A NEW MAP OF GRABEN ON THE LUNAR NEARSIDE: INITIAL OBSERVATIONS AND CLASSIFICATION. Amanda L. Nahm[1], [1]Institut für Planetenforschung, German Aerospace Center (DLR), Rutherfordst. 2, 12489 Berlin, Germany, amanda.nahm@dlr.de.

Introduction: Faults and fractures are visible records of the stresses operating on and in planetary bodies. On the Moon, tectonic structures are concentrated on the nearside, are spatially associated with the maria [e.g., 1], and are divided into 3 main types: wrinkle ridges, lobate scarps, and graben. Lunar graben (or rilles) are long, narrow troughs up to several hundreds of kilometers long and up to 5 km in width. The occurrence of graben on material that formed after basin formation and mare emplacement indicate that graben formed relatively recently [2]. Current model ages suggest that graben formation ceased around 3.6 Ga [1-3] and contractional structures (wrinkle ridges and lobate scarps) formed ~1 Ga [1, 4]. Crosscutting relationships, however, indicate that some wrinkle ridges pre-date the graben [5] and recent work on Rupes Recta, a large normal fault in Mare Nubium, indicates that it is younger than 3.2 Ga [6]. These contradictory observations indicate that a detailed, systematic study of the distribution and timing of graben formation is needed. Here, I present the results from the first part of this systematic study: the mapping campaign.

Mapping: Mapping of graben on the lunar nearside (270° to 90° E, 70°N to 70°S) at a scale of 1:500,000 has been completed. The Lunar Reconnaissance Orbiter (LRO) Wide Angle Camera (WAC) global morphologic map was used as the base map (100 m/px, available at http://wms.lroc.asu.edu/lroc/view_rdr/WAC_GLOBAL). The WAC base map is preferred over other available datasets because it has a generally uniform incidence angle for consistent identification of scarps and it is already complete. LRO WAC digital terrain maps (DTMs), produced at DLR (100 m/px; [7]), and LRO Lunar Orbiter Laser Altimeter (LOLA) [8] Gridded Data Records (GDR) (at 512 and 1024 px/deg) were co-registered with the WAC base map in ArcGIS.

Graben and other fractures were identified primarily based on map view morphology. The primary characteristic was the presence of a pair of abrupt scarps with the portion between them down-dropped relative to the surroundings. In general, the scarps are subtle, with heights up to several hundred meters. Statistics for fault lengths and graben widths and depths have not yet been compiled, but are forthcoming.

The map presented here is a significant improvement over earlier maps produced using low resolution pre-LRO data at scales of 1:5 million and 1:1 million [e.g., 1, 2, 9].

Classification: Based on morphology and map view orientation, the mapped graben have been divided into 4 categories (Fig. 1): *linear graben*, *arcuate graben*, *floor fractured crater fractures*, and *lineaments*. *Linear graben* (Fig. 1A) are structures that are linear or nearly linear, have a relatively flat floor, roughly parallel walls, and approximately constant widths. In contrast, *arcuate graben* (Fig. 1B) meet the criteria of linear graben, but have orientations that vary from linear by more than several degrees and are typically concentric about maria. *Floor fractured crater (FFC) fractures* (Fig. 1C) are undifferentiated fractures or graben that are contained within a FFC identified by [10]. *Lineaments* (Fig. 1D) may have similar trends to identified graben in the area and are shallow curvilinear depressions. These structures may not be graben, but may have formed under similar stress fields and are thus useful for understanding the tectonic history of the nearside.

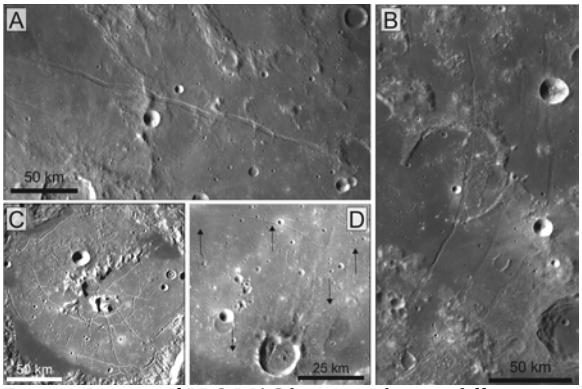

Figure 1. Portions of LRO WAC base map showing different types of structures mapped in this study. N is up in all panels. A) Linear graben, Rima Ariadaeus, centered at 6.48°N, 13.44°E. B) Arcuate graben, Rima Hippalus, centered at 25.6°S, 29.36°W. Mare Humorum is to the west. C) Floor fractured crater fractures within Humboldt crater, centered at 27.02°S, 80.96°E. D) Unnamed lineaments, indicated by arrows, centered at ~76°, 21°E.

