

**NEW GLOBAL MAP AND CLASSIFICATION OF LARGE-SCALE EXTENSIONAL STRUCTURES ON THE MOON.** A. L. Nahm<sup>1</sup>, M. B. Johnson<sup>2</sup>, E. Hauber<sup>1</sup>, T. R. Watters<sup>2</sup>, and E. S. Martin<sup>2</sup>, <sup>1</sup>Institut für Planetenforschung, German Aerospace Center (DLR), Rutherfordst. 2, 12489 Berlin, Germany, (amanda.nahm@dlr.de, ernst.hauber@dlr.de); <sup>2</sup>Center for Earth and Planetary Studies, National Air & Space Museum, Smithsonian Institution, Washington, DC 20560 (watterst@si.edu, martines@si.edu).

**Introduction:** Tectonic structures visible on the surface of a planetary body provide records critical for understanding the temporal and spatial changes in stress states. They also provide information regarding formation mechanisms, which in turn have implications for the body's internal and surficial evolution and geologic processes. Basic information about tectonic structures, such as spatial distribution, orientation, potential clustering, association with certain landforms (like mare filled basins) is easily displayed via global maps.

Several global maps of tectonic structures based on Lunar Reconnaissance Orbiter (LRO) data have been published in 2015: wrinkle ridges [1], small-scale graben [2], and lobate scarps [3]. However, a global map of large-scale extensional structures using the high-resolution LRO datasets has not yet been published.

Recently, however, two maps of large-scale extensional structures on the Moon have been compiled [4, 5]. The map by [4] was restricted to the lunar nearside and was produced at a scale of 1:500,000, while the map by [5] shows the global distribution of all structures with negative relief (including non-tectonic sinuous rilles). The global map presented here represents a compilation of both of these maps. Additionally, a classification scheme for large-scale extensional structures on the lunar surface is presented.

**Mapping:** A global map of extensional tectonic structures at a scale of 1:250,000 has been produced. The base map used for mapping was the LRO Wide Angle Camera (WAC) global mosaic at 100 m/px ([http://wms.lroc.asu.edu/lroc/view\\_rdr/WAC\\_GLOBAL](http://wms.lroc.asu.edu/lroc/view_rdr/WAC_GLOBAL)). LRO Narrow Angle Camera (NAC) images and WAC stereo-derived topography supplemented this basemap where necessary. Graben and other extensional structures were identified primarily by map view morphology. In general, graben are identified by their negative relief and are accompanied by parallel scarps that generally bound long, relatively narrow troughs. Individual scarps are also observed and are again characterized by negative relief, though only one scarp is observed.

**Distribution and Tectonic Setting:** The combined global map is presented in Figure 1. Graben and other extensional structures are concentrated on the nearside and in association with most of the margins of mare basins. Extensional landforms are also found within impact basins not completely flooded

by mare basalt, e.g., Orientale and Schrödinger. Not an insignificant number of graben are located on the farside highlands away from mare basins. In addition, many extensional structures are located in floor materials of impact craters commonly referred to as floor-fractured craters [6]. Notably, there is a dearth of extensional structures in and around Mare Crisium, as well as in the northern parts of Oceanus Procellarum and Mare Imbrium.

Some structures show distinct radial orientations relative to the western portion of Oceanus Procellarum as well as in the central-eastern nearside south of Mare Imbrium. Concentric structures are also observed outside of Mare Serenitatis and Mare Humorum.

**Length statistics:** A total of 4366 structures were mapped, with lengths varying from ~952 m to 519 km. The vast majority of structures (4313, or 98.7%) have lengths between ~952 m and 110 km, while the length bin with the highest number of structures is ~6.1 to 11.3 km, with 1194 segments.

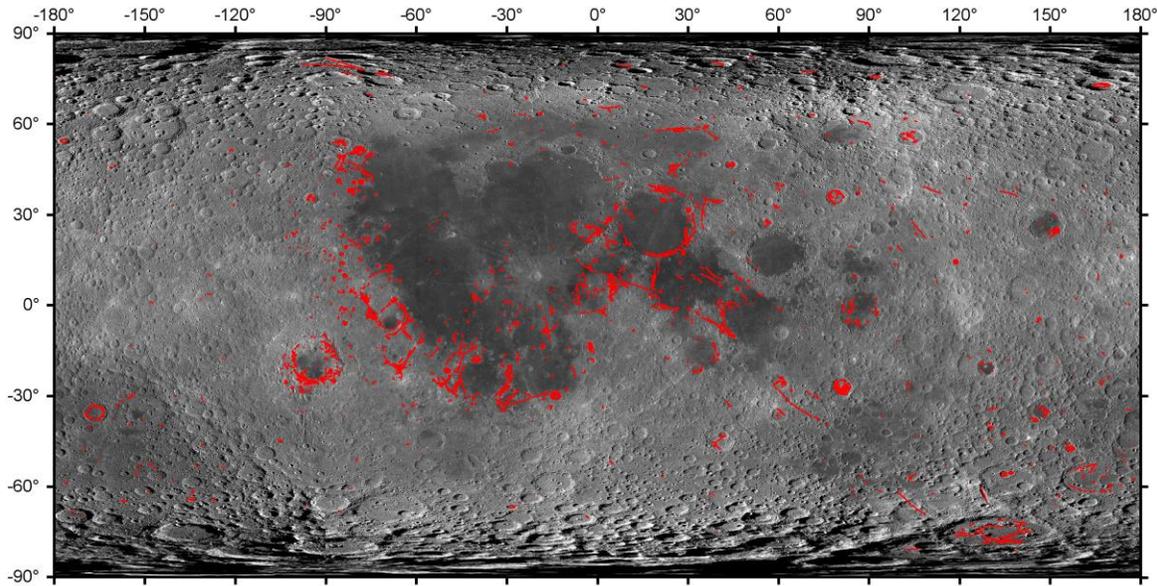
**Classification:** An earlier version of this map [4] classified graben based on morphology and map view orientation into four categories: linear graben, arcuate graben, floor fractured crater fractures, and lineaments. However, for this map, classification groups have been identified based solely on morphology, resulting in 6 categories. The arcuate and linear graben classifications of [4] are legacies from earlier classifications (cf. [7]), and are abandoned here.

