

**THE EFFECT OF A FINE-GRAINED BASALTIC LAYER ON THE EVAPORATION OF ICE UNDER MARTIAN CONDITIONS.** K. L. Bryson<sup>1</sup>, V. Chevrier<sup>1</sup>, and D. W. G. Sears<sup>1,2</sup>. <sup>1</sup>W.M. Keck Laboratory for Space Simulations, Arkansas Center for Space and Planetary Sciences, 202 Old Museum Building, University of Arkansas, Fayetteville, AR 72701, <sup>2</sup>Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701; <kbryson@uark.edu>

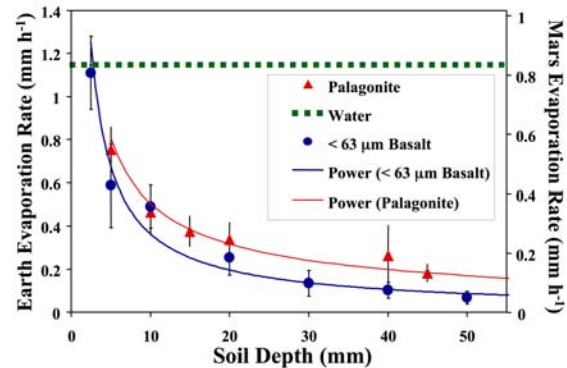
**Introduction:** The presence of liquid water on the present surface of Mars is of considerable significance because of its biological, geological and climatic implications [1]. In previous work we have investigated the evaporation of pure liquid water [2], water as liquid and ice [3] and liquid brines as a function of temperature [4]. These experiments were consistent with the Ingersol model [5], confirming its validity and the quality of our experimental approach.

Subsequently, we have looked at how a layer of regolith on the surface of ice can affect the evaporation rate [6], and compared the data to the predictions of theoretical diffusion through a porous layer. A regolith barrier on top of the ice could extend the lifetime of an ice layer and enable the formation of liquid by slowing evaporation and warming the surface [7]. Elsewhere we report data for the evaporation of water under simulated martian conditions through layers of JSC Mars-1 soil simulant (palagonite) [6]. The rate of water loss was found to be dependent on adsorption, as well as diffusion, and both processes were quantified.

The present study reports new measurements of the evaporation of ice under simulated regolith layers of a material expected to show little adsorption, namely fine-grained basalt. The Mars Exploration Rovers observed basaltic regolith below a thin layer of red dust, when looking back at tire tracks. Since the diffusion of water vapor through a regolith is dependent of grain size, we chose a specific grain size fraction for this work (<63  $\mu\text{m}$ ), intending to extend the measurements to other size fractions later.

**Experimental:** Basalt from Somerset Co., NJ was ground and sieved, baked overnight at 110°C, sealed in a container and cooled in a -20°C freezer. Pure water was frozen in a beaker, a thermocouple placed on the ice surface, and a 2.5 to 50 mm layer of the basalt placed on top. The assemblage was placed in the refrigerator at 0°C to equilibrate. Our planetary environmental chamber [2,3,4], was evacuated to less than 0.09 mbar, filled with dry gaseous CO<sub>2</sub> (g) to atmospheric pressure, and cooled to ~0°C using a methanol/dry-ice slurry. Once stable, the chamber was opened and the sample was placed on a top loading analytical balance inside the chamber. The platform supporting the balance and the sample was then lowered into the chamber. The chamber was then evacuated to 7 mbar. Experiments lasted 1.5 to 2 hours and mass, pressure, temperature and humidity were re-

corded every two minutes. After each run the basalt was placed in an oven at 110°C and the water adsorbed by the basalt during the experiment determined by difference.



**Figure 1-** Experimental evaporation rate as a function of depth for basalt and palagonite [6]. The evaporation rates are very similar between the basalt and palagonite.

Pressure, temperature, and relative humidity were maintained between 6.5 to 7.5 mbar, -12 to 0°C, and 5.03% to 26.0%, respectively. Since the mass of the sample column decreased with time in a highly linear fashion, our experiments achieved steady-state conditions. Thus it is possible to correct the data to standard conditions (0°C and 10 Pa of atmospheric H<sub>2</sub>O) using the relationship:

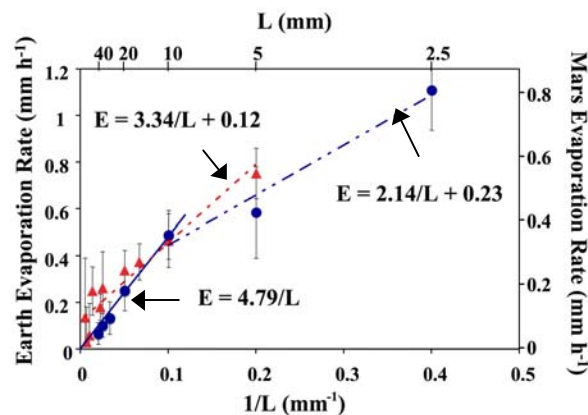
$$E_s = \frac{DM_{H_2O}P_{sat}}{LRT_{st}\mu_{ice}} \left[ 1 - \frac{T_s P_{atm}}{T_{atm} P_{sat}} \right],$$

where  $E_s$  is the sublimation rate,  $D$  is the diffusion coefficient in the regolith,  $L$  is the regolith thickness,  $T_s$  is the temperature of the surface,  $T_{atm}$  is the temperature of the atmosphere,  $p_{atm}$  is the partial pressure of water in the atmosphere,  $\mu_{ice}$  is the density of ice (917 kg m<sup>-3</sup>), and  $R$  is the ideal gas constant. The evaporation rates can also be corrected for Mars' lower gravity by multiplying by 0.726 [2] (Fig. 1).

