MODELING THE STABILITY OF MARTIAN PALEOLAKES. I. Uts[1], E. G. Rivera-Valentin[2], V. F. Chevrier[2], [1]Department of Astronomy, Yale University (ilya.uts@yale.edu), [2]Arkansas Center for Space and Planetary Sciences, University of Arkansas.

Introduction: Recent studies have shown that ancient Martian paleolakes with initial depths greater than ~700 m could sustain brines for several years while the ice cap underwent sublimation [1]. It has also been suggested that these aqueous environments were likely to have sustained organisms [2]. While previous studies only modeled Martian paleolake system in the presence of an ice cap, this work models the complete system. The model takes into account mass transfer through evaporation, freezing, and sublimation. The effect of the decrease in solution activity over time and thus the decrease in the freezing temperature, freezing rate, and evaporation rate is of particular interest. Lower evaporation and freezing rates would indicate a longer brine lifespan, which has important astrobiological implications and may explain thermal features such as crater floor polygons [4].

Methods: A similar framework to Rivera-Valentin *et al.*'s freezing model was used [1]. The presented model describes the activity and freezing temperature changes experienced by a 1 km deep lake as it undergoes mass transfer. The model accounts for the evaporation and freezing of the water within the lake, the sublimation of the ice cap, freezing of the underlying brine, and the evaporation of the brine when it becomes exposed to the atmosphere. Lateral adiabatic processes are assumed to have occurred throughout the lake [1]. Additionally, the current model does not account for the precipitation of salts with decreasing activity. The brine is explored as soon as the ice fully sublimates and the brine is exposed to the atmosphere.

The evaporation rate of brine was modeled by using six solutions given by Tosca *et al.* who provided brine thermal and chemical properties [7].

Evaporation Model: The evaporation process is modeled by combining the 1-D representation of Fick's first law with the definition of the Grashof number. The resulting mass flux of water vapor is given as:

$$J = (0.17)\Delta\eta D \left(\frac{\frac{\Delta\rho}{\rho}g}{\upsilon^2}\right)^{\frac{1}{3}} \quad (1)$$

where $\Delta\eta$ is the water vapor concentration gradient, D is the diffusion coefficient, g is the acceleration due to gravity, $\frac{\Delta\rho}{\rho}$ describes the differences between the surface and atmosphere buoyancies, and υ is the kinematic viscosity for CO_2 [5, 6]. The flux was then converted into a rate, R, and used in the recursive formula below. The remaining mass of water, $M_{H_2O\ i+1}$, can be expressed as:

$$M_{H_2O\ i+1} = M_{H_2O\ i} - \rho_w R\Delta t \quad (2)$$

where ρ_w is the density of pure water and Δt is a small time step.

Freezing Point Depression: The freezing point can be described as:

$$T_f = \left(\frac{1}{T_0} - \frac{(R\ln a_{H_2O})}{\Delta H_{fus}}\right)^{-1} \quad (3)$$

where T_0 is the freezing point of pure water, a_{H_2O} is the activity of water, and ΔH_{fus} is the enthalpy of fusion.

Results:

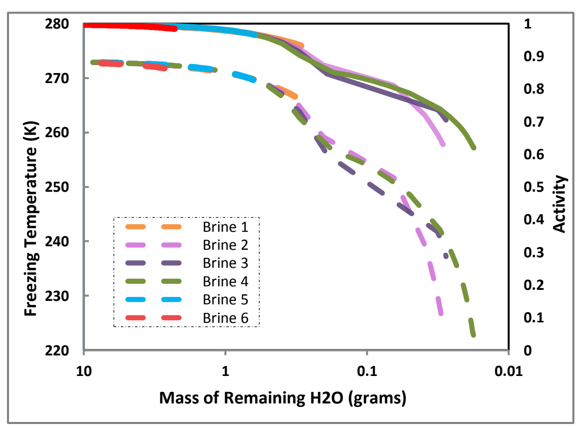

Fig 1 The freezing temperature and activity of each of the six Tosca *et al.* brines are plotted with varying H_2O mass. The top cluster of lines (solid) represents the activities of the brines, while the bottom cluster (dashed) represents the freezing temperature of the brines. The initial mass of H_2O was 1 kg.

