THE SURFACE ROUGHNESS OF MERCURY: INVESTIGATING THE EFFECTS OF IMPACT CRATERING, VOLCANISM, AND TECTONICS

Hannah C. M. Susorney1, Olivier S. Barnouin1,2, and Carolyn M. Ernst2,1

1Department of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 21218, USA (hsusorney1@jhu.edu); 2The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA.

Introduction: The Mercury Laser Altimeter (MLA) on the MErcury Surface, Space ENviroment, GEOchemistry, and Ranging (MESSENGER) spacecraft has acquired high-resolution topographic measurements of Mercury’s northern hemisphere[1]. These measurements permit the quantification of surface roughness on Mercury over a variety of baselines. Surface roughness separates and quantifies the changes in topography at a given length scale[2]. For example, the topographic influence of a small tectonic ridge within a large basin can be assessed relative to the contribution of the larger basin itself. By measuring the surface roughness on Mercury, the contribution of the geologic processes that dominate the evolution of Mercury’s surface, including impact cratering, volcanism, and tectonics, can be identified to quantify how the landscape of Mercury has evolved.

Methods: Previous studies of the surface roughness of Mercury have used median differential slope[1, 3, 4] and the interquartile range of profile curvature[5] to measure the surface roughness of Mercury. We calculate surface roughness instead as the root mean square (RMS) deviation of the difference in height over a given baseline, a method commonly used in terrestrial landscape evolution studies[2]. The RMS deviation of Mercury is computed directly from individual MLA tracks for baselines between 500 m and 250 km. The results are compiled and mapped from 45°N to 90°N. The lower-latitude bound (45°N) is defined to ensure sufficient density of MLA tracks.

Surface Roughness on Mercury: The surface roughness of Mercury’s northern hemisphere reflects the planet’s bimodal distribution: smooth plains have lower roughness values than the intercrater plains and cratered terrain (Fig. 1). The mapped areas of low surface roughness align with areas of smooth plains[6] and are relatively smooth at all baselines investigated.

Impact Craters: The dominant source of surface roughness at baselines of 500 m to 100 km is the topography associated with impact craters. Fresh crater ejecta within the smooth plains (Fig. 2A) have roughness values at shorter baselines (500 m to 10 km) similar to those in the intercrater plains, supporting the interpretation that the intercrater plains may result from the modification of volcanic plains by cratering[e.g.,7,8].

At shorter baselines (~500 m) the continuous ejecta of complex craters appears to be smoother than the distal secondary crater fields (Fig. 2B). At longer baselines (10 km to ~250 km), the roughness associated with complex impact craters is contributed primarily by the craters themselves rather than the continuous ejecta or distal secondary crater fields (Fig. 3). The concentration of complex craters in the intercrater plains is the source of the increased roughness of these plains at longer baselines.

Volcanism: Flood volcanism in Mercury’s northern smooth plains[9] served to reduce surface roughness by infilling the pre-existing topography and generating a smooth surface at scales from hundreds of meters to kilometers. Such volcanism also partially or completely removed any pre-existing impact craters shallower than the thickness of the plains deposit.

Variations in surface roughness at the 20-km baseline (Fig. 3) within the smooth plains may be the result of higher areal densities of impact craters in older flows[5] or variations in the density of tectonic features (wrinkle ridges).

Tectonics: Small tectonic features on Mercury (including wrinkle ridges) contribute in only a minor way relative to craters to the surface roughness at smaller baselines (Fig. 1).

Large tectonic features are barely visible in surface roughness maps at most baselines up to a few hundred kilometers. For instance, the northern rise is indistinguishable from the surrounding smooth plains at 1-km and 20-km baselines (Figs. 1 and 3). At the 250-km baseline, in contrast, the northern rise can be observed, but a series of rupes (including the Carnegie and Victoria rupes) dominates the surface roughness (Fig. 4). These rupes are also collocated with a region of high concentration of magnesium[10] and some of the oldest terrain on the planet[11]. The rupes are not visible at shorter baselines but are substantially rougher than any other region mapped in this study at the longest baselines.

Figure 1. Surface roughness at a 1-km baseline from 45° to 90°N.

Figure 2. The surface roughness of Gaudi (81 km in diameter) and Stieglitz (100 km) at (A) 1-km and (B) 500-m baselines.

Figure 3. Surface roughness at a 20-km baseline from 45° to 90°N

Figure 4. Surface roughness at a 250-km baseline from 45° to 90°N.