NUMERICAL TEST OF THE FORMATIONAL PROCESS OF GROOVES ON PHOBOS. H. Kikuchi and H. Miyamoto, The University Museum, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, h-kikuchi@um.u-tokyo.ac.jp

Introduction: Grooves are one of the most characteristic geological features on Phobos. After several decades, debate on the origin of the grooves continues. Two hypotheses are recognized for the origin of grooves: (1) grooves are some kind of depression formed as tensional fractures [1, 2] and (2) grooves are results of secondary impacts caused by linearly-aligned impactors ejected either from Stickney crater [3] or Mars [4]. We identified 488 grooves and interpreted that these grooves could be classified into three types: type A, B, and C by calculating a pole to a plane of grooves [5]. This result supports hypothesis 2, indicating that the origin of the grooves is the impacts from a collection of smaller fragments which were once held together on a rubble-pile body by self-gravity. We consider the formational process of grooves to be a two-date process: (1) a collection of the smaller fragments is pulled apart and stretched into an alignment by tides during a close approach to Mars, and (2) a part of the part of the aligned collection of fragments impact Phobos with every revolution around Mars. To examine the hypothesis, we test the model to reproduce grooves on Phobos using N-body simulations.

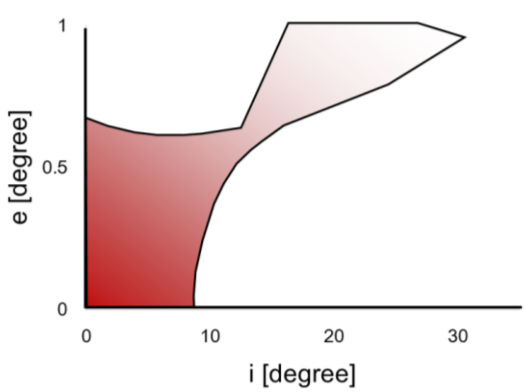

Figure 1. The orbital shapes of particles when θ is 20°. The horizontal axis represents the orbital inclination of impactors. The vertical axis represents the orbital eccentricity of impactors.

Method: We use a starting projectile composed of 5000 particles (rubble pile) with density of 1 - 2 g/cm^3. We determined the velocity vector of projectile using θ and φ. The θ is defined as the angle between direction from the center point of the plane to the medium point of grooves, and the equatorial plane of Phobos. The φ is defined as the angle between the direction, which is projective line to the equatorial plane of Phobos and the direction from the central point of Phobos to Mars. The initial velocity vector of projectile can be divided into 5 statistically; (θ, φ) = (20°, 350°), (20°, 190°), (90°, 90°), (160°, 350°), (160°, 190°), therefore, we compute for individual projectile velocities. The initial magnitude of the velocity vector of projectile is 0.1 - 3.0 km/s. Example for the range of possible orbits are shown in figure 1. The initial position of a small body is set on the same orbit. We regard the shape of Phobos as sphere with radius of 11 km, the orbit of Phobos is circle, tidally locked to Mars and the orbital radius of Phobos is 10000±20 km. In order to reproduce grooves on Phobos, we use N-body situations:

$$\frac{d^2 x_i}{dt^2} = -\sum_{j \neq i} G m_j \frac{x_j - x_i}{|x_j - x_i|}$$

We consider gravities of Mars, Phobos and projectile. The coefficient of restitution is 0.2 - 0.6. Time step is 1 -10 s. In order to determine the initial size of particles, we measure sizes of clear pit chains and, use the size frequency distribution (figure 2). When a particle is in the Phobos (sphere approximation), then we output the position and velocity of particles. We record the coordinate where the velocity vector of the particle from the position intersects with Phobos. The radius of pit is as the 10 times as the radius of a particle.

Results: We found that individual particles (broken rubble pile) have little chance to be stretched into alignment by tidal force of Mars when a projectile's eccentricity is greater than 1. On the other hand, particles can be aligned when the eccentricity is less than 1. This condition is convenient to produce many pit chains. We also found that with a decrease in time step, or the lower the coefficient of restitution, the smaller the width of the alignment of particles. Figure 3 shows the result for one of our simulations which is also consistent with figure 2 or the previous mapping results of grooves [4].

Discussions and Implications: If the number of particles is higher, the morphological feature of the results of numerical simulations would be more similar with the distributions of grooves on Phobos. When the orbits of small bodies are shifted, only 2 small bodies are sufficient to produce pit chains approximating the grooves on Phobos. Furthermore, if small bodies dissipate orbital energy appropriately, only a projectile is sufficient to produce pit chains approximating the grooves on Phobos. From our results of the numerical simulation we suggest that the origin of the grooves on Phobos is the impacts from a collection of smaller fragments which were once held together by low cohesive force and orbited Mars.

