NEW REPORT OF YOUNG LOBATE SCARPS AND RECENT MASS WASTING EVENTS IN THE LUNAR SOUTH POLAR REGION WITH IMPLICATION FOR SEISMIC HAZARD ASSESMENT TO UPCOMING LANDING MISSION. Abhisek Mishra[1, 2] and P Senthil Kumar[1] [1]CSIR, National Geophysical Research Institute, Uppal Road Hyderabad, 500007, India, [2]Academy of Scientific and Innovative Research, Ghaziabad, 201002, India. Email: abhisekmishra81@gmail.com.

Introduction: Lunar surface exposes various tectonic landforms such as wrinkle ridges and lobate scarps that are of compressional tectonic origin and network of grabens marking up the extensional regimes. The wrinkle ridges are localized, large scale complex landforms restricted to the Mare regions where as the lobate scarps are globally distributed, comparatively smaller in scale and found largely in the Terra crustal regions, representing the surface expression of low angle thrust faults [1]. The scarps are common in lunar highlands, and are the dominant landform of the far side [2]. Lobate scarps are the youngest tectonic landforms on the moon [2, 3] and are formed due to compressional stresses arising from crustal shortening because of active lunar contraction [4]. Large numbers of globally distributed young lobate scarps are identified previously by various researchers [5, 6, 7, 8], out of which Watters et al. (2015) and Kumar et al. (2016) includes scarps in the southern polar region.

Previous work has reported the co-seismic occurrence of mass wasting features in and around the seismically active faults, at various locations like Schrodinger basin, Lorentz basin and Orientale basin, which indicate that significantly higher levels of seismic ground shaking originated from the shallow moonquakes along these faults that triggered the formation of mass wasting features [7, 8, 9].

The current study is focused on the southern polar region of the moon, where we have located several new and previously unidentified lobate scarps and boulder fall sites (Figure 1). As the upcoming human landing mission is targeting to lunar south polar region, objective of the study is to assess potential hazards around lunar south pole through geologic analysis and seismic ground motion simulations [9], considering both the new and previously identified scarps.

Data and Methods: The entire work is based on photo-geologic study of the area. We have used LROC quickmap browser for locating the scarps and boulder fall sites, initially. High resolution Lunar Reconnaissance Orbiter Camera (LROC) - NAC (Narrow Angle Camera) images are obtained from USGS-PILOT web portal. The images are processed using POW (Projection on web) interface and downloaded, imported to ArcGIS desktop 10.7 software for digital mapping and analysis. We have used more than 700 LROC-NAC images of 0.5m/pixel resolution in this study for mapping the scarps and boulder falls. LROC- WAC (Wide Angle Camera) images that provides 100m/pixel images in seven colour bands are used for representing the scarps and mass wasting sites and analysing their distribution pattern.

Initial Results and discussion: 58 new scarps are identified at 17 different locations (Figure 1). Except the scarps, located at the base of western wall of an unnamed crater to the east of Petrov crater, the rest of the scarps occupy the lunar highland. Most of the scarps are located within the impact crater both in the floor as well as along the walls of crater, whereas remaining few scarps are occupying the inter crater plains. Number of scarps in the different locations are ranging from a single scarp (e.g., Amundsen crater, Bailly A crater, etc.) to a maximum of 10 scarps (Demonax crater), with varying length of segments. Number of segments for individual scarps is ranging from a single segment to a maximum of 56 segments. The length of individual scarps ranging from a minimum of 620 m (a scarp located at the west of Schrodinger crater having length 620 m) to 79 km (a scarp present in Demonax crater floor having length 80 m), where as the individual segment lengths ranges from a minimum of 20 m to 20 km for scarps of different locations.

The newly identified scarps are generally linear and curvilinear in nature with a few locations showing anastomosing patterns and scarp clusters. Some of the locations demarcating crosscutting of small diameter impact craters by the scarps, and superimposition of very few small impact craters that suggests them to be very young [2, 7]. Some of the scarps are also degraded by younger impacts and their ejecta; like, the scarp situated in the Bailly A crater along its western crater walls is degraded by fresh ejecta rays from adjacent young impact crater (Figure 2), suggesting the scarp to be older than the crater.

