PHOTOGEOLOGIC OBSERVATIONS OF LUNAR NEARSIDE GRABEN. J. A. Petrycki and L. Wilson. Environmental Science Department, Institute of Environmental and Natural Sciences, Lancaster University, Lancaster LA1 4YQ, U.K. (j.petrycki@lancaster.ac.uk)

Introduction and Background

Linear and arcuate rilles (graben) are common tectonic features on the Moon. They are thought to be the result of extensional deformation of the shallow crust [1], initiated by various mechanisms including flexure responding to mare basalt emplacement [2] and extension responding to near-surface dyke emplacement [3]. Using data from Lunar Orbiter IV images, the majority of the lunar nearside has been systematically searched to examine all lunar linear, sub-linear and aligned structures.

Using criteria such as width, freshness and sinuosity, fourteen different types of feature were classified for the purpose of this study. The features included are narrow to medium width, flat-floored rilles that have well defined edges. The overall trend of the rille may be linear or arcuate. Features not included (but that may be examined in future work) are wide degraded valley structures; very narrow, poorly defined rilles; and sets of aligned craters. It is worth noting that in the west, near the Orientale Basin, some graben are nearly buried by Orientale ejecta and in the east, many Orbiter images are degraded or of poor quality. Thus sampling of graben may be incomplete.

Most graben locations have been included on a map compiled as part of this work, which is generally in good agreement with [4]. To determine the geometry of graben, the length and width of each one has been measured, and shadow lengths and interpolated solar elevations have been used to calculate depths. Additionally, data were collected on the location of the graben and the geology of surrounding rocks. Particular care was taken to search for volcanic features and/or deposits associated with the rilles which would support the hypothesis that some graben are the result of near-surface deformation accompanying dyke emplacement within the lunar crust.

Observations

More than 180 individual rilles, belonging to around 60 graben sets, were included in this study. They are seen singly or occurring in parallel, cross-cutting or en-echelon sets [4]. Most have simple geometries and adjacent graben of a set commonly have similar widths and spacings. This may indicate that they are associated with some particular mechanical discontinuity in the lunar crust, supporting the findings of [1]. Furthermore, graben of a set tend to have similar depths.

It was found that graben generally have a width between 1.5 and 3.0 km, for example Rima Hypatia and Rimae De Gasparis. However, some graben are narrower, at 600 - 700 m wide, and others are much wider, 3 - 4 km and more rarely up to 5 - 6 km. Graben widen as they cross topographic highs and crater rims, implying that they are composed of two steeply dipping faults [5]. Wider graben (> 3 km) are located in highland materials, for example Rima Sirsalis. Depths of graben are most often between 50 and 250 m. Some are as shallow as ~20 m, for example Rimae Littrow, and others are deeper at ~500 m, for example Rima Ariadaeus. Graben lengths vary, between ~20 km to ~400 km. Most are shorter than 150 km, and many are around 50 - 100 km long. A significant number are longer than 200 km, for example Rimae Hippalus I, II and III, Rima Hypatia and Rima Hyginus. Some individually named graben of average length apparently abut other graben, and thus could be considered as one long graben. An example of this is Rima Oppolzer, leading west into Rima Flammarion.

Graben were found to be predominant on the nearside of the Moon. This agrees with current understanding, and is thought to be due to the fact that average crustal thickness on the farside is greater than on the nearside [3]. Thus, many dykes that may be present in the farside lunar crust are stalled too deep within the crust to generate graben at the surface. On the nearside, graben are generally found in the region between 40°N and 40°S of the lunar equator. In the west, graben occur further south and are particularly evident in and around Mare Humorum, Mare Orientale, Palus Epidemiarum and to the SW of Oceanus Procellarum. In the east, more graben are seen in the northern hemisphere and they are especially common in and around Mare Tranquillitatis and Mare Serenitatis. They are also observed in and around Mare Vaporum, Palus Putredinis, Lacus Somniorum, Mare Fecunditatis and Mare Frigoris. It is noticeable that not all maria have graben associated with them. Indeed, graben are rare or absent in Mare Nectaris, Mare Crisium and Mare Smythii.

Graben are found cutting through both maria and highland terrains. Some graben do occur exclusively in maria, for example Rimae Plinius which occur at the SE edge of Mare Serenitatis. Others occur only in highlands, for example Rimae Parry. However, most are associated with maria and are found on the edges of maria crossing between mare and highland units, or are in highlands surrounding maria.

Other interesting observations regarding graben, but not explored in detail yet, are that many mare ridges have the same 'habit' as graben. Many ridges run parallel to graben, have similar lengths, and are often off-set in a similar way. Their geometric relationship is similar in many basins [4]. Data from our graben map were compared with the global geologic map of mare basalt types [4, 5]. Graben that cross though maria seem to occur in maria of particular spectral classes such as HDWA, hDWA, mISP, mIG, LBSP, dark mantling and cone and dome material. They do not appear to occur in HDSA, hDSA, hDSP, hDG, LISP, LIG, and LBG spectral classes. This is an issue that could be explored further using data from the Clementine mission.

Many graben are associated with volcanic features, often in the form of volcanic crater chains, occurring directly next to, at the end of, within, or across the rille [6]. Some rilles are associated with dark mantling deposits, others have low domes (interpreted as shield volcanoes) and occasionally cones are observed. All the graben were observed to be at least of Imbrian age or younger, and a few could be interpreted to be of Eratosthenian age.

Using models of stress fields around fluid-filled elastic cracks [7], it was shown by [3] that dykes with mean thicknesses on the order of hundreds of metres, propagating to shallow (~1 – 2 km) depths in the lunar crust, were capable of producing surface stress fields leading to the development of graben with widths of ~1 – 3 km. More recent work [8] suggests that the relationships between graben width, graben depth, dyke width and depth to top of dyke may be more complex than considered earlier when significant inelastic deformation occurs, and we plan to investigate the consequences of this.

Summary

The majority of the lunar nearside graben have been measured for location, width, depth and length. They average 1.5 – 3 km wide and 50 – 250 m deep. Length is variable, but many are between 50 and 100 km long. The are most often associated with maria, at or around mare – highland boundaries. They are usually found within 40° of the lunar equator, and occur further south in the west and further north in the east. They are of at least Upper Imbrian age, and often have volcanic features associated with them. This is may indicate that many graben were formed by near-surface deformation accompanying shallow dyke emplacement.

References

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