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ADSORPTION ON THE MARTIAN REGOLITH: SPECIFIC SURFACE AREA AND MISSING CO₂. Zent, A. P., F. P. Fanale and S. E. Postawko, Planetary Geosciences Division, Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hi. 96822

Estimates of the total amount of outgassed CO₂ on Mars range from 140 mbar to 3000 mbar (1, 2). Only 8 mbar is currently in the atmosphere, less than 10 has escaped to space (3), and no more than a few mbar are in the permanent south polar cap reservoir (4). In the absence of a recycling mechanism, the remainder must be stored in the regolith, either as carbonate rock or in the adsorbed state. Because the problem of maintaining liquid H₂O (necessary for sufficiently fast carbonate production) is formidable, we have examined the adsorptive behavior of Mauna Kea palagonites, a low temperature weathering product of basaltic glass and a good spectral and chemical analog for the Viking soils. We hope to improve estimates of the maximum CO₂ capacity of the regolith, and thereby constrain the amount of carbonate which is necessary to make up the difference.

CO₂ adsorption measurements have previously been obtained on ground basalt (5) and nontronite (6). We expanded this data set by measuring the adsorption of CO₂ on Mauna Kea palagonite at martian conditions of temperature and P_{CO₂}. Initial results have been reported elsewhere (7). The measured surface area of the palagonite was 59.06 m² g⁻¹, while for the nontronite it was 47.0 m² g⁻¹, and for the basalt 5.8 m² g⁻¹. The adsorption isotherms, in terms of g of CO₂ g⁻¹ of adsorbent, were divided by the specific surface area of each adsorbent to get the equation in terms of g of CO₂ m⁻². Although on a gram per gram basis there is a two order of magnitude difference between the adsorptive capacity of the three minerals considered, the minerals differ by less than a factor of three on a gram per square meter basis at martian conditions (Figure 1). For the purposes of this study, we assume that an equation can be written which describes CO₂ adsorption on any basalt or basaltic weathering product in terms of temperature, P_{CO₂} and the specific surface area of the material, without regard to mineralogy. The advantage of this is that while many guesses at the mineralogy of the martian regolith are available, at least one indirect measurement of the surface area of the martian regolith has been made (8).

We employed a least-squares fitting routine to find coefficients for the adsorption expression, and tested its predictive ability against available adsorption data for all three mineralogies. The average error in the equation is on the order of 10%. The equation which describes CO₂ adsorption is

$$\rho_a = A_s \times \delta P^\gamma T^\beta \quad (1)$$

where $\delta = 5.9629 \times 10^4$ g CO₂ m⁻², $\gamma = 0.364391$, and $\beta = -3.83415$. A_s is the specific surface area of the material in m², and P is in mbar. The value of ρ_a is in g adsorbate / g adsorbent. Because available measurements indicate a specific surface area of approximately 17 m² g⁻¹ (8), we can use equation (1) to move toward a point model of CO₂ adsorption on the martian regolith.

Fanale et al., (1982), (4), presented a model of the martian climate in which they considered regolith adsorption to be the primary CO₂ reservoir. They presented results based on two types of regolith mineralogy, basalt and nontronite, and described cap formation of atmospheric pressure as a function of obliquity. Because their model does not include any other CO₂ reservoir, it forms an implicit test of the ability of the regolith to store all of the necessary CO₂ in the adsorbed state. We have reconfigured the model, eliminating explicit assumptions of mineralogy, and substituting equation (1) for adsorption, with a specific surface area of 17 m² g⁻¹. We fixed orbital parameters at current values, and used the thermal constants presented in the original model (4). Our independent variables were the total CO₂ inventory (ΣCO₂), and the depth of the

regolith. Only a limited combination of these variables is compatible with the present atmospheric pressure (6.0 - 8.5 mbar), lack of permanent polar deposits of CO₂, and absence of carbonates (Figure 2).

Our results indicate that at least 450m of regolith, in diffusive contact with the atmosphere, are necessary to store the minimum CO₂ inventory of 140 mbar. Further, if the planetwide average depth of the accessible regolith is 1 km or less, then the maximum CO₂ inventory compatible with the absence of carbonates is only 240 mbar.

We conclude that, while it is not strictly necessary to invoke carbonates as a CO₂ reservoir, it is likely that between 350 and 2700 g cm⁻² of CO₂ is stored as carbonate rock assuming the upper limit of $\Sigma\text{CO}_2 = 3000$ mbar, and the lower limit, $\Sigma\text{CO}_2 = 500$ mbar. Such a carbonate inventory would represent roughly 2 to 14 wt. % of the regolith column, assuming the regolith depth were 100m. If the regolith were assumed to be 1 km, the lower and upper limits would be 0.3 to 3 wt. % of the regolith.

