New discoveries show that Mars may have once been habitable

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A recent study using data from NASA's Curiosity rover and published in the Proceedings of the National Academy of Sciences present data showing the presence of nitrates on Mars. This molecule, composed of one nitrogen and three oxygen atoms, may indicate that there was once a nitrogen cycle on ancient Mars, one of the necessary mechanisms on a planet to sustain terrestrial-like life.

The research was undertaken with an international team led by Jennifer Stern using Curiosity's Sample Analysis at Mars (SAM) instrument suite. In earlier studies of Martian soils and rocks at Gale crater, nitrogen was detected in both scooped and drilled sediment samples. However, it was not clear whether the nitrogen detected was from the surrounding atmosphere, indicating molecular nitrogen, or from the rocks themselves, indicating nitrates. Using SAM and subtracting out the known sources of nitrogen within the instrument, Stern's team was able to show that there were still up to 1100 parts per million (ppm) of nitrogen remaining, depending on the sample analyzed. From this, Stern's team concluded that the nitrogen originated from the sediments and thus from nitrates.

Whether nitrogen is found in the atmosphere or in other forms plays an important role in biochemistry on Earth. While the majority of terrestrial nitrogen is in the atmosphere, making up 78 percent of the air we breath, it is in the inert form of molecular nitrogen (N_2). To incorporate nitrogen into more complex molecules—such as nucleobases, amino acids, DNA, RNA and proteins—it must be in more accessible forms. The nitrate molecule (NO_3) is one of the most prevalent and useful molecules seen on Earth for this purpose.

As such, the strong evidence of nitrates in a variety of different rocks and sediments on the Martian surface implies that, at a very early point in the planet's history, there could have been large amounts of biologically useful nitrogen on the Red Planet.

Stern's research complements a report released three weeks ago in Science which provides strong support for the existence of an ocean of liquid water on the surface of Mars during the planet's early life. The ocean is estimated to have held more water than Earth's Arctic Ocean. That is enough water to cover the entire surface of Mars in liquid 137 meters deep. More likely, the ocean covered almost half Mars' northern hemisphere and reached depths greater than 1.6 kilometers.

This is much larger than previous estimates of a primordial Martian ocean, meaning that the planet's surface could have been wetter for much longer than estimated, perhaps 900 million years. Combined with a thicker, warmer atmosphere, volcanism on the surface and the presence of nitrates, this likely led to rich reservoirs containing the diverse chemical elements needed for life.

This second discovery was made by a team led by Geronimo Villanueva, working with the European Southern Observatory's Very Large Telescope in Chile, and the W.M. Keck Observatory and NASA Infrared Telescope Facility in Hawaii. Using detailed maps of the Martian atmosphere, the scientists were able to distinguish the chemical signatures of two slightly different isotopes of water. The first is the familiar H_2O. The second is the more exotic form HDO, in which one hydrogen atom is replaced by one of its more massive forms, deuterium.

By taking the ratio of H_2O and HDO in Mars' atmosphere and comparing it to those values found in water trapped in a 4.5 billion-year-old Martian meteorite, Villanueva's team was able to measure the atmospheric change in the intervening time span and

determine how much water escaped to space. The forthcoming MAVEN probe will take similar measurements.

These maps were made over the course of three Martian years, amounting to six years on Earth. Beyond showing that Mars once housed a massive ocean, the research also revealed seasonal changes and local weather patterns across what was previously thought to be a mostly homogenous desert climate.

Mars' polar ice caps were also studied, using the same H2O and HDO ratio, as they are suspected to contain a more direct record of water on Mars from 3.7 billion years ago to the present. The researchers found that Mars once had at least 6.5 times the amount of water currently contained in the ice caps, meaning a volume of water on ancient Mars of at least 20 million cubic kilometers. This is in general agreement with the atmospheric study.

Both the nitrogen amounts and water levels now thought to have existed on ancient Mars lead to the question: Where did this all go? Mars today is a barren world with an atmosphere that is 96 percent carbon dioxide and less than 1 percent as thick as Earth's. There is no liquid water on its surface and one has to dig before finding any indication of biologically useable material.

It is suspected that Mars lost its atmosphere to space. The results gathered by the Curiosity rover as a whole are in agreement with *in situ* atmospheric measurements made by the Viking landers from 1976 to 1982, when this idea first gained traction. The three main mechanisms for losing atmosphere include interactions between the atmosphere and the solar wind, a massive impact by an asteroid or other body, and/or the atmosphere escaping as a result of thermal motion and the planet's relatively low gravity. It is not clear which of these mechanisms (if any) is primary.

The loss of the ocean is somewhat more mysterious. Neither the solar wind nor low Martian gravity can account for the loss of liquid water. As the planet cooled and the water froze, one way for the ocean to have disappeared is for the frozen water to sublime into water vapor in the atmosphere and then into space. A more interesting hypothesis is that the ocean didn't go anywhere at all, but was covered up by sediment and dirt as it froze. If so, this would mean that a great deal of water ice is under the northern lowlands of Mars, the Vastitas Borealis basin. It is unknown how far down a probe would need to drill in order to test this idea.

A further question is posed: What is the possibility that life developed on early Mars?

While a great deal more research needs to be done on this subject, these two results are further evidence that at the very least, the conditions once existed on Mars for a life cycle to begin.