THE RESPONSE OF AN EARLY MARTIAN GROUNDWATER SYSTEM TO THE ONSET OF A COLDER CLIMATE. S. M. Clifford, Lunar and Planetary Institute, 3303 NASA Rd. 1, Houston, TX 77058.

With an atmospheric surface pressure of 6.1 mb and a mean equatorial temperature of ~220 K, the present martian climate precludes the stable flow of liquid water on the surface. However, the dissection of the planet's ancient (~4 b.y. old) heavily cratered terrain by integrated networks of small valleys, suggests that Mars once possessed a warmer, wetter climate. If so, atmospheric precipitation should have led to the development of complex multi-tiered groundwater flow system, similar to that found on Earth. How would such a system respond to the onset of a colder climate?

The smallest and most dynamic element of a terrestrial groundwater system is typically a shallow unconfined aquifer that develops within a local topographic basin. Because it is recharged by atmospheric precipitation, the water table generally conforms to the shape of the local terrain (Figure 1). The resulting variation in hydraulic head then drives the flow of groundwater to lower elevations, where it evaporates from the water table, or is discharged to the surface as a lake or spring-fed stream.

Although most basin aquifers are modelled as though they were hydraulically independent, virtually all are part of larger regional groundwater flow systems. In such systems, neighboring basins are linked by networks of intersecting faults and fractures. The extent of this interconnection is not often recognized because the volume of water that participates in interbasin flow usually represents only a small fraction of a basin's total hydrologic budget. Exceptions are noted when there are sizable differences in precipitation between neighboring basins and/or the fracture permeability of the intervening formation is high.

Now consider the response of such a system to the onset of a colder climate. As the surface temperature falls below 273 K, a freezing front develops within the regolith that propagates downward with time (Figure 2). Initially, water is supplied to the freezing front from both the atmosphere and underlying groundwater. However, the atmospheric supply is eventually eliminated by the condensation of ice within the regolith pores. From that point on, the only source of water for the thickening cryosphere is the upward flux of vapor from the groundwater below. Such a flux arises in response to the geothermal gradient, which drives the transport of vapor from the higher temperature (higher vapor pressure) depths to the lower temperature (lower vapor pressure) base of the cryosphere. Given a geothermal gradient of 25 K km^{-1}, and reasonable values of crustal porosity (25%) and pore size (5 μm), ~$2x10^{-5}$ g H_2O cm^{-2} will be supplied to the freezing front each year (Clifford, 1983).

The formation of a global ground ice layer will effectively eliminate the atmospheric recharge of near-surface aquifers. As a result, the elevated water tables that once marked divergent flow boundaries between neighboring basins will ultimately decay (Figure 3). In the absence of these groundwater divides, the continuity of pore space provided by interbasin faults and fractures should allow the regional water table to hydrostatically readjust on a global scale. By way of analogy with Earth, this conclusion is supported by the inferred ~10 md permeability of the top 10 km of the Earth's crust (Brace, 1980), and by the existence of recognized areally-extensive multi-basin groundwater systems in regions that experience little or no precipitation (Pallas, 1980; Issar, 1985; Mifflin and Hess, 1979).

In contrast to the local dynamic cycling of near-surface groundwater that may have occurred during the first half-billion years of martian climatic history, groundwater movement in the post-cryosphere period will be characterized by deeper and slower interbasin flow. The four processes most likely to drive flow under these conditions are tectonic uplift, compaction of water-bearing sediments, geothermal convection, and polar basal melting.

A more detailed analysis of the evolution of the martian cryosphere and hydrosphere is currently in preparation.

REFERENCES

Brace, W.F. (1980) Int. J. Rock Mech. Min. Sci. & Geomech. Abstr., 17, 241-251; Clifford, S.M. (1983) Proc. 4th Int. Conf. on Permafrost, 163-168; Issar, A. (1985) Sci. Am., 253, 104-110; Mifflin, M.D. and J.W. Hess (1979) J. Hydrology, 43, 217-237; Pallas, P. (1980) in The Geology of Libya, Academic Press, 539-594.

