

YOUNG COMPRESSIONAL TECTONIC ACTIVITY AND ASSOCIATED FORMATION OF SMALL GRABEN ON THE MOON. T. Frueh¹, J. D. Clark², R. Hetzel³, H. Hiesinger¹, and C. H. van der Bogert¹. ¹Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str.10, 48149 Münster, Germany, (thomas.frueh@uni-muenster.de), ²School of Earth and Space Exploration, Arizona State University, 3603 Tempe, AZ, USA, ³Institut für Geologie und Paläontologie, Wilhelms-Universität Münster, 48149 Münster, Germany.

Introduction: High spatial resolution images of compressional tectonic landforms and seismic recordings as part of the Apollo missions revealed young and presumably ongoing tectonic activity of the lunar crust. The two major compressional tectonic landforms on the Moon are wrinkle ridges and lobate scarps [1]. Lunar wrinkle ridges exclusively occur within the mare basins [2–4]. They are interpreted to form as a result of thrusting and folding, for which the layered stratigraphy of the mare basalts is needed [5]. Lobate scarps mainly occur within the lunar highlands [1,6,7]. In contrast to the complex wrinkle ridges, lobate scarps are thought to result from a shallow surface-breaking thrust fault [1]. While early wrinkle ridge formation is argued to be mainly linked to subsidence of the mare basalts [8], later formation, along with lobate scarp activities, could be predominantly caused by global contraction from long-term interior cooling [1,9].

Recent studies revealed new activity of both compressional landforms [11–15]. The evidence includes an abundance of boulder fields [13,16], a distinct crisp morphology, crosscutting of small impact craters (<10 m) [14], <1 Ga ages determined from CSFD methods [17], and associated small meter-scaled graben [18,19]. The small meter-scale size and the crisp morphology of these graben imply, at least for some of these graben, a formation within the last 50 Ma, since such small features could only survive on the Moon for a few hun-

dred million years [19]. Since the lunar lithosphere is in a general state of net contraction [1] and because of the spatial association of the small graben with lobate scarps or wrinkle ridges [18], the small graben most likely formed by localized extension due to uplift and flexural bending caused by slip on the underlying thrust faults [11,18]. Therefore, these small graben can be interpreted as evidence for young compressional activity on the Moon [11].

Here, we want to study the recent activity and growth of young compressional structures and the circumstances of small graben formation in more detail by expanding a global map of small graben locations [18], conducting detailed mapping of the spatial associated tectonic features (Fig. 1) and by measuring displacement values and displacement-length ratios.

Data and Methods: In order to map and measure (e.g., length, width, spacing, and orientation [18]) the small meter-sized surface features, we use NAC (Narrow Angle Camera) images from the Lunar Reconnaissance Orbiter Camera (LROC). LROC provides near-global coverage with a resolution of down to 0.5 m/pixel scale. Images with high incidence angles (>55°) contain large and high contrast shadows, and, thus, provide detailed information about the topographic characteristics of the tectonic landforms. Given stereo pair availability, we will create NAC DTMs to inspect

