FROM EARTH TO MARS–

Carbon Dioxide Crystals Help Interplanetary Studies

"If life was once sustainable on Mars, it is important to know what caused Mars to evolve into the cold and lifeless planet it is today. With this knowledge, we can terraform Mars by reversing the process."—Carl Sagan

Technology from the Agricultural Research Service often shows up on farms, in food and industrial plants, and in the home. Soon, ARS technology could find a new theater of operations: the Red Planet.

Mars, with its mountains, valleys, polar ice caps, dry river beds, atmosphere, and relatively moderate climate, is more like Earth than any other body in our solar system. Many scientists believe Mars holds a key to answering questions about the geologic and climatic history of the Earth.

Over the next decade, the National Aeronautic and Space Administration (NASA) will investigate Mars with a number of spacecraft and landers. Several missions are already under way. The Mars Pathfinder began exploring the Martian surface in July of 1997. The Mars Global Surveyor is being readied for its mission of sensing the Martian atmosphere. And discoveries by ARS scientists may play a role in future Mars missions that will look at the planet's polar ice caps.

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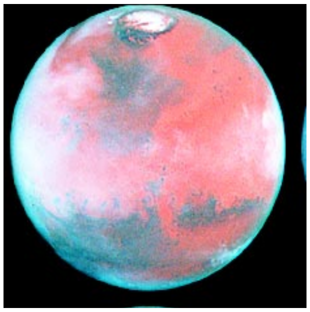

Four views of Mars in northern summer as seen on March 30, 1997, from NASA's Hubble space telescope. Each shows a quarter turn in rotation.

It started a few years ago. Cytologist William P. Wergin and botanist Eric F. Erbe, who are with the ARS Nematology Laboratory at the Beltsville (Maryland) Agricultural Research Center (BARC), developed the first technique for viewing and photographing snowflake crystals with a scanning electron microscope (SEM). Their technique relied on a new procedure for collecting and preserving snow crystals. (See "Anatomy of a Snowflake," *Agricultural Research,* April 1995, pp. 18-21.)

Wergin and Erbe were interested in the crystalline structure of snowflakes as a source of new clues about the potential available water in mountain snowpacks—information vital to irrigated lands in much of the West.

"This was the first time the SEM was used to obtain highly magnified images that clearly show the details of intact and well-focused snow crystals," says Wergin. "And because the viewing stage allows a sample to be viewed at different angles, we were able to record true, three-dimensional images of the crystals."

Unlike conventional microscopes, the SEM does not use light passed through a glass lens to form images of a specimen. Rather, the images are formed by electrons that pass through a magnetic field that serves as a lens. The images can be stored digitally and displayed on a cathode ray tube similar to a TV screen.

The scientists' procedure uses liquid nitrogen to instantly chill snow crystals to -320ºF. This keeps them from melting while the SEM images are obtained.

Now the scientists have adapted the technique to capture the structure of dry ice—frozen crystals of carbon dioxide (CO_2). Gaseous CO_2 is a minor constituent of our atmosphere, making up less than 1 percent. There is no evidence that frozen CO_2 exists in nature on our planet's surface. On Mars, frozen CO_2 makes up most of the planet's polar ice caps.

"We used a special low-temperature SEM to visualize the structure of CO_2 crystals," says Erbe. "The microscope's stage, on which the specimens are placed for viewing, can be cooled to -320ºF."

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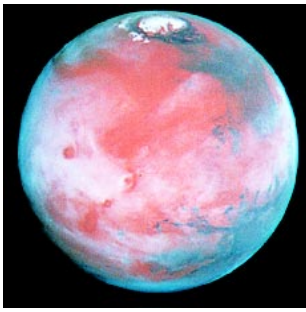

The ARS scientists say that CO_2 crystals are as small as 1/200,000 of an inch. "They're considerably smaller than snowflakes—some only 1/100 the size of snow crystals," says Erbe.

When magnified up to 20,000 times, the CO_2 crystals generally look like eight-sided structures compared to six-sided ones for snowflakes. "Carbon dioxide crystals often appear as two attached four-sided pyramids, called octahedrons," says Erbe.

Carbon dioxide gas freezes to a solid at extremely cold temperatures, around -240ºF compared to 32ºF for water. Earth and Mars are the only two planets in our solar system with ice caps that expand and contract in response to changing seasons. These two facts make the ARS scientists' research of great interest to colleagues at NASA's Goddard Space Flight Center in nearby Greenbelt, Maryland.

