ORIGIN OF CLOSELY-SPACED GROUPS OF PITS IN MARTIAN IMPACT CRATERS:

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Introduction: We propose a model for the formation of the closely-spaced pits found in thin, ejecta-related deposits superposed on well-preserved Martian impact craters (Fig. 1). Following the initial discovery of these deposits [1], higher-resolution images [2 - 6] imply that they are a facies of impact ejecta; probably impact melt-rich breccia or suevite. [2 - 4] proposed that the pits are collapse features produced by escape of water from pockets, or ice from lenses well after deposition of this material. In contrast, [7] suggests that the pits are produced by sublimation of ice distributed more evenly throughout these deposits. However, these models are inconsistent with many characteristics of the pits and pitted material.

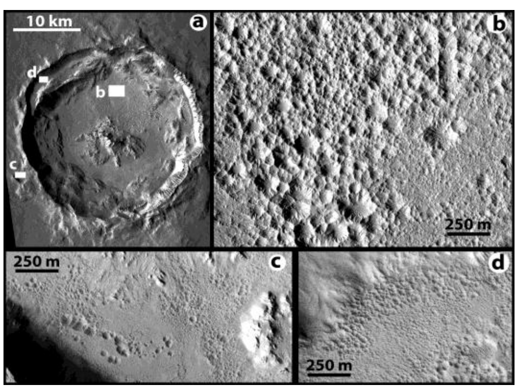

Fig. 1: Example locations of pitted material at Tooting Crater (a), on its floor (b), exterior rim (c), and terrace block (d).

Approach: Our model utilizes previous work by many others on degassing behavior of pyroclastic materials during their transport, deposition, and cooling. We suggest that pyroclastic materials provide the best analog to Martian suevite because they both are composed of initially hot, water-bearing, silicate clasts possessing a wide size distribution. As a result, their degassing behavior should be generally similar, as well as the consequences of the escaping gas.

Our model predicts the explosive degassing of water from the hot suevite. This degassing process is analogous to what happened at the fall-out suevite at Ries Crater in Germany where impact heating of water-bearing target material resulted in the rapid degassing of their water [8]. The Martian environment plays an important role in enhancing the effects of this degassing by increasing the flow-speed of the escaping gas. The high flow-rate of gas through particulate materials, such as pyroclastic deposits, tends to quickly form segregation channels or vent pipes, similar to those found in the Ries fall-out suevite [8]. These pipes act as conduits for the efficient high-speed escape of the gas and entrained clasts from these deposits.

Results and Discussion: Using the pitted material on the floor of Tooting crater (~ 27 km dia.) as a test, we calculate that the gas-flow speeds through the vent pipes could readily exceed 300 m s^{-1} at the vent, but may be as high as 410 m s^{-1}. At these rates, the gas supply would be expended in a few days. In addition, these gas-flow speeds are easily high enough for collisions by gas and entrained clasts with vent pipe walls to cause substantial abrasion, erosion, and flaring of the vents near the surface. This would produce the observed pits, and eject particles as large as a few centimeters in diameter to extraordinary distances (i.e., tens of km [9]), leaving little trace of them around the rims. Fine particles ejected from these vents are likely to be carried upward by the escaping hot steam to form a turbulent, convecting cloud above the deposit. This cloud would interact with the atmosphere at its outer edges, sharing all the properties of the fine ash plumes that form over pyroclastic density currents to produce co-ignimbrite fall deposits. But, depending on local conditions, the fine clasts in the plumes could be blown sideways by the wind, and settle well outside the crater.

Our model also provides an explanation for why isolated pits commonly exhibit low, raised rims, while pits in closely-spaced groups typically lack rims that rise above the surrounding terrain [4], and also form in a pattern that resembles a 2-D cross-section through soap froth [10]. In the case of solitary Martian pits, we suggest that, like the hydroeruption pits (Fig. 2) at Mt. St Helens volcano [11], the high-speed erupting gas, and clasts would produce ejecta deposits with subdued morphology.

In the case of the closely-spaced pits, we suggest that the simultaneity of their eruption is a key factor in producing both their observed rim morphology, and their spatial geometry. This is because pits may grow so large that their rims intersect rims of adjacent pits. With continued eruption, and pit widening, an equilibrium point would be reached where outward enlargement of an individual pit is counterbalanced by growth of the adjacent pits. After this equilibrium is reached, and as eruption continues, all but the coarsest fraction of particles in the ejecta are likely to be removed from around the pits by the high-speed ejection of material from the pit, and adjacent pits. As a result of this intense erosional environment, raised rims are inhibited from forming between closely-spaced pits, instead forming only relatively straight, low ridges (i.e., rims) at the equilibrium distance between the pits. These ridges should be composed dominantly of coarse-grain clasts such as those described by [2 - 4].

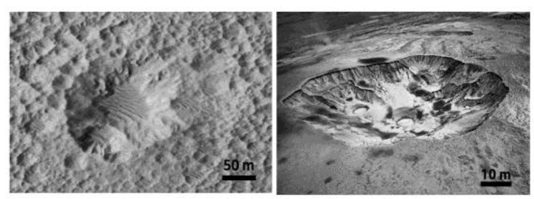

Fig. 2 Left, an oblique view of a large pit in the floor of Tooting Crater. Right, a large hydroeruption pit at Mt. St. Helens volcano that has a similar morphology (caused by explosive degassing of water from pyro-clastic flows deposited over a wet surface).

References: [1] Mouginis-Mark, P. et al., 2003, Int. Mars Conf. VI, Abst. 3004; [2] McEwen, A., et al., 2007, Science 317, 1706-1709; [3] Tornabene, L., et al., 2007, Int. Mars Conf. VII, Abst. 1353; [4] Tornabene, L., et al., 2011, submitted to Icarus; [5] Mouginis-Mark, P., & Garbeil, H., 2007, Meteorit. Planet. Sci. 42, 1615–1625; [6] Morris, A., et al., 2010, Icarus 209, 369–389; [7] Hartmann , W., et al., 2010, Icarus, doi 10.1016/j.icarus.2010.03.030; [8] Newson, H., et al., 1986, JGR, 91, B13, E239-E251; [9] Wilson, L., & Head, J., 2007, J. Volcanol. Geotherm. Res. 163, 1-4, 83-97; [10] Glazier, J., & Weaire, D., 1992, J. Phys. Cond. Matt. 4, 1867-1894; [11] Moyer, T. & Swanson, D., 1987, J. Volcano. Geotherm. Res. 32, 299-319.