Features

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If Lava Mingled with Ground Ice on Mars

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MOC image MOC2-186
JPL/NASA/MSSS/UA

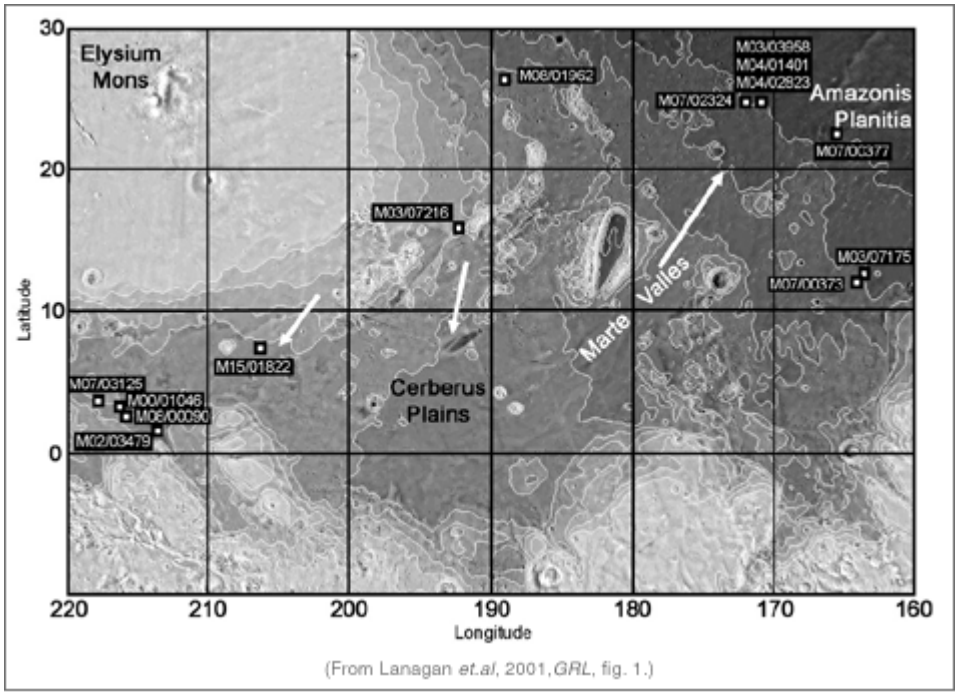
Clusters of small cones on the lava plains of Mars have caught the attention of planetary geologists for years for a simple and compelling reason: ground ice. These cones look like volcanic rootless cones found on Earth where hot lava flows over wet surfaces such as marshes, shallow lakes or shallow aquifers. Steam explosions fragment the lava into small pieces that fall into cone-shaped debris piles. Peter Lanagan, Alfred McEwen, Laszlo Keszthelyi (University of Arizona), and Thorvaldur Thordarson (University of Hawai`i) recently identified groups of cones in the equatorial region of Mars using new high-resolution Mars Orbiter Camera (MOC) images. They report that the Martian cones have the same appearance, size, and geologic setting as rootless cones found in Iceland. If the Martian and terrestrial cones formed in the same way, then the Martian cones mark places where ground ice or groundwater existed at the time the lavas surged across the surface, estimated to be less than 10 million years ago, and where ground ice may still be today.

Reference:

Lanagan, P.D., A. S. McEwen, L. P. Keszthelyi, and T. Thordarson (2001) Rootless cones on Mars indicating the presence of shallow equatorial ground ice in recent times, *Geophysical Research Letters,* vol. 28, p. 2365-2368.

