

H₂O-SILICATE MICROPHYSICS IN ASCENDING VOLCANIC PLUMES ON MARS A. P. Zent,
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Gusev crater is a potential landing site for one of the MER rovers. The units within the crater may include volcanoclastic airfall deposits from Apollinaris Patera [1,2]. In particular, the upper unit in Figure 1 is rapidly deflating without leaving a visible lag deposit, indicating an absence of large particles and



Fig. 1. Upper unit in Gusev is easily deflated, and may be volcanoclastic airfall deposit from Apollinaris Patera. MOC Image E18-00184

probable poor cohesion. The upper surface might be slightly indurated [2].

The MER rover may have the opportunity to examine this deposit, which occurs near the center of the Gusev landing ellipse. The deposition of other airfall units in the Sinus Meridiani region coincides with increased erosional activity there, suggesting a role for airfall deposits in the delivery or mobilization of volatiles [3,4,5].

Microphysical interactions determine how water behaves in the plume and, through release of latent heat, effect plume energetics and sedimentation [6]. The surface properties of ash are altered by condensation, which increases agglomeration and speeds precipitation. Although other workers have investigated the interaction of H₂O and silicates in rising plumes, both on Earth and Mars [6,7,8], they have not considered the possible interaction of H₂O and silicates via adsorption; no vapor is removed from the plume until saturation is reached.

To examine the importance of the silicate-H₂O interaction, we have developed a 5-component model of an ascending volcanic plume, based on the model of Glaze and Baloga [8]. We have expanded their model by allowing H₂O to exist as vapor, unfrozen water (adsorbate or bulk liquid), and ice. We use the scheme shown in Figure 2 to determine the distribution of H₂O among phases. Unfrozen

water exists in all fields. If the plume is in the vapor field, the total H₂O is partitioned between the adsorbed and vapor phases such that the adsorption isotherm is satisfied. Because we do not know the adsorptive response of primary martian ash, we assume here the basalt adsorption isotherm reported by Fanale and Cannon [9].

If the plume is in the liquid phase, all remaining vapor is assumed to condense to liquid, and the presence of liquid sets the vapor pressure in the plume element. When the plume reaches the freezing point, most of the remaining water is frozen, although a small amount of unfrozen water always remains, in equilibrium with the temperature and vapor pressure over ice.

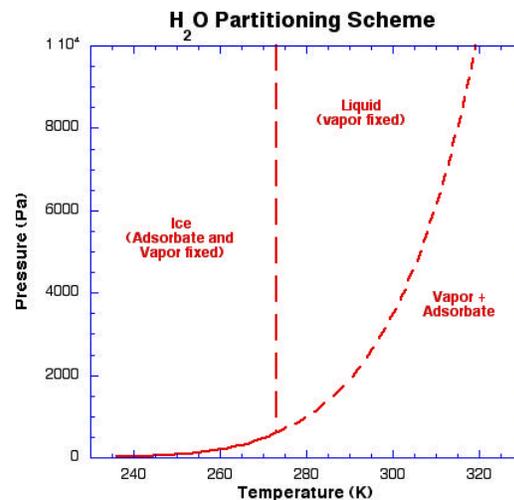


Fig.2. A given mass of H₂O will partition between physical adsorption and the vapor phase. If liquid is stable, the vapor pressure is set, and all remaining H₂O is in the liquid phase. If ice is present, the vapor and unfrozen phases are set by temperature and the ice vapor pressure.

We begin this study with a simple investigation of the role of the particle size frequency distribution on adsorptive scavenging in the ascending cloud. We define a parcel of silicates and H₂O, and allow that parcel to cool, monitoring the total H₂O remaining in the vapor phase. In this case, we have defined 10⁷ kg of silicates in the test volume, with a log-normal size-frequency distribution, a mean grain size of 10⁻⁵ m, and a minimum of 10⁻⁶ m² per particle. This is based on observations of terrestrial ash particles that reveal enormous internal surface area. We assume 10⁵ kg of H₂O (1 wt%). The results of this study show significant dependence of the H₂O sequestered in the adsorbed phase. In Figure 3, we show the

effects of varying the standard deviation (σ) of the log-normal size frequency distribution from 0.2 to 0.4. During cooling of a parcel, a sharply-peaked ($\sigma = 0.2$) distribution will adsorb considerably more water than a broad ($\sigma = 0.4$) distribution. For the surface area distribution and adsorption isotherm assumed here, approximately 80% of the total water is adsorbed by a $\sigma = 0.2$ distribution in cooling to the liquid condensation temperature, and only about 1% by a $\sigma = 0.4$ distribution. This indicates that the partitioning of H_2O is a sensitive function of the total silicate area in ascending plume. Latent heat of

