ON MODELING THE SEEPAGE OF WATER INTO THE MARTIAN SUBSURFACE. B. J. Travis, Los Alamos National Laboratory (EES-2/MS F665, Los Alamos NM 87545; bjtravis@lanl.gov).

Introduction: Water has played a role on Mars in each of its epochs, including the present: ice at the poles, vapor in the atmosphere, both in the near-surface [1]. A number of studies (e.g., [2], [3]) suggest that sizable bodies of water likely were present on the Martian surface in its early history, and that some of that water surely made its way into the subsurface and may still be present there today. There are several avenues by which surface water could enter a subsurface aquifer system, including: the Clifford model of polar cap basal melting and subsequent infiltration and redistribution; infiltration of rainfall or melting of surface snow accumulations; floods of water from surface ruptures associated with magmatic hotspots and volcanic activity; and seepage below a lake or ocean. This study considers details of how water might infiltrate the subsurface, and time spans required.

Conceptual/Numerical Model: The approach used here applies a numerical model (TRACR3D) of saturated/unsaturated water flow in porous media [4] to model infiltration from a surface water source, such as a lake, a stream, or a pool of water from basal melting. TRACR3D has been used for a variety of Earth-bound applications and has been tested successfully against laboratory and field data. It can operate in 1-D, 2-D or 3-D, and can solve the transient Richards' equation or the fully coupled flow equations for water and air. In unsaturated flow, relative permeability plays an important role. Relative permeability is generally a strong function of saturation. The Brooks-Corey formulation is used here, which assumes a power law dependency. In addition to the exponentially decreasing permeability and porosity structure, which begin with a fairly high surface permeability of 100 darcys, and a porosity of 35%, not unrealistic for surface material, a 10 m layer of sediment is assumed to overlay the native rock/soil. The sediment layer permeability is assumed to be 1 darcy, and have a porosity of 30%. This will impede water seepage, but progression of the infiltration is still fairly rapid.

Results: Seepage into the subsurface depends on driving pressure, i.e., depth of an overlying body of water, and on permeability structure of the subsurface. The first TRACR3D simulation described here assumes an initially dry non-frozen subsurface, which could have been the case at least in a very early stage of Mars' history. Water infiltrating with only 1 m of head can inject a significant amount of water to considerable depth. In this simple demonstration (Figs. 1 and 2), infiltrating water has moved several km below the surface within a couple of years. As water moves deeper, it encounters rock of lower permeability and porosity; this causes a fully saturated region to form. The partially saturated zone is large, extending from the surface down to almost 4 km. Saturation in this vadose zone is increasing, from about 30% below the sediment layer to 100% at 4 km depth. However, a fully saturated region doesn't form until a very large, probably unrealistic amount of water has infiltrated, in this case, 400 m of surface water. If a deep lake or a small ocean were present on the surface, say on the order of 100 m depth, a much greater pressure head would exist and seepage into the subsurface would occur much more rapidly, in fact, in just a few months, given the assumptions above about permeability structure (Fig. 3). However, even in this case, the subsurface below the sedimentary layer does not saturate; pore saturations range from a few percent to around 40%. If the subsurface is initially dry but cold, freezing of infiltrating water will of course slow down the process, but warm infiltrating water would drive down a freezing front. This is a situation that will be explored with the MAGHNUM computer code [5].

Subsurface water on Mars is likely to be salty rather than pure water. Salts generally depress the freezing point; e.g., a high salt (NaCl) content can depress water's freezing point by as much as 23 °C. Clark and van Hart [6], based on analyses of Viking data and geochemical and thermodynamic considerations, considered several candidates for Martian salts ($MgSO_4 \cdot nH_2O$, NaCl, $CaCl_2$, and double salts of the form $MgSO_4 \cdot Na_2SO_4 \cdot nH_2O$). More recently, Knauth and Burt [7] argue that the early Martian hydrosphere evolved first into a NaCl brine, and then, after exposure to basaltic or komatiitic rock, into a Ca-Mg-Na-Cl brine mixture, and that $CaCl_2$ brines may be most likely near the surface. Eutectic freezing points span a range nearly 60 ^oC wide [8], e.g., a $CaCl_2$ brine has a eutectic point of about -50 ^oC and a mixture of $CaCl_2$ and $MgCl_2$ has a -55 ^oC eutectic point. Significant presence of salt in subsurface pores will allow the water infiltration process to occur at sub-freezing temperatures.

