PRELIMINARY CONSTRAINTS ON THE VOLUMETRIC CONCENTRATION OF SHALLOW GROUND ICE ON CERES FROM GEOMORPHOLOGY. H. G. Sizemore[1], T. Platz[1,2], N. Schorghofer[3], S. C. Mest[1], D. A. Crown[1], R. A. Yingst[1], D. A. Williams[4], P. M. Schenk[5], M. T. Bland[6], B. E. Schmidt[7], T. H. Prettyman[1] , M. C. De Sanctis[8], C. T. Russell[9], C. A. Raymond[10], and the Dawn Science Team. [1]Planetary Science Institute, Tucson AZ, USA (sizemore@psi.edu), [2]MPI for Solar System Research, Göttingen, Germany, [3]University of Hawai'i, Honalulu, HI, USA, [4]Arizona State University, Tempe, AZ USA [5]Lunar and Planetary Institute, Houston, TX, USA, [6]USGS Astrogeology, Flagstaff AZ, [7]Georgia Institute of Technology, Atlanta, GA, USA, [8]Istituto di Astrofisica e Planetologia Spaziali, INAF, Rome, Italy, [9]University of California Los Angeles, Los Angeles, CA, USA, [10]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction: Several lines of evidence indicate that Ceres may be a water-rich world [*1-6*]. Prior to the arrival of the Dawn spacecraft at Ceres it was anticipated that Ceres' regolith would be desiccated via sublimation to depths of a few to 100s of meters, and ice cemented at greater depth, with the shallowest ice occurring at the poles and the deepest ice occurring at the equator [*7,8*].

Moore et al. [*9*] proposed that sublimation is a solar-system wide geomorphological process that produces terrains characterized by pits and scarps resulting from internal disaggregation of relief-forming material through the loss of its cohesive matrix. Sublimation terrains are associated with sedimentary deposits of volatile-rich material on Mars, Io and Triton, and with non-sedimentary deposits Callisto [*9*]. Pits and hollows on Mercury and Vesta may also be linked to sublimation [*10, 11*]. By analogy with these bodies, we anticipated that similar terrains should occur on Ceres and that regional and/or latitudinal trends in the scale, style, and connectedness of these terrains could provide insights into the distribution and concentration of ground ice at depths not accessible to the Visible and InfraRed Imaging Spectrometer (VIR) or the Gamma Ray and Neutron Detector (GRaND).

Using Framing Camera (FC) data, we are carrying out searches for a variety of morphological features that are potentially diagnostic of the presence and concentration of subsurface ice based on analogies with Mars and the icy satellites. Here, we describe our preliminary global searchs for pits, scarps, and deflation features associated with sublimation (or more energetic gas-phase volatile loss). We make preliminary inferences about the volume fraction of water ice contained in the Cerean regolith, and describe investigations planned for the duration of the mission at Ceres.

Feature Observations: *Overview.* Contrary to expectations, no clear morphological evidence for sublimation or gas phase volatile loss was identified in data acquired during Survey Science Orbit (400 m/px). Limited evidence for pits and deflation was identified in High Altitude Mapping Orbit (HAMO) data (140 m/px). Low Altitude Maping Orbit (LAMO) images (35 m/px) that are becoming available at the time of this writing are expanding the number of identified features, but geographic trends have not emerged for new features at the current stage of analysis.

Pits. The least ambiguous features identified by our search to date are clusters of pits occurring in smooth crater floor materials and smooth ejecta deposits (Fig. 1). These pits are circular to irregular in plan form, and are distinguished from impact craters by their irregularity, their interconnectedness, and their occurance in clusters on smooth materials with low background crater density. In some cases, pit clusters are proximal to lobate flows, and/or follow curvilinear patterns in smooth material (Fig. 2). We identified pit clusters and suspected pit clusters at four locations on Ceres using HAMO data. Early LAMO images suggest that the number of identifications will soon increase substantially. In most features analysed to date, raised rims are not apparent. Distinguishing pits produced by sublimation from impact craters will be an ongoing concern as more candidate features are identified and classified on older terrains. Adding to this ambiguity, some pits associated with smooth crater floor materials may exhibit rims due to rapid post-impact outgassing [*e.g.,12*].

