

**COMPARATIVE MORPHO-TECTONIC ANALYSIS OF LUNAR WRINKLE RIDGES USING TMC-2 AND ANCILLARY DATA SETS.** A. S. Arya<sup>1</sup>, J. Thapa<sup>2</sup>, A. Kundu<sup>2</sup>, D. Dasgupta<sup>2</sup>, Amitabh<sup>1</sup> and R. Basu<sup>2</sup>, <sup>1</sup>Space Applications Centre, Jodhpur Tekra, Ambawadi Vistar, Ahmedabad 380 015, India, e-mail: [arya\\_as@sac.isro.gov.in](mailto:arya_as@sac.isro.gov.in); <sup>2</sup>Department of Geology, Asutosh College, 92, S.P. Mukherjee Road, Kolkata 700 026, India, [joyita.thapa112@gmail.com](mailto:joyita.thapa112@gmail.com).

**Introduction:** Wrinkle ridge is a common contractional feature formed on the surfaces of terrestrial planets, originating due to a combination of folding and thrust faulting. It is visualized as the superposition of a broad arch and asymmetric ridges. They are present across the lunar mare regions/basins and possibly formed and evolved after the emplacement of the recent mare basalt units [1]. These ridges are typically attributed to the shifting from expansion to net contraction once the moon began cooling post-3.6 Ga, which caused the global stress field to shift from extensional to compressional. Using ISRO Chandrayaan-2 orbiter's Terrain Mapping Camera-2 (TMC-2) ortho-images, the Digital Elevation model from the Chandrayaan-2 mission and ancillary data sets, we attempted to conduct a comparative morpho-tectonic analysis of wrinkle ridges from multiple lunar basins in the near side and analyze their stress-strain conditions including their likely time of formation.

**Methodology and results:** Topographic profiles of wrinkle ridges were generated using ArcGIS software from TMC-2 DEM superimposed on LOLA DEM data. The initial and end lengths from each profile were calculated using the profile curves and the Moon coordinate system after the line-and-length cross-section balancing method. In the topographic profiles of the wrinkle ridges, the initial length is shown as the length of the curve line. We calculated these lengths using the mathematical formula for calculating distance, and the shortening of the surface across the wrinkle ridge along the section lines as being equal to the initial length minus the final length [2]. Ortho-images, DEMs from the Terrain Mapping Camera-2 (Chandrayaan-2 mission) and LROC WAC image were utilized to map and study the wrinkle ridges in three mare regions: Mare Frigoris, Mare Serenitatis, and Oceanus Procellarum. The eastern part of Mare Frigoris is dominated by interconnected groups of wrinkle ridges with a variety of orientations (circular, branching, and irregular patterns). A prominent E-W orientation can be seen in wrinkle ridges. The shortening values range from 0.67 to 1.5 (average 0.3%) for the Frigoris' wrinkle ridge (TMC-2 covered). It should be mentioned that the wrinkle ridges close to the Mare Frigoris' eastern border exhibit shortening values between upto 1.17 (on average 1%). The amount of overall shortening of wrinkle ridges

in Mare Frigoris was up to 1.5% (Figure 1). Wrinkle ridge systems in Oceanus Procellarum that are covered by TMC-2 had a shortening of 0.78%-1.9%. The Posidonius crater, located at the northeastern edge of Mare Serenitatis, contains a 1 km long wrinkle ridge visible on the floor of sinuous rilles as observed from TMC-2 orthoimages. Shortening across this wrinkle ridge ranges between 1.25% and 2.5% (Figure 2).

Absolute model ages of the wrinkle ridges were calculated using the crater size frequency distribution (CSFD) approach in order to establish the relationship chronologically. We have used the buffered cratered counting (BCC) method for wrinkle ridges as it aids in establishing the age of linear/curvilinear structural features on the lunar surface. With the aid of the cratertools software in ESRI's ArcGIS, wrinkle ridges were mapped as polygons and the postdated craters that were present on them were marked as three-point circles. The absolute ages of the lunar surfaces were calculated by fitting the derived crater counting statistics with the known crater production function for the moon [3]. In the central part of eastern Mare Frigoris, wrinkle ridges together with those creating the rim of the ghost craters formed around 1.4 Ga, while the wrinkle ridges towards the eastern boundary formed around 3.4 Ga (Figure 3). The absolute model age of the examined wrinkle ridge in Oceanus Procellarum is estimated to be 1 Ga (Figure 3). The wrinkle ridge on the Posidonius sinuous rilles floor spans a total of 15 kilometres. We used the buffered crater counting approach using TMC-2 ortho-images to estimate the age of this wrinkle ridge to be between 45 and 60 Ma (Figure 3).

