EXPLORING POSSIBLE BRINE COMPOSITIONS FOR MARTIAN PALEOLAKES. I. Uts[1,2], 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: Martian paleolakes are ideal environments for exobiology on Mars [1], as testified by the choice of Gale Crater as the MSL landing site. The possible development and evolution of life in paleolakes, though, is highly dependent on the lifetime of these lakes when subjected to evaporation and freezing. Recent studies have shown that salt-rich martian paleolakes could sustain liquids for several thousand years under a sublimating ice cap [2]. Here we model the stability of martian lakes using a large range of possible solution compositions. The model takes into account mass transfer through evaporation, freezing, and sublimation. The effect of the decrease in water 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 [3].

Methods: We used the freezing model developed by Rivera-Valentin *et al.* [2]. The presented model describes the activity and freezing temperature changes experienced by a 1 km deep lake as it undergoes water mass loss. The model accounts for 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 [2]. At this point it is assumed that no salt precipitation occurs within the system, though it is expected. The brine evaporation is studied as soon as the ice fully sublimates and the brine is exposed to the atmosphere. The possible chemical compositions explored are derived from six solutions given by Tosca *et al*. [4] who provided brine thermal and chemical properties. The initial activities and other physical properties of the brines have been listed in Table 1.

Evaporation Model: The evaporation process is modeled via the Ingersoll equation, which combines 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:

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

where $\Delta\eta$ is the water vapor concentration gradient, D is the diffusion coefficient, g is the acceleration due to gravity, $\Delta\rho/\rho$ describes the differences between the surface and atmosphere buoyancies, and υ is the kinematic viscosity for CO_2 [5, 6, 7]. The flux was 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:

$$M_{H_2O_{(i+1)}} = M_{H_2O_{(i)}} - \rho_w R \Delta t \tag{2}$$

where ρ_w is water density and Δt is a discretized time step.

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

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

where T_0 is the freezing point of pure water, a_{H2O} is the activity of water, and ΔH_{fus} is the enthalpy of fusion [6].

	Brine 1	*Brine 2*	*Brine 3*	*Brine 4*	*Brine 5*	*Brine 6*
a_{H2O}	0.9937	0.9543	0.8816	0.8525	0.8423	0.7350
SO_4	0.0000	1.7331	3.0165	3.2870	3.1630	2.3340
Cl	0.0250	0.2576	0.38649	0.5200	0.6594	0.8368
Mg	0.0010	1.7800	2.5611	2.3485	2.3095	2.1936
Fe(II)	0.0000	0.0018	0.55851	1.0980	1.0984	0.9535

Table 1 Some of the physical properties of Tosca *et al*.'s brines are presented here. For a complete list of all of the properties refer to Tosca *et al*.'s paper [4]. Compositions are in mol/kg.

Results:

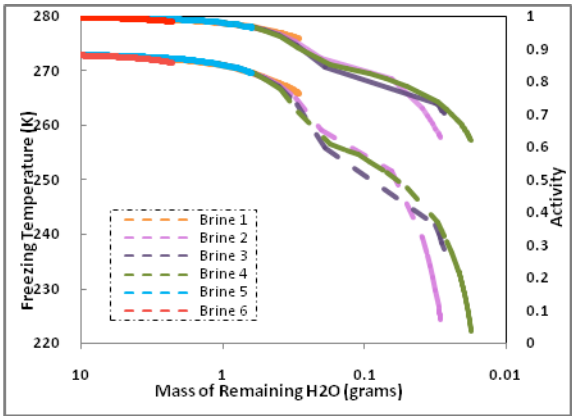

Fig. 1: The freezing temperature and activity of each of the six Tosca *et al.* brines are plotted with varying H_2O mass. The top cluster of lines (solid) represents the activities of the brines, while the bottom cluster (dashed) represents the freezing temperature of the brines. The initial mass of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

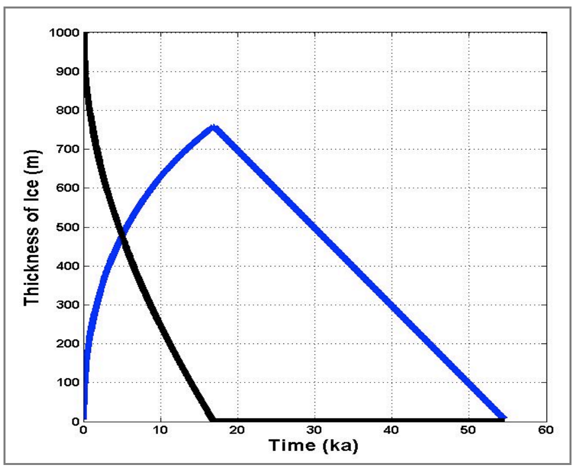

Fig. 2: The thickness of the remaining liquid (black) is plotted alongside the thickness of the ice cap (blue).

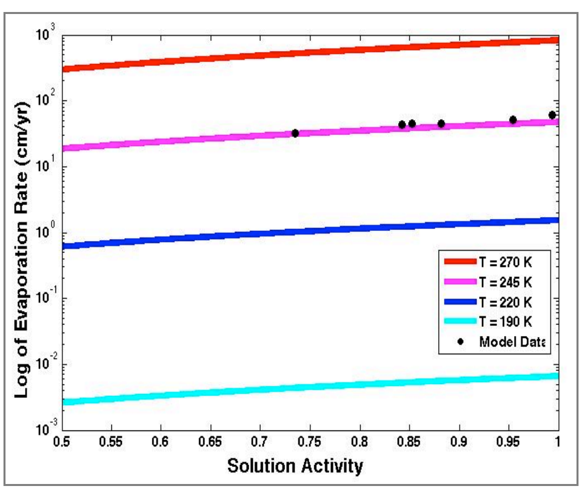

Fig. 3: The evaporation rates of the six brines given by Tosca *et al.* [4] against their respective water activity. The various lines represent the expected evaporation rate at average minimum temperature (cyan), average temperature (blue), average maximum temperature (red), and average evaporation temperature (pink).

Discussion: Freezing temperatures of brines 3, 4, and 5 can reach around 220 K, which is the global average annual temperature on Mars. Implying that some 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 the studied brines 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 [2]. An evaporation rate of 44.4 cm/yr, which corresponds to an activity of 0.853 (Fig. 2), indicates that the brine could remain exposed to the Martian atmosphere for ~113 years assuming no solid phase change. The brine used in Rivera-Valentin *et al.*'s [2] simulation had a significantly lower activity than the solutions discussed here. 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.

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 evaporation rate model to the remaining brine once the ice cap has fully sublimated in order to account for the expected phase change cycle experienced by the remaining brine. Wray *et al.*'s [8] 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. Geochemist's workbench or Frezchem will be used to model 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 including initial dissolved salts.

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