Latitudinal Dependence of Asteroid Regolith Formation by Thermal Fatigue

*Maximilian Hamm[1], Hiroki Senshu[2], Matthias Grott[1]

1. German Aerospace Center, Institute of Planetary Research, 2. Chiba Institute of Technology, Planetary Exploration Research Center

Asteroids are covered by a layer of broken up material called the regolith, which is composed of fragments with constituent sizes ranging from meter-sized boulders to decimeter-sized rocks and millimeter- to submillimeter-sized fine grains. The main regolith forming process is thermal fatigue, i.e., the thermally induced breakdown of rocks [1], which is much more efficient than rock breakdown by micrometeorite impacts. Thermal fatigue describes the repeated chipping and cracking of rock mass due to temperature induced stresses, which act on scales varying from comets [2,3] to boulders and granular microstructures [4,5,6].

Two common ways to parameterize the efficiency of thermal fatigue are the local temperature gradient, which drives the breakdown of homogeneous rocks [5], as well as the amplitude of diurnal temperature variations, which drive thermal fatigue in heterogeneous assemblages such as chondrites [6]. In this study we investigate how the strength of these processes depends on solar declination and the thermal inertia of the considered rocks and determine the latitudes at which they are most efficient. To this end we calculate temperature-depth profiles on a sphere, assuming orbital parameters as appropriate for the Hayabusa2 target asteroid (162173) Ryugu. We vary the thermal inertia from 500 to 3000 $J\ K^{-1}m^{-2}s^{-1/2}$, corresponding to the thermal inertias of CM2 and E4-type meteorites [7]. The solar declination is varied between 0° and 85° to account for the unknown tilt of the rotation axis.

We find that the maximum temperature gradient and amplitude follow similar latitudinal trends with respect to solar declination and both reach maximum latitudes around 45° of solar declination. However, maximum temperature gradients are confined closer to the equator when compared to the diurnal temperature amplitude for a given thermal inertia. Furthermore, the latitudes of maximum temperature gradients are much more sensitive to changes of the rock’ s thermal inertia when compared to the latitudes of maximum diurnal temperatures, which stay close to constant irrespective of thermal inertia. Finally, the absolute magnitude of both maximum temperature gradient and amplitude strongly depend on the assumed thermal inertia, with low thermal inertia values resulting in large temperature differences.

Here we will present the expected pattern of regolith generation by thermal fatigue and the influence of varying solar declination and thermal inertia will be discussed. The results will then be applied to the Hayabusa2 [8] and OSIRIS-REx [9] target asteroids and predictions about their respective regolith structures will be made.

References: [1] Delbo M. et al. (2014) Nature, 508, 233-236. [2] Kührt E. (1984) Icarus, 60, 512. [3] Auger N. et al. (2018) Icarus, 301,173-188. [4] Čapek D. and Vokrouhlický D. (2010) A&A, 519, A75. [5] Molaro J. et al. (2017) Icarus, 294, 247-261. [6] Molaro J. et al. (2015) JGR Planets, 120, 255-277. [7] Opeil C.P. et al. (2010) Icarus, 208, 449-454 [8] Tsuda Y. et al. (2013), Acta Astronautica, 91, 356-362 [9] Lauretta DS. et al. (2015) Meteoritics & Planetary Science, 50, 834-849

Keywords: Asteroid Surfaces, Thermal Fatigue, Hayabusa2