FIGURE 1

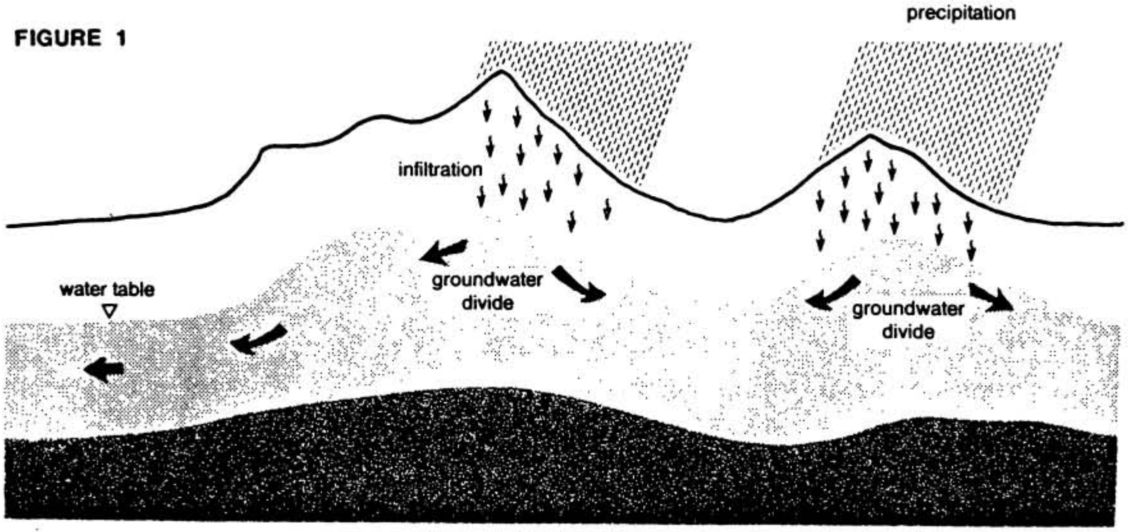

FIGURE 2

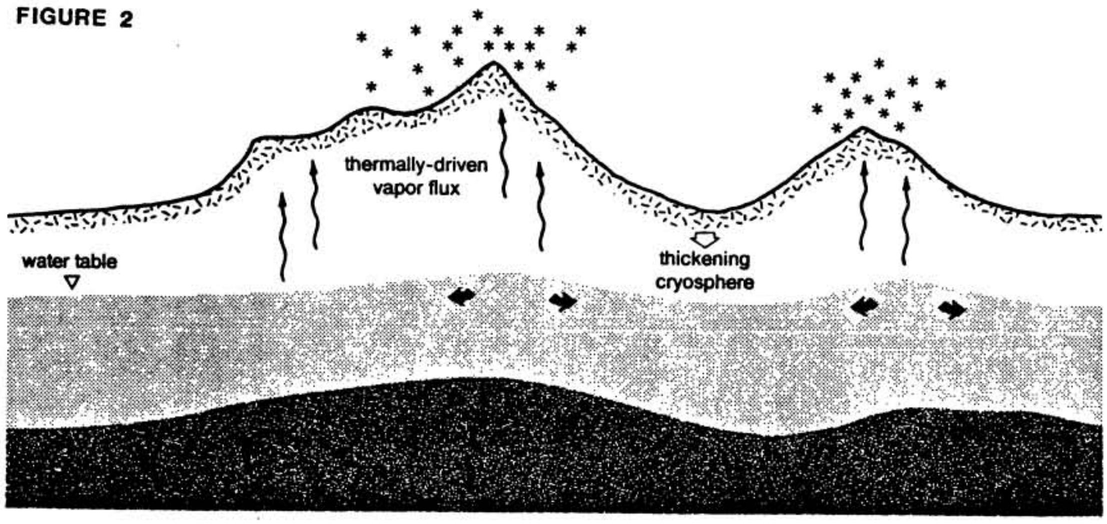

FIGURE 3