OBSERVATIONAL EVIDENCE FOR DIELECTRIC BREAKDOWN WEATHERING ON THE MOON.

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Introduction: To interpret remote sensing observations of lunar regolith, it is important to understand how space weathering has affected the surface. Much work has focused on how bombardment by solar wind and micrometeoroids changes the reflectance spectrum of lunar soil. These processes, however, may not cause all reflectance features seen in lunar swirls and latitudinal trends. Instead, a newly predicted process—dielectric breakdown (i.e., "sparking")—may be responsible.

Puzzling observations: Recent work has suggested that the solar wind causes a significant amount of weathering. Lunar swirls, which are high albedo, sinuous features, have near-infrared spectral characteristics that are similar to those associated with latitudinal trends of much of the lunar surface, when binned by iron content [1]. Since swirls are associated with magnetic anomalies that likely block the solar wind, and the average flux of the solar wind decreases with increasing latitude, it seems solar wind bombardment can explain both.

In the case, however, of iron-rich (>20 wt% FeO) soils, this explanation creates three puzzles. First, the maria's soils that are richest in iron tend to have latitudinal trends that are different from the swirl trends [1]. It is unclear how the solar wind could create both, suggesting another process may be at work.

Second, a high-iron (~21 wt%) swirl, Reiner Gamma, appears to be brighter at 750 nm than expected for soil that receives no solar wind [2]. This suggests there is a process that weathers both the equatorial *and* polar regions yet is inhibited by the swirl's magnetic field.

Finally, in 1064 nm, there is evidence that soils richest in iron *darken* with increasing latitude [2]. In 750 nm, all maria soils brighten with increasing latitude, with soils of increasing iron abundance having trends that become almost flat. This trend with iron content is also clear in 1064 nm, except that the highest-iron soils darken toward the poles. Again, this implies another weathering process may be at work.

Dielectric breakdown weathering: A newly predicted process may explain these observations. Dielectric breakdown is predicted to occur in the top ~1 mm of lunar soil during large solar energetic particle (SEP) events [3-6]. These charged particles cause significant deep dielectric charging in cold (≤120 K) soil. The conditions for breakdown are well-understood and appear to be met on the nightside of the Moon and in permanently shadowed regions [3, 6]. Breakdown weathering may have melted and vaporized ~3-10% of all impact-gardened soil [6].

This would make it comparable to micrometeoroid impact weathering [6]. Like impacts, breakdown may create melt and vapor deposits on grains [4, 7], and it is known to create submicroscopic iron particles [7-9]. Also, breakdown should be more significant in colder regions, that is, toward the poles [6].

Puzzles explained: Because of this, dielectric breakdown weathering may explain the three observational puzzles. First, the puzzles all concern soils richest in iron. Experiments show that breakdown is more likely when a mineral contains iron than when it does not [7] and that, as long as the electrical conductivity remains low, a larger fraction of metallic inclusions makes a material more susceptible to breakdown [10]. In addition, these soils would experience more breakdown weathering near the poles, explaining the puzzle of such soils getting darker in 1064 nm with increasing latitude. Finally, breakdown weathering is likely inhibited by magnetic anomalies; they can block a large fraction of lower-energy (≤30 keV) SEP electrons, which dominate charging [6, 11]. If so, then the polar regions may experience more breakdown weathering and thus perhaps more net weathering than Reiner Gamma.

Conclusion: Lunar soils richest in iron exhibit some puzzling characteristics, but these are consistent with dielectric breakdown weathering. Consequently, this process should be considered when analyzing remote sensing observations of lunar regolith and when interpreting lunar soil samples.

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