The 6 categories of extensional structures identified here are *scarp*, *elliptical trough*, *catena*, *flat floored trough*, *narrow-deep trough*, and *subdued trough*. *Scarp* structures (Fig. 2A) consist of an individual or non-paired scarp. An *elliptical trough* (Fig. 2B) is an elliptical to elongate rimless depression that does not occur in association with a sinuous rille or extensional structure; some structures are long and narrow, while others are short and wide. *Narrow-deep troughs* (Fig. 2C, blue arrow) are deeper than they are wide and are identified by two visible scarps, though the floor may be in shadow. *Subdued troughs* (Fig. 2C, yellow arrow) are linear to curvilinear narrow depressions. Their walls appear to converge, creating the appearance of a line along the floor. The structures are v-shaped in cross section and wall crests appear rounded or subdued. Their morphology may be subdued due to overlying deposits, such as crater ejecta or pyroclastic deposits, or surface degradation. A *catena* (Fig. 2D) is composed of an aligned

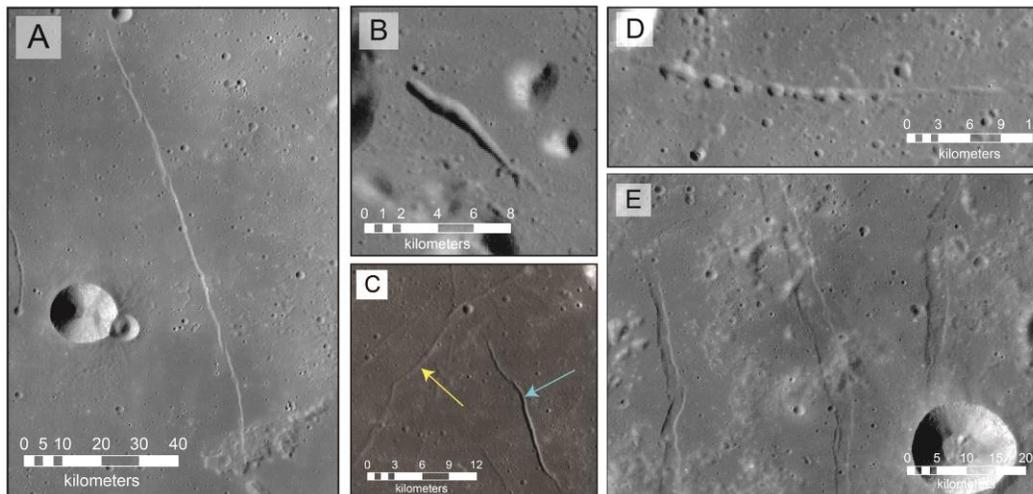
series of circular to elliptical rimless depressions or pits; pits may be distinct or separate from each other, or may connect. These structures may or may not be associated with single scarp structures or graben, either continuing along trend of graben or contained within graben. *Flat floored troughs* (Fig. 2E) are

wider than they are deep with flat floors, have clearly delineated paired antithetic scarps, and are often segmented.

**Outlook:** The next step is to assign each mapped structure a classification and to get orientation statistics.



**Figure 1.** Global map of uncategorized graben, mapped in red. Graben mapped at 1:250,000 scale. Base map: 100 m/px LRO WAC global morphologic map. Image credit: Arizona State University.



**Figure 2 (above).** Portions of LRO WAC global morphologic map showing an example of each classification group. A) Scarp (Rupes Recta), figure centered at  $\sim 21.6^{\circ}\text{S}$ ,  $7.7^{\circ}\text{W}$ . B) Elliptical trough, figure centered at  $\sim 6.1^{\circ}\text{N}$ ,  $29.3^{\circ}\text{E}$ . C) Narrow-deep (blue arrow). Subdued or V-shaped (yellow arrow), figure centered at  $\sim 28.7^{\circ}\text{N}$ ,  $17.4^{\circ}\text{E}$ . D) Catena, figure centered at  $\sim 8.4^{\circ}\text{S}$ ,  $26.8^{\circ}\text{E}$ . E) Flat floored trough (Rimae Hippalus), figure centered at  $\sim 29.2^{\circ}\text{S}$ ,  $22.7^{\circ}\text{W}$ .

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