Volume estimation of fluidized ejecta of Martian DLE craters in Utopia Planitia.

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Introduction: Ejecta of Martian impact craters are famous for having distinctive morphologies which differ from those on other solid bodies. Their morphological features suggest that ejecta would be transported and emplaced by a (some) radial ground-hugging flow(s) generated at the time of the impact. Because the radial ground-hugging flow is considered to be generated by the unique environments on Mars (ex. the atmosphere [*e.g.* 1] and/or the subsurface volatiles [*e.g.* 2]), understanding the generation and emplacement processes of the radial ejecta flow could elucidate the nature of the near-surface volatiles and their temporal variation.

Double Layered Ejecta (DLE) is one of the major subclasses of Martian ejecta morphologies [3]. DLE are composed of two lobes: a thick and concave inner lobe with deep moat at near the rim [4] and a faint outer lobe without distal rampart. The inner and outer lobes of DLE craters obviously differ in their facies, which suggest that (at least) two separate processes of ejecta emplacement would be generated in a single impact. In addition, numerous radial striations are observed on the surface of the inner lobe [4]. These striations are straight and cross the edge of the inner lobe to continue to the surface of the outer lobe. From these observations, ejecta flow forming the outer lobe would be considered to have enough momentum to erode the surface of the inner lobe and generate these striations.

Here we focus on the formation processes of the characteristic morphologies of Martian DLE craters in conjunction with the basic physics of the mass movement in a radial flow. We examined the interaction between a vortex ring and a particle layer, and made a regime diagram in which the thresholds of particle motion in a vortex ring are indicated [5]. However, erosional processes and erosion/emplacement volumes by the radial flow are not investigated quantitatively. This presentation consists of two parts. 1) Volumetric analysis of these two ejecta deposits by DEM and image analysis. We focus on the volume fraction between the inner and outer lobes of DLE craters. 2) Laboratory experiments on erosion and emplacement in the interaction between a vortex ring and a particle layer. We measured mass distribution associated with the radial flow resultant from the interaction between a vortex ring and a particle layer.

Volume Estimation by five different interpolation methods: We select Utopia Planitia where many of well-preserved DLE craters are observed [e.g. 6] as a survey area (0N˚ - 60N˚, 90E˚ - 150E˚). Seven craters are selected to examine precisely according to the following criteria. 1) Settling alone. 2) The diameter is larger than 5 km, 3) Having clear view of outer lobe on THEMIS night images. We consider this as the indicator of the freshness. 4) Having enough accuracy on MOLA 1/128 deg. grid. Because MOLA grid data is