**Results:** Figure 1 shows a summary of our present data, compared with data from our previous study of ice evaporation through palagonite. As expected, the fine-grained basalt caused a greater attenuation in evaporation than the palagonite, but the difference is small. Most important, for both types of regolith, evaporation rate decreases by at least a factor of 10 for 50 mm of regolith and greater depths cause relatively

little change. Evaporation rates for the present data (for standard conditions) range from  $1.11 \pm 0.17 \text{ mm h}^{-1}$  for 2.5 mm of basalt to  $0.07 \pm 0.03 \text{ mm h}^{-1}$  for 50mm of basalt, compared to calculated value for bare ice of  $1.14 \text{ mm h}^{-1}$  [6].

**Discussion:** The theory for diffusion through a porous medium [e.g. 7] suggests that the evaporation rate is inversely proportional to the depth of the medium,  $L$ , and that a plot of evaporation rate versus the inverse depth has a slope proportional to the diffusion coefficient (Fig. 2). The present data show a difference in slope below 10 mm and above, and neither of these slopes are equal that for palagonite. One explanation is that at  $\sim 10$  mm diffusion through the atmosphere becomes important in addition to diffusion through the dust layer, which dominates at greater depths.



**Figure 2-** Experimental evaporation rate versus inverse depth for fine-grained ( $<63\mu\text{m}$ ) basalt regolith (blue circles) and palagonite [6] (red triangles). A regression line has been drawn through the palagonite points (red dashed line) and the basalt data points  $<10$  mm (blue dashed line). The regression line through the basalt data points  $>10$  mm (blue solid line) is also pushed through zero since at the infinite depth no evaporation should occur.

In our previous studies of evaporation through palagonite we observed an apparent increase in the evaporation rate for regolith depths  $>50$  mm, which was due to desorption of water [6]. This is not the case in the present study as samples of basalt without ice did not show desorption when run alone.

Nevertheless, even if our results show that adsorption is only a minor effect, to further understand the adsorption properties of the fine-grained basalt we calculated the effective grain size surface area of the present samples from the mass of water adsorbed which we routinely measured after each run. Letting  $m_a$  be the mass of water adsorbed, and  $A_s$  the effective grain surface area, the percent coverage of the surface is given by:

$$\theta = \frac{m_a}{\mu_{\text{H}_2\text{O}} A_s l}$$

where  $l$  is the monolayer thickness and  $\mu_{\text{H}_2\text{O}}$  is the density of water. The value of  $A_s$  was varied until there was a fit to the Langmuir Isotherm:

$$\frac{1}{\theta} = 1 + \frac{1}{\alpha P}$$

Where  $P$  is the partial pressure of water and  $\alpha$  is the Langmuir adsorption constant which we found to be  $0.013 \text{ Pa}^{-1}$ . Thus the corresponding effective surface area for our fine-grained basalt was  $8.3 \pm 0.9 \times 10^4 \text{ m}^2 \text{ kg}^{-1}$ , which is in reasonable agreement with literature value, i.e.  $1.8 \times 10^4 \text{ m}^2 \text{ kg}^{-1}$  [8].

The slope of the line through our data for layers  $>10$  mm deep yields a diffusion coefficient of  $2.49 \times 10^{-4} \text{ m}^2 \text{ s}^{-1}$ , in comparison with  $1.74 \pm 0.70 \times 10^{-4} \text{ m}^2 \text{ s}^{-1}$  for palagonite. The small difference in diffusion coefficient probably reflects the larger porosity of the basaltic soil (67%) compared to the palagonitic soil (54%) [9], but this is subject to further study.

**Conclusions:** Experimental determination of the rate of evaporation of ice under layers of fine-grained basalt shows that a 5 mm layer causes a factor of 2 decrease while a 50 mm layer causes a factor of 17 decrease. Depths greater than 50 mm are believed to cause little difference in the evaporation rate. The results for basalt and palagonite are very similar; a slightly higher diffusion coefficient for basalt is probably due to the higher porosity of the regolith in the present experiments. Unlike palagonite, adsorption and/or desorption of water by basalt do not strongly affect the diffusion process. At shallow depths ( $<10$  mm) the diffusion of water is complicated since it is governed by diffusion through atmospheric  $\text{CO}_2$  molecules as well as diffusion through the basalt layer.

**References:** [1] Malin, M.C. et al (2006) *Science*, 314, 1573. [2] Sears, D.W.G and Moore, S.R. (2005) *GRL* 32 (16) L16202. [3] Moore, S. R. and Sears, D.W.G. (2006) *Astrobiology*, 6, 644. [4] Sears, D.W.G. and Chittenden, J.D. (2005) *GRL*, 32, L23203. [5] Ingersoll, A.P (1969) *Science*, 168. [6] Chevrier, V. et al (2007) *GRL*, in press. [7] Farmer, C.B. (1976) *Icarus*, 28, 1344. [8] Zent, A.P. and Quinn, R.C. (1997) *JGR*, 102, 9085. [9] Allen, C.C. et al. (1998) *LPSC*, XXIX (1690).

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