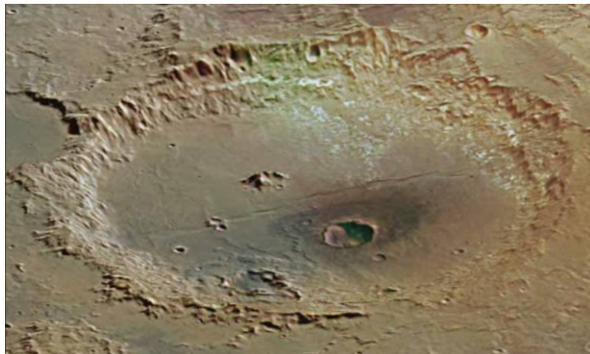


**GEOCHEMICAL MODELING OF THE EVAPORATION OF AN ANCIENT PALEOLAKE IN COLUMBUS CRATER, TERRA SIRENUM, MARS.** T. S. Altheide<sup>1</sup>, V. F. Chevri er<sup>1</sup>, E. G. Rivera-Valentin<sup>1</sup>, J. J. Wray<sup>2</sup>. <sup>1</sup>Arkansas Center for Space and Planetary Science, MUSE 202, University of Arkansas, Fayetteville, AR, 72701, <sup>2</sup>Department of Astronomy, Cornell University, Ithaca, NY 14853. [talthei@uark.edu](mailto:talthei@uark.edu)

**Introduction:** Recent observations of the martian surface have revealed what are thought to be ancient paleolake environments, which at some point in history contained standing bodies of liquid water [1, 2]. Such features are of special importance because they may hold clues to the habitable nature of early Mars. To date, these aqueous environments have not been studied with respect to the local geochemistry and its effects on the stability of liquid water. We propose to describe the longevity of liquid water in an ancient paleolake scenario using established evaporation theories [3, 4], and geochemical and thermal modeling [5]. In this study, we will focus on the geochemical modeling aspect.

**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 [1]. Various hydrated minerals have been identified in the crater rim and floor by the MRO-CRISM instrument. These minerals include: gypsum, Mg-sulfate, and kaolinite [1]. Gypsum, Mg-sulfate, and kaolinite occur mainly in the crater rim, approximately 0.6 km above the crater floor, while jarosite, monohydrated sulfates and possible Fe/Mg smectites occurred on the crater floor. The deposits in the crater rim suggest a lower limit on the volume occupied by liquid water at ~ 5000 km<sup>3</sup>. For this reason, we will use this value as our initial water reservoir, 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 [1]. Two mosaic HRSC images are overlaying a digital eleva-

tion model. Light-toned hydrated mineral deposits are visible in the top portion of the crater rim.

**Evaporation model:** The evaporation of liquid water, pure or brine, is modeled using the modified semi-empirical Ingersoll equation [3, 4], which accounts for the buoyancy of water vapor in the heavier CO<sub>2</sub> atmosphere:

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

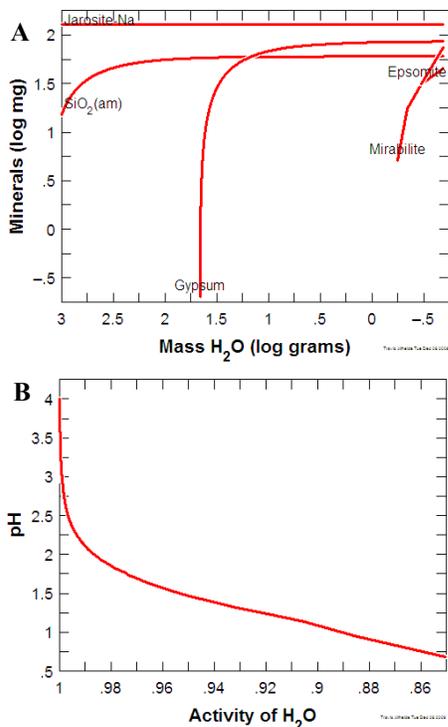
where  $E$  is the evaporation rate,  $\rho_{sat}$  is the saturation density of water vapor,  $\rho_{atm}$  the atmospheric density of water vapor,  $\rho_{sol}$  is the brine/solution density,  $D_{H_2O/CO_2}$  is the interdiffusion coefficient of CO<sub>2</sub> and water vapor,  $a_{H_2O}$  is the water activity in solution,  $\Delta\rho/\rho$  is the relative density difference between the surface and the atmosphere,  $\nu$  is the kinematic viscosity of CO<sub>2</sub>, and  $g$  is the acceleration due to gravity (in m s<sup>-2</sup>).

According to our previous studies [3,4] 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 [4]. Water activity is directly affected by the presence and concentration of ions in solution, so mineral precipitation is important in determine the evolution of water activity, and thus, the evaporation of a paleolake environment.

