Martian meteorite carbonates 3.9 billion years old

By John Ira Petty

A new study of the carbonate minerals found in a meteorite from Mars shows they were formed about 3.9 billion years ago. Scientists believe the planet had flowing surface water and warmer temperatures then, making it more Earth-like. Giant meteorites were blasting huge craters in its surface.

This study doesn't directly address the possibility that life once existed on Mars. But "It's another piece in the puzzle," said Larry E. Nyquist of the Planetary Sciences Branch of JSC's Earth Science and Solar System Exploration Division. Nyquist, one of the authors of an article in *Science*, a weekly publication of the American Association for the Advancement of Science, was the principal investigator.

Researchers at JSC and the University of Texas at Austin did the study, using different techniques. Both produced similar results, establishing the carbonates' age within comparatively narrow limits.

The 4.2 pound meteorite is believed to be part of an igneous rock formation formed about 4.5 billion years ago as Mars solidified from a molten mass. The meteorite probably was blasted from the planet when a huge comet or asteroid struck Mars 16 million years ago.

It fell in Antarctica about 13,000 years ago, and was found in 1984 by an annual expedition sponsored jointly by NASA, the National Science Foundation, and the Smithsonian Institution. Called ALH84001, after the Allan Hills in Antarctica where it was found, it was returned to JSC where it has been preserved in the Meteorite Processing Laboratory.

It subsequently was recognized as one of more than a dozen meteorites with unique Martian characteristics.

Just how the carbonates were deposited within this igneous rock is the topic of lively debate. Some scientists believe water saturated with carbon dioxide from the atmosphere seeped down to the subsurface site where the igneous rock formed and created the carbonate deposits. On Earth, living organisms often play a role in carbonate formation. In 1996 scientists at JSC and Stanford University examined the carbonates in ALH84001 using electron microscopy and laser mass spectrometry, and reported evidence suggesting primitive life may have existed in them.

Other scientists believe the carbonates formed when hot, carbon-dioxide-bearing fluids were forced into cracks in the rocks when a meteor struck Mars.The 3.9-billion-year age of the carbonates eliminates neither possibility.

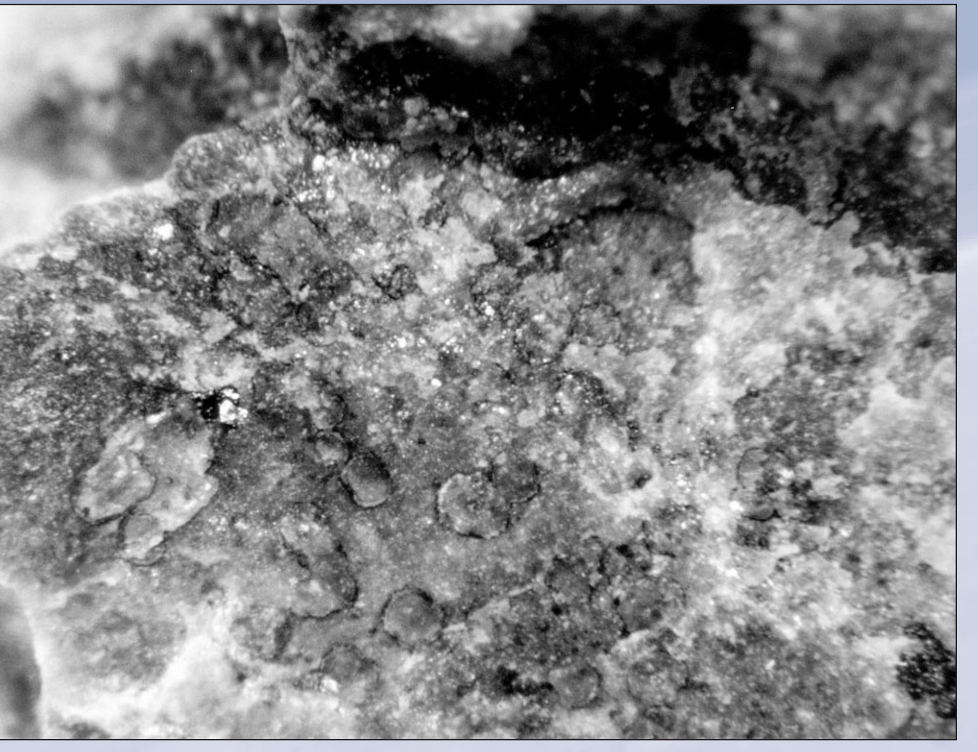
The carbonates themselves are tiny deposits, reddish globules, some with purplish centers and many surrounded by white borders. The different colors are due to variations in the compositions of the carbonates: purplish manganese-bearing calcium carbonate, reddish iron carbonate, and white magnesium carbonates. The globules were found along fractures in the meteorite and make up about 1 percent of its volume.

