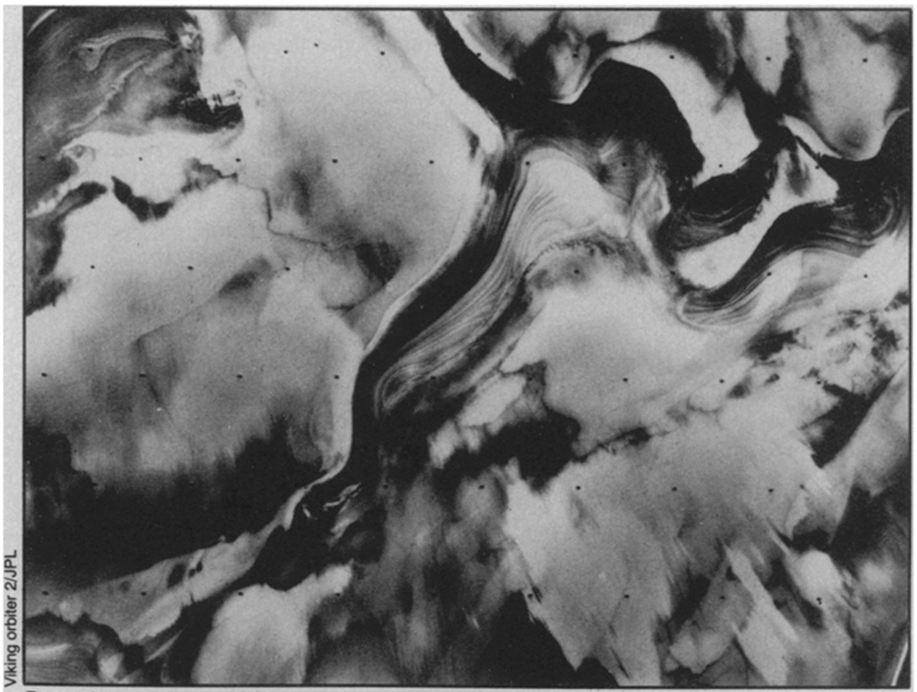
MARS: THE WET LOOK

Even on a planet-sized desert, water makes the difference

BY JONATHAN EBERHART



Viking orbiter 2/JPL

Part of the most conspicuous Martian water reservoir — the residual north polar cap.

Viking orbiter photo: R. L. Huguenin

Parched. Arid. A world of dust, which colors the sky, carves the aged and desiccated rocks and accumulates in trackless dunes that graphically symbolize billions of years of unimaginable drought.

It is Mars. A bleak, rusted wasteland, by comparison with which the most remote deserts of earth seem as luxuriant oases.

Yet Mars is not without its water. There is water in the atmosphere, water on the surface, and probably a lot of water beneath the surface. By some standards, in fact, it is almost abundant: Although the most water-logged portion of the atmosphere — the far north in summer — is more than 100 times drier than the air humans breathe, for example, the thin Martian "air" (less than a percent as dense as earth's) is considerably wetter than earth's at corresponding pressure levels. On the surface, the whole residual north polar cap appears to be made of water, and almost halfway to the equator, frost has been observed to linger on the surface for as much as a third of the 688-day Martian year. Elsewhere, as night turns to day, pale hazes rise through the dawn, ascending in an exquisitely sensitive temperature balance to the faint warmth of the sun from the crags and fissures to which they had clung in the chill darkness. Below ground level, many researchers believe, there may be a kilometers-thick layer of water held in near-permanent stasis by a combination of the cold and the rocky "lid" overhead. The planet's very "soil," in fact, appears to be rich in clay-like minerals that depend for their slippery structure on chemically bound water of hydration.

All this water on such an overtly dry world holds a special fascination for the scientists studying the planet, even without invoking Martians to build canals in which the life-giving liquid might flow. For water plays a role in the weather, the climate and the changing of the seasons, and the water on today's Mars may be what remains from a supply that once did much to shape the surface that is now on spectacular display.

Martian water (still defined as H_2O) is thus a topic of constant study, particularly since the Viking mission's orbiters and landers have provided such a direct, long-term view of its presence and effects. New findings abound.

On Sept. 13, 1977, more than two-thirds of the way through the Martian northern-hemisphere winter, the Viking 2 lander took a photo showing its site at about 48°N latitude to be dotted with patches of white frost (SN: 10/8/77, p. 228). The temperature indicated the substance to be either water or a "clathrate," in which the carbon dioxide of the atmosphere had become trapped in the molecular structure of frozen

Water, frozen out of the atmosphere, whitens much of the surface of the Viking 2 lander's site in Utopia Planitia on Mars. Taken May 18, early in the northern hemisphere's winter, the photo is one of a series showing the condensate to have been deposited at a rate very similar to the previous winter's episode, except that this time there was no preceding dust storm to provide what was expected to be a necessary abundance of grains onto which the water could nucleate. Researchers are uncertain whether the material is frost — frozen directly onto the surface from the vapor phase — or "snow," in which the water froze above the ground and descended to the surface in solid form.

