**LOBATE SCARP IN THE VICINITY OF CHANDRAYAAN-3 LANDING SITE IN THE SOUTHERN HIGH LATITUDES OF THE MOON: INSIGHTS INTO FORMATION AGE AND SEISMICITY.**

R. K. Sinha[1], A. Rani[1], T. Ruj[2], and A. Bhardwaj[1], [1]Planetary Sciences Division, Physical Research Laboratory, Ahmedabad 380009, Gujarat, India (rishitosh@prl.res.in), [2]Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Sagamihara, Kanagawa 252–5210, Japan.

**Introduction:** Lobate scarps are geologically recent thrust fault-derived tectonic structures on the Moon and they are seismically active recently [1-3]. We have found evidence of a ~58 km long segment of lobate scarp situated at an average horizontal distance of ~6 km in the west of the proposed primary landing site (PLS; it is located between Manzinus and Boguslawsky craters in an area between 68 and 70° S and 31 and 33° E) of ISRO's Chandrayaan-3 lander-rover based mission [Fig. 1]. The Chandrayaan-3 lander has a seismometer instrument for Lunar Seismic Activity (ILSA) studies, which is going to measure ground acceleration (up to a range of 0.5 g over a bandwidth of 40 Hz) due to shallow moonquakes [4]. The shallow moonquakes can induce ground shakings likely related to the movements along lobate scarps [5], which in turn can trigger boulder-falls and landslides [6-8]. Therefore, it is imperative to estimate the timing of the formation of lobate scarp and associated potential seismic activity, which would provide significant clues regarding the geologically recent seismic hazard potential of the PLS of the Chandrayaan-3 mission. Moreover, it will enhance our understanding of the potential of ILSA in detecting seismicity within the PLS in relation to the potential movements along the lobate scarps.

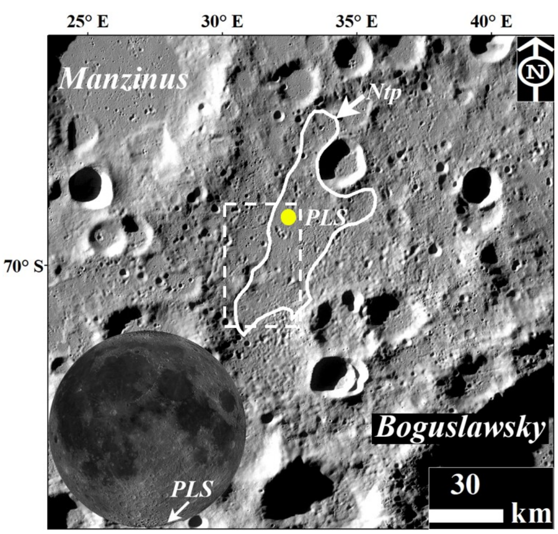


*Figure 1 – LRO WAC mosaic-based geological context view of the Primary Landing Site (PLS- yellow circle). Dashed white lines – location of lobate scarp shown in Figure 2.*

**Observations and Results:** The PLS region corresponds to 'Nectarian Plains (Ntp)' primarily comprising of 'terra mantling and plains material' of the Nectarian geological epoch [9] [Fig. 1]. The geological units within Ntp could have originated from primary and secondary ejecta of Nectarian aged basins and large craters [9].