Results and Discussion: Graben cross-sectional morphology can change significantly along strike (e.g., Fig. 2). The cross-sectional topography of some graben on the lunar near has been used to determine that they formed from dikes at depth as well as the characteristics of those dikes [11]. Cross sections of graben distributed over the nearside and different materials will be investigated to determine the formation mechanisms of graben on the Moon.

It should be noted that the interior of Orientale basin contains many observed fractures. Its interior contains impact-related material (such as impact melt with entrained debris) [e.g., 12], resulting in many

fractures that may be entirely unrelated to larger-scale tectonic deformation. Therefore, only those fractures that seem to have preferred orientations or are morphologically similar to those outside of Orientale were mapped.

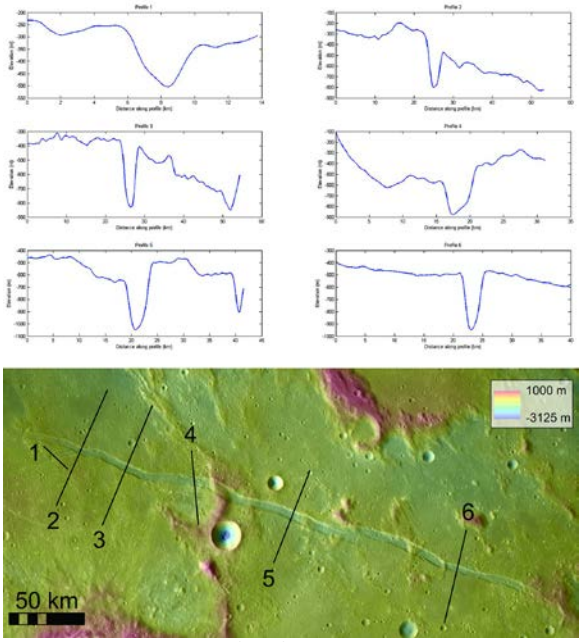

Figure 2. Topographic profiles from several locations along Rima Ariadaeus, classified in this study as a linear graben. Profile numbers in lower panel correspond to profile numbers above. All profiles from approx. (left) to approx. N (right). WAC DTM topography overlain on WAC base map.

A total of 1812 segments were mapped (Fig. 3). Each fault may have been mapped as one segment or a series of segments. Of these segments, 478 were classified as arcuate, 398 were classified as FFC fractures, 442 were classified as lineaments, and 494 were classified as linear (Table 1). Each group comprises approximately 25% of the total mapped fractures.

Table 1. Number and percentage of graben segments for each of the 4 assigned classifications.

Fracture class	Number of Segments (Σ = 1812)	% of total segments
Arcuate	478	26.4
FFC	398	22.0
Lineament	442	24.4
Linear	494	27.2

Generally, mapped graben are concentrated near the margins of the nearside maria as observed previously, but some structures have been mapped within the maria or in the highlands far from mare margins. In some places within and on the margins of the maria, graben are observed to cut 'highland islands,' that is, graben cut older highland terrain but not mare. This observation indicates that graben in these locations are younger than the highland material but older than the maria, providing a means with which to constrain the timing of faulting, critical for understanding the temporal distribution and evolution of stresses on the lunar nearside. In addition, these observations will help determine the source(s) of stress responsible for the formation of graben on the lunar nearside.

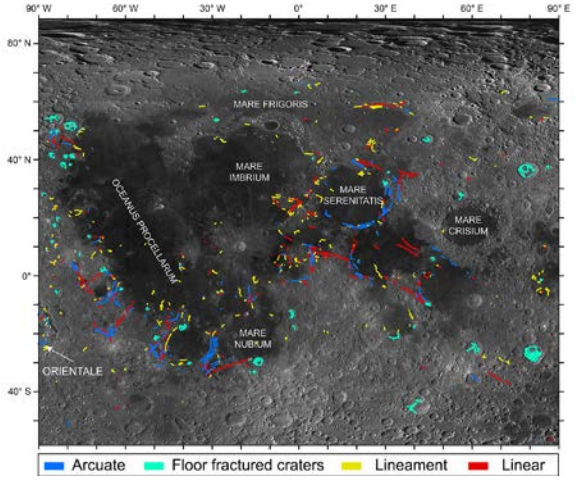

Figure 3. Map of the nearside of the Moon with mapped graben. Colors correspond to assigned classification group. Graben mapped at 1:500,000 scale. Base map: LRO WAC global morphologic map. Image credit: ASU.

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