Researchers using the University of Arizona-led HiRISE camera aboard NASA's Mars Reconnaissance Orbiter, or MRO, have found eight sites where thick deposits of ice beneath Mars' surface are exposed in faces of eroding slopes.

These eight scarps, with slopes as steep as 55 degrees, reveal new information about the internal layered structure of previously detected underground ice sheets in Mars' middle...
The ice was likely deposited as snow long ago. The deposits are exposed in cross section as relatively pure water ice, capped by a layer 1 to 2 yards (or meters) thick of ice-cemented rock and dust. They hold clues about Mars' climate history. They also may make frozen water more accessible than previously thought to future robotic or human exploration missions.

Researchers who located and studied the scarp sites with the HiRISE, or High Resolution Imaging Science Experiment, camera on MRO reported the findings on Jan. 11 in the journal Science. The sites are in both the northern and southern hemispheres of Mars, at latitudes from about 55 to 58 degrees, equivalent on Earth to Scotland or the tip of South America.

"There is shallow ground ice under roughly a third of the Martian surface, which records the recent history of Mars," said the study's lead author, Colin Dundas, of the U.S. Geological Survey's Astrogeology Science Center in Flagstaff, Arizona. "What we've seen here are cross sections through the ice that give us a 3-D view with more detail than ever before."

**Windows Into Underground Ice**

The scarps directly expose bright glimpses into vast underground ice previously detected with spectrometers on NASA's Mars Odyssey orbiter, with ground-penetrating radar instruments on MRO and on the European Space Agency's Mars Express orbiter, and with observations of fresh impact craters that uncover subsurface ice. NASA sent the Phoenix lander to Mars in response to the Odyssey findings; in 2008, the Phoenix mission confirmed and analyzed the buried water ice at 68 degrees north latitude, about one-third of the way to the pole from the northernmost of the eight scarp sites.

"The discovery gives us surprising windows where we can see right into these thick underground sheets of ice," said Shane Byrne of the UA Lunar and Planetary Laboratory, a co-author on the new report. "It's like having one of those ant farms where you can see through the glass on the side to learn about what's usually hidden beneath the ground."

Scientists have not determined how these particular scarps initially form. However, once the buried ice becomes exposed to Mars' atmosphere, a scarp likely grows wider and taller as it "retreats," due to sublimation of the ice directly from solid form into water vapor. At some of them, the exposed deposit of water ice is more than 100 yards, or meters, thick. Examination of some of the scarps with MRO's Compact Reconnaissance Imaging Spectrometer for Mars, or CRISM, confirmed that the bright material is frozen water. A check of the surface temperature using Odyssey's Thermal Emission Imaging System, or THEMIS, camera helped researchers determine they're not seeing just thin frost covering the ground.

Researchers previously used MRO's Shallow Radar, or SHARAD, to map extensive underground water-ice sheets in middle latitudes of Mars and estimate that the top of the ice is
less than about 10 yards beneath the ground surface. How much less? The radar method did not have sufficient resolution to say. The new ice-scarp studies confirm indications from fresh-crater and neutron-spectrometer observations that a layer rich in water ice begins within just 1 or 2 yards of the surface in some areas.

**Astronauts' Access to Martian Water**

The new study not only suggests that underground water ice lies under a thin covering over wide areas, it also identifies eight sites where ice is directly accessible, at latitudes with less hostile conditions than at Mars' polar ice caps.

"Astronauts could essentially just go there with a bucket and a shovel and get all the water they need," Byrne said.

The exposed ice has scientific value apart from its potential resource value because it preserves evidence about long-term patterns in Mars' climate. The tilt of Mars' axis of rotation varies much more than Earth's, over rhythms of millions of years. Today the two planets' tilts are about the same. When Mars tilts more, climate conditions may favor buildup of middle-latitude ice. Dundas and co-authors say that banding and color variations apparent in some of the scarps suggest layers "possibly deposited with changes in the proportion of ice and dust under varying climate conditions."

This research benefited from coordinated use of multiple instruments on Mars orbiters, plus the longevities at Mars now exceeding 11 years for MRO and 16 years for Odyssey. Orbital observations will continue, but future missions to the surface could seek additional information.

"If you had a mission at one of these sites, sampling the layers going down the scarp, you could get a detailed climate history of Mars," suggested MRO deputy project scientist Leslie Tamppari of NASA's Jet Propulsion Laboratory in Pasadena, California. "It's part of the whole story of what happens to water on Mars over time: Where does it go? When does ice accumulate? When does it recede?"

The UA operates HiRISE, which was built by Ball Aerospace & Technologies Corp. of Boulder, Colorado. The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, leads MRO's CRISM investigation. The Italian Space Agency provided MRO's SHARAD instrument; Sapienza University of Rome leads SHARAD operations; and the Planetary Science Institute, based in Tucson, leads U.S. involvement in SHARAD. Arizona State University leads the Odyssey mission's THEMIS investigation. JPL, a division of Caltech in Pasadena, California, manages the MRO and Odyssey projects for the NASA Science Mission Directorate in Washington. Lockheed Martin Space, Denver, built both orbiters and supports their operation.

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