Regolith formation and space weathering on Mercury

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Mercury has a unique surface composition and space environment. It is not an easy task to understand the chemical and physical processes and the resulting regolith formation and optical effects of space weathering (Sasaki and Kurahashi, 2004; Domingue et al., 2014).
Previously the surface of Mercury was discussed implicitly assuming its similarity with the lunar surface. The albedo of Mercury is lower than that of the lunar nearside, which consists of 30percent by area Fe-rich basalt. With less iron (<4 wt. percent Fe), Mercury’s composition is very different from the Moon. The surface is in a reducing condition, where iron is in the metallic state or in sulfides. Other unique factors are higher peak surface temperatures, greater mean impact velocities, and its surface is partially shielded from solar wind by intrinsic magnetic field.

Cintala (1992) calculated that the volume of material excavated by a dust particle (micrometeoroid to centimeter-size material) of a given size is 7 percent higher on Mercury than on the Moon. When impactor size is larger than 1cm, the much greater impactor flux on Mercury compared with that on the Moon results in a deeper regolith on Mercury. For micrometeoroids <1 cm in diameter, excavation (movement of material from depth) and retention of impactor material per impact is nearly equivalent at the Moon and Mercury.
Lunar samples contain 1–4 percent of exogenic meteoritic material. The order of magnitude (or more) greater impact flux on Mercury leads to an order of magnitude greater overturn rate and retention of impactor material within the regolith. Mercury’s surface has thus been postulated to contain 5–20 percent meteoroidal material to a depth equivalent to that sampled on the Moon (Domingue et al., 2014)

Cintala (1992) showed that varying the impact velocity by a factor of 2 results in factors of ~3 variations in melt production and 4 to 5 in vapor production, so that at Mercury ~15 and ~20 times more melt and vapor is produced, respectively, than at the Moon. The melt produces agglutinate glass within the regolith, and the vapor produces coatings or patinas on nearby regolith particles.
Lunar soil studies show that npFe0 particles in agglutinates are at least twice as large as those in grain rims (a few nm). In some lunar agglutinates such npFe0 particles may approach 100 nm in diameter (Noble et al. 2007).
On Mercury, impacts produce substantially more melt and vapor than on the Moon, and we expect more agglutinates and vapor-deposited rims; it is plausible that npFe0 particles will be larger. Nanophase Fe particles may be large within agglutinates because regolith grains with npFe0-bearing rims are melted to form the agglutinates and the npFe0 coalesces to form larger particles. The formation, melting, and re-formation of agglutinates from prior agglutinates would be an environment for the growth of npFe0 particles. Another mechanism that has been postulated to coalesce and grow npFe0 particles on Mercury is Ostwald ripening (Noble and Pieters 2002).

Mercury’s extreme thermal condition due to solar heating should be noted. Since one Hermean year is 88 days and one Hermean day is 176 days (one trip of the sun over Hermean sky). The maximum temperature at equator is 700K and the minimum temperature is 110K. On Mercury’s surface rocks, the heat wave may penetrate deeper and resulting thermal tree may be larger than those on lunar rocks. Thus,

thermal fatigue may be another prevailing process for regolith formation.

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