PIT CRATER CHAINS: EVIDENCE FOR SUBTERRANEAN TECTONIC CAVES. D. Y. Wyrick[1] and D. L. Buczkowski[2], [1]Southwest Research Institute, San Antonio, TX, USA (danielle.wyrick@swri.org), [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA (Debra.Buczkowski@jhuapl.edu).

Introduction: Pit crater chains are surface features comprised of linear assemblages of collapsed depressions that are identified on several solid bodies throughout the Solar System. On Earth, they have been observed to form when dilational motion on normal faults causes the overlying materials to collapse into the dilating segment of the buried fault [1, 2]. It has been hypothesized that pit crater chains observed on Mars [1], Enceladus [3], and various asteroids [e.g. 4: *See Buczkowski and Wyrick, this meeting*] formed by the same process. Dilational fault movement can also create subsurface permeability pathways for fluid/volatile transport and trapping [5,6,7], thus studying pit crater chains and tectonic caves on planetary bodies has implications for both in situ resource utilization and astrobiology, and should be consider as a potential driver for determining exploration targets.

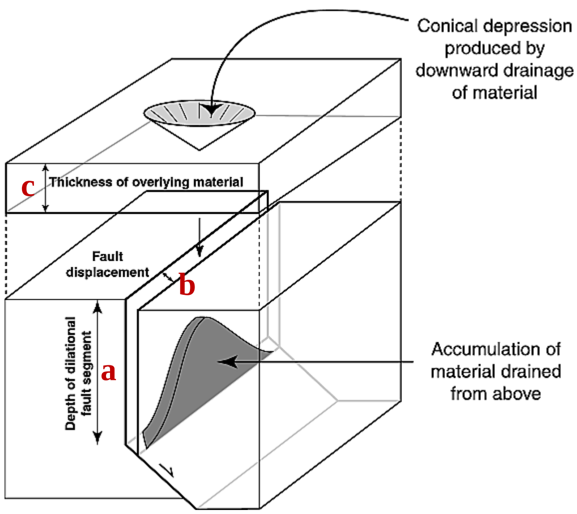

*Figure 1. Schematic illustration from [1] demonstrating dilational faulting. Pit volume is a function of (**a**) depth of the dilational fault segment, (**b**) increased displacement along the fault, or (**c**) the thickness of the overlying unconsolidated material.*

Dilational Faulting and Pit Crater Chains: Dilational faulting can occur on normal faults that traverse mechanically strong stratigraphic layers, or where hybrid mode failure (Mode I opening combined with either Mode II sliding and/or Mode III tearing) occurs under low differential stress [8]. Where the stratigraphy varies from mechanically strong rock to mechanically weak layers, the fault dip will also vary, creating steep vertical fault segments. Under such conditions, a void is produced in the subsurface, into which overlying unconsolidated or mechanically weak material can drain (Fig. 1) producing chains of pit craters [1]. The pit volume is a function of several factors, including the depth of the dilational fault segment, the degree of fault displacement along the fault, and the thickness of the overlying weaker stratigraphic layers. Subterranean void space can be estimated by calculating the volume of the overlying pit crater chain volume [1], as this represents the minimum volume of subsurface void space that must be available to accommodate the collapsed material. (Fig. 1).

Dilational Fault "Caves": Pit crater chains on Earth have been observed forming over dilational normal faults (Figs 2,3), illustrating the large volume of void space that exists in the subsurface beneath these surface features. These same terrestrial dilational faults become permeability pathways for groundwater flow and storage (Fig 2), suggesting that similar features observed on other planetary bodies may also provide volatile and fluid transport and potential reservoirs. On Mars for example, outflow channels have been mapped directly emanating from pit crater chains, which are interpreted to have been structurally controlling the groundwater in the region [9]. Understanding these structural controls on groundwater (and other volatiles) is critical toward understanding what resources may be available both for astrobiology and future human exploration. Very few endogenic geologic processes operate across-the-board on such a wide variety of planetary bodies with disparate lithologies and geologic histories. The identification of pit chains on these wide ranging bodies – from small asteroids to icy moons to large terrestrial planets – raises important questions regarding the near-surface crustal properties of solid bodies in our solar system and their capacity to store vital resources. The ubiquitous nature of pit crater chains makes them an easily identifiable target on many planetary bodies that may provide a peek into the subsurface.