The JSC-UT team, using a binocular microscope and tools resembling dental picks, over a period of months painstakingly separated out enough of the carbonate material for their analyses. After experimenting with terrestrial calcium, iron, and magnesium carbonates, they developed a way to selectively dissolve carbonate material of differing compositions, enabling them to separate different elements from the carbonate solutions.

The study established the age of the carbonate deposits by measuring the decay of rubidium to strontium and of uranium to lead. The techniques are similar to carbon dating, which is used for much shorter time periods. The investigators used the dual approach because "we wanted to make sure we had a result we could believe in and that other people could believe in," Nyquist said.

The leading author of the *Science* article is Lars E. Borg, formerly of the National Research Council and JSC and now at the University of New Mexico in Albuquerque. Other authors are James N. Connelly of the University of Texas at Austin, Chi-Yu Shih, Henry Weismann, and Young Reese of Lockheed Engineering and Science in Houston. K. Manser of the University of Texas contributed to the investigation.

The age of the carbonates, said Everett K. Gibson of JSC and an author of the 1996 study that reported evidence of microbial life in the carbonates, had been "one of the real mysteries" of indications of life on Mars. Had the carbonates been formed more recently, when the planet's surface was devoid of water, it would have been unlikely they were associated with primitive life on Mars. Dating them at 3.9 billion years, when there apparently was surface water on Mars is, Gibson said, very important, and could "suggest events were very similar in the inner solar system" as primitive life arose. ■



CARBONATES IN SITU—This photomicrograph shows the carbonate minerals in ALH84001 in situ against a background of orthopyroxene, the dominant silicate mineral in this igneous rock. These carbonates are typical of the "globule carbonates" found in ALH84001, although some carbonates with other shapes also are found. At the center is manganese-bearing calcium carbonate, surrounded by iron-carbonate, and enclosed in a layer of magnesium-carbonate. The dark rims surrounding the carbonates are iron sulphides.

CARBONATE-BEARING FRAGMENTS—This photomicrograph shows a few fragments of ALH84001 picked from a portion of the meteorite that was crushed for analysis. The background is the bottom of a beaker in which the fragments were placed for use as a control sample for the age study. Dark sulphide rims are visible on the silicate grains. The large, nearly transparent, grain at the lower right is plagioclase; the others are orthopyroxene. These grains were subjected to the same chemical dissolution procedures as was a much larger sample used for the actual age-dating analysis reported in the *Science* article. The carbonates were slowly and selectively dissolved using progressively stronger dissolution reagents and procedures. The amounts of calcium, iron, and magnesium released during each step were determined and used to verify that carbonates of varying composition were dissolving. Isotopic measurements of rubidium, strontium, uranium, and lead released with the major components determined the age of the carbonates to be 3.9-4.0 billion years old.

ALH84001,0—This photograph was taken during the initial processing of ALH84001. Dull, dark fusion crust covers about 80% of the sample..

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> – Larry E. Nyquist