ARS and NASA scientists are collaborating to adapt the Beltsville scientists' SEM technology to interplanetary studies of the Martian surface. Collaborators include climatologist James L. Foster, physicist Al T.C. Chang, and hydrologist Dorothy K. Hall at NASA's Laboratory of Hydrospheric Processes, and geologist J. Barton of General Sciences Corp. in Greenbelt.

Foster says that the "SEM technology, together with modeling studies and experiments using microwave radiometers, may allow us to assess, for the first time, the thickness of the seasonal Martian ice caps. On Mars, as on Earth, ice plays a role in large-scale climate processes. However, unlike Earth, Mars has polar ice caps made up of both frozen water and frozen CO_2," says Foster.

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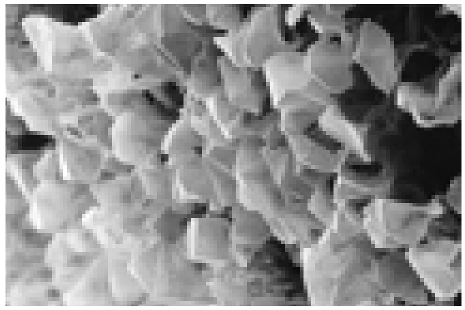
"Knowing the size and shape and scattering properties of both types of frozen crystals will tell us how these crystals behave and scatter energy in different parts of the microwave portion of the electromagnetic spectrum," he says.

This information should lead to more accurate estimates of the thickness and extent of frozen material covering the Martian surface.

What It's Like on Mars

More than 20 years ago, Viking I and II spacecraft recorded various spectral data on this Martian CO_2 mantle. Future missions will be making measurements of Mars in the mi-

ERIC ERBE



Carbon dioxide crystals, magnified about 600x.

crowave region of the spectrum. In order to model how CO_2 crystals scatter and absorb microwave radiation, NASA scientists needed to know the exact shape and size range of CO_2 crystals.

Foster says, "The ARS studies have enabled us to look at the CO_2 crystals in much more detail than ever before." The ARS scientists think that other gases that freeze at ultralow temperatures—such as ammonia and methane—could also be observed using this technique.

Back on Earth, seeing the crystalline structure of CO_2 will give ARS and other scientists clues that may help them learn more about how frozen CO_2 can cause rain to fall, as in cloud seeding.

"Dry ice crystals are among the most effective materials used for cloud seeding," says Wergin.

He believes that CO_2 crystals serve as nuclei around which water vapor freezes, forming snowflakes. Eventually, the flakes melt to form raindrops if the temperature at the ground is above freezing.

Studies of CO_2 crystals may help scientists identify more efficient or economical materials for cloud seeding. More importantly, the SEM technology may help them learn how gaseous CO_2 contributes to the greenhouse effect.

"Carbon dioxide ranks first among the greenhouse gases—along with nitrous oxide and methane—that contribute to global warming as they increase in the Earth's atmosphere," says Gary R. Evans. Formerly chief scientist to the Secretary of Agriculture on global change issues, he is director of the ARS Natural Resources Institute at BARC.

"Knowing the crystalline structure of solid CO_2 may give us clues as to the capacity of the gas to absorb and re-radiate energy," says Evans.

"Carbon dioxide can be sequestered by the way we manage farming practices," he says. "Plants take up CO_2 through photosynthesis. After harvest, their residue gets returned to the soil and becomes organic carbon. So farmers have a chance to reduce CO_2 by improving their management of agricultural systems to increase soil organic carbon."

The spinoff benefits from increased soil organic carbon, Evans says, are reduced soil erosion and better soil tilth—an indicator of soil health.—By **Hank Becker,** ARS.

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William P. Wergin and Eric F. Erbe are at the USDA-ARS Nematology Laboratory, 10300 Baltimore Ave., Beltsville, MD, 20705-2350; phone (301) 504-9027, fax (301) 504-8923, e-mail wwergin@ggpl.arsusda.gov

James L. Foster is at the NASA Laboratory of Hydrospheric Processes, Goddard Space Flight Center, Greenbelt, MD, 20771; phone (301) 286-7096, fax (301) 286-1758, e-mail jfoster@glacier.gsfc.nasa.gov

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