

TERRESTRIAL ATMOSPHERE WEATHERING OF LUNAR SAMPLES,
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Typical weathering of terrestrial rocks and soils is a complex process involving both chemical and physical changes. Studies of initial exposures of lunar samples to air, oxygen, nitrogen and water vapor indicate a similar complexity. Exposure to air or oxygen, of samples that have previously been in a reducing atmosphere (atomic hydrogen) results in a two stage process of rapid (minutes) followed by slow (months) surface oxidation.¹ This two stage process has been interpreted as the oxidation of the immediate external surface followed by a slow penetration of oxygen into high defect structure of the outer metamict amorphous layer (500 - 2000 Å) of samples exposed to solar wind and micrometeorite bombardment. Not surprisingly, nitrogen has no apparent affect (either chemical or physical) on lunar samples at temperatures below about 200°C. In contrast, exposure to water vapor can achieve chemical changes (on dehydroxylated surfaces) as well as significant structural changes as evidenced by water retention at low pressures and extensive low pressure adsorption isotherm hysteresis.

Previous studies of a wide range of soils have shown considerable variation in the magnitude of such irreversible phenomena.^{2,3} Possible explanations include the opening up of existing, but unavailable, pore structure or the creation of new surfaces through either the fracturing of adhering materials or dissolution of amorphous materials. We wish to report water adsorption and (nitrogen) surface area studies on three selected samples: a sawed surface rock fragment (15015, 29), a compacted soil sample (15565, 3G) and an anomalous soil sample (74220, 46). Both optical and electron microscope examinations were made on all three samples. Experimental apparatus and procedures have been described previously.^{1,2}

Surface area measurements (N_2 at -196°C) with multilayer adsorption hysteresis, gave a surface area of 0.17 m²/g for 15015, 29. The particular sample would appear to be best described as a lunar volcanic cinder, certainly the highly vesicular, porous external surface could only have been created by gas evolution through a molten rock matrix.⁴ After outgassing at 150°C, water adsorption resulted in a type II isotherm exhibiting multilayer hysteresis only. After outgassing at 300°C, however, the isotherm exhibited extensive low pressure hysteresis and water retention at 10⁻⁶ torr and 25°C.

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Subsequent recycling, without high temperature outgassing, lead to an isotherm essentially identical with that obtained after outgassing at 150°C provided the low pressure water retention was discounted. In the absence of any evidence for either solution of amorphous materials or of sample microfracturing, it would appear that the 300°C outgassing removed chemisorbed (as well as physically adsorbed) water, dehydroxylating the surface and apparently exposing additional micropore structure (the surface area apparently doubled). Reexposure to water vapor, however, rehydroxylates the surface and appears to reduce the internal surface area effectively reversing the situation created by the high temperature outgassing.

Sample 15565, 3G, a compacted soil, showed a slightly altered isotherm shape (type II, multilayer hysteresis) and a small irreversible increase in the surface area [0.51 to 0.56 m²/g] when the outgassing temperature was raised from 150° to 300°C. In this case, it would appear that fracturing had created some new surface or pore structure, however, water chemisorption (or the reverse process) did not appear to seal off (or expose) significant existing micropore structure.

Sample 74220, 46 in agreement with other workers,⁵ underwent drastic changes in its adsorption characteristics the extent depending on the outgassing temperature. Our investigations, which are not yet complete, indicate that these changes are not fully reversible. Here, pore blockage and/or fracturing, but not solution of amorphous materials, appear to be possible explanations.

Prior to water/oxygen exposure we see the surfaces of lunar samples as dehydroxylated and reduced. Exposure to water vapor leads to surface hydroxylation and possible existing micropore blockage. Water vapor adsorption-desorption cycling can, in some cases, lead to the irreversible creation of new surface area apparently through fracturing of weakly bonded material.

1. D. A. Cadenhead, B. R. Jones, W. G. Buergel and J. R. Stetter, Proceedings 4th Lunar Sci. Conf. Vol. 3, pp. 2391-2401. Pergamon Press, New York (1973).
2. D. A. Cadenhead, N. J. Wagner, B. R. Jones and J. R. Stetter, Proceedings 3rd Lunar Sci. Conf. Vol. 3, pp. 2243-2257. The M.I.T. Press, (1972).