Viking 2 lander photo: K. L. Jones/JPL

Photomosaic from orbit shows Solis Lacus, a basaltic plain in the Martian southern hemisphere that has been called "the wettest spot on the planet." The region may contain substantial amounts of water, some of it as liquid, only centimeters beneath the surface.

water. Unfortunately, it proved extremely difficult for Viking's scientists to determine when the frost had first appeared, since photo coverage in the preceding few months had been limited, lighting conditions had not been chosen for frost-hunting, and a few of the fabled Martian dust storms had made the atmosphere less than crystal-clear. How much frost had there actually been?

When the next Martian winter came around, however, the Viking team at Jet Propulsion Laboratory in California was ready. The dramatic, 112° panorama at the bottom of these pages is part of the result. It was taken at about noon on May 18 of this year, from lander 2's outpost in the Plains of Utopia, and this time there are earlier and later photos to show how the frost advances and retreats.

The previous frost episode, says Kenneth L. Jones of the lander team, covered about 234 Martian days (which are less than an hour longer than days on earth), judging from careful examination of the available photos, and this winter's "frosting" followed a similar pattern. In fact, says Jones, "we're amazed at how repeatable all of this is." Yet there's a difference: The former frost followed dust storms that prompted researchers to speculate that it was the storm-borne dust on which the water condensed (nucleated) and descended to the surface. This time there were no storms, but the condensate deposition rate is similar to that following the storms. "So maybe we don't need dust *storms* for nuclei," Jones says, "but we do need dust." The frozen water may be extremely thin — perhaps a few microns — but it is clearly widespread, extending throughout the panoramic photo. The subtle temperature balance is indicated in the trough-like feature crossing the image, in which a number of drift-like shapes (probably surface undulations rather than frost piles) are bright on one side, darker on the other. The dark sides, says Jones, face the sun when the sun is at maximum elevation, so they get slightly warmer and retain fewer condensates. "Condensates," in fact, may be an appropriately careful word, since "frost" implies that water vapor condensed directly onto the sur-

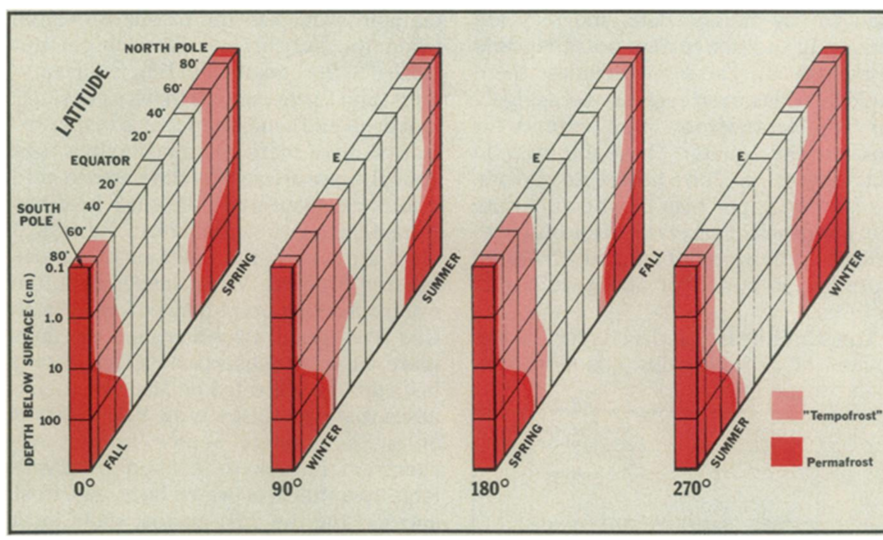


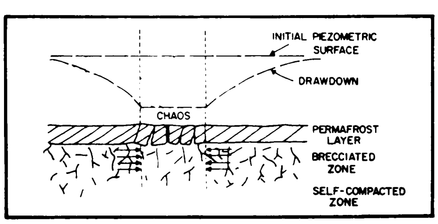
Diagram after C. B. Farmer. Design: J. Eberhart, illus: J. R. Ellis

Diagram shows depth beneath the Martian surface of the top of possible permafrost and seasonal "tempofrost" layers for different latitudes and seasons. Each "slab" represents a different heliocentric longitude (L_s), with seasons opposed in the northern and southern hemispheres due to the planet's tilt. Inter-hemispheric differences in tempofrost extent are due to phase lag between northern and southern seasons. Variations in seasonal tempofrost boundaries at greater depths are due to the growing influence, with depth, of the planet's internal temperatures.

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 H_2O 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 CO_2 — 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 H_2O 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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