Conclusions: Infiltration of water into the Martian subsurface may not follow a simple view of piston flow. Rather, simulations indicate that a partially saturated condition will exist to considerable depth before a fully saturated region develops. A surface body of water can drain fairly quickly – in months – into an initially dry non-frozen subsurface. Further, while an overlying low permeability sedimentary layer will be fully saturated, the underlying material will be only partially saturated to considerable depth. This has implications for development of a cryosphere from surface infiltration. For example, basal polar cap melting might not produce a large pressure head since the upper km or two may only be partially saturated. This would impact the possibility of water flow equatorward Seepage below a surface lake could occur before much of the lake freezes. The presence of significant salt in pore water will allow these results to apply to colder surface conditions. Piston flow of a saturated front should occur, however, if the permeabilities in the Martian regolith are much lower than what is assumed here. A 2-D version of this study is in progress, including thermal effects, looking specifically at polar region and basal melting and the subsurface distribution of water.

References: [1] Boynton, W.V., et al (2002) *Science 297*, 81-85. [2] Clifford, S. M. 1991 *JGR 98(E6),* 10973-11016.. [3] Carr, M. H., & J. W. Head, 2003. *JGR 108*, 5042. [4] Travis, B. J., K. H. Birdsell, 1991, Los Alamos Report LA-11798-M. [5] Travis, B. J., N. D. Rosenberg, J. N. Cuzzi, 2003. *JGR-Planets 108(E4),* 8040. [6] Clark, B. C., and D. C. van Hart (1981) *Icarus 45*, 370-378. [7] Knauth, L. P., D. M. Burt (2002) *Icarus 158*, 267-271. [8] Brass, G. W. (1980), *Icarus 42*, 20-28.

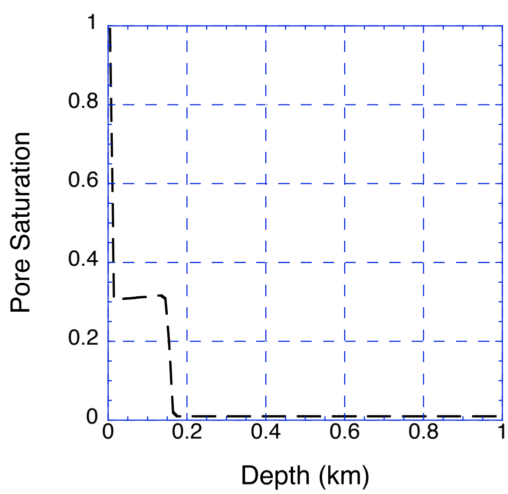

Fig. 1 Water saturation in the subsurface after 1 month of infiltration below a 1 m deep surface water body. A total of about 15 m height of water has infiltrated. Subsurface saturation remains at roughly 30%, below the fully saturated sedimentary layer.

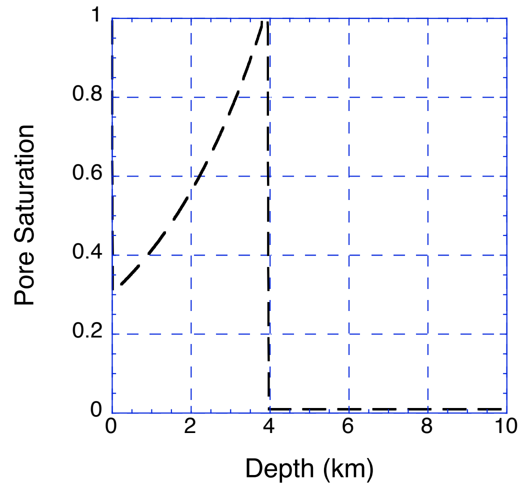

Fig. 2 Pore water saturation vs depth after 2 years of infiltration beneath a 1 m deep standing surface body of water. Finally, a fully saturated region is developing, but not until about 400 m equivalent surface water depth has seeped into the subsurface.

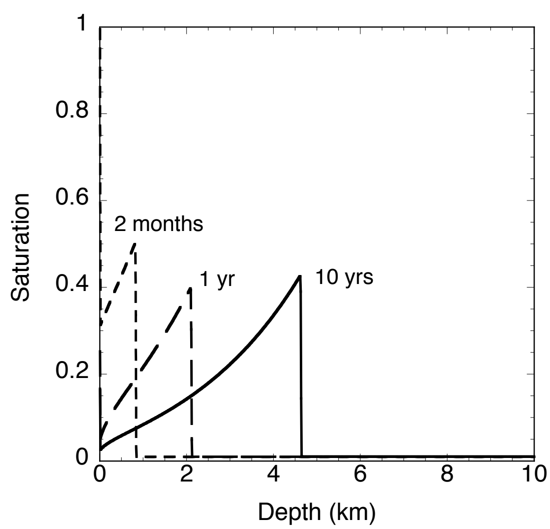

Fig. 3 Pore water saturation vs depth for several times. In this model, a 100m deep ocean drains in just two months; however, redistribution downward of pore water in the subsurface continues for years, and except for the 10 m thick sedimentary layer, the subsurface is only partially saturated.