

HIRISE DIGITAL ELEVATION MODEL OF PHOBOS: IMPLICATIONS FOR MORPHOLOGICAL ANALYSIS OF GROOVES. R. Hemmi¹ and H. Miyamoto², ¹The University Museum, The University of Tokyo (7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-0033, Japan, hemmi@seed.um.u-tokyo.ac.jp), ²Department of Systems Innovation, School of Engineering, The University of Tokyo

Introduction: Linear narrow depressions commonly known as “grooves,” can be observed on a variety of small bodies including Phobos, Gaspra, Ida, Eros, and small saturnian satellites [1]. Characteristics of grooves may reflect geological events, inherent in individual bodies. The surface of Phobos is mostly covered by grooves many of which are less than ~1 km wide. It remains controversial whether their morphologies represent past internal (e.g., tidal disruption [2]) or external processes (e.g., crater chains [3,4], rolling boulders [5], etc.). The presence of raised rims on grooves is an important diagnostic of impact cratering processes as opposed to extensional stress which would form rimless depressions [6]. Groove rims were previously identified from images [6–8]; however, their detailed topographies have not been well investigated. This is primarily due to limited spatial resolutions of previous digital terrain models (up to 100 meters) which are similar to the widths of target features (a few hundreds of meters). In this study, we produce a digital elevation model (DEM) from Mars Reconnaissance Orbiter’s High Resolution Imaging Science Experiment (HiRISE [9,10]) stereo pairs of Phobos [11]. The method we successfully employ was described in a previous feasibility study [12], and allows for the extraction of topographic profiles of grooves using the new DEM.

Data and Methods: HiRISE Experimental Data Record (EDR) products of RED4 and RED5 CCD image data of the stereo pair, PSP_007769_9010 and PSP_007769_9015 [11], were used for stereo-photogrammetry (Fig. 1). Following our established

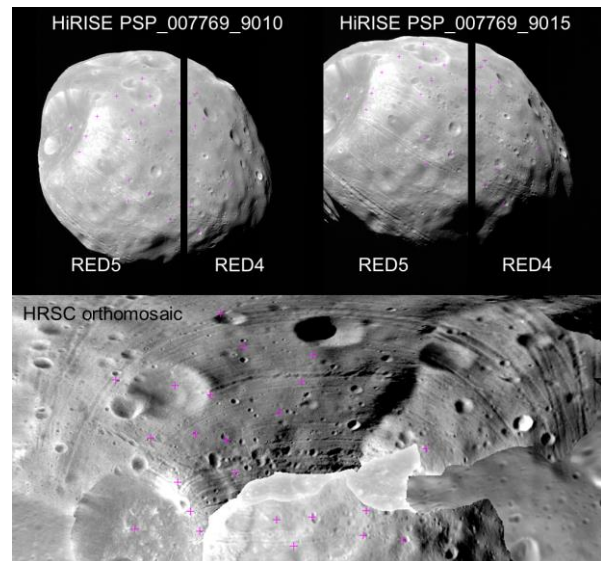


Fig. 1. HiRISE stereo pair images of Phobos (upper images) and a part of HRSC global orthomosaic (lower image) with ground control points (magenta crosses).

methods for producing HiRISE DEM of Mars surface [13, 14] (Fig. 2), we used the Integrated Software for Imagers and Spectrometers (ISIS) version 3.4.1 developed by the U.S. Geological Survey [15] to perform processing the HiRISE EDRs (i.e., radiometric calibration, noise removal, importing SPICE kernels, creating control network, bundle adjustment, correcting camera distortions and jitters, map projection etc.). From the four HiRISE RED images, a total of 23 tie points were