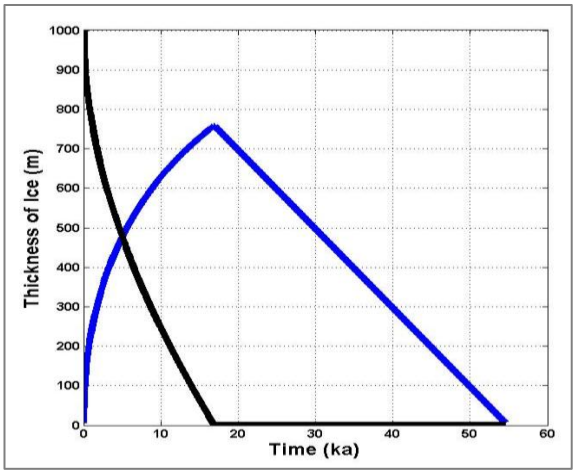

Fig 2 The thickness of the remaining liquid (black) is plotted alongside the thickness of the ice cap (blue). The initial brine resembled Tosca *et al.*'s fourth brine.

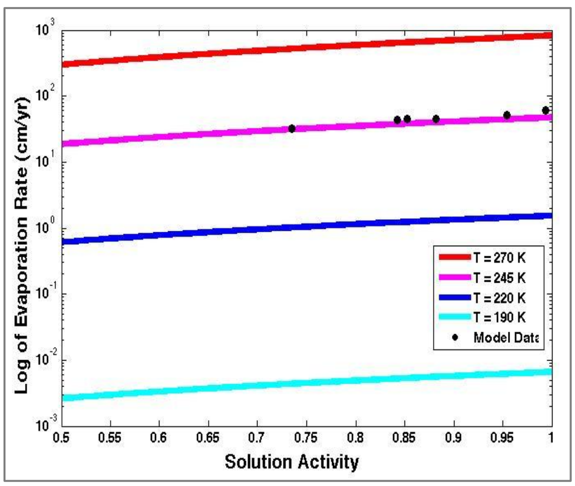

Fig 3 The evaporation rates of the six brines given by Tosca *et al.* are plotted against their activities. The cyan line represents the minimum average annual temperature. The blue line represents the annual average temperature and the red line represents the maximum average annual temperature.

Discussion: Figure 1 shows that the freezing temperatures of brines 3, 4, and 5 can reach around 220 K, which is the global average annual temperature on Mars. This means that brines described by Tosca *et al.* could be liquid on the Martian surface for a portion of every year.

According to figure 2, some of Tosca *et al*.'s brine would remain liquid below the ice cap for approximately 17 ka after which full solution freezing occurs and the ice cap sublimates in 54 ka.

A 1 km deep paleolake could produce ~50 meters of brine under an ice cap [1]. If an evaporation rate of 44.4103 cm/yr, which corresponds to an activity of 0.8525, is selected from figure 2, it suggests that the brine could remain exposed to the Martian atmosphere for ~113 years assuming no phase change cycle. The brine used in Rivera-Valentin *et al.*'s simulation had a significantly lower activity than the solutions discussed here [1]. A lower activity would suggest a lower evaporation rate. Rivera-Valentin *et al.*'s brine would therefore remain exposed to the Martian atmosphere for a much longer time [1].

Conclusion: A lifetime of ~2300 years for a high activity lake has significant implications for biological processes in solutions with lower activities. Future research will apply the theoretical evaporation rate model to account for all of the mass transfer and heat transfer occurring in a Martian paleolake. Wray *et al.*'s detailed description of the salts found in the Columbus crater (29.8°S, 166.1°W) will be incorporated in the modeling of a complete paleolake in the crater [9]. Geochemist's workbench will be used to account for the precipitation of salts that occurs as a result of the evaporation of water. This will give the first complete model of a Martian paleolake.

References: [1] Rivera-Valentin *et al*. (2011) *LPSC XXXVII*, Abstract #1074. [2] Barnhart *et al*. (2006) *LPSC XXXVII*, Abstract #2437. [3] Newsom *et al.* (1996) *JGR*, 101. [4] El Maarry *et al.* (2010) *JGR*, 115. [5] Ingersoll *et al.* (1970) *Science*, 168. [6] Chevrier *et al.* (2008) *GRL*, 35. [7] Tosca *et al.* (2011) *JGR*, 116. [8] Sears *et al.* (2005) *GRL*, 32. [9] Wray *et al.* (2011) *JGR*, 116.