INVESTIGATING SURFACE SCOURING PROCESSES AND EJECTA DEPOSITION BY IMPACT GENERATED WINDS. A. Suzuki1 (ayako@eri.u-tokyo.ac.jp), O. S. Barnouin-Jha2, 3, I. Kumagai4, Y. Nagata5 and K. Kurita3, 1Earthquake Research Institute, 2Dept. of Engineering and Complexity Science, U. Tokyo, Japan, 3JHUAPL, Laurel, MD, 4Institut de Physique du Globe de Paris, 5Fac. of Engineering, Tokyo University of Agriculture and Technology.

Introduction: The Martian atmosphere and subsurface volatiles could both contribute to the formation of fluidized ejecta on Mars. In this study, we investigate the late stages of ejecta deposition and surface scour by atmospheric winds generated during an impact. We focus on both the mechanics of surface scour as well as transport of material generated by strong winds generated from an impact. We will emphasize both the formation of surface lineations in order to address their existence on pedestal craters [1, 2, 3, 4] (recently also called double layered ejecta (DLE) craters [5, 6]), and the mechanics of how such winds generate ground-hugging surface gravity currents.

We consider only the very late stages of ejecta emplacement, when a ring vortex produced by an ejecta curtain advancing into an atmosphere [7] becomes decoupled from the curtain to strike and erode the target surface. We decouple this vortex from the ballistic ejecta curtain by conducting experiments in a water tank, examining the interaction between a vortex ring and a layer of surface particles. Our results indicate that even present Martian conditions are sufficient to form surface lineations seen on fluidized ejecta of pedestal craters. These experiments also show that gravity flows resulting from plumes of particulates uplifted by the vortex ring help generate the fluidized appearance of ejecta when deposited by an atmosphere.

Experimental Approach: Many laboratory experiments examine the role of the atmosphere during impact cratering [7, 8, 9, 10]. These experiments consider primarily ejecta entrainment and transport processes, and to a lesser extent emplacement. Our experiments differ because they detail the late stage interactions between the impact-derived vortex ring and particles sitting on a surface. They are somewhat idealized in that they do not include prior entrainment and transport of ejecta before the arrival of a curtain-derived vortex ring on the surface.

Figure 1: A cross-sectional schematic view of the experimental setup. The downward displacement of the piston forces water through the cylinder, causing flow separation and the generation of a vortex ring.

Our experiments were carried out in a transparent rectangular tank filled with a mixture of water and sugar or salt, at the bottom of which we placed a layer of glass beads uniform in size (Figure 1). A vortex ring generator, which is composed of a piston and a cylinder, was placed at the top of the tank. The water is pushed through the cylinder by dropping the piston leading to flow separation at the edge of walls of the cylinder and subsequent generation of a vortex ring [e.g., 11]. The displacement length and velocity of the piston controls the flow velocity in the vortex ring. We vary this velocity and the ambient fluid conditions by mixing in sugar or salt into the water. We also change the size of the glass beads.

Each experiment is filmed with a high speed camera, and fluid motion is measured using Particle Image Velocimetry (PIV). After each experiment, we analyze the deposits created in the particle layer.

Results: We find that three surface morphologies are generated in the particle layer following interactions with a vortex
ring (Figure 2): (Mode 1) petal-like features and radial lineations formed as the vortex ring sweeps, lifts, transports and deposits the glass beads; (Mode 2) a circular erosion zone with few radial lineaments formed as the vortex ring only sweeps beads aside without lifting them; and (Mode 3) nothing happens as the vortex ring is too weak.

Figure 2: Three modes of vortex ring-surface interactions. Each column represents an oblique view of one mode (illuminated from upper right; black area is the shadow of vortex generator). Bright and dark area indicates regions of particle displacement. (Second row) Outlines of a circular erosion (red) and petal-like deposition zone (blue).

Our results indicate that these three styles of interaction between the vortex ring and the surface depend on the parameters we varied. All these variables can be expressed by two dimensionless numbers, \( \theta \) and \( Re \) (Figure 3). The variable \( \theta \) is the ratio of inertial resistance of the surrounding fluid to buoyancy acting on the particles in the surface layer [e.g., 12]. The Reynolds number \( Re \) is the ratio of inertial to viscous forces acting on these same particles. The greater \( \theta \) and \( Re \) the more likely Mode 1 occurs; the smaller these values the more likely nothing or Mode 3 occurs.

Our experiments also show how little gravity currents are generated by the particles uplifted in the vortex when Mode 1 occurs. These little plumes collapse under gravity to form flows akin to debris flows or powdery snow avalanches leading to a fluidized features.

Discussion: Figure 3 illustrates that the range of \( \theta \) and \( Re \) obtained in the laboratory is equivalent to those that can be achieved on Mars for winds ranging from 10-100m/s under current atmospheric conditions. Thus all three modes of vortex ring-surface interactions are possible on Mars. Consequently, some craters that possess finer ejecta may have lineations form, while others will not. Winds strengths could be another contributing factor.

While scour is expected only under some conditions, transport of material is expected under many impact conditions on Mars because, contrary to these experiments, the ring vortex already possesses entrained ejecta before it reaches a target surface. This material will be deposited as a gravity flow, as illustrated in these experiments in Mode 1.

Figure 3. Regime diagram of the experimental results between \( \theta \) and \( Re \) differentiating the various modes of vortex ring-surface interactions (see text). The red lines indicate Martian condition; positive slopes indicate the variation of wind velocity; negative slopes indicate the variation of particle diameter.