HORIZONTAL FORCES WITHIN LUNAR CRUST: INTRIGUING A QUESTIONING MIND

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SUMMARY

We suggest from the study of en-echelon faults and related features, a local scale horizontal transport is visible in lunar crust, devoid of plate tectonics.

1. INTRODUCTION

Surface morphological features of planetary bodies have been extensively used for structural and kinematic studies [1], [2], [3] by comparing such features with similar looking terrestrial ones; the later act as analogues and aid to a better understanding of the processes of their formation.

The basic assumption for such a correlation is that we believe the processes that led to the formation of any earthly regional scale feature remains same for the development of a similar feature on planetary bodies.

We here describe a topographic feature on the lunar crust that is found in the active strike slip zones of the earth, where the faults accommodate the horizontal displacement [4], [5], [6]. The term 'en-echelon faults' refers to closely spaced, parallel or sub-parallel, overlapping in a step-like minor faults in rock, which lie oblique to the overall structural trend of the strike slip fault system. We describe similar features from the Earth's moon and discuss on its tectonic significance. The paradox lies in the fact that presence of dynamic stresses are absent within Earth's moon.

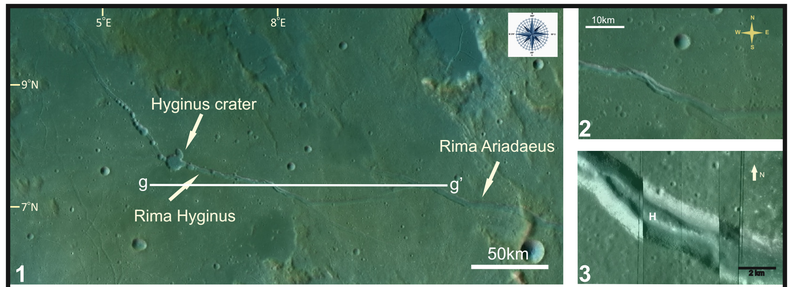

Fig. 1, 2, 3: LRO-WAC mosaic image of Hyginus crater (HC) showing Rima Hyginus (RH) and Rima Ariadius (RA). Note that the RH and RA are arranged in en-echelon pattern with a cross graben similar to a transverse fault. Within the segment 'a' sharp change in the strike of the graben margin from NW-SE to almost E-W is seen,implying a change in the orientation of the principal stress within the overall stress regime. Segment 'b' is a blown up image showing thickening of the graben wall within the RH.

2. STUDY AREA

We concentrate on the geometry and fracture pattern of one such rille, Rima Hyginus (RH), located south of the Mare Vaporum in the near side of the moon (Fig.1). RH is situated within Imbrium basin, structurally a broad structural trough, believed to have a fault related origin, extending for 220 km and nearly 3 km in width. The depth of the graben is around 500±80 m. The general topography is gently undulating (Fig. 4).

3. DATA SET USED

We have utilized Digital Elevation Models (DEM) from the LOLA and LRO-WAC (100m/pixel), LRO-NAC datasets from the Lunar Reconnaissance Orbiter (LRO) and processed them with J-Mars [7], ENVI.

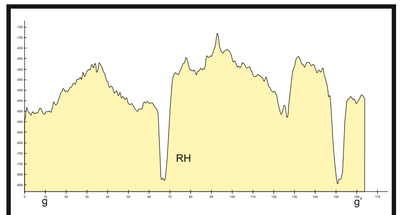

Fig. 4: This section is drawn in E-W section from LRO-WAC equatorial DTM. 100 times vertically exaggerated.

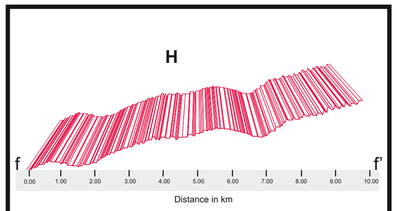

Fig. 5: 3D section showing the presence of the horse in the study area.

