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Definition

- Space weathering describes a set of processes and their effects on the physical, chemical, and mineralogical properties of regoliths on airless bodies.
- Space weathering on Mercury is informed by lunar, asteroid, and laboratory studies, however:

Space weathering on Mercury will be influenced by Mercury’s unique environment and composition.
Approach

• Examine each process and look at how each affects the surface of the Moon and asteroids
• Look at laboratory simulations of the space weathering process.
• Re-examine each process at Mercury, keeping in mind the unique conditions and environment of this planet
The Processes

Same as those involved in the formation of Mercury’s Exosphere
Processes

Laboratory

Mercury

Introduction

Mineralogical Changes

Same as those involved in the formation of Mercury’s Exosphere

- Different minerals grind down at different rates
- On Moon we see mechanical size fractionation within the regolith
- Lunar soil is 3-5% impact glasses and 25-30% agglutinates
- Average lunar grain sizes of 20 µm with 10-20% smaller than 20 µm (Cameron et al., 1991)

- Rinds with npFe₀
- Experiments show different npFe₀ production rates for different minerals
- Reduces volatile content

- Photon-Stimulated Desorption and Thermal Evaporation
- Ion Sputterion of Meteoroids
- Vaporization of sub-microscopic (nanometer scale) particles of iron, npFe₀

Low Energy

High Energy
Different minerals grind down at different rates — on the Moon we see mechanical size fractionation within the lunar samples.

Rinds with npFe⁰ experiments show different npFe⁰ production rates for different minerals.

Sputtering of material devolatilizes surface materials.

Hydration of upper layers of surface grains reduces volatile content.
Chemical Changes

- Darkening of materials;
- Lowers the intrinsic albedo
- Reduction of materials
- Oswald ripening of grains (esp. npFe₀)

![Photon-Stimulated Desorption and Thermal Evaporation](image)

*Figure 1* Reflectance vs. wavelength for forsteritic olivine (Fo₆₃) for cavity temperatures of 80 K to 400 K. Grain size 32-63 μm wet sieved. Sample courtesy of L. Moroz
Laboratory Experiments


• Ion bombardment has been simulated in ion radiation experiments (Brunetto and Strazzulla 2005, Marchi et al. 2005, Strazzulla et al. 2005, Brunetto et al. 2006)

• npFe$^0$ has been produced in these laboratory simulations, supporting the role of these particles in producing the effects attributed to space weathering.
Laser and Ion Irradiation

• Mostly targeted to explain/understand the weathering process on asteroids
  – Lower micrometeorite impact velocity than experience on Moon
  – Relative roles of ion versus micrometeorite bombardment

• All minerals do not weather the same:
  – Sasaki et al. (2002) irradiated low-iron olivine and pyroxene with nanopulse laser: olivine showed larger spectral changes
  – Marchi et al. (2005) ion irradiated low-iron olivine and pyroxene: olivine showed larger spectral changes

• The rate and magnitude of weathering is mineral dependent
Mercury

• Fluxes:
  – Cintala (1992) predicted 5.5 times more flux at Mercury than the Moon
  – Borin et al. (2009) predict 76 times greater flux than Cintala’s prediction
  – Mouawad et al. (2010) show mismatch w/Borin predict & exospheric sodium ion abundance from impact vaporization. They predict ~6 times that calculated by Cintala

• Impact velocities
  – Moon: 12.75 km/s (Cintala 1992)
  – Mercury: 20.5 km/s (Cintala 1992) 16.81 km/s (Borin et al. 2009)

• Glass, agglutinate, & vapor production
  – 14 times more melt, 20 times more vapor produced at Mercury compared to Moon (Cintala 1992)
  – 0.06 to 5 time more than Cintala’s calculation (Morgan et al. 1988, Mouawad et al. 2010)
Predictions

• Higher glass and agglutinate production
  – 3-5% impact glass on Moon, 25-30% agglutinates on Moon
  – Cintala (conservative prediction) suggests 14 times more melt....glass and agglutinates could comprise more than 50% of the regolith

• Increased vapor rim production
  – Thicker coatings?
  – What type of nano-scale particles will there be?
Mercury

- Ions need to reach the surface, with some flux and velocity, to sputter and implant materials...
- Mercury has an intrinsic magnetic field so...
- What can make it to the surface?
• Particles can make it to the surface
• Not just during reconnection events
• Most of the action is happening on the night side from the tail region
• No obvious latitudinal dependence to the ion bombardment flux
Predictions

• Closer to the Sun, thus higher density of solar wind species interacting with the Mercury system
• Need to quantify the rates of implantation and sputtering compared to the Moon in terms of:
  – Ion species present
  – Flux and velocity
• More reducing environment?
Burger et al. (2010) found that the primary source of sodium during the M1 flyby was PSD by solar UV radiation.

- Higher flux of UV solar radiation at Mercury than at the Moon.
- Higher temperatures are experienced at Mercury than at the Moon.
Predictions

- Higher UV radiation will increase the rate and role of PSD in modifying the regolith (release of volatiles)
- Higher thermal temperatures will lower the albedo of minerals compared to the Moon
- Oswald ripening will coarsen or enhance grain growth
Composition

• These processes are all composition dependent
  – Mechanical fractionation
  – Production of npFe$^0$, native Fe & Ti
  – Glass & agglutinate properties

• Mercury and the Moon are not compositionally the same
  – low abundance of Fe-bearing silicates
  – Fe and Ti are present
    • NS observations (Lawrence et al. 2010) indicate 8-22 Fe-equivalent wt%, or 3-8 T-equivalent wt%, or 14 & 5 Fe-Ti-combined wt% (respectively).
    • MDIS color observations indicate presence of Fe-Ti opaque oxides (such as illmenite or ulvospinel) of 15 to 40 vol%
  – Abundances of glass and agglutinates
    • What is the composition of these compared to the Moon?
    • Are they more ‘reduced’?
NOTES

• Role of composition
  – Nano-scale materials
  – Form of iron (silicate, opaques, glasses)
  – Process effects

• Time
  – Magnetic field characteristics
  – Solar wind characteristics
  – Regolith formation/processing