Most of the scarps are located along the crater walls (e.g., Klaporth H crater) that is suggesting the reactivation of crater wall normal faults along which thrusting took place later to produce these scarps [8, 9]. The sites, where the scarps are located within the craters, the crater size varies in diameter ranging from 20 to 125 km and in two of the locations the craters are with central peaks (e.g., Amundsen crater, Demonax crater), whereas in the other locations craters are simple to complex in nature with absence of central peaks or peak rings.

Several boulder fields are noticed along the scarps and the host craters along the crater wall slopes and central peaks. Eight locations showing evidence of mass wasting events are also identified (Fig. 1). More locations with such evidence are expected and requires further detailed observations. Some of these locations showing non-degraded boulder trails which are lacking of any superposed large sized impact craters (>10-20m diameter) and also the boulder which are rolled down the slopes are found to be preserved, that suggests the mass wasting events are quite younger [7, 8, 9]. These boulder falls could be triggered by the shallow moonquakes whose epicenter may lie along any of these scarps [7, 8, 9].

Considering the shallow moonquake catalogs by Mohanty et al. (2020), the shallow moonquakes with moment magnitude (M_w) range of 1 to 4 is expected in next few decades as the recurrence period for these moonquakes would be on the order of few years to tens of years. Assuming a maximum possible occurrence of M_w 4 moonquake in near future, the seismic ground motion simulation suggests the PGA (Peak Ground Acceleration) generated by it for any focal depth <5km will be effective for few kilometer to few tens of kilometer only [9]. Length of the 58 newly identified scarps and the distance of respective scarps from the pole (Fig. 3) show the nearest located scarp at around 96 km (a scarp south of Ibn Bajja Crater). The preliminary result suggests that even if the faults are active today and any shallow moonquake with M_w 4 occurs in the near future, the seismic ground shaking would be expected to a maximum distance of 50 km from the epicenter and it would not affect the south pole area in and around Shackleton crater. Hence, the south pole area may be seismically safe for upcoming landing mission. Further analysis is in progress.

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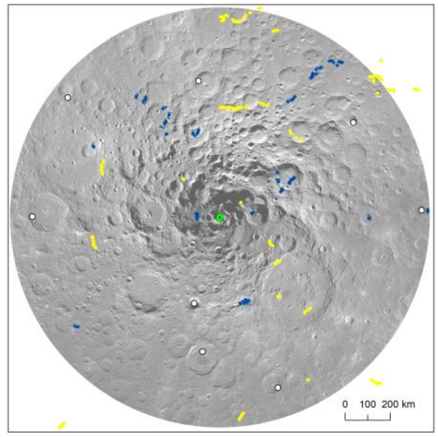

Figure 1. LROC-WAC mosaic showing the newly identified lobate scarps (Indigo lines) and those reported previously (yellow lines) in the south polar region. The boulder fall sites are marked by white circles. Green circle is the south pole.

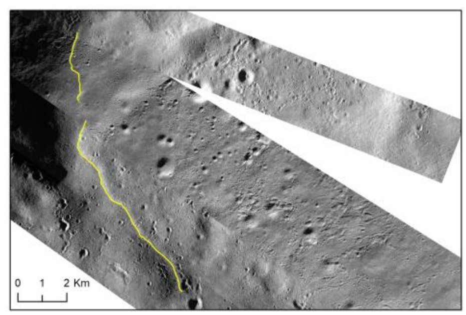

Figure 2. LROC NAC image mosaic showing the lobate scarps along the crater wall of Bailly A crater.

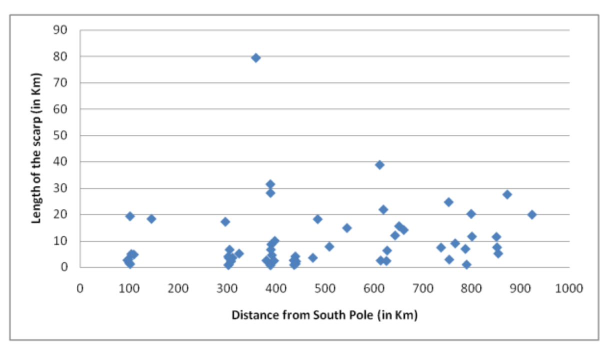

Figure 3. Scarp length vs. distance from south pole for 58 newly identified individual scarps.