MODELING THE STABILITY OF AN ANCIENT PALEOLAKE IN COLUMBUS CRATER, TERRA SIRENUM, MARS. T. S. Altheide[1], V. F. Chevrier[1], E. G. Rivera-Valentin[1], J. J. Wray[2]. [1]W. M. Keck Laboratory for Space Simulation, Arkansas Center for Space and Planetary Science, MUSE 202, University of Arkansas, Fayetteville, AR, 72701, talthei@uark.edu. [2]Department of Astronomy, Cornell University, Ithaca, NY 14853.

Introduction: Numerous fluid flow features [1-3] and abundant hydrous minerals [4-6] have been detected at the martian surface, including large deposits of sulfates, as well as those of chlorides [7, 8], minerals which have most likely evaporated from a liquid water source. Certain hydrous minerals also provide a mechanism for stabilizing liquid water under martian surface conditions by freezing point depression [9], making their presence on Mars significant for maintaing the water cycle.

Experimental studies have reported that salts can further stabilize liquid water by lowering the evaporation rate under simulated martian surface pressure and temperature [10], and have shown the evaporation of liquid water is dependent on the concentration of salt in solution [12], as well as, on the precipitation of hydrated mineral phases from solution [13]. The stability of brines on the surface of Mars has been additionally characterized through the mergering of kinectic behavior with thermodynamic processes, specifically, describing evaporation processes during phase changes in solution [13].

With the information provided by previous studies, we propose to more accurately describe the stability of a potential paleolake on Mars, as a function of martian temperature and humidity, with respect to evolving changes in solution concentration over time. This paleolake is located in an impact crater, which simplifies the geometry of the system.

Columbus Crater: The martian scenario used in the present study is Columbus crater (Fig. 1), located in Terra Sirenum, approximately 29.8°S, 166.1°W. It is roughly 100 km in diameter, with a depth of ~1.5 km, however, sedimentary materials have filled the crater over time so that the original depth may have been at least twice as much [14]. Various hydrated minerals have been identified in the crater rim and floor by the MRO-CRISM instrument. These minerals include: gypsum, Mg-sulfate, kaolinite, and possibily jarosite and ferrous sulfate [14]. Gypsum, Mg-sulfate, and kaolinite occur mainly in the crater rim, approximately 0.6 km above the crater floor. The deposits in the crater rim suggest a lower limit on the volume occupied by liquid water at ~ 5000 km^3. For this reason, we will use this value as our initial water resevoir, with the detected hydrated minerals as the components in the system.

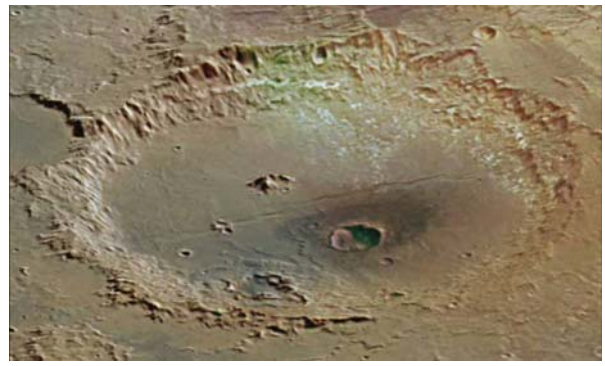

Figure 1. Perspective view of Columbus crater from the High Resolution Stereo Camera (HRSC) on Mars Express [14]. Two mosaic HRSC images are overlaying a digital elevation model. Light-toned hydrated mineral deposits are visible in the top portion of the crater rim [14].

Evaporation model: The evaporation of liquid water, pure or brine, is modeled using the modified semi-empirical Ingersoll equation [12, 13], which accounts for the buoyancy of water vapor in the heavier CO_2 atmosphere:

$$E = 0.17 D_{H_2O/CO_2} a_{H_2O} \frac{\rho_{sat} - \rho_{atm}}{\rho_{sol}} \left[\frac{\Delta\rho / \rho \, g}{\nu^2} \right]^{\frac{1}{3}} \qquad (1)$$

where E is the evaporation rate, ρ_{sat} is the saturation density of water vapor, ρ_{sat} the atmospheric density of water vapor, ρ_{sol} is the brine/solution density, $D_{H2O/CO2}$ is the interdiffusion coefficient of CO_2 and water vapor, a_{H2O} is the water activity in solutioin, $\Delta\rho/\rho$ is the relative density difference between the surface and the atmopshere ν is the kinematic viscosity of CO_2 and g is the acceleration due to gravity (in m s^{-2}).

According to our previous studies and eq. (1), the determination of the evaporation rate requires the following parameters (Fig. 2): temperature, total pressure, humidity in the atmosphere, water activity and phases precipitating out of the liquid [12]. Therefore, several independent models, including the evaporation model, will be applied together.

