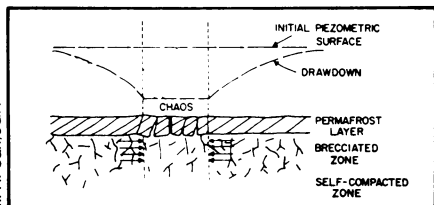


face. Some researchers have actually used the term "snow"—not to evoke classically large, hexagonal snowflakes, but merely to indicate that the water froze out onto the dust nuclei before it descended. The result, says Jones, would be less like a snowfall than like an extremely fine mist.

The far greater amount of frozen water that may lie *beneath* the surface has not been directly detected (or sought) by spacecraft missions to date. (Some scientists have proposed sending "penetrators" that would be dropped from orbit to punch through the surface to sample materials a meter or more down.) The possibilities, however, have been calculated by Crofton B. Farmer of the California Institute of Technology, who used data from the Mariner 9 spacecraft (Viking's predecessor) to work out the depth below the Martian surface at which the temperature never gets higher than the maximum atmospheric frost-point temperature—the depth, in other words, below which any subsurface water would simply stay there as ice. The results, as he reports with P.E. Doms of UCLA in the June 10 *JOURNAL OF GEOPHYSICAL RESEARCH*, are "essentially unchanged" by Viking's data, and they are striking: In addition to near-polar deposits of permafrost, Farmer concludes, there could be widespread regions of seasonally varying "tempofrost" that extend far closer to the equator. The Viking data, in fact, suggest that, "on a time scale of years, the Martian vapor may be in equilibrium with a subsurface reservoir of ice buried to a depth of between 10 cm and 1 m, at all latitudes poleward of about 46°N and 35°S."

The thickness of that layer—the amount of ice it contains—is a different



M. H. Carr/JGR

Early Martian flooding may have been caused by water, sealed under high pressure in crushed rock layers between compacted, nonporous rock below and permafrost above. Disruption of the permafrost could have released the water to the surface, undermining the surface and leading to collapse of the overlying strata.

sort of problem, largely confined so far to estimates based on atmospheric composition measurements suggesting how much water could have "outgassed" from the planet's interior when it was young. In the July 6 *SCIENCE*, James B. Pollack and David C. Black of the NASA Ames Research Center in California compare nitrogen-carbon and water-nitrogen ratios for Mars and earth to conclude that "Mars outgassed an amount of H₂O equivalent to an ice layer 80 to 160 m deep, uniformly covering the

planet."

Still, with ice below, vapor above and frost—even snow—in between, isn't there any liquid? The stuff, on a desert planet, of a cool drink? "I wouldn't be at all surprised," says Farmer. Just as an ice-block igloo can keep a body warm, the Martian residual north polar cap—it's too warm for frozen CO₂—may well keep out the cold so well that liquid water flows beneath it. Similarly, flowing "groundwater" may circulate beneath the permafrost, and replenish the "tempofrost" from beneath when the sun's heat is depleting the seasonal ice layers from above.

A fascinating example of that very process may exist in a region centered at about 25°S and 85° longitude, where Robert L. Huguenin of the University of Massachusetts thinks there may be what he has called "an oasis" and "the wettest spot on the planet." To astronomers, it is known as Solis Lacus—Lake of the Sun—because it is the closest point on the planet to the sun when Mars is at the most sunward point in its orbit, sometimes getting as warm as 290°K—about 63°F. It is certainly not a lake, and it just squeaks onto Farmer's tempofrost map in the middle of winter, when the subsurface water might get closest to the equator. But Huguenin maintains (and Farmer agrees that it's possible) that dust- and sand-sized grains in the surface material there could maintain a tight enough pressure seal on the water to hold it in place, even while the sun's heat has turned the ice to liquid. In fact, he says, if there are salts in the water such as those inferred from the Viking lander data, the water's freezing point may be low enough that it is liquid all year round. Furthermore, although subsurface H₂O has not yet been directly detected on Mars, Huguenin notes that past dust storms that began at Solis Lacus were shown in narrow-spectrum images to contain relatively large quantities of water haze and frost surrounding the dust clouds, while local dust clouds in numerous other regions did not. The region also cools more slowly after sunset and stays warmer through the night than other areas, he says, consistent with a substantial water reservoir near the surface.

One possible—and controversial—role for liquid water in the Martian past is the cutting of channels, riverbeds and floodplains over major portions of the planet. Some such "fluvial" features have been ascribed by various researchers to other causes, but Michael H. Carr of the U.S. Geological Survey asserts that the large floodlike channels could have been cut when groundwater, held under pressure by overlying permafrost, burst free due to meteorite impacts, or simply from growing pressure as the permafrost thickened. Though such floods might have remained liquid for only a few days, Carr calculates that the initial discharge rates could have been as high as 100,000 to 10 million cubic meters of liquid water per second. □

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