FORMATION OF THE NORTHERN PLAINS LOMONOSOV CRATER DURING A TSUNAMI GENERATING MARINE IMPACT CRATER EVENT.

F. Costard[1], J.A.P. Rodriguez[2], A. Séjourné[1], A. Lagain[1], S. Clifford[3], K. Kelfoun[4], F. Lavigne[5], I. and S. Bouley[1], [1]GEOPS-Géosciences Paris Sud, Université Paris-Sud, CNRS, Université Paris-Saclay, 91405 Orsay, France. francois.costard@u-psud.fr, [2]Planetary Science Institute, Tucson, Arizona, [3]Lunar and Planetary Institute, Houston, Texas, [4]Laboratoire Magmas et Volcans, OPGC, Clermont-Ferrand, France. [5]Université Paris 1, Laboratoire de Géographie Physique, Meudon, France.

Introduction: The hypothesis that the northern plains may have been covered by a Late Hesperian ocean remains one of the most interesting and controversial discoveries in Mars exploration. Evidence of the potential occurrence of impact-generated tsunamis, including the observation of widespread sedimentary lobes (Thumbprint Terrains) and associated backwash channels along the dichotomy boundary, has been recently documented [1-3]. These results further support the ocean hypothesis. The formation of Lomonosov Crater (Fig. 1), which is located in northern Acidalia Planitia, likely produced the proposed tsunami event [2]. The geomorphology of a marine impact crater have been investigated [4, 5]. However, the resurfacing effects of tsunami waves remain poorly constrained.

Here, we present the results of an on-going study of the Lomonosov Crater as a potential marine impact crater. Our investigation includes the production of a highly detailed geologic map of Lomonosov (1: 250,000 scale). Also, we are developing new numerical models, which combine high spatial (cell area 10 km^2) and temporal (millisecond scales) resolution. The mapping and the modeling will allow us to investigate in detail the evolution of the impact generated ocean cavity, and its effect on the crater's landscape. Our results will provide the first set of diagnostic geomorphic criteria for the identification of tsunami-forming impact events.

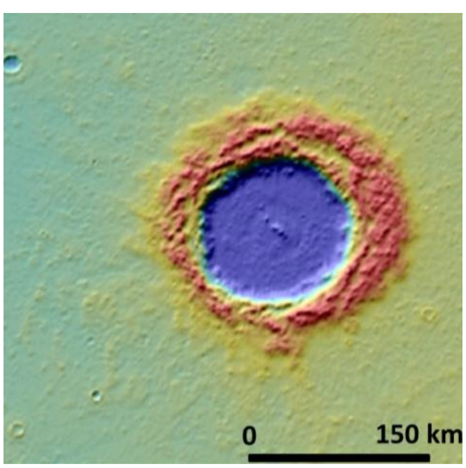

Figure 1: View of Lomonosov crater (MOLA DTM) at 50.52°N/16.39°E. Courtesy of NASA/JPL/USGS.

Lomonosov crater as a unique Martian marine impact crater: Lomonosov crater is a ~150 km diameter impact crater characterized by a double rim and a relatively small central peak area. The crater's south-western periphery appears highly eroded (Fig. 1). Of particular interest is the observation of a set of valleys in its southern rim area (Fig. 2). Numerical models [1, 2] indicate that Lomonosov crater was likely produced by an impact into a shallow ocean (≤ 1km deep). These numerical results suggest that the crater was significantly affected by the collapse of an impact generated ocean cavity.

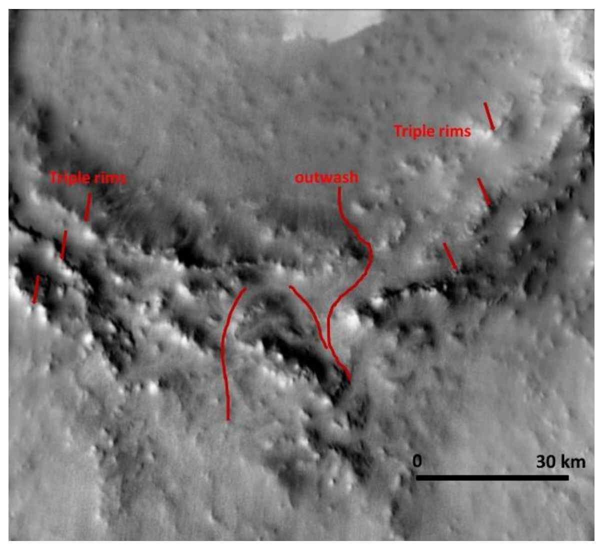

Figure 2: The southern rim of the Lomonosov crater showing various structural landforms cut by potential inflow paths (in red). Courtesy of NASA/JPL/USGS.