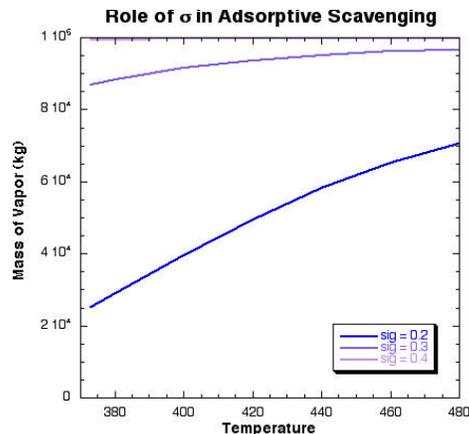


Fig. 3. Only about 20% of the initial H_2O remains in the vapor phase after cooling to 373K when surface area is large ($\sigma = 0.2$), but virtually all remains as vapor when $\sigma = 0.4$.

adsorption would be released gradually in the $\sigma = 0.2$ plume, with only 20% of the original H_2O available for rapid condensation to liquid, the process that initiates moist convection in ascending plumes. Virtually all H_2O remains in the vapor phase in the $\sigma = 0.4$ plume.

We next examine the role of varying grain size distributions in an expanding and cooling plume. The ambient atmosphere is assumed to be dry in this initial calculation. The rise of a 1 wt % H_2O ash plume is integrated from the ground upwards via a Runge-Kutta technique. The standard deviation of the size frequency distribution of the silicate materials is varied to establish the limits of qualitatively similar behavior. An interesting result is shown in Figure 4.

When the standard deviation of the size frequency distribution is 0.4, the initial conditions of the plume ($T_0 = 525$ K, $r_0 = 10$ m) force the plume into the superheated liquid phase even at temperatures well above 373K. However, if $\sigma = 0.3$, then adsorptive equilibration depresses the vapor pressure in the plume, preventing condensation to liquid in the ascending plume, and inhibiting the latent heat release that initiates moist convection.

Selection of plausible values for the variables of choice indicates that Martian volcanoes may be near the boundary between two qualitatively different behaviors. The degree of water in the magma probably won't vary by more than a factor of 2, but doubling the magma H_2O content to 2 wt % saturates available silicate surface area, and a $\sigma = 0.3$ plume condenses liquid just as a $\sigma = 0.4$ plume.

Entrainment of ambient atmosphere with H_2O will also tend to increase adsorptive coverage, and lead to condensation of liquid-phase H_2O . However, even in the terrestrial tropics, plume

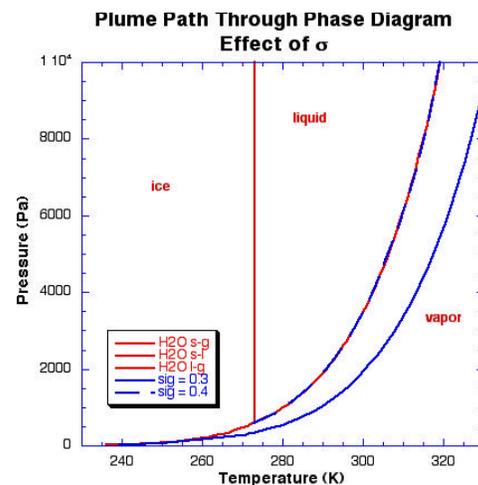


Fig. 4 More surface area per unit mass in the silicate component of the plume adsorbs more water. In this simulation, adsorption prevents the plume from ever entering the liquid H_2O field when σ is reduced from 0.4 (dashed blue line following phase boundary) to 0.3 (solid blue line).

ascent can do no more than triple the initial H_2O content [6]. Therefore, a cold-dry Martian atmosphere may not hold enough H_2O to saturate in an ascending plume with high surface area. Under warmer, wetter conditions, adsorptive scavenging is unlikely to prevent condensation, perhaps leading to enhanced agglomeration and sedimentation of volatile-rich deposits near the source.

References:

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