**THE SPATIAL RELATIONSHIP OF GRABEN AND PIT CRATERS AT RIMAE DANIELL AND THE IMPLICATIONS OF SCARP FORMATION.** C. J. Ahrens<sup>1</sup>, M. E. Banks<sup>1</sup>, N. Petro<sup>1</sup>, <sup>1</sup>NASA Goddard Space Flight Center, Solar System Exploration Division, Greenbelt, MD (Caitlin.ahrens@nasa.gov).

Introduction: A geomorphologically complex and understudied region on the Moon is Rimæ Daniell, situated in Lacus Somniorum [1]. This region is characterized by a set of NNW-SSE-oriented grabens, which have been implied to be underlain by dikes through topographic measurements of ground displacements and faulting processes [1]. The coverage of topographic measurements with the Lunar Orbiter Laser Altimeter (LOLA) [2] aboard the Lunar Reconnaissance Orbiter (LRO) now allows for an indepth morphologic analysis of lunar grabens [1]. Lunar grabens, in general, occur peripheral to some near-side mare units [3], within floor-fractured craters [4], and inside larger impact structures [5]. From [1], LOLA data across Rimæ Daniell indicate that these grabens are located atop broad rises that stand 100-150 m above their surroundings. Although [1] has mapped out the northwestern most grabens at Rimæ Daniell, this area has a complex geologic history, including pit chain craters and the transition of the graben system to a steep scarp, which is disrupted by knobby terrain (Figure 1).

Here, we describe preliminary analysis of the pit craters associated with the graben complex at Rimæ Daniell, as well as imply the formation of the scarp directly southeast of the grabens.



**Figure 1:** LROC image of the Rimæ Daniell area with labeled prominent structures as discussed in this report: Grabens (gold lines), pit craters (blue circles), kn obby terrain (grey polygons). Arrow points north. Scale bar is 10 km. (NASA/GSFC/ASU).

**Graben and Scarp:** Described by [6], a graben is formed when two steep, inward-dipping normal faults create a down-dropped block between them. These down-dropped blocks are usually evident as long, relatively straight, trough-like depressions that can extend for tens to hundreds of kilometers.

There are three main sets of graben systems at Rimæ Daniell: (i) the NW graben system in the shape of a Y in which [1] measured; (ii) the Major graben where the NW graben converge. This graben is the main branch that transitions to the major scarp; and (iii) a Minor graben system that runs parallel to the Major graben complex but is terminated at the transition to the scarp.

The scarp area continues the graben complex orientation NW-SE for approximately 30 km. At this scarp, we find that the slope of the scarp measured from LOLA is  $8 - 10^{\circ}$ , where the graben complex slopes are estimated to be  $4 - 7^{\circ}$ . From 3D oblique views of the graben-scarp transition (Figure 2), it appears that the graben complex is bounded by a relatively higher-elevated plateau, which slopes downward and terminates, exposing the southward graben wall as the scarp. More elevation profiles need to be taken to see the full transition of this uplifted plateau and the scarp area.



**Figure 2:** 3D oblique view (15x exaggeration) of the graben complex – scarp transition. Scale is ~3 km.

**Pit craters:** Pit craters have been observed on many planetary surfaces [6-11]. They are typically circular to elliptical depressions distinguished from impact craters by the lack of a raised rim [6, 10]. 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 [6, 10].

From [6], pit crater chains are often associated with normal faults and graben, which implies an origin at least in part due to tectonic activity [11].

Faulting has been invoked as a pit formation mechanism because such faulting creates void-space 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 [10]. Alternatively, some pit craters may be influenced by dikes [8, 12, 13]. Dike intrusions could produce cavities from volcanism when the dike comes in contact with water in the shallow subsurface, or purely from devolatilization at the dike tip [12, 13].

At Rimæ Daniell, pit craters are situated both within and outside of graben. However, the pits are aligned with the dominant NNW-SSE orientation. Similar to pit crater chains on Mars [6], larger and deeper pits trend with smaller and shallower ones. In Figure 3, there is a correlation between the minor ax is length of these pits (crater width here) and their measured depth. This relationship, according to Kling et al. [6], shows a property of faults in which fault displacement scales in proportion to fault length [14-15]. Although parts of the pit craters do not lie within a graben, their proximity and orientation to the graben complex suggests some element of fault (or dike) control in their emplacement.



**Figure 3:** Pit crater depth versus minor axis length axis for nine mapped pit craters (labeled in Figure 1). The fit between these variables has an  $\mathbb{R}^2$  value of 0.77.

**Concluding Remarks:** The relationship shown here between the graben complexities and pit craters and the transition to the large scarp section suggests that there are underlying processes that need to be further explored. This exploration of Rimæ Daniell also proposes more questions as to dike-controlled grabens, faulting, and the graben-scarp transition from a seemingly elevated plateau that terminates at the end of the pit craters. Further exploration would include observing potential gravitational anomalies and measurement of the stresses associated with the formation of the scarp and graben complexes.

## Acknowledgments:

This research was supported by an appointment to the NASA Postdoctoral Program at the NASA Goddard Space Flight Center, administered by Universities Space Research Association under contract with NASA.

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