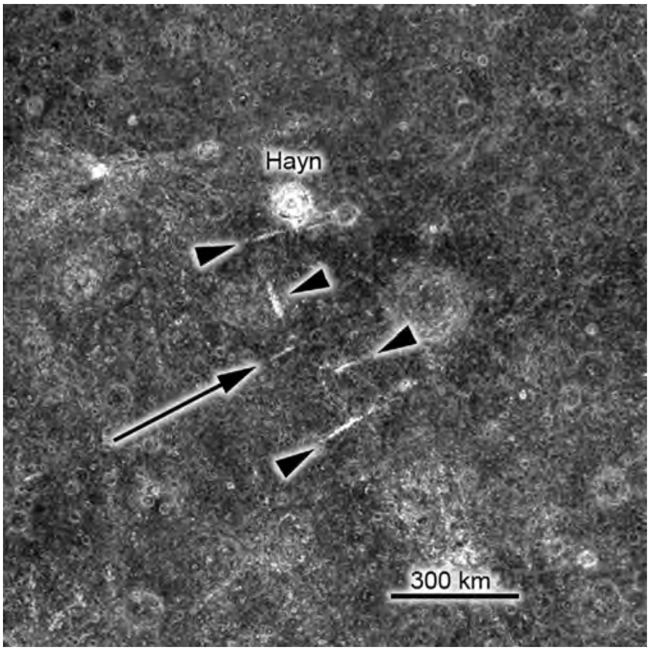

Fig. 10. Roughness map of the northeastern limb region of the Moon centered at 53°N 90°E, 115 m baseline, local Lambert azimuthal equal-area projection; brighter shades denote higher roughness. Arrows show five distinctive rough lineaments not associated with crater ray systems. Long arrow marks the lineament shown in Fig. 11.

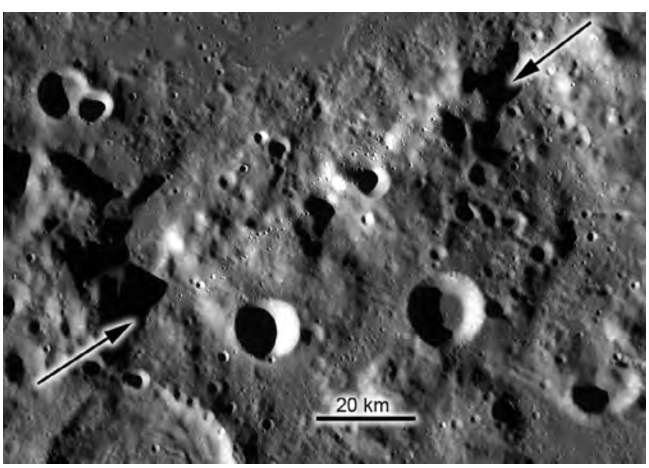

Fig. 11. Dense elongated cluster of relatively sharp craters (between arrows) coincides with the roughness lineament shown with a long arrow in Fig. 10. The scene is centered at 52.5°N 84.5°E; a portion of LROC WAC global mosaic, local equirectangular projection.

are not seen in this figure, but are apparent in higher-resolution images). There are no hints of an endogenic origin of these craters in their morphology and settings; they are impact craters. Neither do they show morphologies suggestive of low-velocity or highly oblique impact. For comparison, the proximal secondary craters on the Moon always show typical morphologies of slow and/or grazing impacts, while the secondaries in the distal parts of the long roughness rays generally do not. The prominent roughness signature suggests a geologically young (Copernican) age. One of these clusters (the northernmost marked in Fig. 10) is superposed over proximal ejecta of Hayn, a large Copernican-age crater, and hence postdates the Hayn impact. In high-resolution images (LROC NAC) the cluster-forming craters look softened; they obviously underwent significant regolith gardening and are not very recent.

These dense crater clusters are highly elongated and linear. We determined their axes and fitted great circles to them. We estimate that in two cases (the cluster in Fig. 11 and the southernmost marked in Fig. 10) the accuracy of our axis direction determination is better than 2°. The fitted great circles (admitting 2° variations of the axes direction) do not extend to the vicinity of any large (>20 km) crater with prominent roughness signature in Figs. 2 and 3. This fact, together with their peculiar morphology, suggests that these dense crater clusters are not typical clusters of secondaries.

The origin of these objects is unknown. A straightforward idea that these are clusters of primary craters formed by tidally disrupted rubble-pile objects seems not to be viable. On one hand, we observe the results of such impacts both on the Moon (e.g., Melosh and Whitaker, 1994) and on other bodies (e.g., Schenk et al., 1996), but these examples look very different: they are chains of larger craters rather then dense clusters of smaller craters. On the other hand, dynamical considerations (Bottke et al., 1997) show that such events are rare and we should not expect a large number of such impacts on the Moon. Another idea is some kind of "sesquinary" impacts: either impacts of the objects ejected from the Earth, or impacts of the objects ejected from the Moon into geocentric orbits and returned to the Moon after one or a few revolutions. Dedicated dynamic modeling is needed to assess the viability of these ideas.

In addition to these enigmatic objects and the roughness rays, the hectometer roughness maps reveal a large number of other rough lineaments. The longest and roughest of them extends from the center farside to the South Pole and farther to the southern nearside (Fig. 3). It has a roughness similar to or a little higher than the most prominent roughness rays. Its roughest segments are associated with clusters of craters very similar to the clusters of distal secondaries within the roughness rays; however, it is not straight. It ends (or begins) close to Jackson, but it is not obvious if it is genetically related to it. There are also numerous low-contrast (just slightly rougher than the background) short lineaments without obvious association with craters.

4.3. Background roughness variations

As we noted in Section 3, primary boundaries of geological units usually do not have a prominent expression in the map of hectometer-scale roughness (Figs. 2 and 3). There are some exceptions. The highland–mare boundary can be traced in a few locations. A sharp contrast between volcanic plains of Mare Tranquillitatis (smoother) and Mare Serenitatis (rougher) coincides with a well-expressed geological contact. Weak roughness contrasts outline units of the Orientale impact basin; a few segments of other impact basin rims can be traced in the roughness map.

There are opposite examples, where roughness contrasts look like contrasts between distinctive units, but do not correspond to known geological boundaries. There is a sharp linear boundary between the southern rough part of Mare Humorum ($r = 1.1$) and the much smoother northern part ($r = 0.84$). This boundary does not correspond to any obvious geological contact, albedo or color contrast.

Aristarchus Plateau provides an interesting example of a roughness contrast that does coincide with a prominent geological contact. The largest pyroclastic deposit on the Moon (e.g., Gaddis et al., 2003) covers the plateau and overlies both more ancient Imbrium basin ejecta and superposed impact-related regolith, and is embayed by mare basalts along the plateau margin (Zisk et al., 1977; Lucey et al., 1986). The pyroclastic deposit is noticeably smoother than typical surfaces ($r = 0.7$) and has a distinctive, sharp boundary.