TRANSIENT SLOPE LINEAE: EVIDENCE FOR SUMMERTIME BRINY FLOWS ON MARS? A. McEwen[1] L. Ojha[1], C. Dundas[1], S. Mattson[1], S. Byrne[1], J. Wray[2], S. Cull[3], S. Murchie[4] [1]LPL, U. Arizona (mcewen@lpl.arizona.edu), [2]Cornell Univ., [3]Washington U., [4]JHU APL.

Introduction: While long known [1], there has been much new evidence for salts on Mars, which depress the freezing point and reduce the evaporation rate of liquid water [2-10]. Such briny water is far more stable on the surface of Mars than is pure water. It has been suggested that the Phoenix lander observed transient droplets of water on the lander legs [11], but definitive evidence for liquid water at the landing site [12] or elsewhere on Mars is lacking.
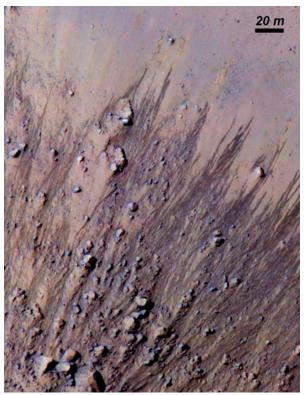

Figure 1. TSL on central hills of Horowitz crater, PSP_005787_1475. Colors have been strongly enhanced to show the subtle differences.

In a companion abstract we describe HiRISE observations of features we call transient slope lineae (TSL) [13]. TSL are defined as narrow (up to a few m wide) albedo markings on steep (>20°) slopes that are transient—present in some HiRISE images but not others. They extend downslope, typically from bedrock outcrops or from rocky areas, and are often associated with and may form small channels (Figure 1). TSL are very different from slope streaks that form on dust-mantled slopes, as summarized in Table 1.

TSL temperatures: Temperature as a function of season, time of day, depth, and thermophysical properties has been described for past landing sites [14]. TSL locations have thermal inertias similar to those of the Viking, MPF, and MER landing sites, but slightly lower albedos. The summertime temperature variations on steep equator-facing slopes in the mid-southern latitudes should be most similar to the summertime variations of the Spirit landing site in Gusev Crater (14.6° S). At this site (flat ground) the subsurface temperature at the hottest times should exceed 273 K down to ~0.8 cm depth and exceed 253 K to ~2 cm. 273 K is the melting point for pure water ice and 253 K is the lowest temperature with demonstrated metabolic activity in terrestrial methanogens [15]. Some brines melt at temperatures as low as 206 K [6, 7], exceeded at all depths.

Table 1. Slope Streaks vs. TSL

Attribute	Slope streaks	TSL
Slope albedo	High (>0.25)	Low (<0.2)
Contrast	Slightly darker	Slightly darker
Dust index*	High (e<0.94)	Low (e>0.95)
Thermal inertia	Low (<100)	180-340
Width	Up to 500 m	Up to 5 m
Slope aspect preferences	None [16]	Equator-facing (also E, W)
Latitudes; Longitudes	Corresponds to dust distribution	-30 to -50; all longitudes
Formation L_s	All seasons [16]	L_s 260-20
Fading timescale	Years to decades	Months
Associated with rocks	No	Yes
Abundance on a slope	Up to tens	Up to hundreds form concurrently
Regional mineralogy	Mars dust	Hydrous minerals common
Topography	Thin surface layer removed	None resolved
Formation events	1 event per streak or streaks	Incremental growth

* 1350-1400 cm^{-1} emissivity [17]

TSL origins: The strong dependency of TSL formation on latitude, slope aspect, and season indicates a temperature-dependent process. However, equatorial slopes (in some orientations) get just as warm as do mid-latitude equator-facing slopes, yet no definitive TSL have been seen in equatorial regions. Hence temperature effects alone, such as thermal expansion driving mass wasting, are not sufficient. Instead, some volatile with a latitude-dependent distribution near the surface must change state to drive the activity. CO_2 sublimation drives many dynamic phenomena on

Mars, but probably never forms on these equator-facing slopes and certainly is not present in the summer. Water or brines, if present, could melt or remain liquid at the surface to drive TSL formation. Brines are far more likely than pure water because (1) water or ice would rapidly sublimate to dry out these slopes, and (2) some activity occurs near the end of summer when temperatures should be too cold for pure water.

Our favored model at present for TSL formation is that shallow brines mobilize thin flows, as first proposed for slope streaks [18]. To produce flows, there must be sufficient liquid to fill the pore space between particles; interfacial water [19] is not sufficient. The TSL mechanism may resemble that of [20], again for slope streaks, except that no runaway process is needed as TSL form incrementally. These flows may advance a little near the warmest time of each day, or they may advance by greater amounts on some days but not others.