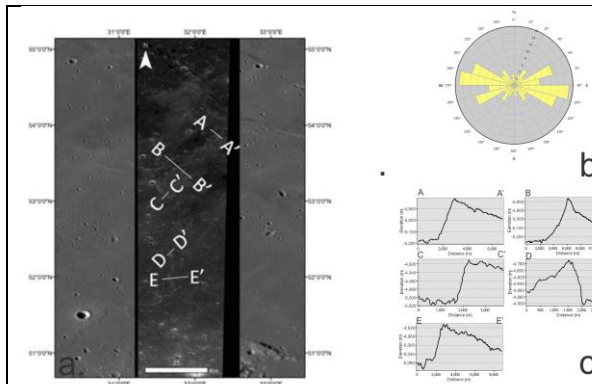


Figure 1: (a) TMC-2 ortho-image of wrinkle ridges present in the eastern region of Mare Frigoris; (b) superimposed on LROC WAC mosaic; rose plot of wrinkle ridges in the eastern region; (c) TMC-2 DEM generated topographic profiles of wrinkle ridges.

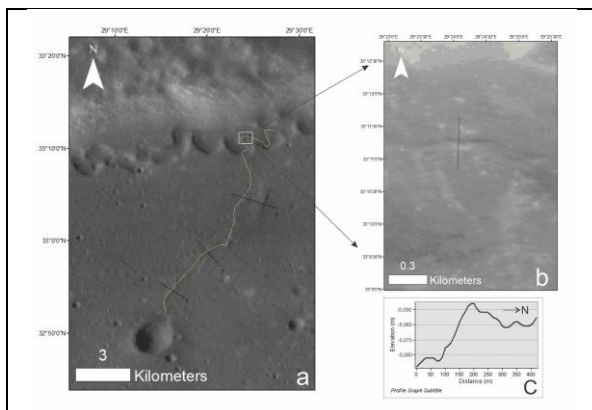


Figure 2: (a) LROC WAC image of wrinkle ridge cutting the Sinuous rilles within Posidonius crater; (b) TMC-2 ortho-image of wrinkle ridge within the floor of the sinuous rilles; (c) cross-section of the wrinkle ridge as shown in b.

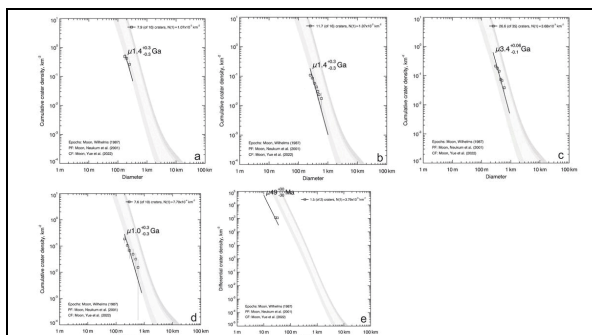


Figure 3: (a, b, c) Lunar model age estimation of wrinkle ridges derived from buffered crater counting approach; age for wrinkle ridges of Mare Frigoris; (d) age for wrinkle ridge of Oceanus Procellarum; (e) age for wrinkle ridges on the floor of sinuous rilles within Posidonius crater.

**Conclusion:** A morpho-tectonic examination of wrinkle ridges in three mare zones using the TMC-2 DEM shows various degrees of shortening, ranging from 0.67 to 2.5% depending on the concentration of compressional stress present in that regime. The formation of wrinkle ridges occurred over different time periods until the present. It can be assumed that the wrinkle ridge created within Posidonius sinuous rilles were generated relatively recently (45-60 Ma) compared to wrinkle ridges developed in other lunar basins between 1 and 3.5 Ga timeframe. The mechanism responsible for the "neo-tectonic" wrinkle ridges are yet to be ascertained but there may still be compressional forces at play, which points to the presence of a neo-compressional stress regime. This throws a challenge to the global lunar research community to have a holistic data analysis in future, including the Lunar Ground Seismic observations. It should be noted that wrinkle ridges as young as 10 Ma and a few 10s of Ma have also been found in the inner part of the Imbrium basin [4]. Therefore, it is crucial to consider the localised compressional stress in addition to the moon's general contraction in morpho-tectonic study for Lunar Crustal Shortening.

It is noteworthy to state that due to ever evolving data versions of TMC-2, the results are likely to be refined further.

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**References:** [1] Schultz R. A. (2000) *JGR.: Planets*, 105(E5), 12035–12052. [2] Marshak S. and Mitra G. (1988). *Prentice-Hall, Inc.*, 232-233. [3] Kneissl T. et al. (2015) *Icarus*, 250, 384-394. [4] Yu Lu et. al.(2019) *Icarus*, 329, 24-33