EJECTA EMPLACEMENTS OF LIMTOC IMPACT ON PHOBOS. H. Kikuchi[1], [1]Department of System Innovation, School of Engineering, The University of Tokyo, Japan. (kikuchi@seed.um.u-tokyo.ac.jp)

Introduction: Investigation of the surface on Phobos, the 26 x 22 x 18 km satellite of Mars, is clue for understanding its origin and evolutionary history. The surface topography is rough, and there are some craters in different kind of degradation states. Stickney crater, about 9.4 km in diameter, is the largest crater of Phobos and moderately well preserved. From the crater densities, the age of Stickney is about 4.2 Gyr, and the oldest surface is 4.3 Gyr under the assumption that Phobos has orbited Mars since its earliest history and experienced the same crater flux as Mars [1]. On the other hand, the survival time of boulders near Stickney crater suggest an age of ~100 Myr [2]. This latter estimate is based on several meter-size boulders identified on the east of Stickney crater, using MGS image data [3]. Image analysis shows most of large boulders are related to Stickney. One cause of such discrepancy comes from the difficulty in estimating the impact flux for the Marian satellite due to the complex process of secondary and sesquinary impactors [4, 5]. Therefore, another approach is required.

The surface of the Martian satellite Phobos is divided into two spectral units: red and blue. The distribution of the blue spectral unit may be related to the ejecta from Stickney. Because Phobos has been losing altitude as time passes (due to tides of Mars) Phobos' spin rate was slower in the past. Thomas (1998) [6] suggested that a symmetrical ejecta curtain from Stickney traveling at low velocity would re-impact at the location where the blue unit is found to the east of Stickney if the orbital semi-major axis is 3-3.4 times to Mars radius (and the spin rate were slower than today). Images from the HRSC camera have recently confirmed blue units in the southern region around Stickney crater [7]. This blue unit on the southern area could not be explained with a symmetrical ejecta from Stickney.

Instead of focusing on Stickney crater, we focus on eject from the Limtoc crater located inside of Stickney (Fig 1) to explain the distribution of the blue spectral unit. We simulate ejecta emplacements of Limtoc impact, using numerical simulations with the shape model of Phobos.

Analysis: Ejecta particles released from Phobos will experience a strong gravitational influence from both Mars and Phobos. Therefore, we neglect the Sun and other planetary bodies, and solar radiation pressure, which is low influence compared to solar gravity perturbations. We make use of the three-body problem physics model. However, because the shape of Phobos is distorted, it is necessary for the simulation to consider this shape in order to grasp the accurate intersection where ejecta particles re-collide with Phobos. Therefore, using three-body simulations and a shape model of Phobos, we investigate the region where launched particles from Limtoc crater collide again with the shape model. Initial conditions of Phobos are as follos: The surface of Phobos is approximated by 25350 vertices aggregated from Gaskell shape model [8]. The orbit of Phobos about Mars is a circle, and the range of the orbital radius (R_{Ph}) is, 2.77, 3.54, 4.43 R_M. With respect to the inertial coordinate system of Mars, its default Cartesian position is given as: -R_{Ph}, 0, 0. Initial velocity vector $\left(0, -\sqrt{GM_M/R_{Ph}}, 0\right)$ and inclination (zero) of Phobos are also inputted into the simulations.

In order to set initial positions of ejecta particles, we measured three coordinates along the Limtoc crater rim on the map prepared by [9] rendered onto a shape model, using Small Body Mapping Tool [10]. We determine the horizontal plane for Limtoc crater using three points selected from the rim. We set the particles at equal intervals on the circle in increments of 1 degree, for a total of 360 particles. Initial particle launch angle from the horizontal plain, is set to either 35.4° or 45°. These values are derived from Z = 2.71 for the Mars conditions or Z = 3 in Maxwell's Z-model. The magnitude of relative initial velocity of particles to Phobos is 3, 4, 5, 6, and 7 m/s.

We consider the gravity of Mars and Phobos. The mass and size of particles are assumed zero. Coordinate

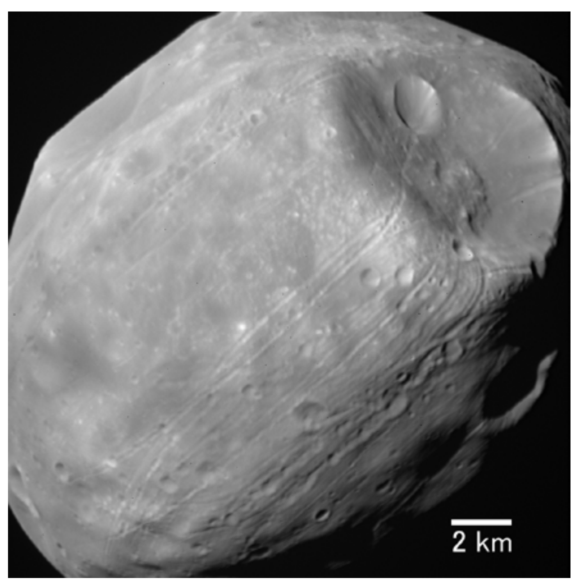

Figure 1. Limtoc crater inside Stickney crater. Part of HRSC image h4447_0005_sr2.