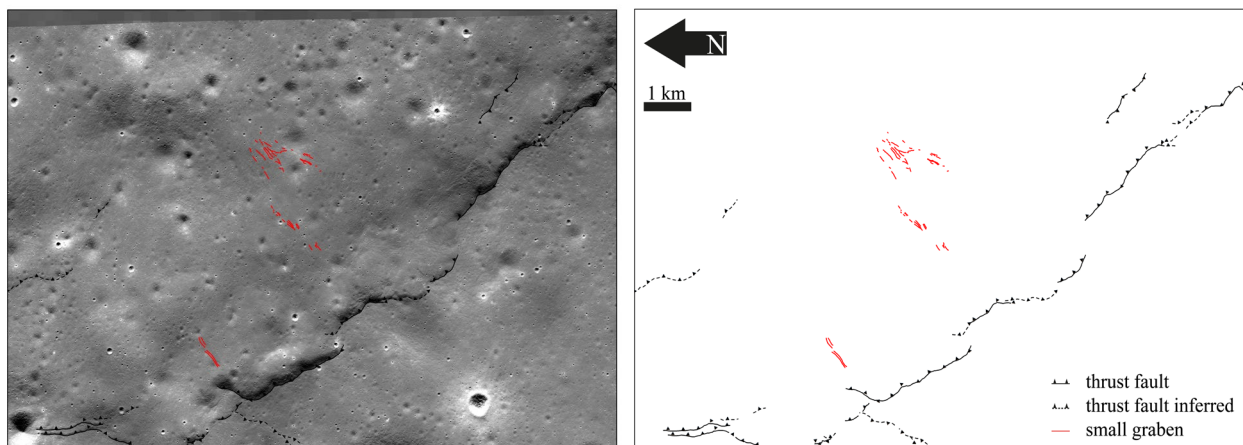


Figure 1. Example of perpendicular small troughs (red) in the hanging wall of a lobate scarp located east of Mädler crater (10.7°S, 31.5°E). Left image is a NAC image (M1108082617LE) with sunlight coming from the east (north is towards the left). The right image shows a preliminary sketch of the inferred structures. Mädler lobate scarp is accompanied by perpendicular troughs on its hanging wall [18].

the topography of these graben. Newly identified graben will be added to the map of [18] to create a more complete small graben database.

Discussion and Preliminary Results: The existence of flexure zones in the hanging wall of thrust faults is known from Earth-based studies [20,21]. Surface ruptures form due to flexing and brittle shearing of hanging-wall anticlines. Parallel crestal graben are known to form if shortening is perpendicular to the thrust front. Oblique crestal graben and shear zones are able to form if shortening occurs obliquely to the thrust front [21]. The oblique or perpendicular orientation of shear zones and tensile cracks is consistent with tensile stresses in anticlines that form in the hanging wall of active thrust faults [21].

In the case of wrinkle ridges and lobate scarps, the orientation of the troughs can be parallel and perpendicular to the thrust fault (Fig. 1-2) [15,18]. In some cases, only perpendicular sets of troughs occur (Fig. 1), while in other mainly parallel troughs are visible. Others show patterns of parallel and perpendicular features (Fig. 2). Many Earth-based thrust faults and surface ruptures formed in single events that are easier to identify [20–22], however, constraining the number of events that formed the lunar small graben continues to be a challenging task. Additionally, the underlying strata differ for both cases, in particular for lobate scarps where the layered mare basalts are absent. Nevertheless, the location and orientation of the small graben could give insights into the regional stress field near wrinkle ridges and lobate scarps.

The low erosion rate on the Moon's surface [23] provides ideal conditions for studying fault morphologies without the problem of Earth-like weathering. This could give insights into fault propagation, uplift rates, and ultimately into the origin of involved stresses, i.e. potential triggers for recent tectonic activity on a regional or even global scale.

Conclusion and Further Work: The existence of small graben at lobate scarps and wrinkle ridges implies significant recent tectonic activity on the Moon [10,18,19]. The detailed study of these young thrust faults and associated small graben could give insights into the formation and evolution of lunar thrust faults, and the recent stress fields.

Acknowledgments: I am thanking and acknowledging the use of the Planetary Data System (<https://pds.nasa.gov/>) and QuickMap (<https://quickmap.lroc.asu.edu/>), a collaboration between NASA, Arizona State University & Applied Coherent Technology Corp.

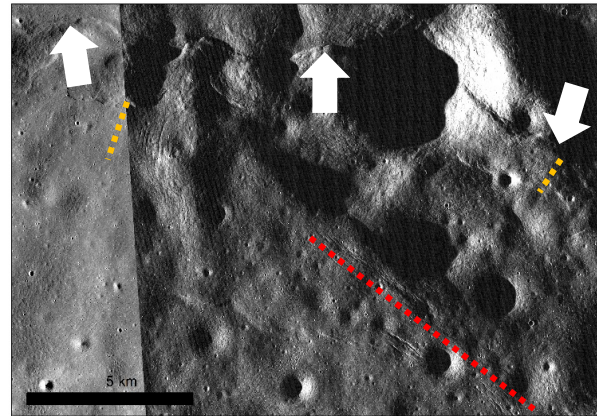


Figure 2. NAC images (M1350473085LE, M1292904231RE) of a wrinkle ridge in Mare Tranquillitatis north of Ross crater (12.9°N, 21.5°E). The hanging wall is located south of the thrust fault (white arrows; North is up). Graben occur perpendicular (orange line) and sub-parallel (red line) to the thrust fault.

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