**Geochemical Modeling:** We use the Gechemical Workbench software and the *thermo-phrpiz* database, updated for ferric and ferrous components [6], as well as for aluminum species and activity coefficients [7]. This model allows us to determine the phases precipitating once the solution reaches saturation (Fig. 3A and 4A) and also the activity of water in the liquid (Fig. 3B and 4B), which affects the evaporation rate [3, 4]. We used an initial fluid composition derived from acidic weathering of basaltic rocks [8], with the aluminum concentration based on standard terrestrial values. We used two reaction configurations to investigate various environmental constraints on the formation of secondary minerals: flow-through and back reaction allowed.

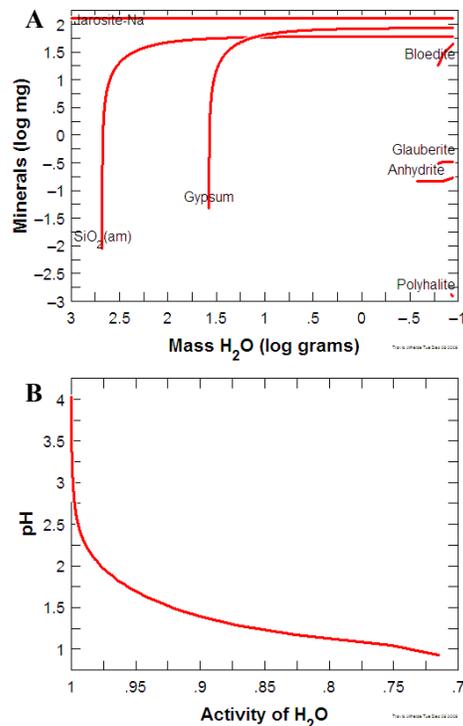
**Discussion:** The minerals predicted to form from the geochemical models are similar with those identified in Columbus crater to date (Fig. 2A). These minerals include jarosite, gypsum and Mg-sulfate. During the evaporation of the fluid, the pH and activity of water lower due to increasing ion concentration (Fig. 2B).

If the temperature of the evaporating fluid is increased to 30°C, other Ca, Mg and Na sulfates precipitate from the system, as well as a chloride species (Fig. 3A). The activity of water is further decreased compared to the simulation at 0°C due to the precipitation of these new phases (Fig. 3B). If precipitated mineral phases are allowed to back react with the remaining fluid, ferric sulfate is now predicted to form instead of Mg-sulfate (Fig. 4). More than likely, both flow-through and back reactions would have occurred naturally in an evaporitic setting on Mars.

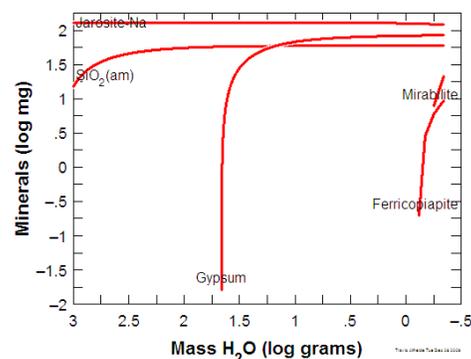


**Figure 2.** Results from the evaporation model of a sulfur-rich solution [3], at a temperature of 0°C. Phyllosilicate phases were intentionally suppressed from the simulation, as they are not considered evaporitic minerals but formed from basaltic weathering. (A) Precipitated phases. We can compare these results to CRISM observations and directly validate the model. (B) pH and water activity in solution.

**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 [5] and evaporation models [3, 4], for determining longevity of liquid water in the paleolake as a function of concentration, surface temperature and humidity. Preliminary models show that factors such as temperature can greatly influence mineral precipitation, which can in turn control the activity of water in solution. This work is an important step toward a more accurate understanding of water stability on the surface of Mars over time.



**Figure 3.** Evaporation of fluid used in Fig. 3A, except at a temperature of 30°C. Phyllosilicate phases were suppressed from the simulation. (A) Minerals precipitated from solution. (B) pH and activity of water during evaporation of fluid.



**Figure 4.** Evaporation of sulfate rich fluid modeled in Fig. 3A, except using the back reaction configuration. This allows any precipitated minerals to react with the remaining solution. Phyllosilicate phases were suppressed. Temperature = 0°C.

**References:** [1] Wray, J. J., *et al.*, (2009) *LPSC* XL, 1896. [2] Di Achille, G., *et al.*, (2009) *GRL* 36, L14201. [3] Chevrier, V. and T. Altheide, (2008) *GRL* 35, L22101. [4] Altheide, T., *et al.*, (2009) *EPSL* 282, 69-78. [5] Rivera-Valentin, E.G., *et al.*, (2010) *LPSC, this conference*. [6] Tosca, N. J., *et al.*, (2008) *JGR* 113, 05005. [7] Marion, G. M., *et al.*, (2009) *GCA*, 73, 3493-3511. [8] Catling, D. C., (1999) *JGR* 104, 16453-16469.