundred meters, with large variations from place to place due to local factors such as volcanic activity and thermal properties of rocks. On Mars, such increase has never been measured (this is the task of the recently launched InSight lander), which makes it difficult to predict where water could be today.

Currently, the only viable way to search for water over an entire planet is from orbit, and the only effective method to search for it at depth is a technique called ground penetrating radar (GPR). We are used to the fact that cell phones work inside buildings, which happens because radio waves can propagate through solids. This property is also the basis for GPR, transmitting radio pulses at a low frequency that penetrate into the ground and are reflected by changes in its structure and composition. Mapping such reflections over an area provides the local subsurface structure while analyzing their characteristics can give information on its nature and composition.

On Earth, GPR has been used to probe polar ice sheets since the fifties of last century. Liquid water is the most reflecting natural material for radio waves, and subglacial lakes have been identified in Antarctica, Greenland and, more recently, in the Canadian Arctic because of the very strong radar echoes they produce even under thousands of meters of ice. Similar to terrestrial GPR's, the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) was put on board the European Space Agency Mars Express spacecraft to look for water on Mars. In 2007, MARSIS recorded echoes, coming from a depth of 3.7 km under the South polar icy deposits, which were stronger than surface echoes. However, Martian polar caps differ from Earth's in that they contain also CO_2 ice, which is less reflecting and more transparent than water ice: eventually, dry ice proved to be a more plausible explanation for the observed echoes than the presence of water. The search continued, however, and after several years it was possible to identify a 20 km area of strong radar reflections coming from a depth of 1.5 km, again beneath the south polar cap.

Several potential explanations of the findings were considered, such as the presence of CO_2 ice and a complex subsurface geometry. All of them were studied to understand how they would shape radar echoes. Eventually, the only one capable of reproducing all characteristics of the data was water. However, because the mean surface temperature in this area is about 160 K, it is hard to explain how the melting point of ice could be reached at just 1.5 km depth. Probably, water is saturated with salts that strongly depress its freezing point and are found everywhere on the planet. Very cold and salty water isn't the ideal place for life, but there are microorganisms capable of thriving in similar environments on Earth. Thus, many questions are raised by this discovery on the possibility of life to exist in these conditions, on the long-term stability of such an environment, and on its possible connection with the Martian past. The answers lie in future efforts to retrieve and analyze water from Mars.