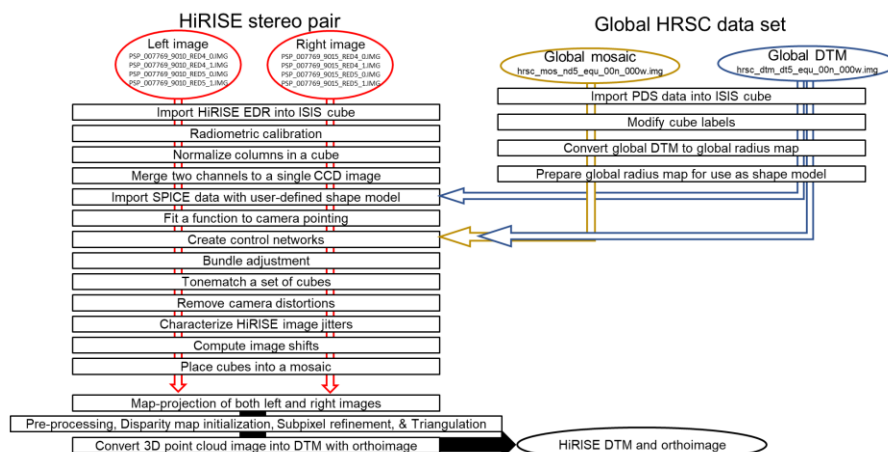


Fig. 2. Flowchart showing image processing of HiRISE stereo pair of Phobos

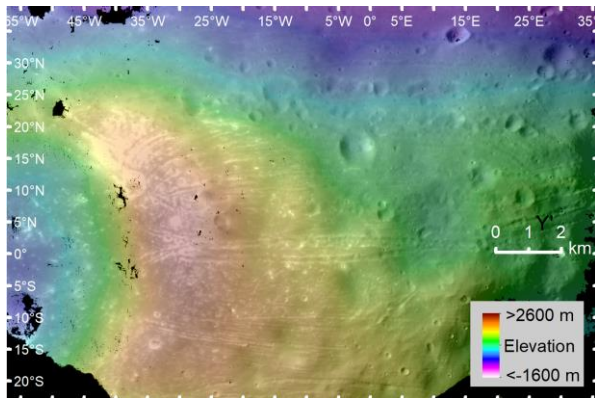


Fig. 3. Color-coded HiRISE DEM of Phobos. Base map is the grayscale orthoimage.

manually picked and then tied to global HRSC orthoimage mosaic [16] (~12.1 m/pixel) and the global radius map (100 m/pixel) derived from HRSC digital terrain model [17]. After applying bundle adjustment, a pair of RED4 and RED5 images were mosaicked and map-projected. Assuming a 0.2-pixel matching error, its parallax-height ratio and expected vertical precision were calculated to be ~0.343 and ~4.17 m, respectively. Finally, NASA Ames Stereo Pipeline [18]’s triangulation routine was used to derive a 3D-coordinate at each of matched pixels from the two images. Resultant 3D-point cloud image was converted to a map-projected DEM (elevation values relative to 11.1-km sphere) and an orthorectified image at spatial pixel scale of 20 m and ~6.56 m, respectively, in equidistant cylindrical projection.

Result and Discussion: As shown in Fig. 3, the newly-created DEM is rendered with its orthoimage using ESRI’s ArcMap 10.2 software. Our DEM covers most areas between ~60° W to ~60° E and ~30° S to ~70° N, including the eastern rim of Stickney crater, grooves, impact craters, and the redder and bluer units

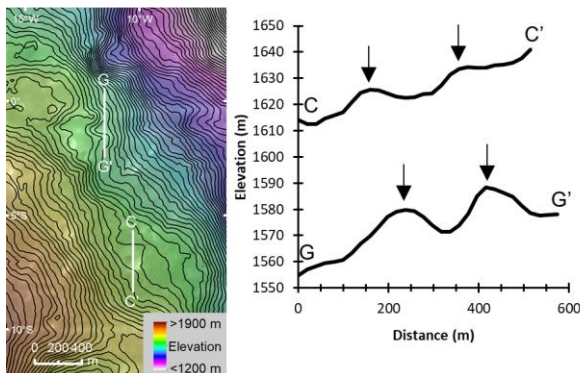


Fig. 4. Example of cross-sectional profiles (right) of crater (C-C') and groove (G-G'). Arrows represent crater and groove rims. Sectional lines are shown in the DEM with 10-m contours (left).

[2]. In most areas, elevation values range between ~-1900 m and ~2700 m.

Using our DEM, the cross-sections of grooves on the nearside of Phobos were extracted and compared with those of craters with similar widths (e.g., Fig. 4). Some parts of craters and grooves have raised rims which extend beyond the vertical error in the DEM and are consistent with rims suggested by previous observation (e.g., [6]). These rims are also expressed in contour and shaded relief maps of the DEM.

If these features represent true rims rather than pre-existing topography, some of previously proposed hypotheses can be precluded. Raised rims of grooves favor impact cratering rather than extensional stress. Also rolling and bouncing boulders hypothesis may not be able to produce the 10’s m-high raised rims. Further study is necessary to clarify the relationship between heights of raised rims and most likely hypothesis explaining groove formation.

References: [1] Morrison S. J. et al. (2009) 262–270. [2] Hurford T. A. et al. (2016) *JGR*, 121, 1054–1065. [3] Nayak M. and Asphaug E. (2016) *Nat. Geosci.*, 7, 12591. [4] Kikuchi H. and Miyamoto H. (2014) *LPS XXXV*, Abstract #2007. [5] Ramsley K. R. and Head J. W. (2018) *PSS*, in press. [6] Thomas P. (1979) *JGR*, 84, 8457–8477. [7] Thomas P. (1979) *Icarus*, 40, 223–243. [8] Basilevsky A. T. et al. (2014) *PSS*, 102, 95–118. [9] McEwen A. S. et al. (2007) *JGR*, 112, E05S02. [10] McEwen A. S. et al. (2010) *Icarus*, 205, 2–37. [11] Thomas N. et al. (2011) *PSS*, 59, 1281–1292. [12] Ivanov A. B. and Thomas N. (2010) *LPS XXXI*, Abstract #1923. [13] Hemmi R. and Miyamoto H. (2017) *PEPS*, 4, 26. [14] Hemmi R. and Miyamoto H. (2018) *Geosciences*, 8, 152. [15] Anderson J. A. et al. (2004) *LPS XXXV*, Abstract #2039. [16] Wählisch M. et al. (2014) *PSS*, 102, 60-73. [17] Willner K. (2014) *PSS*, 102, 51-59. [18] Beyer R. A. et al. (2018) *ESS*, 5, 537–548.