THE UNCERTAIN NATURE OF POLAR LUNAR REGOLITH

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Lunar polar regions are receiving considerable attention because they might contain sizeable quantities of H₂O, which could be useful for lunar development and space commerce [1]. Plans to use those resources are limited by our ignorance of the nature of polar regions. Major uncertainties are outlined here. All can be addressed by missions to permanently shadowed polar regions on the Moon.

Regolith characteristics: The typical lunar regolith has a mean grain size of ∼100 µm, with ∼10% of the material smaller than 10 µm [2]. However, the polar regions are in the most ancient lunar highlands, which have been subjected to the most intense bombardment for more than 4 billion years. Hartmann [3] suggests that the upper hundreds of meters have been reworked so extensively that it resembles the typical lunar regolith. Since the heavy bombardment ceased about 3.8 billion years ago, the upper several meters of the Moon have been modified by micrometeorite impacts. That regolith may be much finer grained than typical regolith as it developed on hundreds of meters of fine-grained material. If so, we cannot predict with confidence the physical properties of the regolith (porosity, thermal conductivity, shear and bearing strength, angle of repose, tribology). A finer grain size provides a much larger surface area for a given mass of regolith, which could enhance adsorption of H₂O and other volatiles and their reaction with regolith grains.

Characteristics of the H₂O deposits: There is clear evidence for enrichment in H in lunar polar regions [4], but what form is it in? Models depict the observed enrichments in hydrogen as being due to solar wind hydrogen, water ice deposited by H₂O released from soil grains that have been bombarded with solar wind hydrogen, and more complex ices released by impacting comets. These deposits could form thin films around regolith grains (adsorbed chemically or physically [5]), partially- to completely-filled pore spaces, or form layers of ice (in the case of comet impacts). Each of these scenarios leads to potentially different physical and geotechnical properties of the regolith, and different properties of the resource. To show the complexities, consider a cometary source for H₂O. In this case the H₂O would be accompanied by CO, CO₂, CH₄ and other gases. If the H₂O precipitated as one of the many forms of ice, it could be relatively pure because of the low solubility of gases it in, but might be associated with deposits of less stable carbon gases. If the H₂O precipitated as amorphous ice, the amorphous ice might contain dissolved CO and other gases. When heated during exploration or extraction, the amorphous ice would crystallize, releasing the trapped gases and possibly producing jets of dust and gas, as happens as comets are heated [e.g., 6]. Moreover, the crystallization is exothermic, possibly leading to a runaway effect, release of CO₂ from its frozen form, loss of the resource, and possibly damage to extraction equipment. At the very least it prevents us from knowing how to design equipment for surface mobility or to extract volatiles from polar regolith. Finally, whatever its state, we do not know how the H₂O resource is distributed with depth or laterally.