A difficulty with this model is the source of water for brines. Equator-facing slopes reaching the melting point should be too warm to preserve ground ice. Deliquescent salts could trap atmospheric water vapor, but this process should also operate in the northern hemisphere if salts are present there. TSL formation is likely a non-equilibrium process to some degree.

An alternative model is that adsorbed water, which makes grains sticky, is released in the summer, allowing dry mass wasting. However, the association with bedrock and rocky slopes is left unexplained by this hypothesis. Rockfalls may trigger mass wasting, but this does not explain hundreds of flows or their concurrent incremental growth.

We have not yet found any definite TSL in the northern hemisphere. This may be explained by the current seasonal asymmetry, in which southern summers are shorter and hotter, by differences in bedrock geology, or both. We note in particular that the putative chloride deposits, hypothesized to result from ponding of surface runoff or groundwater upwelling, are much more abundant in the southern hemisphere [10]. Some brines might be buried before they can desiccate, or form underground at a later time, and might be stable over geologic time. That is, until formation of a crater or trough exposes the brine layers (perhaps frozen) on equator-facing slopes. This could explain the association of TSL with bedrock layers. Continued mass wasting of the slope may be needed to expose new brines as the surface desiccates.

Discussion: Evidence for present-day water on Mars?: Actual water on Mars today has been suggested previously. This is one model for the origin of the active mid-latitude gullies [21], although new observations suggest that gullies are active in the winter and in places where seasonal CO_2 is present, so CO_2 may be the driving volatile [22-23]. Briny flows have also been suggested [24] for high-latitude dunes during defrosting of CO_2, but again the CO_2 is the more likely driving volatile [25]. Brines have been suggested for slope streaks [18, 20], but temperatures on these dusty slopes are able to melt brines only at the immediate surface, and there is no seasonality to the streak formation [16]. Liquid brines at the Phoenix landing site remain controversial [11-12]. Perhaps the TSL represent the most viable targets for actual liquid on Mars today, although habitability remains questionable if the brines are highly concentrated [26].

A Candidate landing site in Horowitz crater: We likely need rover exploration of a TSL site to understand if present-day habitability is possible. A good candidate landing site exists in Horowitz crater. The crater floor east of the TSL-rich central peaks is smooth at MOLA scales over an area 15 km in diameter. At the meter scale the roughness is qualitatively similar to the Gusev crater landing site. The MOLA elevation is -500 m. At -32° latitude, winters should be survivable on equator-facing slopes, which is also the science target of interest. The central peaks contain chlorite and Al-rich clay or hydrated silica [27], of interest independent of the TSL.

References: [1] Clark, B.C. (1978) Icarus 34, 645-665. [2] Bridges, J.C. (2001) Space Sci. Rev. 96, 365-392. [3] Knauth, L. and Burt, D. (2002) Icarus 158, 267. [4] Squyres, S. et al. (2004) Science 306, 1709-1714. [5] Sears, W. and Chittenden, J. (2005) GRL 32, L23203. [6] Chevrier, V. and Altheide, T. (2008), GRL 35, L22101. [7] Altheide, T. et al. (2009) Earth and Planet. Sci. Lett. 282, 69-78. [8] Zorzano, M.-P. et al. (2009) GRL 36, L20201. [9] Hecht, M.H. et al. (2009) Science 325, 64-67. [10] Osterloo, M. et al. (2010) JGR 115, E10012. [11] Renno, N. et al. (2009) JGR 114, E00E03. [12] Stoker, C. et al. (2010) JGR 115, E00E20. [13] Ojha, L. et al., this conference. [14] Ulrich, R. et al. (2010) Astrobiology 10, 643-650. [15] Rivkina, E. et al. (2002) Dokl. Biol. Sci. 383, 179-181. [16] King, C.M. et al. (2010) LPSC 41, 1542. [17] Ruff, S. and Christensen, P. (2002) JGR 107. [18] Ferguson, H. and Lucchitta, B. (1984) NASA TM 86246, 188-190. [19] Kossacki, K. and Markiewicz, W. (2010) Icarus 210, 83-91. [20] Kreslavsky, M. and Head, J. (2009) Icarus 201, 517-527. [21] Malin, M.C. et al. (2006) Science 314, 1573-1577. [22] Dundas, C. et al. (2010) GRL 37, L07202. [23] Diniega, S. et al. (2010) Geology 38, 1047-1050. [24] Kereszturi, A. et al. (2010) Icarus 207, 149-164. [25] Hansen, C. et al. (2010) Icarus 205, 283-295. [26] Tosca, N. et al. (2008) Science 320, 1204-1207. [27] Wray, J. et al. (2009) Geology 37, 1043-1046.