References: [1] Thomas P. et al. (1979) *JGR*, *84*, 8457-8477. [2] Fujiwara A. and Asada N. (1983) *Icarus, 56*, 590-602. [3] Veverka J. and Duxbury T. C. (1977) *JGR*, *82*, 4213-4223. [4] Murray J. B. and Heggie D. C. (2014) *PSS*, *102*, 119-143. [5] Kikuchi H. and Miyamoto H. (2014) *LPSC, XLV*, #2007

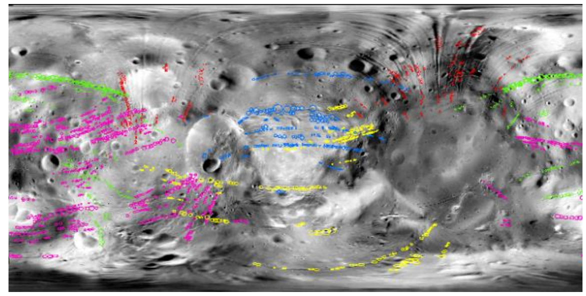

Figure 2. Mapping results of clear pit chains on equidistant cylindrical projection mainly based on images from the HRSC. Same color pits represent the same type. We measure the size of pit, and determine the initial condition of our simulations. Blue and pink circles correspond to type A grooves, red circles correspond to type B grooves, and yellow and green circles correspond to type C grooves.

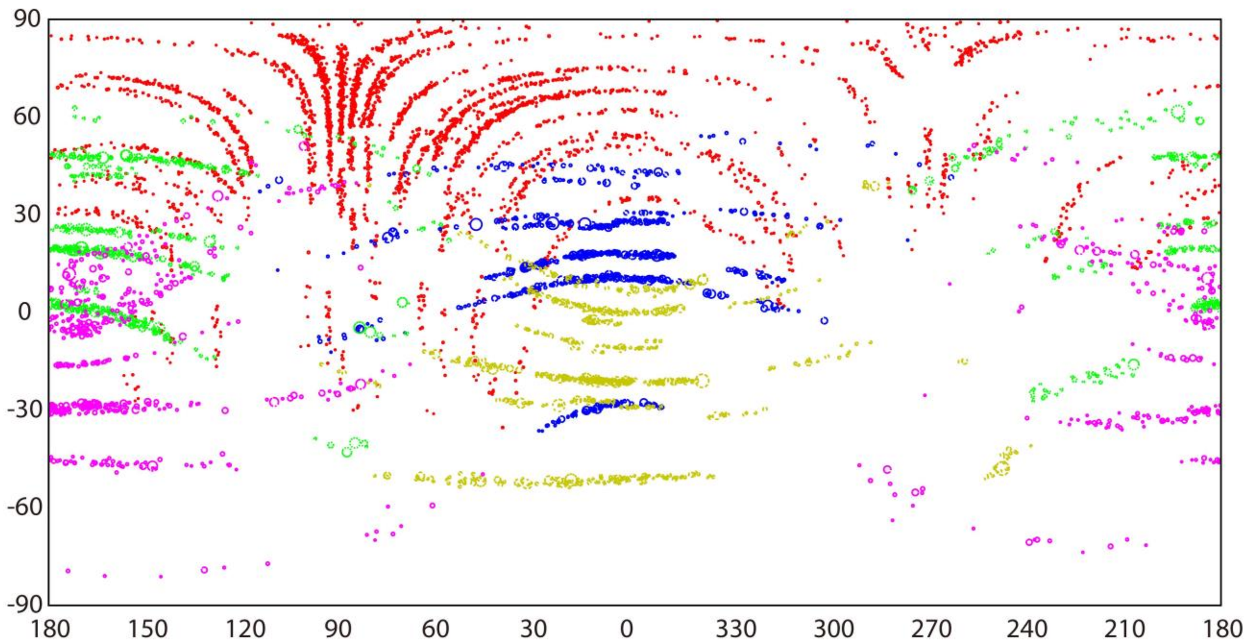

Figure 3. The result of our simulation for reproducing grooves on Phobos. The colors of pits correspond to those of types of grooves shown in figure 2. This distribution is consistent with figure 2 or previous mapping results of grooves [4].