

ATMOSPHERE - SURFACE H₂O EXCHANGE TO SUSTAIN THE RECURRING SLOPE LINEAE (RSL) ON MARS, Alian Wang¹, Z. C. Ling², Y. C. Yan¹, A. S. McEwen³, M. T. Mellon⁴, M. D. Smith⁵, B. L. Jolliff¹, J. Head⁶, ¹Dept. Earth and Planetary Sciences and McDonnell Center for Space Sciences, Washington University in St. Louis, St. Louis, Missouri, 63130, USA; ²Institute of Space Sciences, Shandong University, Weihai, 264209, China; ³Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, 85721, USA; ⁴Applied Physics Laboratory, Johns Hopkins University, Laurel, Maryland, 20723, USA; ⁵NASA Goddard Space Flight Center, Greenbelt, Maryland, 20771, USA; ⁶Dept. Earth, Environmental and Planetary Sciences, Brown University, Rhode Island, 02912, USA; (alianw@levee.wustl.edu)

Introduction: On present-day Mars, Recurring Slope Lineae (RSL) are one of the most active H₂O-involving phenomena occurring every year [1-2]. Their source materials, and especially their water source, are hot research topics [3-8].

We used a set of experiments [9-12] and calculations to demonstrate that the Cl-bearing hydrous salts are the most likely source materials for RSL, and that the H₂O exchange among martian atmosphere and hydrous salt layers in the shallow subsurface can be a mechanism to sustain the observed RSL activities.

Our hypothesis includes two aspects: (1) the deliquescence of hydrous chlorides and oxychlorine salts (HyCOS) in the subsurface under suitable temperature (T) and relative humidity (RH) conditions would generate briny fluid that could trigger the RSL; (2) the rehydration of HyCOS through direct gas-solid reaction when the atmospheric H₂O vapor front moves down from the North Polar region during a cold season would partially recharge H₂O back to HyCOS for RSL to occur in the subsequent year.

To validate this hypothesis, we conducted four sets of experiments and obtained the following results: (1) the T-RH conditions required for deliquescence of HyCOS agree with those existing in martian subsurface salty layers; (2) the deliquescence rates of HyCOS are high and match with the development rate of RSL in warm seasons on Mars; (3) the direct reaction of H₂O vapor - HyCOS salts can occur at very low temperatures relevant to martian winter; (4) the rehydration rates of HyCOS under Mars conditions with atmospheric H₂O as supply are extremely fast that would support the recurring of RSL. In addition, we accomplished two sets of calculations to support the details of this brine model for RSL.

The generation of RSL: We conducted 270 temperature (T) & relative humidity (RH) driven deliques-

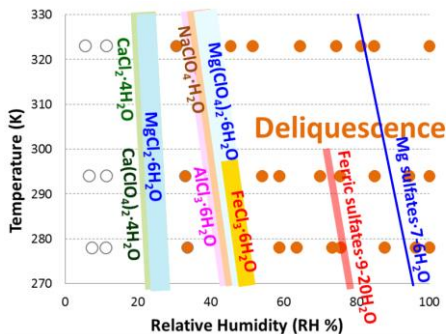


Figure 1. T-RH conditions for deliquescence of HyCOS and sulfates

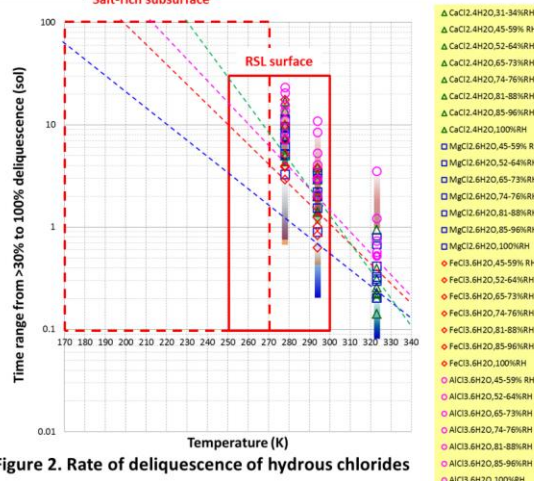


Figure 2. Rate of deliquescence of hydrous chlorides

cence/dehydration reactions for nine HyCOS at ten RH and three T levels. We have two major findings: (1) the suitable RH ranges for the deliquescence of HyCOS (RH > 22-33% or > 43-46%, Fig.1) are much lower than those of hydrous sulfates (RH > 90-92%, or > 75-79%, Fig. 1); (2) the suitable RH ranges are NOT strongly dependent on T.

The first finding suggests that on present-day Mars, the RH conditions for deliquescence of HyCOS would be more easily met than for sulfates. The second finding suggests that the deliquescence of HyCOS would not be seriously affected by local T, e.g., latitude difference (high latitude or

equatorial regions) on Mars.