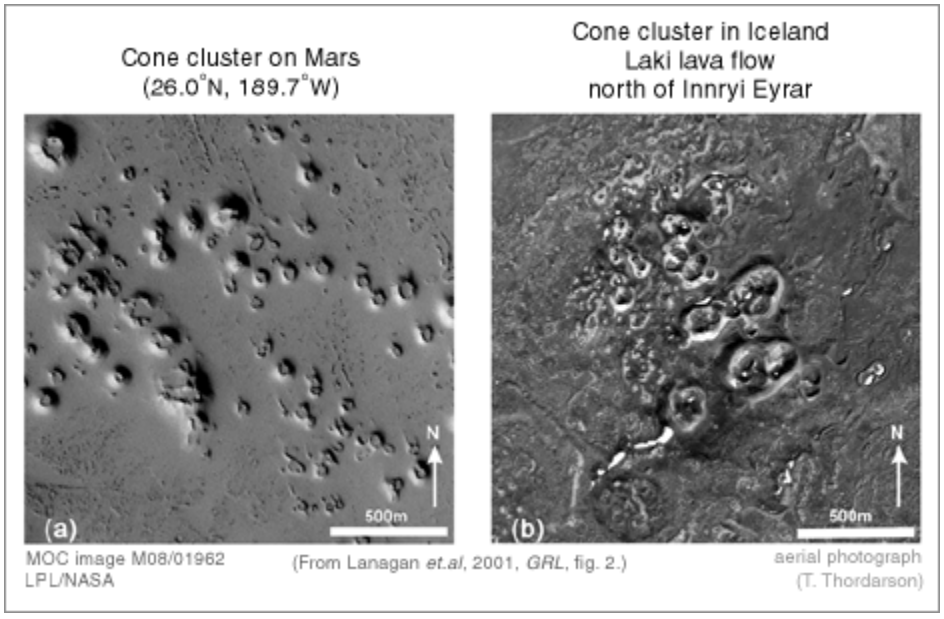
Location and Description of Martian Cones

Cone-shaped structures on the Martian volcanic plains were first identified and interpreted as rootless cones in the 1970s with Viking imagery. Their occurrences were reported in Chryse Planitia, Deuteronilus Mensae, Acidalia Planitia, Isidis Planitia, and Elysium Planitia. Using the higher-resolution MOC images, Lanagan and colleagues identified cones in the Cerberus plains, Marte Valles, and Amazonis Planitia. The cones appear to be superimposed on the surface of low volcanic plains near recognized outflow channels. Using crater counts and other geologic evidence, William Hartmann (Planetary Science Institute) determined the lava flows may be as young as 10 million years.



This regional topographic map of the area around Cerberus Plains has white contour lines (at 200-meter intervals) superimposed over a Viking image. Low areas have darker shading. White arrows indicate downstream directions of known outflow channels. The small black squares with white dots mark locations of cone clusters identified by Lanagan and colleagues in MOC images.

The cones seen in the MOC images have base diameters ranging in size from 20 meters to 300 meters. Summit craters on the cones have diameters about half as wide as the bases. Martian cones are found in clusters ranging from a few to many hundreds of cones. These dimensions and arrangements are consistent with explosive rootless cones found in Iceland.

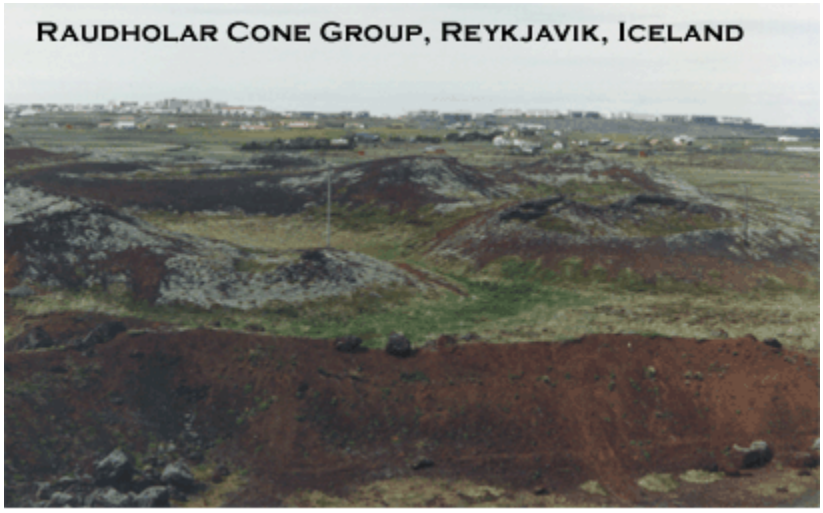


Overlapping and clustered cones (a) on Mars and (b) in Iceland. The scale of the Martian and terrestrial cones are comparable.

