IMPLICATIONS OF DIELECTRIC BREAKDOWN WEATHERING FOR THE LUNAR POLAR REGOLITH. A. P. Jordan[1,2], J. K. Wilson[1,2], T. J. Stubbs[3,2], N. A. Schwadron[1,2], H.E. Spence[1,2], N. R. Izenberg[4], [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]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723.

Introduction: Solar energetic particles (SEPs) can penetrate the lunar regolith to depths of ~1 mm, causing deep dielectric charging. Because the regolith is an electrically insulating material, or dielectric, it does not readily dissipate this buildup of charge. Regolith in permanently shadowed regions (PSRs) is extremely cold (≤ 50 K) [1] and consequently has a discharging timescale on the order of weeks—much longer than an SEP event [2]. As a result, very large SEP events can significantly charge the regolith, possibly to the point where the subsurface electric fields are strong enough to cause dielectric breakdown, or sparking [2].

Such events have occurred approximately once per year during the space age [3]. Regolith that has been gardened, or mixed, by meteoritic impacts has been exposed to these SEP events for ~10^6 years. Consequently, gardened regolith in PSRs has experienced ~10^6 SEP events capable of causing breakdown. The Cosmic Ray Telescope for the Effects of Radiation (CRaTER), aboard the Lunar Reconnaissance Orbiter (LRO), has detected two potentially breakdown-causing SEP events during LRO's mission [3]. We build on this previous work to suggest how this breakdown weathering might affect the regolith in the Moon's polar regions and what it implies for exploring PSRs.

Possible Importance of Breakdown Weathering: Dielectric breakdown, or sparking, occurs when a strong internal electric field rapidly vaporizes a channel through a dielectric. Almost all of the energy in the electric field converts into Joule heating the material in the channel. Therefore, we can estimate the rate at which very large SEP events deposit breakdown energy into PSR regolith and then compare it with the energy needed to vaporize and/or melt all the regolith. We find that breakdown weathering may vaporize and melt PSR regolith at a rate of 1.8-3.4 x 10^{-7} kg m^{-2} yr^{-1} [4]. Consequently, breakdown weathering may have affected ~10-25% of gardened regolith, which is comparable to meteoritic weathering (see Table 1) [4]. This suggests that breakdown weathering may play a significant role in how PSRs evolve.

Possible Effects of Breakdown Weathering: Because SEPs charge the regolith over a depth of ~1 mm, any breakdown is expected to occur over that depth,

Weathering process	Energy flux ($\mathrm{J\,m^{-2}\,yr^{-1}}$)	Vapor + melt production ($\mathrm{kg\,m^{-2}\,yr^{-1}}$)	% Gardened soil melted or vaporized
Meteorites	12	1.8×10^{-7}	$\sim 10\%$
Breakdown	0.88	$1.8 - 3.4 \times 10^{-7}$	$\sim 10 - 25\%$

Table 1. Comparison of meteoritic and breakdown weathering and how they affect PSR regolith (from [4]).

which is much greater than a typical grain size. In other words, any sparks are expected to traverse many grains. Dielectric breakdown creates tiny (≤ 1 μm in diameter) tree- or fractal-like cracks in dielectrics, particularly along mineralogical boundaries ([5]; see Figure 1). Some of these cracks enlarge explosively during breakdown, ejecting a mixture of fragments, melt, and vapor. Even if breakdown does not fragment a grain, it can still make it more susceptible to being subsequently fractured by a meteoroid impact. At least 10% of the regolith may have experienced breakdown, so this explosive cracking may significantly affect comminution.

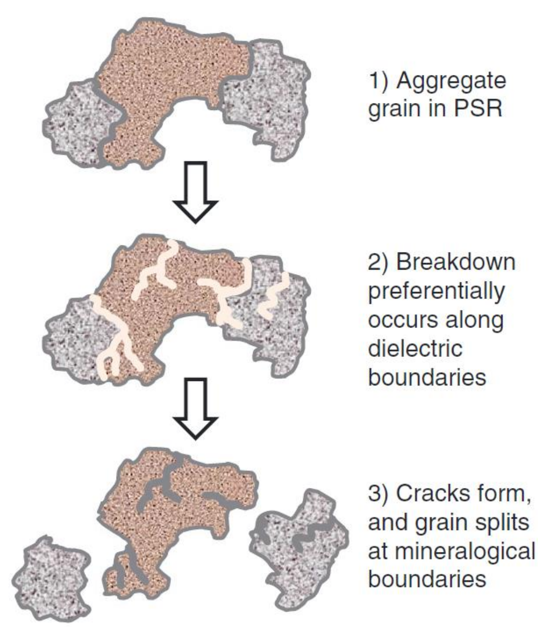

Figure 1. Cartoon showing how dielectric breakdown could fragment and weaken a regolith grain (from [3]).

We employ a statistical approach to estimate how breakdown weathering may evolve the distribution of PSR grain sizes. We also consider what fraction of a typical grain may be melt or vapor deposits created by breakdown. We can thus estimate the fraction of grains in the upper ~1 mm that may have experienced breakdown during the two large SEP events detected by LRO/CRaTER.

Our initial modeling motivates and informs future experiments about how breakdown weathering affects comminution and the resulting optical properties, not just in lunar PSRs, but perhaps on the Moon's nightside, on Mercury, and on asteroids with high obliquities. In lunar PSRs, comminution effects are also important for planning future robotic missions. For example, breakdown weathering might affect the geotechnical properties of the regolith, thus having operational implications for a rover like Resource Prospector to travel in a PSR [6]. Also, a rover's instruments may be able to detect any breakdown that occurs in the regolith during a very large SEP event, since ~1% of breakdown energy is dissipated in emissions from radio to ultraviolet [7-9].

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