During each of these experiments, we recorded the time ranges of a visible deliquescence (often >30% brine/salt ratio) and the full deliquescence (100% brine) of tested HyCOS, as the function of T & RH (Fig.2 shows chlorides). We first found that the deliquescence rates of HyCOS are all strongly dependent on temperature (T). This property matches with the seasonality of RSL [1, 2]. When we extrapolate the time (sol) vs. temperature (K) correlations from experiments to lower T relevant to salt-rich subsurface on Mars [13,14], our data (Fig. 2) indicates that the deliquescence of HyCOS can develop fast and far enough (30-100%) in < 100 sols on Mars. This property matches with the observed growth of RSL during a warm season on Mars (>100 sols [1, 2]).

The strong T-dependence of deliquescence rates of HyCOS implies that with fast raising of T, especially at the peak T during a few mid-afternoon hours in a warm

season on Mars, a large amount of HyCOS brine can be generated in a short time to trigger a RSL. We considered two models: a *full-brine-wetted-track model* and a *combined wet-dry-flow model*.

Using two constraints that we built based on orbital sensing and on sample analysis of water-tracks in Antarctica [15, 16], our calculation indicates that a 0.5 m × 0.5 m × 1.0 m HyCOS layer would be needed to generate a RSL of 0.5 m width and 100 m length in *full-brine-wetted-track model*. Based on a conservative consideration, we would suggest that most of RSL should be granular flows triggered by HyCOS brine fluid, i.e., a *combined wet-dry-flow*. The detected hydrous oxychlorine salts at four RSL sites [17] should be salts accumulated after many years' RSL activities.

The recharge of H₂O back to HyCOS: Fig. 3 shows the evidence of a direct gas–solid reaction that recharged H₂O back to a HyCOS salt at dry-ice temperature (-78°C). The highest hydration degree (CaCl₂·6H₂O) was reached within a 5-6 hour experimental duration. Fig. 4 shows the rehydration of CaCl₂ started almost instantaneously, i.e., the Raman peak of CaCl₂·2H₂O is detectable in a few minutes, after the CO₂+H₂O gas was input to the Mars chamber at 251 K. On Mars, the starting HyCOS in such gas-solid interactions can be either the dehydrated HyCOS from a previous warm season when the local RH was low (i.e., the unfilled points in Fig.1); or the HyCOS that underwent deliquescence but the briny fluid has not flowed far enough to reach a cliff thus simply re-solidified in place during the following cold season.

Another issue relevant to the H₂O recharging is the amount of H₂O supplied by the atmospheric circulation and the amount of the H₂O flux diffused into a subsurface HyCOS layer. Starting from a moderately high column value of 15 (pr-μm) H₂O [18, 19, 20] and the commonly accepted thermal properties of martian surface regolith, our calculation indicates a 0.03 g/cc H₂O flux during 100 sols to the subsurface at 1 cm depth. Using this flux as the H₂O supply, our calculation of the increase of hydration degree of most HyCOS is < 1 H₂O per molecule.

Therefore, regardless the extremely high rehydration rate that allows the fast recharge of HyCOS to occur at very low temperature whenever H₂O is available (Fig. 3, 4), the supply of H₂O during the current annual cycle, from the polar cap through atmospheric circulation and down-ward diffusion is limited, which

Fig. 3. Feasibility of CaCl₂ rehydration at -78°C

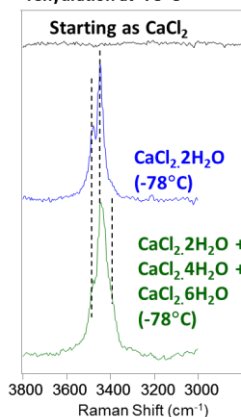
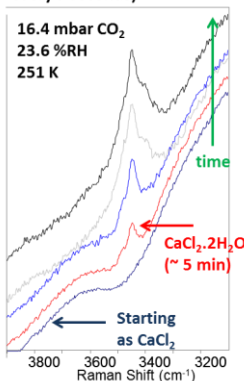


Fig. 4. Rehydration rate of CaCl₂ (in Mars chamber w/Raman spectra taken at every 9 seconds)



can only supports partial rehydration of HyCOS. Possibly, most of the H₂O stored in HyCOS was added during the recent past, with Mars' obliquity greater than that of current period. If so, then RSL activity might persist for only limited years at each site.

Conclusion: Studies [21] suggested that H₂O ice would be stable at Mars equatorial (& mid-

latitude) regions when obliquity > 45° (or > 30°). Four > 45° periods occurred in 5.8 to 5.4 Myr ago, with durations of 0.019, 0.028, 0.026, and 0.008 Myr [22]. A period >30° happened 500 kyrs ago and lasted for 10's of kyrs. During these periods, HyCOS in subsurface reached their highest hydration degrees, which formed the H₂O reservoir for RSL. On present-day Mars, the deliquescence of subsurface HyCOS-layers during peak T hours can generate large amounts of brine fluid in a short time to stimulate RSL at many sites. During a cold season, the fast rehydration rate of HyCOS with limited H₂O vapor supply would partial rehydrate HyCOS. Our experiments and calculations suggest that the annual recurrence of RSL would be an unbalanced process, whereas imply large amounts of Cl-salts existing in the martian subsurface at RSL sites.

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