SPATIAL AND TEMPORAL RELATIONSHIPS OF PIT CRATERS AND GRABEN WITHIN NOCTIS LABYRINTHUS, MARS. Corbin L. Kling[1], Paul K. Byrne[1], Danielle Y. Wyrick[2], and Karl W. Wegmann[1], [1]Planetary Research Group, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 2800 Faucette Drive, Raleigh, NC 27695, USA, [2]Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78238, USA.

Introduction: A geomorphologically complex and relatively understudied region on Mars, Noctis Labyrinthus is situated between the Tharsis Rise and Valles Marineris, and is characterized by a set of polygonal mesas that are bounded by troughs interpreted as graben (**Figure 1**). In addition to normal faulting, the region hosts numerous pit craters (near-circular or elongate depressions that are volcanic and/or tectonic in nature) that often occur inside and/or aligned with the graben.

Previous studies of Noctis Labyrinthus focused only on specific aspects of the region, such as the normal faulting therein, or on the organizational structure of the pit craters [1,2]. Here, we describe preliminary results of a project in which we incorporate observations and measurements of both the pit craters and normal faults in Noctis Labyrinthus, to determine the spatial and temporal relationships between the two types of structures, as well as how they pertain to the formation of this region of Mars.

Graben: A graben is formed when two steep, inward-dipping (i.e., antithetic) normal faults create a downdropped block between them. These downdropped blocks are normally manifest as long, relatively straight, trough-like depressions that can extend for tens to hundreds of kilometers. Within Noctis Labyrinthus, there is an abundance of graben oriented dominantly N–S between 0°N and 5°S, which transition to progressively more E–W orientations from 5°S to 15°S (**Figure 1**).

We classified the graben in Noctis Labyrthinus into separate populations on the basis of cross-cutting relations and structure orientation (i.e., strike). This approach resulted in the identification of three graben sets. The northern portion of this region is dominated by generally linear, north–south-oriented graben, with little cross cutting between adjacent structures. At 5°–8°S, the number of cross-cutting graben increases, with multiple orientations of these structures producing a network of polygonal, fault-bound mesas. That multiple sets of graben are present in this area suggests that either two or more stress orientations prevailed in series here, or a horizontally isotropic stress field was present that produced extensional structures without a single, dominant orientation. Farther south again, graben become more curvivlinear and appear roughly concentric around the northern flank of Syria Planum (**Figure 1**). These structures are characterized by larger vertical offsets (up to 2 kilometers) and much more slumping along the fault scarps than is seen in the more northerly parts of the region.

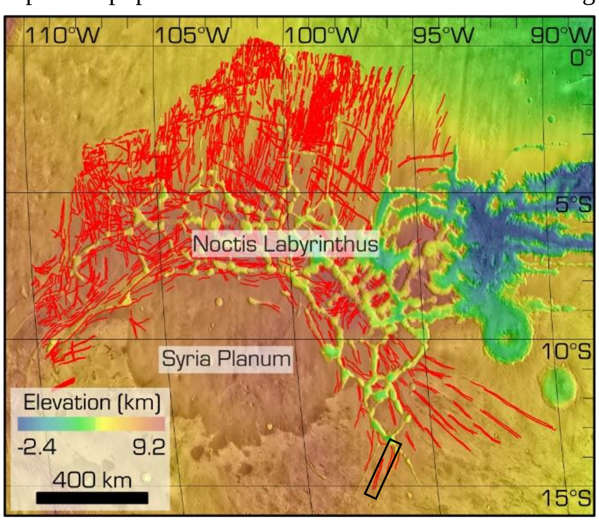

*Figure 1. Color-coded, shaded-relief structural map of the Noctis Labyrinthus region; normal faults are shown as red lines. The location of the pit crater chain in **Figure 2** is shown by the black box.*

Pit Craters: Pit craters are circular to elliptical depressions distinguished from impact craters by the lack of a raised rim [8]. They have been observed on the surfaces of many planetary bodies [3–9]. Although pit craters are widespread across the Solar System, their formation mechanism(s) are not fully understood. Nonetheless, two leading formation hypotheses have emerged: intrusive magmatic activity and dilational faulting [8].

Pit craters are often found in association with normal faults and graben, which strongly implies an origin at least in part due to tectonic activity [9–10]. Dilational faulting has been invoked as a pit formation mechanism because such faulting creates voidspace within the subsurface where fault dip angles change. Loosely consolidated surficial material may then drain into these subsurface voids, producing conical depressions at the surface [8]. On the other hand, some pit craters may have a volcanic origin, as many examples are found within areas thought to be underlain by dikes [4,11,12]. Dike intrusions could produce cavities from explosive volcanism when the dike comes in contact with water in the shallow subsurface, or purely from devolatilization at the dike tip in the shallow subsurface [3,11–13].

