CAN A SHORT-LIVED, DEBRIS-FLOW-LIKE PROCESS FORM CURVILINEAR GULLIES, LOBATE DEPOSITS AND PITTED TERRAIN ON VESTA AND CERES? J. E. C. Scully(1), E. M. Carey(1), M. J. Poston(2), S. R. Baker(1/3), J. C. Castillo-Rogez(1) and C. A. Raymond(1). (1)Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (jennifer.e.scully@jpl.nasa.gov), (2)Southwest Research Institute, San Antonio, TX, USA, (3)University of Chicago, Chicago, IL, USA.

Introduction: Prior to the Dawn mission, Vesta was thought to be depleted in volatiles while Ceres was predicted to be volatile rich [1]. Ceres, with water ice and postulated clathrates, was confirmed to be volatile rich [e.g. 2-4]. Unexpectedly, the discovery of pitted terrain [5], curvilinear gullies and lobate deposits in vestan impact craters [6] indicated that Vesta, at least locally, might not be as depleted in volatiles as anticipated.

It has been hypothesized that localized deposits of subsurface water ice were heated by impacts, releasing liquid water onto the walls of newly formed impact craters [6]. This liquid water would not be stable, but was proposed to be transiently present for a sufficient time to form curvilinear gullies and lobate deposits via a debris-flow-like process (in a timescale on the order of tens of minutes). It is further suggested that vaporization of the liquid water led to the formation the pitted terrain [6]. Similar geomorphological features (e.g. pitted terrain) have been observed on Ceres [7]. We evaluate this hypothesis via laboratory experiments, which investigate the behavior of liquid water/brine under vestan/cerean conditions shortly following an impact (e.g. transient atmospheric pressures of ~10^{-4}-10^{-5} torr [8]).

Methodology – experimental set-up: We perform the experiments in the JPL Extraterrestrial Materials Simulation Laboratory (EMSiL)/Ice Physics Lab. The main components of our experimental set-up are: (i) a pre-existing 2.65 cubic-foot cryogenic vacuum chamber (main chamber), (ii) an antechamber and (iii) a large valve that connects the main chamber to the antechamber (Figure 1). The valve allows us to isolate the internal pressure of the antechamber from the main chamber. We place the sample container in the base of the antechamber, on top of a mass balance (Figure 2). Samples thus far have consisted of pure water, brine and pure water or brine mixed with glass beads.

During the experiments, we output the following data to LabView: (i) pressure from both chambers, (ii) temperature of the antechamber/sample, and (iii) mass of the sample. We also record video of the experiments through the top viewport of the antechamber (Figure 2). Three thermocouples are taped to the inside of the sample container, which report temperatures from the same depth in the sample container in each experiment. Pressure gauges monitor the pressures in the antechamber and main chamber throughout the experiment.

To reduce potential complications in interpretation caused by changes in ambient temperature, we use heat tape to keep the antechamber at a consistent temperature, slightly above ambient (~25°C). This temperature is representative of the hotter than average temperatures expected at the surface of an impact crater shortly after formation.

Methodology – experimental procedure: We prepare the experiment by pumping the main chamber down to 10^{-4}-10^{-5} torr by a combination of active pumping and cryogenic cold trapping on the shrouds in the main chamber. This effectively eliminates interparticle collisions on the size scale of our apparatus (mean-free-path greater than the distance between chamber walls) and simulates the transient atmospheric pressures expected on the surfaces of Vesta and Ceres shortly following an impact into a volatile-rich target.

We slightly decrease the pressure in the antechamber to degas the sample, so that dissolved atmospheric gases will not complicate our observations. We note that on Vesta and/or Ceres, dissolved gases may exist, and may inhibit or slow freezing, thus making our experiments a conservative case. The liquid water/brine in the sample container is stable at the pressures (~18 torr) and temperatures (~25°C) in the antechamber prior to initiation of the experiment. This simulates the stability of liquid water beneath the surfaces of Vesta/Ceres, after it was released from localized deposits of subsurface water ice by heating during the crater-forming impacts.

By opening the valve, we suddenly expose the liquid water/brine to pressures of 10^{-4}-10^{-5} torr, simulating the sudden release of the liquid(s) onto the crater walls. The liquid water/brine is not stable because conditions are near or below the triple point. We measure the time it takes for the liquid water/brine to evaporate/freeze, to test if liquid would be present long enough to form the curvilinear gullies and lobate deposits, before vaporization formed the pitted terrain. We test whether liquid longevity is effected by composition and the presence or absence of particles of varying sizes and shapes.