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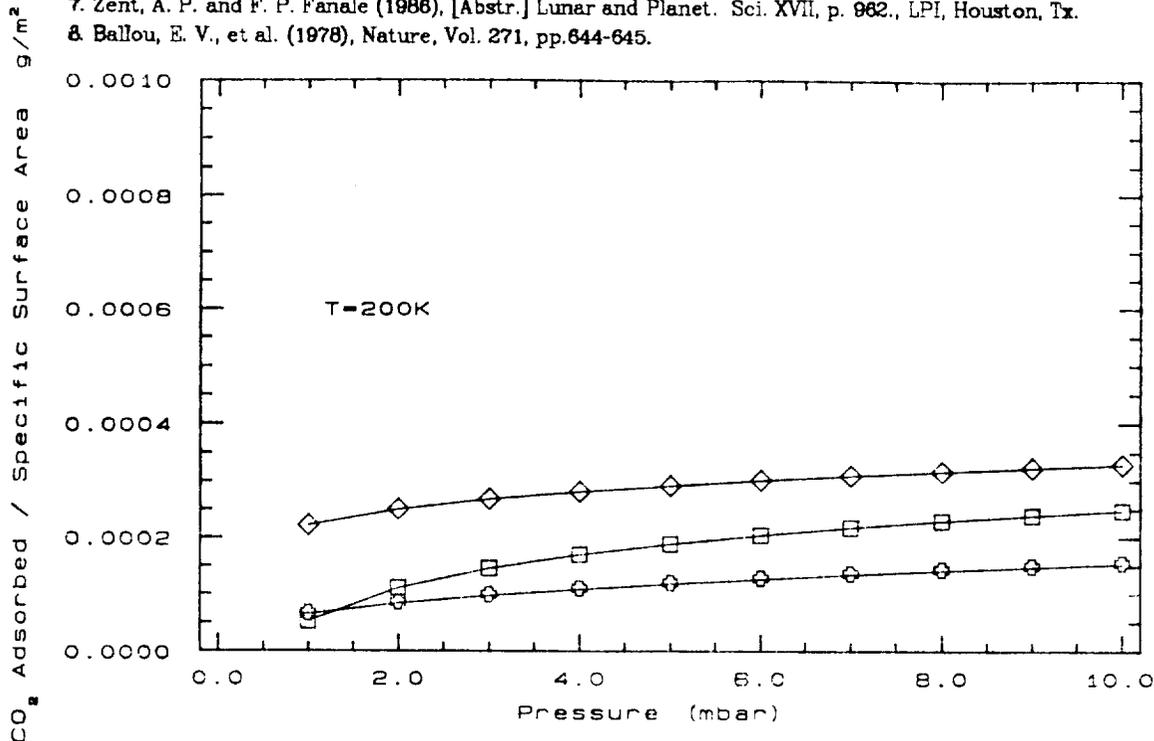


Fig. 1 - The amount of CO₂ adsorbed on each m² of particulate surface area for three mafic materials at martian pressures and T=200K. The uppermost curve is for palagonite, the middle for basalt and the bottom for nontronite. When surface area is accounted for the adsorptive capacities of these materials differ by two orders of magnitude.

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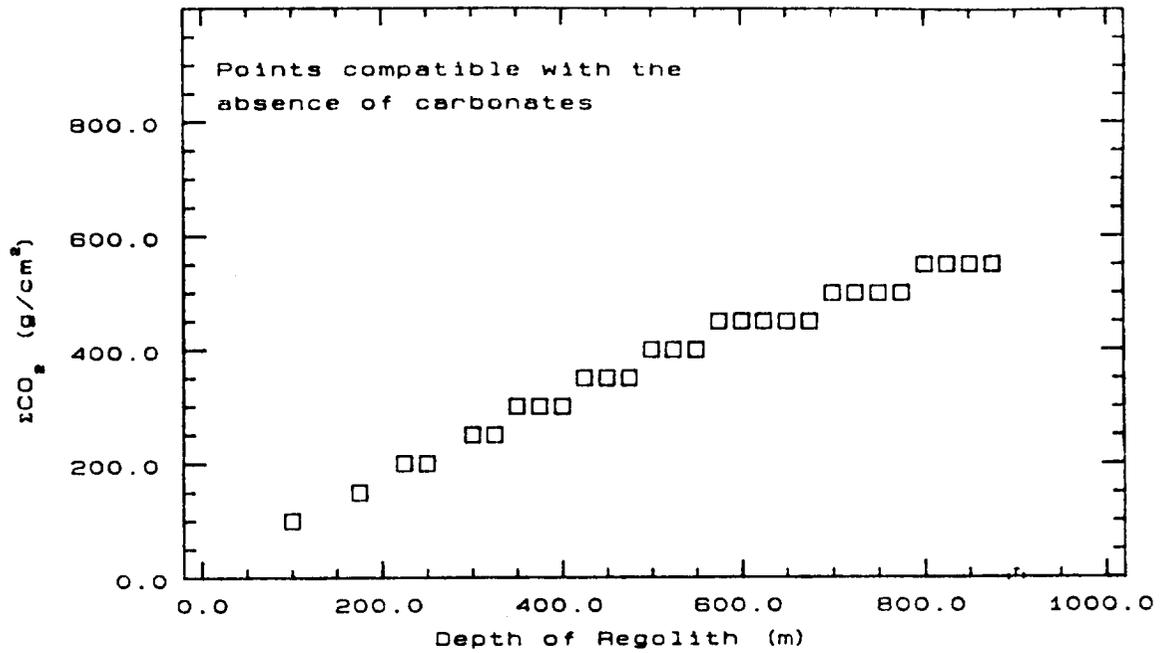


Fig. 2 - The combination of ΣCO_2 and regolith depth compatible with (1) the present atmospheric pressure, (2) the absence of polar caps, and (3) the absence of carbonates. For comparison, $\Sigma \text{CO}_2 = 600 \text{ g cm}^{-2} \sim 240 \text{ mbar}$.