Understanding the evolution of an impact-generated transient ocean cavity: There are several unknowns regarding the hydrodynamic evolution of impact generated transient cavities -- including the direction, thickness, velocity, and geometry of inflowing water during the cavities' collapse. We plan to numerically simulate these to determine the wave's effect on the impact crater's overall shape. Our approach will build upon the modeling of a parabolically-shaped transient cavity [2]. Previous numerical modeling [6-7] provided the first hydrodynamic descriptions of the tsunami wave propagation from a marine impact crater on Mars. However, in their models, the temporary cavity was mathematically meshed as a cylinder, which is an unrealistic geometry, and thus the modeling component of the backflow phase was overly generalized. Our new modeling approach [e.g., 8, 9] will permit the integrated analysis and synthesis of the effects that the ocean depth, gravity, and regional slope have on both the resulting shape of the impact transient cavity and the detailed hydrodynamics of the inward flowing water.

Preliminary Results: Investigations of marine impact craters on Earth reveal that their rims were affected by the inward collapse of the transient cavity and modified by the erosion from the inflowing water [4, 5, 10]. The long travel distances to the Lomonosov crater's center from the cavity walls (~100 km) suggest that there could have been significant changes in the geometry of the collapsing transient cavity. Our preliminary results indicate that the SW rim was modified in this way, where we have identified potential rim overflow erosional paths as well as broader structural alignments consistent with a preferential gravitational collapse of the SW wall (Fig. 2).

Crater counts methods and results: Dating of the proposed tsunami lobes is well-constrained in time to the Late Hesperian and Early Amazonian boundary [1-3]. The age spread is most likely due to various degrees of younger resurfacing by wind and periglacial processes [11]. The late Hesperian is also the timing of peak outflow channel activity, and thus it is consistent with the presence of a transient northern ocean ~3 Ga [12].

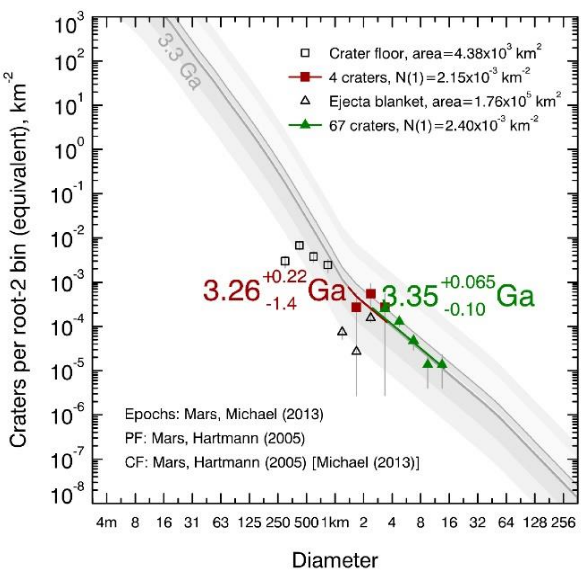

Figure 3: Dating of the ejecta blanket and the crater floor of Lomonosov crater with Hartmann (2005) chronology system.

The crater size-frequency distribution measured on the crater floor was performed for craters with diameters larger than 350 m and on the ejecta blanket for craters with diameters larger than 2.5 km in diameter. The results indicate that this crater formed during the Late Hesperian ~3.3 Ga (Fig. 3), which is consistent the Thumbprint Terrains lobes dating [1-3, 11].

Summary: From our geomorphological and numerical studies, the Lomonosov crater appears to be an excellent candidate for a marine impact crater. Shortly, we will look for further evidence of erosion associated with the inflow of water during the collapse phase of the ocean transient cavity. The southern rim asymmetry might reveal new details in higher resolution datasets. We plan to more precisely compare the rim morphology to the backwash pattern from numerical modeling. Furthermore, to refine the diagnostic morphologic criteria, we will conduct numerous high-resolution simulations to match the fine-scale geology. Not just in bedform patterns, but also in mass distributions. The knowledge gained through this mapping will serve as the basis to look for other similar impact craters throughout the northern plains. We are conducting a more extensive search for such craters using HiRISE images, which reveal the crater's geomorphologic characteristics at the highest spatial scales.

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References: [1] Costard F. et al. (2017) *48th LPS abstract* #1171. [2] Costard, F. et al. (2017) *JGR Planet*, in review. [3] Rodriguez J.A.P. et al. (2016) *Scientific Reports*, 6, 25106-1788. [4] Ormo J. et al. (2002) *J. Geophys. Res.*, 107(E12), 5120. [5] Shuvalov, V. V., and I. A. Trubestkaya (2002), *Sol. Syst. Res.*, 36, 417–430. [6] Matsui T.I. et al (2001) *LPS XXXII*, 1716-1717. [7] Iijima, Y. K. et al. (2014) *Physical Processes in Geology*, 576. [8] Kelfoun, K. and Druitt T. H. (2005) *J. Geophys. Res.*, *110*, B12202. [9] http://lmv.univ-bpclermont.fr/volcflow/. [10] Melosh, H. J. (1989) *Impact Cratering: A Geologic Process*, 245 p. [11] Tanaka K.et al. (2014) *Geologic map of Mars* 3292. [12] Clifford, S. M., and T. J. Parker (2001), *Icarus*, 154, 40–79.