Initial results: *Pure water in the sample container*. The initial state of the sample, following degassing, is water in the liquid form. Once the valve to the main chamber is opened, the liquid water is at or below triple point conditions. Thus, it rapidly evaporates/boils and the liquid rapidly changes state to a solid and a gas. No liquid remains several seconds after the valve is opened: frozen liquid water is left in the sample container/antechamber and vapor migrated to the cold shrouds in the main chamber.

Brine in the sample container. The initial state of the sample, following degassing, is brine in the liquid form. To date, we have used NaCl brines at the eutectic concentration. Once the valve to the main chamber is opened, there is rapid evaporation/freezing of the top of the sample. However, in contrast to the pure water, freezing does not progress down throughout the sample: a solid lid forms on top of the brine, which remains liquid below. The solid lid initially appears to be water ice. The underlying liquid brine periodically breaches the solid lid, and freezes on the surface to become an opaque white solid. This opaque white solid appears brighter than the material that appears to be water ice, and it may be a NaCl hydrate. After ~55 minutes, all of the underlying liquid brine is gone, and the opaque white solid remains in the sample container. Upon returning to atmospheric pressure, the opaque white solid melts at -21°C, consistent with a eutectic NaCl-water mixture.

Pure water or brine mixed with glass beads in the sample container. The initial state of the sample, following degassing, is liquid water or brine mixed with glass beads (~20% liquid and ~80% beads) to simulate the debris-flow-like material that is hypothesized to form the curvilinear gullies and lobate deposits. The behavior of these samples does not significantly vary whether the liquid component is pure water or brine: once the valve to the main chamber is opened, rapid evaporation/freezing occurs, so that no liquid remains several seconds after the valve is opened. The rapid freezing is likely because the glass beads act as nucleation sites. The liquid behavior does not change significantly when pure water or brine is mixed with 297-420 µm, 595-841 µm and/or 1.1 mm diameter glass beads.

Initial conclusions and future work: A brine forming curvilinear gullies and lobate deposits is plausible on Ceres, because there are numerous salts available [e.g. 9] to mix with impact-melted water. For Vesta, we plan to investigate the possibility that water/rock interactions could also make limited amounts of salts/brines.

During the coming year, we plan to test brines made from other common cerean salts (Na_2CO_3, NH_4Cl). We will also develop a method to agitate the samples, which will be more analogous to the debris-flow-like process proposed to form the curvilinear gullies and lobate deposits, in which the material flows rather than remaining static. We hypothesize that agitating the sample will prolong the presence of the liquid water/brine.

We will also continue our geomorphological analyses of curvilinear gullies, lobate deposits and pitted terrain in specific vestan and cerean impact craters, to investigate whether there are additional geomorphological indicators for the presence of volatiles.

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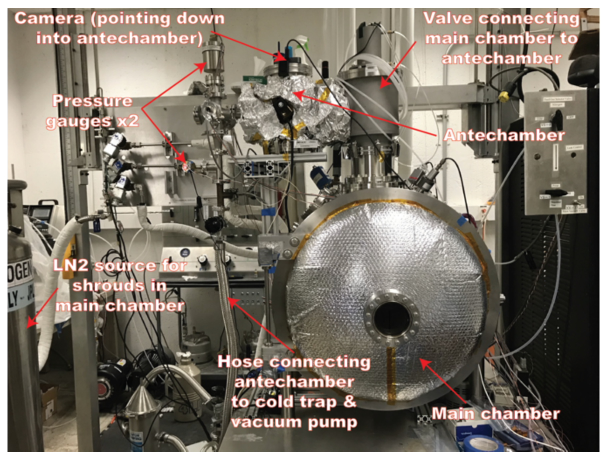

Figure 1. Side view showing the main components of the experimental set-up.

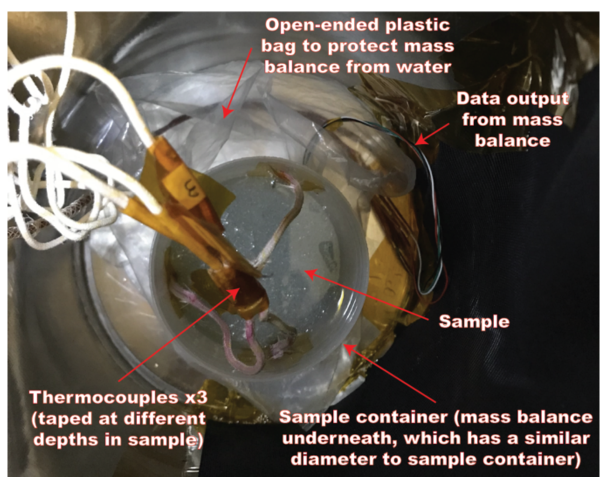

Figure 2. View through the top window of the antechamber, showing the sample container (6.5 cm wide).