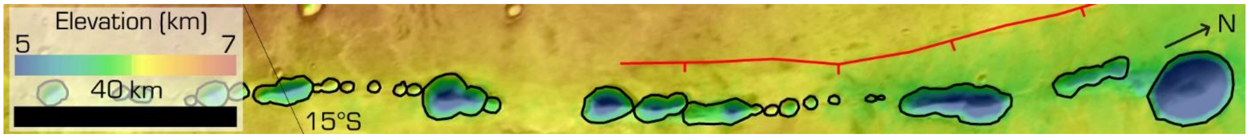

Figure 2. *An examplar pit crater chain in Noctis Labyrinthus. Pit craters are outlined in black, and normal fault are shown in red, with ticks indicating inferred down-dip fault direction. The pits here were used for the analysis shown in* ***Figure 3****. North is to the top right in this figure.*

At Noctis Labyrinthus, pit craters are situated both within and outside of graben. However, the majority of pits are aligned with the dominant north–south orientation of normal faulting that characterizes much of the region (**Figure 1**). An examplar chain of pit craters is shown in **Figure 2**. Here, there is a north–south progression of larger and deeper pits that trend towards smaller and shallower ones. We show in **Figure 3** a strong correlation between the minor axis lengths of these pits and their depth. This relationship indicates that the minor axes values (which we take as pit crater "width") scales linearly with depth, such that the *shape* of these landforms is self-similar across a range of scales. This self-similarity mirrors a principal property of faults, in which maximum fault displacement scales in proportion to fault length for discrete populations of structures [14–15]. Although the pits in **Figure 2** do not obviously lie within a graben, their close proximity and comparable orientation to at least one normal fault scarp suggests some element of fault control in their formation.

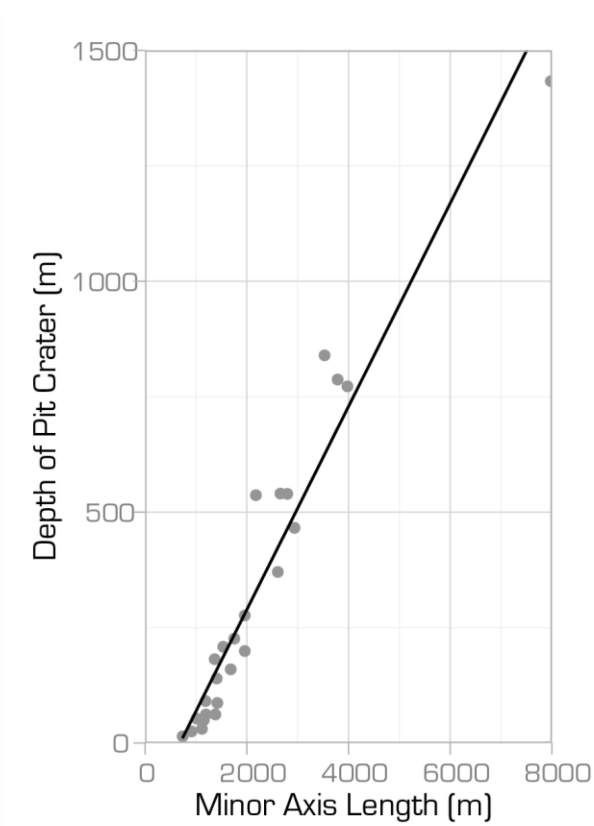

Figure 3. *Pit crater depth versus minor axis length axis for the 25 mapped pit craters in* ***Figure 2.*** *The fit between these two variables is shown, with an* R^2 *value of 0.93.*

Concluding remarks: It is readily clear that both normal faults and pit craters are widespread throughout Noctis Labyrinthus. The relationship shown here between minor axis length and depth for a select set of pit craters in the southern reaches of Noctis Labyrinthus suggests that at least some pits in this region are fault controlled. As yet, it remains unclear whether there is a volcanic component to these pits: for instance, we have yet to identify any unambiguous instances of lava flows emanating either from pits (like those found at Craters of the Moon National Monument and Preserve in Idaho) or from normal faults across Noctis Labyrinthus. If this finding holds throughout our survey, we might reasonably infer that volcanism has played at most a limited role in the evolution of this enigmatic part of Mars.

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