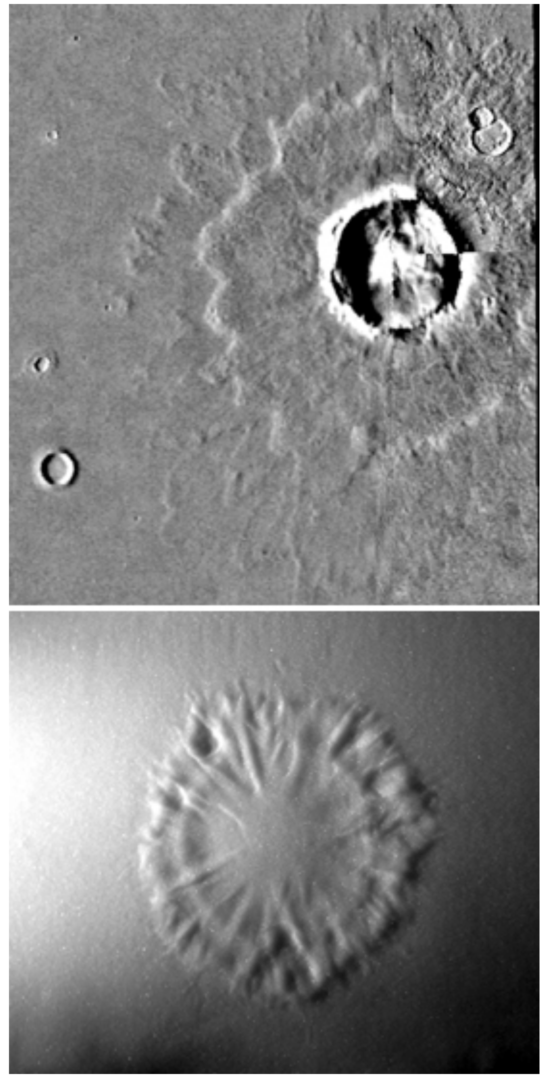

Fig. 1: (top) Viking MDIM 2.1 photomosaic of a Martian crater (33.2N˚, 118.4E˚) with about 24 km in diameter. (bottom) An example of surface morphology of the particle layer after the interaction by a vortex ring. The diameter of the morphology is about 15 cm. Although there is no crater cavity, double concentric ridges and sinuous outline are similar to the Martian ejecta qualitatively.

composed of MOLA PEDR data, the accuracy would be low where the coverage of PEDR orbit is low.

In the volume estimation of ejecta, it is the most important to determine the pre-impact surface. Up to now, it is only possible to determine the pre-impact surface by interpolating the topography of the surrounding area. Although many types of landforms are examined by means of several interpolation methods [*e.g.* 7], it is still unclear which method is best for a certain type of the surface. Here we report a slightly different approach. We use five different interpolation methods to determine the pre-impact surface (plane fitting, parabolic fitting, linear interpolation, minimum curvature surface interpolation, and Kriging interpolation) and select one or two practically "best" method in the following approach.

First we consider the surface roughness and the crater diameter would be the most effective parameters to estimate the pre-impact surface. We divide the survey area into 4 categories by the surface roughness [8]. On each category, we virtually draw the ejecta outline as an imaginary ejecta on the surface without large craters. Then we can interpolate the topography inside of the outline of the imaginary ejecta, and can compare the estimated topography with the actual topography to obtain the error. When we use the outline which is the same shape and size as that of a crater, we could obtain the error for the crater. Comparing thus-obtained errors among 5 different methods, one or two best one is selected.

The obtained results show that the volume of the inner lobe (even it includes the volume of uplifting of the pre-impact surface under the rim) occupies over 60% of total ejecta volume. In addition, the volume ratio of the inner lobe to the total ejecta would be proportional to the crater diameter, even the number of investigated craters is not enough. We discuss the possible models which could explain this result.

Experimental setup: In order to examine the erosion process, we set up the measurement system for the microtopography of the surface of the particle layer. The experimental setup consists of a water tank (40cm x 40cm, 47cm in height) with a vortex generator and an aluminum frame (60cm x 60cm, 90cm in height) encasing the water tank. Small fine particles (~ 200μm in diameter) are paved at the bottom of the water tank as a layer, and the tank is filled with water. The vortex generator, which is a cylinder (100mm in diameter) with an orifice (60mm in diameter), is placed on the top of the tank. The aluminum frame supports two linear actuators horizontally just above the water tank. The linear actuators are emplaced orthogonally as x- and y-axes. A photoelectric sensor is put on the x-axis actuator to measure the height of the top of the particle layer.

When the cylinder moves upward with a certain velocity, water flows out from the orifice and rolls up to develop a vortex ring on the edge of the orifice. Consequently, the vortex ring translates toward the particle layer and interacts to form the characteristic morphologies. The vortex ring first erodes the particle surface and entrains particles during the interaction [5]. Then radial flows of suspensions are formed by the collapse of the vortex ring. They propagate outward as a kind of gravity current. Finally the suspended particles fall down to form topography. In this series of the experiments, two dimensionless numbers based on particle scale (Reynolds number and Shields' parameter) fall within the same range as that of Martian craters [5]. Therefore, this interaction can be considered as the Martian analog. The linear actuators controlled by a computer scan the surface of the particle layer. When we compare the topography of the surface between before and after the interaction, we could obtain the volume of erosion and emplacement during the interaction between a vortex ring and a particle layer. We report the first results of the volumetric distribution associated with radial flows to compare ejecta morphology.

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