Wet and mild: Researchers take the temperature of Mars's past

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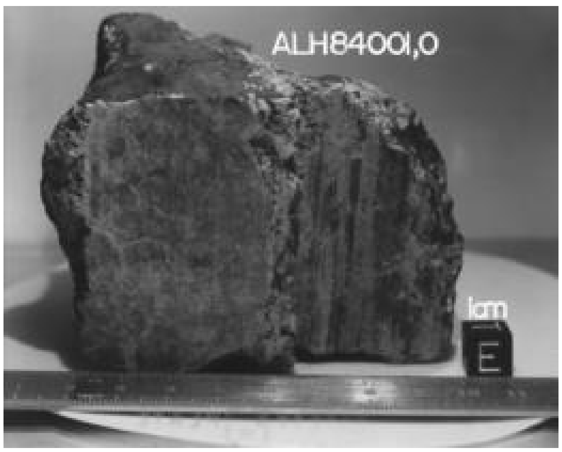

The meteorite called ALH84001 is sliced to show its interior. Found in the Allan Hills ice field in Antarctica in 1984, the four-billion-year-old rock is one of the oldest in the world. The meteorite likely originated just below the surface of Mars. About 16 million years ago, another meteorite struck the area, blasting it off into space before it landed on Earth about 13,000 years ago. [Credit: NASA]

(PhysOrg.com) -- Researchers at the California Institute of Technology (Caltech) have directly determined the surface temperature of early Mars for the first time, providing evidence that's consistent with a warmer and wetter Martian past.

By analyzing carbonate minerals in a four-billion-year-old meteorite that originated near the surface of Mars, the scientists determined that the minerals formed at about 18 degrees Celsius (64 degrees Fahrenheit).

"The thing that's really cool is that 18 degrees is not particularly cold nor particularly hot," says Woody Fischer, assistant professor of geobiology and coauthor of the paper, published online in the Proceedings of the National Academy of Sciences (*PNAS*) on October 3. "It's kind of a remarkable result."

Knowing the temperature of Mars is crucial to understanding the planet's history—its past climate and whether it once had liquid water. The Mars rovers and orbiting spacecraft have found ancient deltas, rivers, lakebeds, and mineral deposits, suggesting that water did indeed flow. Because Mars now has an average temperature of 63 degrees Celsius, the existence of liquid water in the past means that the climate was much warmer then. But what's been lacking is data that directly points to such a history. "There are all these ideas that have been developed about a warmer, wetter early Mars," Fischer says. "But there's precious little data that actually bears on it." That is, until now.

The finding is just one data point—but it's the first and only one to date. "It's proof that early in the history of Mars, at least one place on the planet was capable of keeping an Earthlike climate for at least a few hours to a few days," says John Eiler, the Robert P. Sharp Professor of Geology and professor of geochemistry, and a coauthor of the paper. The first author is Itay Halevy, a former postdoctoral scholar who's now at the Weizmann Institute of Science in Israel.

This photograph shows globules of orange-colored carbonate minerals found in the Martian meteorite dubbed ALH84001. The origin of the carbonate minerals has long puzzled scientists, but by determining that the carbonate formed at about 18 degrees Celsius, Caltech researchers say they might have an answer. The mild temperature is also consistent with the theory that Mars was once warmer and wetter than it is today. [Credit: NASA]

To make their measurement, the researchers analyzed one of the oldest known rocks in the world: ALH84001, a Martian meteorite discovered in 1984 in the Allan Hills of Antarctica. The meteorite likely started out tens of meters below the Martian surface and was blown off when another meteorite struck the area, blasting the piece of Mars toward Earth. The potato-shaped rock made headlines in 1996 when scientists discovered tiny globules in it that looked like fossilized bacteria. But the claim that it was extraterrestrial life didn't hold up upon closer scrutiny. The origin of the globules, which contain carbonate minerals, remained a mystery.

"It's been devilishly difficult to work out the process that generated the carbonate minerals in the first place," Eiler says. But there have been countless hypotheses, he adds, and they all depend on the temperature in which the carbonates formed. Some scientists say the minerals formed when carbonate-rich magma cooled and crystallized. Others have suggested that the carbonates grew from chemical reactions in hydrothermal processes. Another idea is that the carbonates precipitated out of saline solutions. The temperatures required for all these processes range from above 700 degrees Celsius in the first case to below freezing in the last. "All of these ideas have merit," Eiler says.

Finding the temperature through independent means would therefore help narrow down just how the carbonate might have been formed. The researchers turned to clumped-isotope thermometry, a technique developed by Eiler and his colleagues that has been used for a variety of applications, including measuring the body temperatures of dinosaurs and determining Earth's climate history.

In this case, the team measured concentrations of the rare isotopes oxygen-18 and carbon-13 contained in the carbonate samples. Carbonate is made out of carbon and oxygen, and as it forms, the two rare isotopes may bond to each other—clumping together, as Eiler calls it. The lower the temperature, the more the isotopes tend to clump. As a result, determining the amount of clumping allows for a direct measurement of temperature.

The temperature the researchers measured—18 ± 4 degrees Celsius—rules out many carbonate-formation hypotheses. "A lot of ideas that were out there are gone," Eiler says. For one, the mild temperature means that the carbonate must have formed in [liquid water](). "You can't grow carbonate minerals at 18 degrees other than from an aqueous solution," he explains. The new data also suggests a scenario in which the minerals formed from water that filled the tiny cracks and pores inside rock just below the surface. As the water evaporated, the rock outgassed carbon dioxide, and the solutes in the water became more concentrated. The minerals then combined with dissolved carbonate ions to produce carbonate minerals, which were left behind as the water continued to evaporate.

Could this wet and warm environment have been a habitat for life? Most likely not, the researchers say. These conditions wouldn't have existed long enough for life to grow or evolve—it would have taken only hours to days for the water to dry up. Still, these results are proof that an Earthlike environment once existed in at least one particular spot on Mars for a short time, the researchers say. What that implies for the global geology of Mars—whether this rock is representative of Martian history or is just an isolated artifact—is an open question.

The research described in the *PNAS* paper, "Carbonates in the Martian meteorite Allan Hills 84001 formed at 18 ± 4 °C in a near-surface aqueous environment," was supported by a Texaco Postdoctoral Fellowship, NASA, and the National Science Foundation.

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