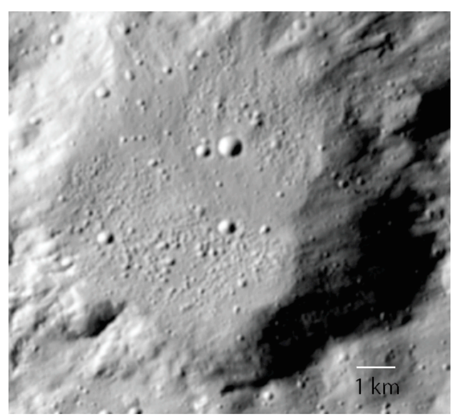

Fig. 1. LAMO image of pit clusters in smooth crater floor material.

Scarps. No arcuate scarps clearly distinguishable from crater rim materials were identified in HAMO images. Two candidate features have been identified in LAMO images at the time of this writing.

Deflation. We have identified several candidate locations for landscape deflation in HAMO images. Some high latitude cratered regions on Ceres show textural similarities to deflated terrains on Callisto [*13*], but detailed crater counting will be necessary to determine if there is a deficit of small craters in these regions and if an analogy to Callisto is appropriate. Likewise, an extended smooth region north of Urvara crater may reflect deflation of volatile-rich ejecta; a large curvilinear trough transecting this region may have formed in part via the expansion of individual craters in a chain of secondaries. However, classical pits and scarps are absent in the Urvara region and detailed mapping is necessary to test a deflation/sublimation interpretation. Finally, early LAMO images also indicate that individual lobate mass wasting features [*14*] may show some signs of deflation.

Locations of interest. Concurrent global searches for a range of morphologies indicative of ground ice have identified two groups of features whose locations will be scrutinized for evidence of sublimation during LAMO. Schmidt et al. [*14*] described three classes of lobate flows, whose morphology exhibits weak latitudinal trends. As noted above, some flows show evidence of deflation and disaggregation. LAMO Cycle 0 and Cycle 1 images indicate that the number of identified flows will soon increase dramatically, allowing comparative studies of the age and degredation of these flows. Additionally, Sizemore et al. [*15*] identified 29 large domes (1-5 km relief, 10s to >100 km diameter) that may have intrusive or extrusive origins. At the time of this writing, two of these domes have been examined in LAMO images; no clear evidence of sublimation was found.

Discussion: Pits, arcuate scarps, and deflation are surprisingly rare and localized in Ceres images analysed to date, given theoretical predictions of abundant shallow ice. One possible explanation is that impact structures, which dominate the surface morphology, destroy or obscure pits and scarps. Although mid- and low-latitude sublimation rates of order 10s of m/Gyr outstrip the impact gardening rate of ~10 cm/Gyr [*16*], a small number of individual impacts could visually disrupt scarps and pits 10s of meters deep. Another possible explanation is that salts (possibly abundant in the regolith) are left behind when ice sublimates, and may increase the mechanical strength of the desiccated lag in the manner of terrestrial and martian duricrusts [*17*], slowing disagregation. A final explanation is that the volume fraction of ice in the upper 10s to 100s of meters of the subsurface may be low (<50%), so that loss of ice does not compromise the volume or mechanical strength of desiccated material.

All of these scenarios likely contribute to the paucity of identified features. Despite the ambiguity introduced by impact processes, the lack of multikilometer scale pits and scarps makes it *unlikely* that ice is volumetrically dominant in the upper 10s to 100s of meters of the Cerean subsurface over large regions. Our results are most consistent with ground ice typically filling or *under-filling* pores in a regolith mechanically supported by mineral grains, with localized areas of higher volumetric ice concentration. This conclusion is consistent with analysis of crater relaxation [*18*], as well as early LAMO results from GRaND [*19*] and VIR [*20,21*]. Continued analysis in LAMO will place additional constraints on the concentration and geographic distribution of ice.

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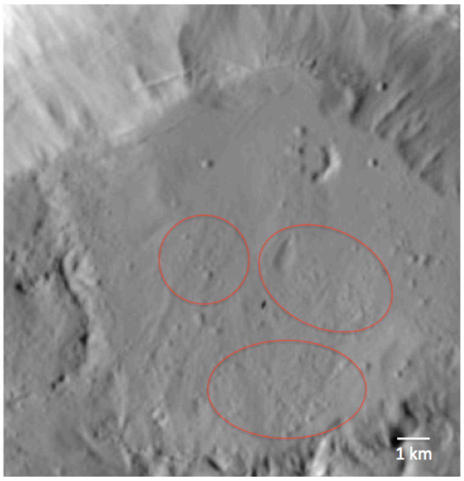

Fig. 2. LAMO image of pit clusters in Kupalo crater. Pits are associated with sinuous patterns on the smooth crater floor material. Lobate flows are visible in the upper right hand corner.

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