Temperature Model: The evaporation rate is strongly dependent on the temperature of the brine/solution. We developed our own model to determine the evolution of the surface temperature with time [15]. An important hypothesis is that we will not consider variations of precipitating phases with temperature. Indeed, most geochemical models calculate precipitating phases with evaporation (like GWB) or

freezing like FREZCHEM [16], but not both simulataneously. In our case, we will consider that if the surface temperature drops under the freezing temperature of the solution, the lake is frozen. Our ultimate goal is the determine the minimual lifetime of the lake, which depends mostly on the evaporation.

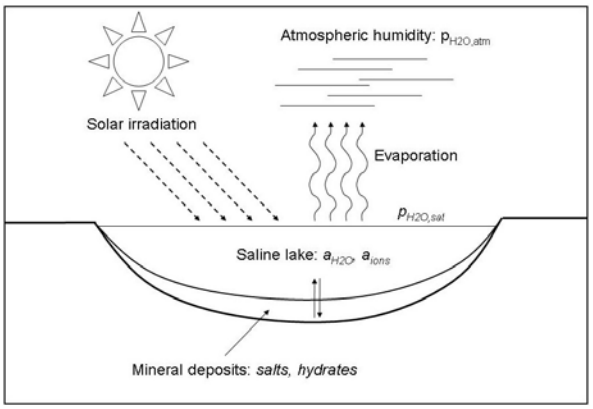

Figure 2. Conceptual model of the evaporation of a crater lake. Major controls on the evaporation rate are the insolation of the surface (temperature), atmospheric humidity, activity of water in solution (concentration of dissolved ions) and the nature of the precipitating phases.

Geochemical Modeling: We use the Gechemical Workbench software and the *thermo-phrqpiz* database, updated for ferric and ferrous components [17]. This model allows us to determine the phases precipitating once the solution reaches saturation (Fig. 3A) and also the activity of water in the liquid (Fig. 3B), which affects the evaporation rate [12, 13].

Humidity and pressure determination: Humidity directly affects the evaporation rate, and also the stability of the solution. Pressure mostly affects $\Delta\rho/\rho$ in eq. (1) and the diffusion coefficient, therefore, we will model humidity and pressure fluctuations using the GCM model [18].

Conclusions: We are modeling the stability of a potential paleolake using a combination of established models: GWB, for mineral precipitation and water activity, and our temperature and evaporation models, for determining longevity of liquid water in paleolake as a function of concentration, surface temperature, and humidity (using GCM), during periods of low and high obliquity. This work is an important step toward a more accurate understanding of water stability on the surface of Mars over time, which ultimately will address issues of geochemical evolution and potential habitability.

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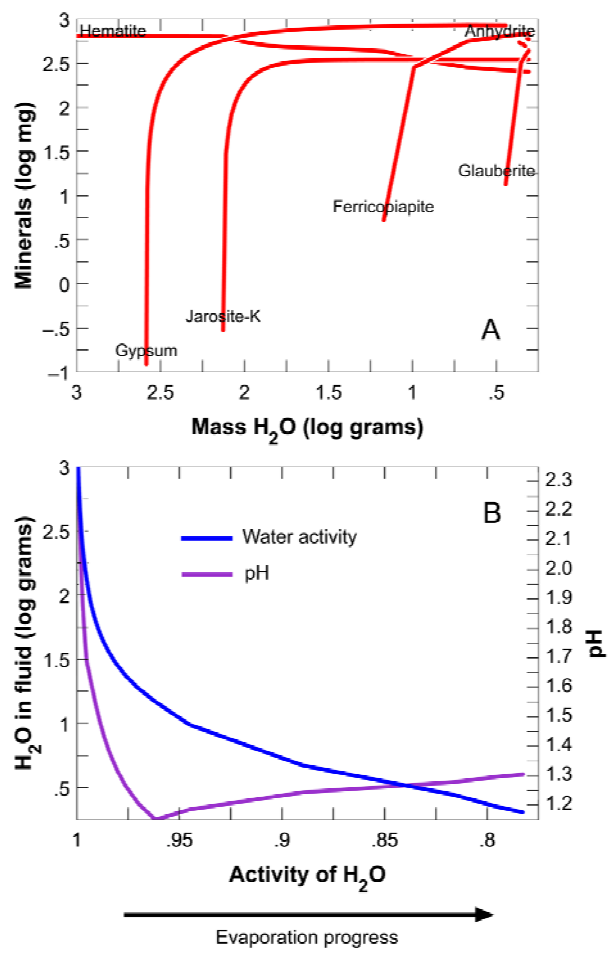

Figure 3. Results from the evaporation model of a sulfur-rich solution [12]. **(A)** Precipitated phases. We can compare these results to observations by CRISM and directly validate the model. **(B)** pH and water activity in solution. The water activity is used to calculate the evaporation rate at each step.