OUTGASSING/REGOLITH INTERACTIONS AND LUNAR HYDRATION. A. P. S. Crotts[1] and C. Hummels[1], [1]Columbia University, Department of Astronomy, 550 West 120th Street, New York, NY 10027 (arlin, chummels@astro.columbia.edu).

Introduction: Several developments in the past few years inspire us to question how volatiles might leak from the lunar interior and how this might manifest itself in existing or future data. Among these developments are 1) the discovery that picritic glass spherules from the deep lunar magma, liberated in fire fountains, are relatively rich in water and sulfur [1,2]; 2) the finding that some eroded areas on the lunar surface inconsistent with impact craters were modified relatively recently, probably in the past several million years, in a manner consistent with a massive outgassing event [3], 3) the locations of episodes of ^{222}Rn outgassing, as observed on *Apollo 15* and *Lunar Prospector*, are geographically coincident with sites that have consistently produced over history reports by observers of optical transient lunar phenomena (TLPs), as are the residuals of recent ^{222}Rn outgassing as traced by ^{210}Po [4,5], and 4) the discovery of hydrated lunar regolith, especially near the poles [6,7,8] (but not specifically in permanently-shadowed crater cold traps) which corresponds closely in geographical distribution to the predictions of a model in which endogenous water vapor is leaking from the interior into the regolith [9].

We also ask if TLPs might be generated by outgassing. Until 20 to 30 years ago, optical transients on the lunar surface (Transient Lunar Phenomena: TLP or LTP) were considered important, outstanding lunar mysteries meritting study [10,11,12]. Since then, we have gained little understanding of TLPs, excepting developments listed above. The debate on even the reality of TLPs as a coherent physical effect (as opposed to observer error) has been limited to the popular literature, both pro and con [13,14]. We find the results of our model interesting in context of this debate.

Models of Explosive Outgassing: In a recent paper, we explore the interaction of gas penetrating the regolith via seepage, fluidization and explosive disruption [9]. The latter is calculated for a source of gas rising from the interior and meeting the base of the regolith as a point source. For a 15 m regolith depth, a gas flow of greater than about 2 g s^{-1} is sufficient to build up a sufficient overpressure (amounting to about 1 tonne for 20 AMU gas) such that the gas punctures the regolith and is explosively liberated into the vacuum. After this heavy regolith particles (larger than about 0.1 mm) quickly fall into the crater blown by this explosion, but lighter particles expand into a partially ballistic/partially gas-supported cloud that expands over several km radius and for several minutes before disappearing. The area affected and timescale of this model event turns out to be similar to the observed quantities typical of TLPs. The lightest dust particles can be accelerated up to about 50 km altitude. A layer of fresh regolith is generated which can likely be detected to about 1 km radius for of order 1000 y before being lost to gardening effects, and much longer in the central crater (~ 30 m diameter). We also discuss how during the outburst event pressures inside the cloud linger near the Paschen minimum condition and speculate that charge separation within the cloud might cause coronal discharge effects. We discuss in detail how these hypotheses based on this straightforward model might be tested via remote sensing.

Seepage through the Regolith: We also calculate [9] the conditions in the past under which water vapor leaking from the interior might have undergone a phase change in order to produce water ice at significant depths in the regolith (of order several to 10 m or more), and for large regions near the poles find that ice might accumulate into significant masses (depending on the outgassing rate). These might be expected to survive over geological time scales. We discuss at length how these might be detected via remote sensing, as well. This model successfully predicted the detection of hydrated lunar regolith concentrated within about 20° in latitude of the poles (Fig. 1), which was revealed thereafter by *Chandrayaan-1*/M^3 mapping of the 2.9 μm hydration absorption signature [6]. This signal is not limited to permanently-shadowed crater cold-traps; neither is the subsurface hydrogen signal (probing ~0.1 m deep) revealed by reduced epithermal neutron return [15]. The patchy distribution of the observed hydrogen distribution near the poles is consistent with the likely inhomogeneous source distribution of interior outgassing into the regolith [9].

With the possible long-term presence of water ice within the regolith, we speculate that an eventual outcome of this interaction might be the filling of regolith particle interstices by motile material in a manner similar to cement. This requires further investigation, but would possibly result in a concrete-like layer formed over the ice, tending to thicken as the ice migrates downward due to regolith thermal evolution.

We will detail at the meeting strong evidence that some minerals at specific lunar sites are hydrated endogenously in a way that cannot be easily explained by solar wind interactions with the regolith [16].

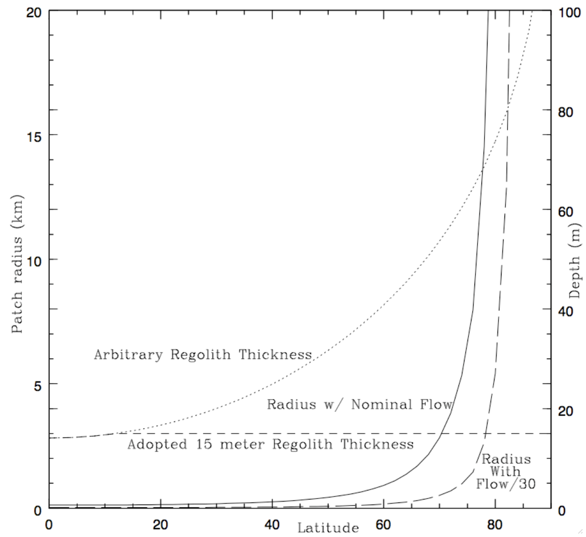

Figure 1: The amount of regolith hydration expressed as radius of subsurface ice patches and the maximum depth at which we should expect growth of ice, as a function of latitude. The case described in the text corresponds to the solid curve (for ice patch radius - left axis) and the short dashed curve (for ice depth - right axis). The arbitrary 15 m limit is adopted assuming that the low diffusivity regolith overlays a higher diffusivity megaregolith which discourages the growth of ice. If the regolith is actually deeper, or if an ice cap might actually encourage growth of ice at greater depth, in principle the ice layer could extend to the dotted curve (reading the right axis), this would likely encourage the growth of more ice at a given flow rate. (If the regolith were surprisingly deep, the ice patch area might grow larger by a factor roughly the ratio of the dotted curve to the dashed curve.) The long-dashed curve is similar to the solid curve, simply showing the size of the ice patch if the flow rate is reduced by a factor of 30 (to 0.0033 g s^{-1} of water). This curve does not account for time required to reach the equilibrium radius. Smaller than this flow, ice patches might not grow near the equator. (Adapted from [9].)

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