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Rocky outcrops and low crater densities on lunar wrinkle ridges: Evidence for recent tectonic activity?

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1. Introduction

Lunar wrinkle ridges are prominent elongated and topographically up to a few hundred meters high geologic features found in lunar maria [1,2]. Their formation is linked to a combination of folding and thrust faulting tectonic processes and are thought to have formed when the bulk of lunar maria magmatism was active, around ~4-3 Ga ago [3-5].
Recently, with the help of high resolution images a number of geologically young tectonic structures have been identified by various workers. Observations of small lunar graben depths and their crater crosscutting relationships indicate recent (<50 Ma) extensional tectonism [6]. Investigations of, contractional lunar lobate scarps using stratigraphy and crater size frequency distribution (CSFD) measurements has also shown that they are between 1 Ga to <100 Ma old [7,8]. In our work, we analyze several lunar wrinkle ridge systems in various lunar maria. Stratigraphic relationships and the lack of large superimposing craters suggests that wrinkle ridges in our study regions are Copernican, i.e. <1.1 Ga in age. For selected wrinkle ridge surfaces we derive model ages (AMAs) from CSFD measurements which result in ages below 30 Ma. Analyzed lunar wrinkle ridges appear morphologically crisp and include various degrees of pristine rocky outcrops. This suggests that they are geologically young because estimates of lunar boulder obliteration rates imply that rock populations on the lunar surface are fully destroyed in ~300-1500 Ma [9-12].

2. Methods and Data

In this work for CSFD measurements and stratigraphic analysis we use the Lunar Reconnaissance Orbiter Narrow Angle Camera (LRO NAC) dataset. Dating by the CSFD measurement technique has been previously used by various studies for small scale structures on the Moon such as lobate scarps, Irregular Mare patches (IMPs), impact ejecta and basalt flows [8,12,13]. This procedure relies on well-established lunar chronology and production functions [15,16]. For the identification of high concentrations of lunar boulders we use LRO Diviner instrument rock abundance maps derived from night and day time thermal infrared temperatures [17].

3. Results

All of the analyzed wrinkle locations across the Moon are shown in Fig. 1. Selected areas for CSFD analysis have exhibited very low crater frequencies. This lack of craters results in low derived absolute model ages (AMAs) from our CSFD measurements, all <30 Ma in age. One example wrinkle ridge cumulative CSFD plot can be seen in Fig. 2. All wrinkle ridges contain from low to high rocks abundancies. One wrinkle ridge system exhibits particularly high boulder concentrations in northern Mare Humorum, which is ~100 km in length, contains up to 5 different braids and has high thermal

Figure 1. Global view of analyzed wrinkle ridge locations. Larger circle area can be seen in Fig. 3. LRO WAC 100 m/px base map.

inertia values. The high reflective properties of these up to 5 meter boulders can be seen in Fig. 3.

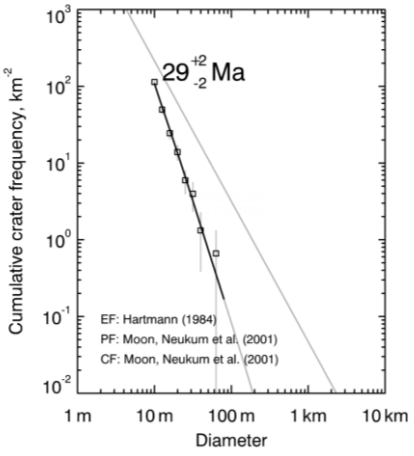

Figure 2. Cumulative CSFD plot and its model age for wrinkle ridge count area in Mare Imbrium.

4. Discussion and Conclusions

Our results suggest that there is some correlation between rocky terrains and low crater densities for wrinkle ridge areas analyzed in this work. The northern part of Mare Humorum (Fig. 3) according to standard dating techniques is 3.45 Ga of age [5]. The other mare regions exhibit similar old ages. The low model ages from CSFD measurements and the extremely rocky regions in Mare Humorum as well as other areas suggest of late Copernican (<100 Ma) global tectonic processes in the lunar maria. A recent study [18] has shown that along wrinkle ridges there are global stress fields. The processes that could excavate such amounts of lunar regolith and reshape the top layer of lunar maria is unknown. However, past Apollo missions have recorded deep and shallow lunar quakes [19,20]. The findings presented in this work and by other workers [7,8] point to a more complex lunar thermal and late stage tectonic evolution.

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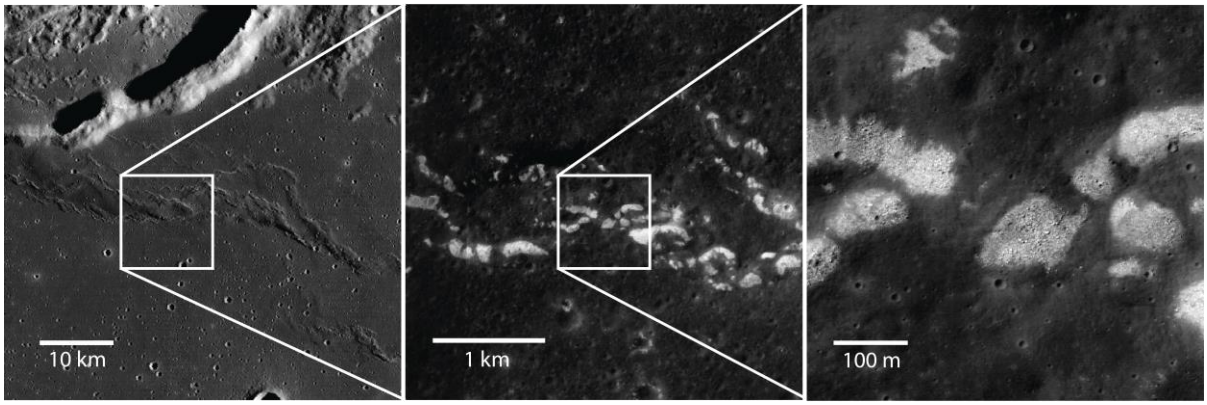

Figure 3. Context image of wrinkle ridge system in Mare Humorum (left). Close up images of rocky outcrops (center & right). LRO WAC and NAC (M183781901) images respectively. NAC low incidence angle image shown to emphasize the contrast between surrounding regolith and rocky outcrops.