Implications: Understanding the relationship between pit crater chains, dilational faulting and subsurface voids space will be critical in future solar system exploration. Dilational faulting, and the tectonics caves they can produce, have direct implications for the transport and storage of volatiles and fluids in the lithosphere on Earth. Pit crater chains on Mars appear to have also provided permeability pathways for groundwater, and may be regions of ground ice storage. Similarly, pit crater chain identification on the moon and other small bodies suggest that there may be significant subsurface void space to sequester volatiles and ices. Because pit crater chains are a more easily observed surface feature, they can serve as good proxy indicators of subterranean cavernous voids. With better constraints on the relationship between these features, we will gain a better understand of where to pursue in situ resources and look for habitable zones in the solar system.

References: [1] Wyrick, D. et al. (2004) *JGR 109*(E6) doi:10.1029/2004/JE002240 [2] Ferrill D. A. et al. (2011) *Lithosphere*, *3*(2), 133–142. doi:10.1130/L123.1 [3] Whitten J. L. and Martin E. S. (2019) *JGR* [4] Buczkowski D.L. and Wyrick D.Y. (2014) *Volcanism and Tectonism Across the Inner Solar System*, VolTecSS-867 [5] Randolph, L. and Johnson B. (1989) GSA Abs. w/ Program, 21, 242 [6] Scholz C.H. and Anders M.H. (1994) The mechanical involvement of fluids in fault-ing: U.S.G.S. Open-File Report 94-228, 247–253 [7] Caine J. S. et al. (1996) Geology, 24 (11), 1025–1028. doi: 10.1130/ 00917613(1996)024<1025:FZAAPS> 2.3.CO;2 [8] Ferrill D.A. and Morris A.P. (2003) *JSG 25*, 183–196 [9] Coleman N. et al. (2007) Icarus, 189, doi:10.1016/j.icarus.2007.01.020.

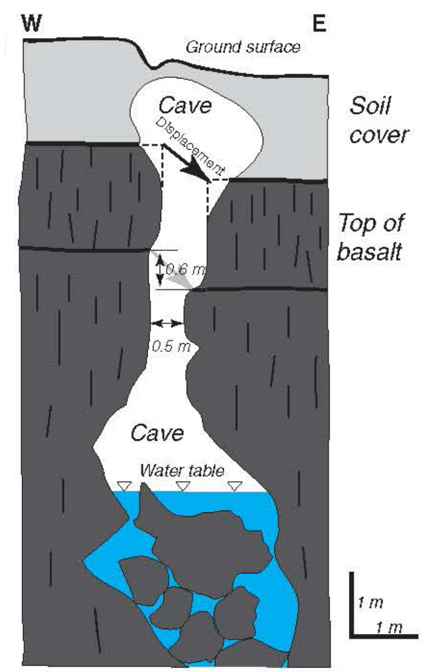

Figure 2. Schematic cross-section of a tectonic cave associated with a dilational fault segment as shown in figure 3 (from [1]).

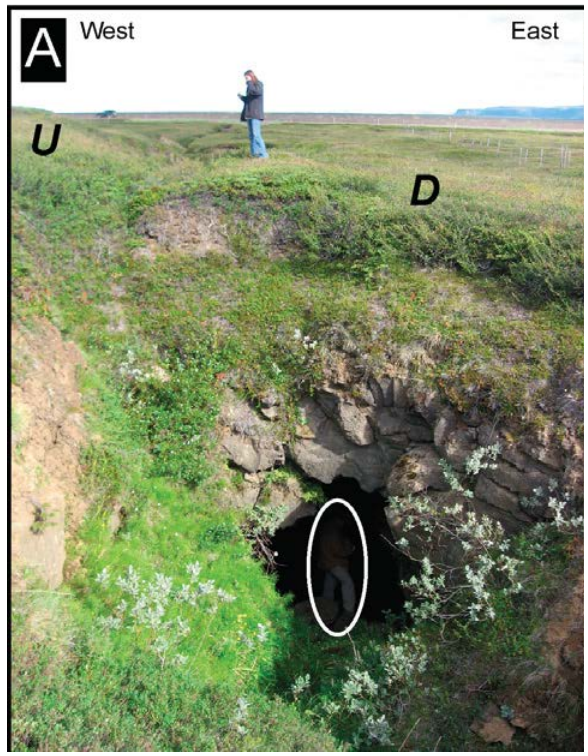

Figure 3. Image from [1] showing a pit crater chain in Iceland. Note person at surface mapping pit crater while person (white oval) maps the subsurface dilational fault segment.

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