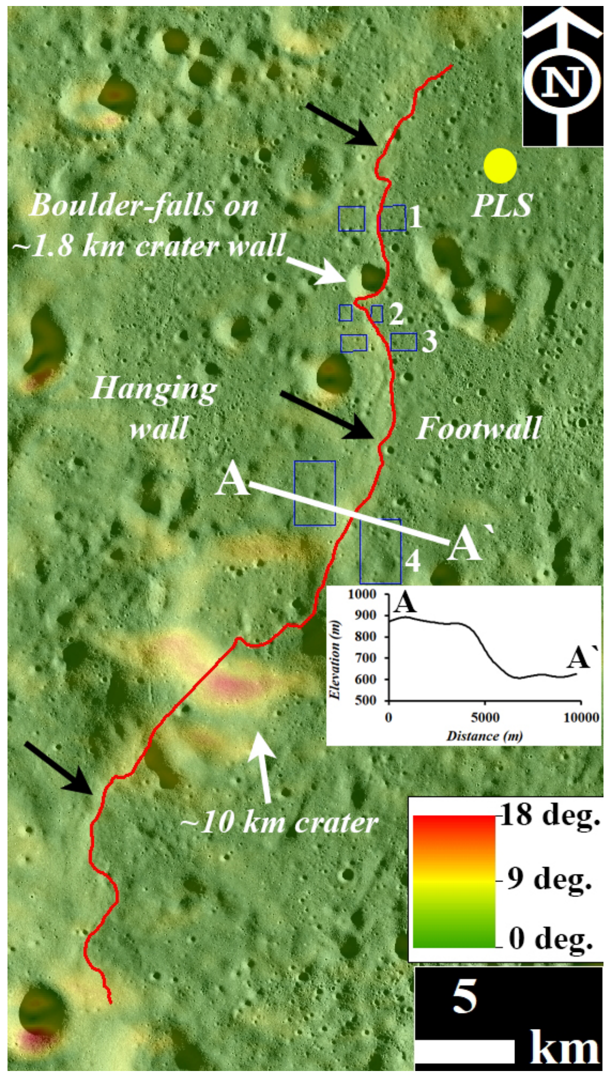


*Figure 2 – Kaguya-TC orthoimage over LRO WAC DTM based slope map of the region. Red line - Lobate scarp. Black arrows – NW-SE propagation direction. Blue boxes – 1-4 crater count areas. Locations of ~10 km crater modified by scarp and ~1.8 km crater with boulder-fall trails on the walls are shown.*

The general slopes on exposed faces of lobate scarp are <10° and its height typically varies between 100 and 250 m [profile A-A` in Fig. 2]. The vergent side of the lobate scarp is oriented in the upslope direction, which suggests that the propagation direction of lobate scarp is NW-SE [Fig. 2].

*Morphological evidence indicative of recent activities.* The lobate scarp shows crosscutting relationships with the craters in the diameter range of ~50 to 1000 m. Moreover, a ~10 km crater is found to be significantly modified by the potential movements along the scarp [Fig. 2]. Additionally, fresh and faded boulder-fall trails are evident on the wall of a ~1.8 km crater positioned over the face of the lobate scarp [Fig. 2].

*Formation age of the lobate scarp.* We have performed crater counts over four areas each on the hanging and footwalls of the lobate scarp [Fig. 2]. The crater size-frequency distribution (CSFD) based best-fit age illustrates that the lobate scarp is late Copernican in age (~50 Ma) [Fig. 3].

