PHYSICAL MODELS OF PIT CHAIN FORMATION OVER DILATIONAL FAULTS ON MARS. D. W. Sims[1], A. P. Morris[2], D. A. Ferrill[1], D. Y. Wyrick[1], S. L. Colton,[1] CNWRA, Southwest Research Institute® (6220 Culebra Road, San Antonio, TX 78238, USA, dsims@swri.edu), [2] Department of Earth and Environmental Sciences, University of Texas at San Antonio, San Antonio, Texas, 78249, USA

Introduction: Pit craters are collapse features that are circular, elliptical or corrugated in plan view and frequently occur as alignments (pit chains) in the highlands of the western hemisphere of Mars. Pit chains are often associated with extensional faults, particularly bounding graben structures. Pit chains may consist of aligned individual pits or overlapping pits that produce troughs with irregular scalloped walls. Numerous mechanisms have been suggested for pit chain formation that implicitly require creation of void space at depth, including deep fissuring in response to crustal extension [1]. Ferrill et al. [2] show that steeply dipping to vertical dilational faulting in consolidated rock is likely to occur as a response to crustal extension on Mars, possibly to depths of 5 km, resulting in the creation of significant tabular void space. We test dilational faulting as a mechanism for pit chain formation using analog methods. Results show that all pit chain morphologies observed in Mars imagery may be produced by collapse of weak material over continuous or discontinuous vertical tabular voids at depth.

Methodology: We use dry sand as an analog for the shallow deposits that host pit chains, and mobile rigid plates and/or cohesive powders to produce tabular void spaces (fissures) at depth. Although surface regolith on Mars is sufficiently weak to collapse into voids below, imagery of exposures in pit walls indicates layered inhomogeneities in surface material. Vertical or near-vertical pit walls are not observed within the limits of Mars image resolution, indicating that surface regolith has low cohesive strength and is analogous to poorly or unconsolidated surficial deposits on Earth. The ability of Mars regolith to transmit tensile stresses appears negligible, and behavior under stress should be rate independent under likely conditions of pit formation. Dry sand is a suitable analog for Mars regolith, having a low cohesive strength, an angle of repose of approximately 30° [3], and is strain rate independent.

Open fissures with steep walls demonstrate that rock beneath the regolith is more cohesive and has elastic strength. The prevalence of basalt on the surface [4] indicates that the crust of Mars likely consists of rock with similar strength characteristics [2], [5]. Our models are not sensitive to substrate type and test only the applicability of tabular void formation to pit chain genesis. For convenience, we use constant thickness (1–3 cm) rigid wooden or aluminum plates and/or a layer of cohesive powder to represent dilating fissures at depth. The aluminum plates form linear, smooth boundaries, whereas wooden plates provide boundary irregularities. Plates are initially edge-to-edge, and tabular voids are created by separating the plates in increments of approximately 0.1 mm. In some experiments, a constant thickness layer of cohesive powder is used in place of or in combination with rigid plates. The cohesive powder will support steep to near vertical walls under small loads, and serves to form voids with an irregular trace in plan view. In early stages of void formation, this powder forms discontinuous *en echelon* segments that later link to form a through-going dilational fault. The resulting fault trace is slightly irregular or corrugated [6], similar to faults observed on Earth and Mars. Although the cohesive powder may be partially representative of behavior that is transitional between the non-cohesive surface regolith and cohesive rock at depth, its primary purpose is to provide some morphology to the tabular void. A near constant-thickness (0.5 mm) layer of dry white or dyed sand (poorly sorted within grain size range 180–500 microns) representing Mars regolith is placed over the adjacent plates and/or cohesive powder layer. In our models, the minimum amount of displacement or dilation necessary for the formation of collapse features (range from 0.3 to 1.0 mm) is controlled by grain size of the sand and does not accurately scale to displacements in the crust of Mars. Rather, the analog models are intended to replicate the general behavior and geometric evolution of Mars collapse features.

Results: Modeled pit chains follow a uniform developmental sequence from individual circular pits of varying size to elongate pits that intersect to form continuous troughs. In the first stage, individual pits of varying size form in alignment (Fig. 1). Pit spacing may be variable or regular. In the second stage, individual pits grow by increasing radius or length, and new pits continue to develop. In the final stage, intersecting pits link to form elongate troughs with irregular edges that can resemble narrow grabens (Fig. 2). Each stage of development may be present simultaneously along a single chain. Model pit chains tend to form somewhat irregular map traces, even where formed over parallel rigid plates. In some experiments, pit formation is preceded or accompanied by the formation of elongate grabens. In such cases, pit formation is usually along a single bounding fault (Fig. 3).

Conclusions: Most pit chain morphologies observed on Mars, including (i) chains of isolated circular or irregularly shaped pits, (ii) elongate pits, (iii) pit chains grading to troughs along trace, and (iv) pit chains along graben bounding faults, are reproduced in physical models of dilational voids opening under low cohesion material representing regolith. In each case, pit chain formation follows a progression from (i) isolated aligned circular pits, to (ii) isolated irregular or elongate pits and continued formation of new pits, to (iii) elongation of pits by growth and coalescence to form interspersed pits and discontinuous troughs, to (iv) elongate troughs that may appear as narrow grabens along the entire length of the buried dilational fault or fissure. During the formation of a single pit chain, all stages of development may appear simultaneously prior to the formation of a through-going trough.

References: [1] Tanaka, K. L., and Golombek, M. P. (1989) *Proc. Lunar Planet. Sci. Conf. 19*, 383–396. [2] Ferrill, D. A. et al. (2002) *Geol. Soc, Am. Abstr. Prog. 34(6)*, 82. [3] Lucchitta B. K. et al. (1992) in *Mars*, Univ. Arizona Press. [4] Gornitz, V. (1997) in *Encyc. Planet. Sci.*, 441–450. [5] Schultz, R. A. and Lin, J. (2001) *J. Geophys. Res. 106 (B8)*, 16,549–16,566. [6] Ferrill, D. A. et al. (1999) *J. Struct. Geol. 21*, 1,027–1,038.

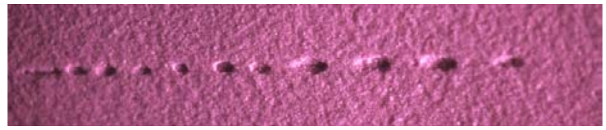

Fig. 1. Model pit chain consisting of circular and elongate pits. Illumination from right. Image width is approximately 17 cm.

Fig. 2. Image showing slightly irregular trace of model pit chain. Trough at right consists of intersecting pits. Illumination from lower right. Image width is approximately 18 cm.

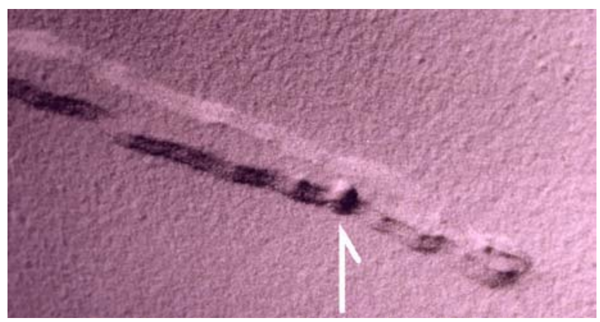

Fig. 3. Image showing pits (white arrow) developed in bounding fault of extensional graben. Graben bounding faults show corrugated trace produced by linking of originally en echelon fault segments. Illumination from lower right. Graben width is approximately 1 cm.