How Rootless Cones Form

The mingling of lava and water is a violent interaction creating explosions and ejections of hot lava fragments. The

process begins when lava flows across a wet landscape, perhaps a marsh, shallow lake, shallow aquifer or possibly even icy ground. Although the surface of the lava cools to a hardened crust, molten lava continues to surge through internal tubes. Water that comes into contact with the hot lava becomes heated and flashes to steam. When the steam pressure exceeds the pressure of the lava above it: boom. Repeated explosions build cone-shaped structures of ash and larger pieces of spattery lava. Crowned with summit pits, the cones sit on top of the lava crust. These cones are called "rootless" because they are not fed by a magma source vent lying directly underneath. Lava moving laterally through internal tubes to the explosion site feeds rootless cones. The cones are characteristically distributed in small clusters with no obvious alignment along fissure vents and they do not erupt lavas themselves. Thordarson has found that Icelandic rootless cones are clustered in marshy regions where water-saturated sediments and lava mix thoroughly. By analogy, Lanagan and co-authors say that rootless cones on Mars may require sufficient shallow ground ice to produce water-saturated sediments.



(Courtesy of Thorvaldur Thordarson, Univ. of Hawai'i.)

Raudholar Rootless Cone Group at Reykjavik, Iceland. This group is located about 1.5 kilometers from the eastern edge of town (see apartment buildings on the horizon for scale.) The cone group is in the Leitin lava flow, which covered a small shallow lake here. The cluster is located about 27 kilometers from the source vents of the lava.

Implications for Recent Equatorial Ground Ice on Mars

If the cones identified on Mars are evidence of geologically recent shallow ground ice near the equator of Mars then we can begin to make some assumptions about how far down the ice might have been. Based on calculations by C. Allen (Johnson Space Center), lava-water explosions on Mars driven by steam pressure would require the water or ice to be at a depth of no more than half the thickness of the lava flow. Lava flows in the Marte Valles region have been mapped at 10-meters thickness. Therefore, any ground ice available for creating rootless cones on Mars was no deeper than 5 meters below the surface lava. Shallow ground ice present on Mars less than 10 million years ago, the researchers argue, would mean that deposits of shallow ground ice probably persist near the cones today.

Lanagan and colleagues list three possible sources for the shallow Martian ground ice. It could be relic ice leftover from the planet's formation. It could be recondensed water vapor from the ground-atmosphere water vapor exchange. It could be recharge from surface flooding events. The researchers favor the third case, citing the proximity of the cones to outflow channels. They note that it is unlikely that relic ground ice has survived for four billion years in equatorial regions of Mars, but perhaps plausible that vapor exchange between the ground and atmosphere, as modeled for Mars by Sarah Fagents and Ronald Greeley (Arizona State University), was sufficient to recharge the ground ice.

Confirming the presence of shallow ground ice in the equatorial region of Mars would be an exciting discovery. A satellite launched April 7, 2001 carries the technology to collect the data we need. The Gamma Ray Spectrometer onboard the 2001 Mars Odyssey mission will supply data on the distribution and abundance of chemical elements at or

near the surface of Mars, and may provide the key to finding water ice in the shallow subsurface. Its expected arrival at Mars is October 24, 2001, with a primary science mission scheduled for January, 2002 through July, 2004. Finding ground ice and understanding its distribution, if it truly exists, may soon be within our reach.

Additional Resources

Allen, C. C.(1980) Volcano-Ice Interactions on the Earth and Mars, in *Advances in Planetary Geology, NASA TM-81979,* p. 161-264.

Fagents, S. A. and R. Greeley (2000) Formation of pseudocraters on Earth and Mars (abstract), *Volcano-Ice Interactions on Earth and Mars,* p.13.

Hartmann, W. K. and D. C. Berman (2000) Elysium Planitia lava flows: Crater count chronology and geological implications, *Journal of Geophysical Research,* vol. 105, p. 15011-15025.

Lanagan, P.D., A. S. McEwen, L. P. Keszthelyi, and T. Thordarson (2001) Rootless cones on Mars indicating the presence of shallow equatorial ground ice in recent times, *Geophysical Research Letters,* vol. 28, p. 2365-2368.

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2001 Mars Odyssey.

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