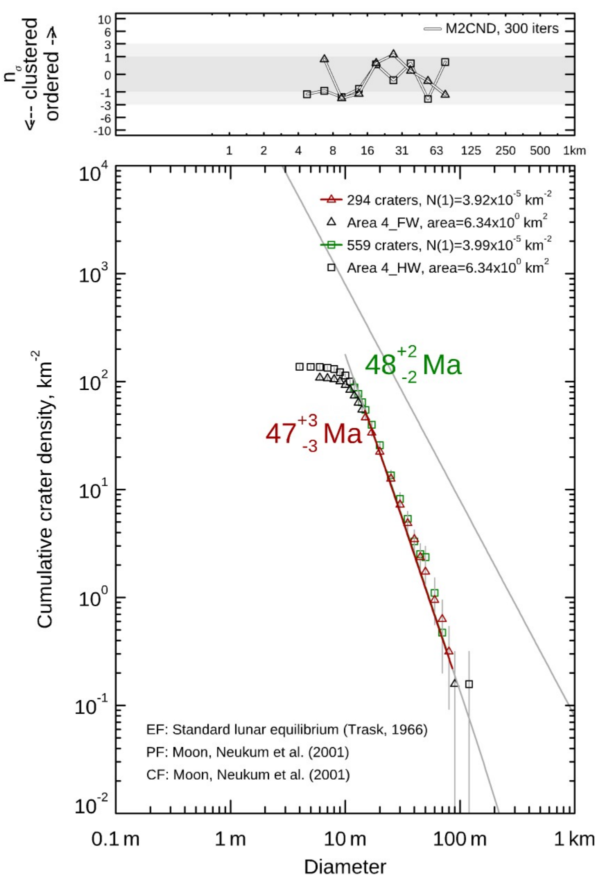


***Figure 3** – Best-fit ages of the area no. 4 selected on the footwall (FW; red) and hanging walls (HW; green). All the crater count areas have slopes <10° and all areas (except area 2) are >1 km$^2$ [3]. Randomness analysis confirms absence of crater clusters at the diameters of craters counted in this study.*

*Measurement of seismicity associated with the lobate scarp.* Our estimation of moment magnitude ($M_w$) depicts a cumulative moment magnitude of Mw 9.2. The focal depth of potential shallow moonquakes is estimated to vary from 9.3 to 21.4 km. Previously, it has been shown that the $M_w$ 7 moonquakes occurring at 15 km focal depth could produce peak ground acceleration (PGA) up to 2 g at the near fields (within a 10 km radial distance) [10]. Therefore, the $M_w \geq 7$ events could produce ground shakings and trigger boulder-falls up to a radial distance of 80 km (focal depth ≤ 15 km), given that a threshold PGA value of 0.6 g is required for triggering boulder-falls [10].

**Inferences and Implications:** The lobate scarp around PLS is a younger generation lobate scarp [11]. The evidence of boulder-fall trails might suggest potential recent activity associated with movements along the lobate scarps, which implies that the lobate scarp has been seismically active recently. Hence, it would be worth giving special attention to the seismic measurements recorded by the future ILSA instrument. However, it is important to mention that in absence of Earth-like plate tectonics on the Moon, a higher magnitude of moonquakes is not possible currently. Nevertheless, we suggest that shallow moonquakes with a maximum possible moment magnitude of 9.2 could have occurred in the past within the period (~50 Ma) of the estimated ages of the lobate scarp investigated in this study [3,5,12].

**Key Conclusions:** We conclude that the PLS of the Chandrayaan-3 mission might be safe from any potential seismic hazards happening currently. Nonetheless, it is expected that the ILSA can characterize the spatio-temporal patterns of potential $M_w$ 4 shallow moonquakes, provided that it is occurring currently in the PLS region at a focal depth of <1 km.

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**References:** [1] Binder A.B. (1982) *The moon and the planets, 26(2), 117-133.* [2] Watters T.R. et al. (2015) *Geology, 43(10), 851-854.* [3] van der Bogert C.H. et al. (2018) *Icarus, 306, 225-242.* [4] John J. et al. (2020) *Current Sci., 118(3).* [5] Watters T.R. et al. (2019) *Nat. Geosci., 12(6), 411-417.* [6] Kumar P.S. et al. (2016) *JGR Planets, 121(2), 147-179.* [7] Ruj T. et al. (2022) *Icarus, 377, 114904.* [8] Kumar P.S. et al. (2013) *JGR Planets, 118(2), 206-223.* [9] Wilhelms D.E. et al. (1979) *Department of the Interior, US Geological Survey,* [10] Mohanty R. et al. (2020) *JGR Planets, 125(12), e2020JE006553*. [11] Mishra A. and Kumar P.S. (2022) *GRL, 49(18), e2022GL098505.* [12] Nahm A.L. and Velasco A.A. (2013) *LPS XLIV, Abstract #1422.*