in the calculation is the inertial system having Mars as the center. We compute positons of particles (x_i) by using the following equation:

$$\frac{d^2x_i}{dt^2} = -GM_M\frac{x_M - x_i}{|x_M - x_i|^3} - GM_{Ph}\frac{x_{Ph} - x_i}{|x_{Ph} - x_i|^3}$$

where x_M is the positon of Mars (0,0,0), M_M is the mass of Mars, M_{Ph} the mass of Phobos. When a particle transects somewhere within 100 m from the Phobos shape model during a simulation, then the resulting output includes position. From this information, the location of particles that impact the surface of Phobos can be determined.

Results: In every case, the ejecta particles released from Limtoc collides with the wall of Stickney crater's rim on the north side, while on the south side the particles tend to collide with a wide range of the southern hemisphere beyond the wall of Stickney crater's rim because the dynamic height is relatively low. This is good agreement with the observation that the range of blue unit is relatively small on northern hemisphere of Phobos. By comparing the launch angles, fewer particles reach the northern hemisphere at 35.4° than at 45°. Comparing each orbital radius: when R_{Ph} = 4.43 R_M, particles with the initial velocity of 6 m/s will collide with the surface of Red East region. Therefore, smaller orbital radii produce collisions which tend to be consistent with the range of blue unit. Furthermore, the blue region near Stickney crater was extracted and compared with the result of numerical simulations. In cases of the current orbit or 3.54 R_M, and the release angle of 35.4°, the distributions of both have a lot of similarities (Fig. 2).

Discussions and Implications: Our results show that the distributions of the low velocity ejecta emplacements are consistent with the blue unit on the southern region. This could support the symmetrical ejecta model about Stickney crater [6]. Therefore, using the orbital evolution by tidal force of Mars dominated by the second order term, we could write the past orbital distance of Phobos as

$$R_{Ph}(t) = \left(R_{Ph}(0)^{13/2} + \frac{13}{2}\cdot\frac{3k_2}{Q}\sqrt{\frac{G}{M_M}}M_{Ph}R_M^5\Delta t\right)^{2/13}$$

where k_2 is the Love number and Q is the tidal quality factor of Mars. Using this equation, we could estimate the Stickney age is 33 - 280 Myr, this is similar to the survival age of boulders [3].

The geology such as landslide in Phobos correlates with the current gravitational field [11], and our result also indicate the surface of Phobos has recorded information from when the orbital distance was the near of the liquid Roche limit (~100 Myr). This may support the model that Phobos formed repeatedly by destruction and reaccumulation [12].

Conclusions: Using three-body simulations with a shape model of Phobos, we examine the emplacement of Limtoc impact. The distributions are consistent with the blue unit to the south of Stickney crater. Thus, the formational process of blue unit could be contributed to not only Stickney but also Limtoc impacts.

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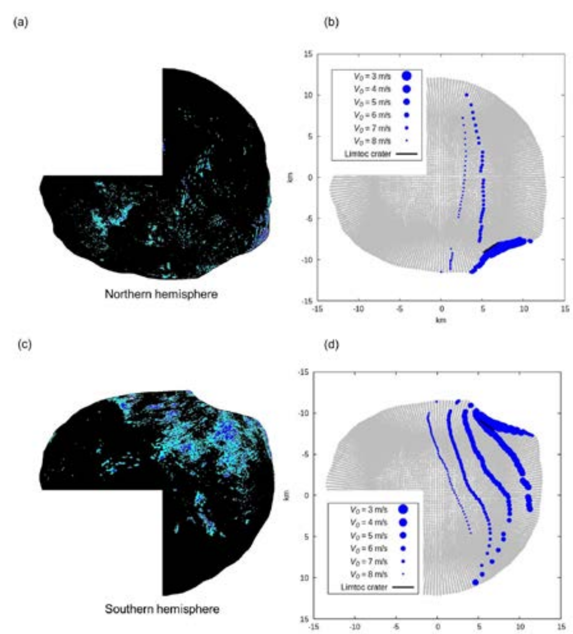

Figure 2. Comparisons observations of Blue Units with results of three-body simulations with a shape model. On the Northern hemisphere, the blue unit region (a) is consistent with the result of the simulations (b). On the Southern hemisphere, the blue unit region (c) is consistent with the result of the simulations (d).