DIELECTRIC BREAKDOWN WEATHERING OF LUNAR REGOLITH. A. P. Jordan[1,2], T. J. Stubbs[3,2], J. K. Wilson[1,2], P. O. Hayne[4], N. R. Izenberg[5], N. A. Schwadron[1,2], H.E. Spence[1,2], [1]EOS Space Science Center, University of New Hampshire, Durham, NH (first author email address: a.p.jordan@unh.edu), [2]Solar System Exploration Research Virtual Institute, NASA Ames Research Center, Moffett Field, California, USA, [3]NASA Goddard Space Flight Center, Greenbelt, MD, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [5]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723.

Introduction: The surfaces of airless bodies in the Solar System may be weathered by a process that commonly affects spacecraft. When spacecraft pass through a planet's radiation belt, they are bombarded with energetic charged particles that penetrate electrical insulators, or dielectrics, and cause deep dielectric charging. The ensuing internal electric fields, if strong enough, can cause dielectric breakdown, or sparking. Over half of all spacecraft anomalies in Earth's magnetosphere are due to breakdown [2], and even Voyager 1 experienced breakdown 42 times in Jupiter's radiation belts [3].

Like spacecraft, airless bodies can be exposed to energetic charged particles, particularly solar energetic particles (SEPs), which can penetrate ~1 mm into regolith. Regolith is an effective dielectric: on the Moon, for example, regolith in permanently shadowed regions (PSRs) is so cold (≤50 K) [4] that it has an internal discharging timescale on the order of weeks—much longer than an SEP event [2]. Sufficiently large SEP events thus appear capable of charging the regolith to the point of dielectric breakdown [5].

Because these large SEP events occur about once per year, gardened regolith in PSRs has likely experienced ~10^6 events capable of causing breakdown (two such events have been detected by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER), aboard the Lunar Reconnaissance Orbiter, or LRO) [6]. The resulting breakdown weathering may have affected ~10-25% of gardened regolith in PSRs—comparable to the cumulative effect of meteoritic weathering—which suggests that breakdown weathering may significantly affect how PSRs evolve [7]. We expand on previous work to determine whether breakdown weathering occurs outside PSRs, and we discuss briefly how it might affect regolith on other airless bodies in the Solar System.

Breakdown Weathering on the Moon: Following the approach developed in [6], we use the JPL proton fluence model [8] to estimate SEP event rates. We then combine those rates with discharging timescales on the Moon's nightside to estimate the rate of events that can cause breakdown in regolith of a given temperature. To derive the timescales, we estimate the temperatures on the Moon's nightside at a depth of 1 mm by using thermal modeling [9]. The nightside can reach temperatures ≤100 K, which correspond to discharging

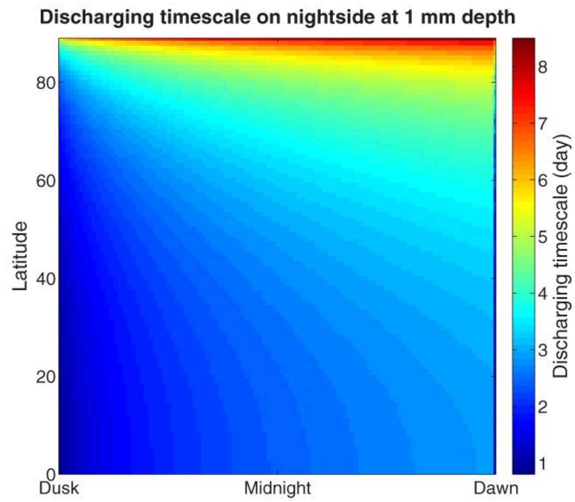

Figure 1. Timescales needed for discharging internal charge in regolith on the Moon's nightside, as a function of local time and latitude.

timescales of more than a few days (Figure 1). We can thus determine the rate at which breakdown may occur as a function of latitude.

Breakdown driven by these SEP events will melt and vaporize a percentage of the regolith determined by the energy density of the electric field created by the deep dielectric charging. Following [7], we estimate the percentage of gardened regolith affected as a function of latitude (Figure 2). At least ~1% may be affected by breakdown near the equator, and ~12% near the poles. We sum this over the entire lunar surface to find that breakdown may have affected at least ~2% of gardened regolith on the entire lunar surface.

Consequently, some of this material may have been collected by the Apollo astronauts. To distinguish breakdown characteristics in regolith grains from impact characteristics, experiments are needed to determine the characteristics of melts and vapor deposits created by breakdown. Experiments may also show how breakdown weathering affects comminution and the regolith's optical properties. We discuss how to detect a breakdown event in situ, such as with Resource Prospector, or remotely with LRO/CRaTER and Diviner.

Breakdown Weathering at Other Airless Bodies: Better understanding breakdown weathering may also aid interpreting remote sensing data from other airless bodies. Mercury has a nightside with temperatures similar to those on the Moon's nightside [10], has PSRs with temperatures <100 K [11], and is exposed to a higher SEP fluxes than is the Moon [e.g., 12]. Consequently, it may experience significant breakdown weathering. Furthermore, many bodies, such as Phobos, Deimos, and Vesta, have obliquities relative to the Sun that keep their poles in shadow for a significant fraction of their orbits [13-16], thus making the polar regolith cold enough [e.g., 13, 16] for breakdown. Finally, Jupiter's innermost satellites Metis, Adrastea, Amalthea, and Thebe orbit within the radiation belt, which has fluxes of relativistic electrons [17] that appear sufficient to cause breakdown on these satellites. The environment that caused the breakdowns Voyager 1 experienced in the radiation belt [3] may continually weather their surfaces.

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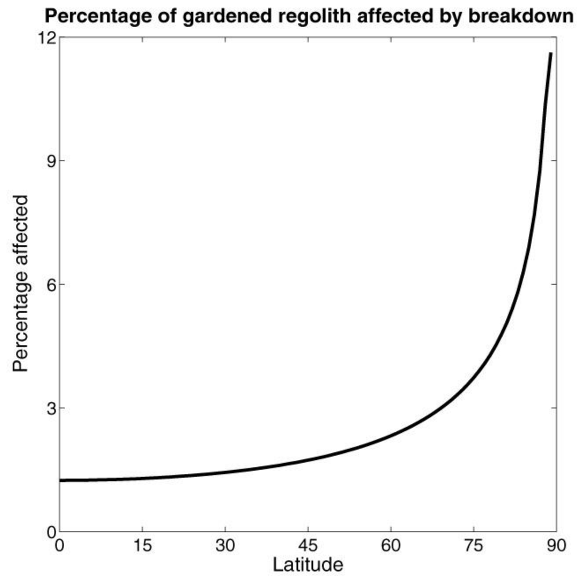

Figure 2. Percentage of gardened regolith that has been melted or vaporized by dielectric breakdown during large SEP events.