4. STRUCTURAL GEOMETRY OF THE STUDY AREA

Close inspection reveals RH is segmented into smaller linear grabens, arranged in en-echelon pattern often with a sharp change in the trend of these grabens (Fig. 1, 2 and 3). The topography is gently undulating with a thin veneer of pyroclastic material resting upon the basaltic floor [8]. Our analyses of RH reveal that the trend of the graben rotates from E-W to NW-SE indicating rotation of the stress regime. This is accompanied by thickening of the graben wall on its either flank. Profile sections drawn indicate presence of horses (marked by H) (Fig. 5) on the southern flanks of RH. We infer that the extensional stress has produced small scale faults en-echelon to the major fracture responsible for graben formation (Fig. 3). The tip lines of two adjacent en-echelon faults rotate and join to form a continuous graben and these horses remain as central remnant of en-echelon fractures (Fig. 5). Horses, within the median portions of two en-echelon faults, are reported from the moon for the first time.

It is seen that in some regions affected by normal faulting too, the fault propagate along strike in an en-echelon pattern with a cross fault joining the tips of the laterally offset faults (Fig. 6). In such cases, differential slip along the lengths of the fault may ultimately lead to the formation of tectonic horses within the fault zone [9].

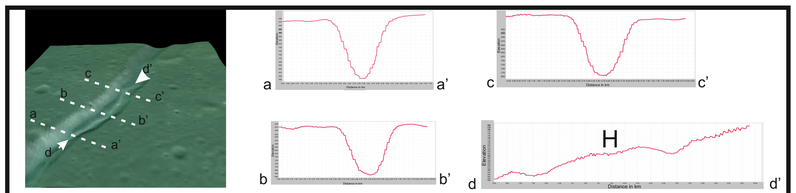

Fig. 6: LRO-WAC mosaic image of Rima Hyginus draped on LOLA DEM (100m), the elevation profiles across four transects, a-a'; b-b'; c-c'; and d-d' are shown below. Note the presence of horses (marked by H on d-d' profile plot) on Rima Hyginus (3D generated by ACT).

5. DISCUSSION

The en-echelon fault systems are mainly associated with the active strike slip tectonic zones of the earth where simple shear plays a dominant part in the overall stress regime of the area. Some recent reports [10] of incipient stresses leading to new fracture formation in the lunar crust has spurted new thoughts in believing the existence of tectonic activity in the lunar crust. Our study shows that some amount of shear stress is operative on the lunar crust leading to limited horizontal displacement of crustal blocks.

The tectonic horses within the lunar crust can therefore form in either of the two stress regimes a) under shear stress regime or b) tensile stress regime. The two stress regimes greatly differ in the principal stress vector orientations [11]. Large scale horizontal displacement as seen on earth is unlikely in moon for the absence of plate tectonics. The major stress is impact induced [2] and this stress gets transmitted through long distances within the lunar crust producing fractures [1] in the lunar crust. These fractures are typically segmented and often in an en-echelon pattern to the major fault zone (Fig. 7). The obliquity of such fracture system to the major graben wall and the slip along these oblique fracture planes probably lead to a concentration of shear stress on a local scale. We suggest that small scale horizontal transport occurred within the lunar crustal blocks, at least to a local scale, even in the absence of plate tectonics.

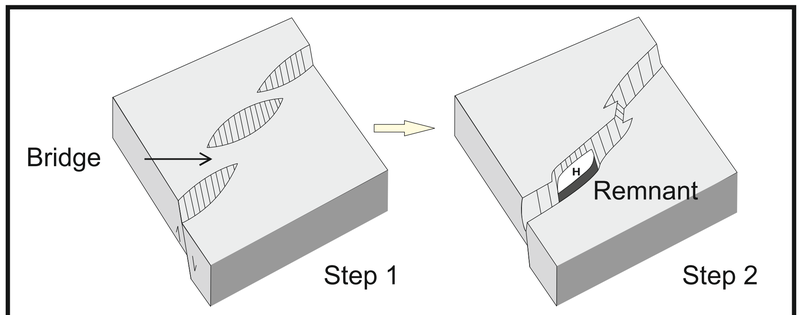

Fig. 7: Figure showing the systematic development of horse.(redrawn after Ramsay and Huber, 1997, p. 533).

6. REFERENCES

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