ROLLING BOULDERS AND THEIR TRACKS ON LUNAR SLOPES

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Introduction:

Lunar rock boulders were the subject of intense studies since the 1960–70's as obstacles for safe landing and indicators of thickness of the regolith layer [e.g. 1, 2, 3, 4]. New possibilities to study them appeared since the Lunar Reconnaissance Orbiter Narrow Angle Cameras (LROC NAC) started to provide to the scientific community images of the lunar surface with a resolution of ~ 1 m and locally even higher [5]. Combined with other scientific information this led, in particular, to estimations ofthe lifetime of lunar boulders exposed on the surface of the Moon [e.g., 6, 7]. This fact provided again, a possibility to estimate the absolute ages of small craters based on the measured spatial densities of boulders in their ejecta, and to use these ages to estimate the times of formation of other lunar landforms [e.g., 8]. Characteristics of tracks formed by boulders bouncing on slopes allowed one to estimate bearing capacities of surface materials in some usual and specific geologic environments [9]. In the present work we consider rock boulders and their tracks on lunar slopes as a tool to understand episodes of recent geologic history in the studied areas. We consider LROC NAC images and LOLA-based topographic information for the NW inner slopes of the 320 km crater Schrodinger and the NE part of the South massif in the Taurus-Littrow valley.

The crater Schrodinger NW inner slope:

Under study was the 13 × 10 km area which included the Schrodinger inner slope, as well as the sub-horizontal surfaces above and below it (Fig. 1).

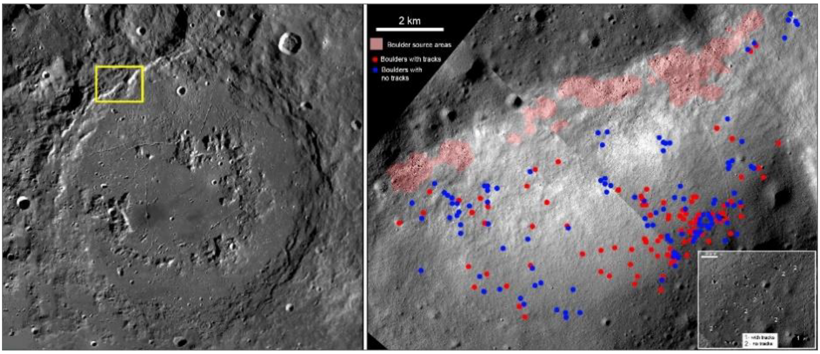

Fig. 1. Left is LROC WAC mosaic showing a position of the study area in the NW rim of crater Schrodinger.Right is the mosaic of LROC NAC images showing boulders with (red) and without (blue) associated tracks.

We analyzed a mosaic of LROC NAC images with resolution 2 m per pixel using the Photoshop program and measured the vertical (a) and horizontal (b) dimensions of theilluminated parts of the boulders and selected for further study those which had 5 pixels at least in one dimension. The total lengths of the illumination parts $1=\sqrt{\left(a^2+b^2\right)}$ were calculated and presented in meters. Outlines of selected boulders were marked and thus mapped. This procedure led to the mapping of 211 boulders. The length of the illuminated partof the boulders ranges from 13 to 80 m, with a median size of 17 m, the average size is 20 m. Ninety-eight (46%) boulders are associated with tracks whose width is about the boulder size, and 113 (54%)are without tracks. Most mapped boulders are located on the slopes whose inclinations are in the range of 20 to 25o. In the upper part of the slope there areareas with numerous no-track boulders (pink-colored areas in Fig. 1). These areas seem to be sourceregions of the boulders we observed on the slope below.

Taurus-Littrow — NE slope of South massif:

This study area is 7.4 × 9.2 km2 and includes parts of the South massif, its NE slope, anda small portion of the Taurus-Littrow valleyfloor (Fig. 2).

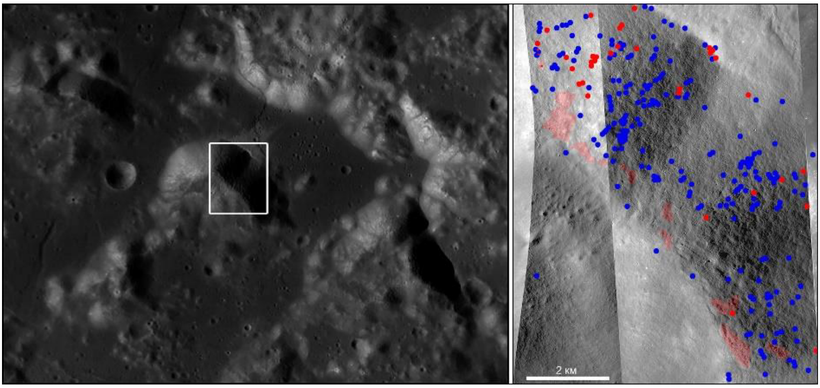

Fig. 2. Left is LROC WAC mosaic of Taurus-Littrow valley; Right is the mosaic of LROC NAC images showing boulders with (red) and without (blue) associated tracks.

Here we analyzed mosaics of the LROC NAC images with resolution 0.43 m per pixel performing all of the procedures as described in the above section of the paper. This led to a mapping of 249 boulders.The length of the illuminated part of the boulders ranges from 4 to 23 m, with a median size of 7 m, and an average size of 8m. Thirty-two (13 %) boulders have as sociated tracks whose width is about the boulder size, and 217 (87%) are without tracks. Most mapped boulders are located onslopes of 20 to 25o steep. In the upper part of the slope there are areas with numerous no-track boulders (pink-coloredin Fig. 2). As in the Schrodinger study area, these seem to be source regions of the boulders observed on the slope below.

Discussion and conclusions:

The above considered study areas are on the slopes of pre-mare landforms which evolved for 3–3.9 Ga. During this time period the slopes represented an areawhere the slope retreat via down-slope material movements, including a supply of boulders from the mentioned source regions, was accompanied by destruction of the bouldersby meteorite impacts and thermal fatigue. The lifetime of the meter-sized rock boulders (T) was estimated as 200-300 Ma, with half of the new-formed ones being destroyed within a time of ~ 50 Ma [e.g., 6-8]. New boulders appeared on the surface of the above shown slopesand produced tracks consisting of chainsof crater-like pits. The track lifetime can be roughly estimated as the lifetime of a crater with a diameter equal to the track width; in our cases this is onaverage ~ 10–20 m. For craters of this size the lifetime was found to be t = 2.5D, where tis in Ma and D is in meters [10]. In our cases t could be 25 to 50 Ma. But this is an estimate for craters on sub-horizontal surfaces. On slopes as steep as 20–25o the crater lifetime is by an order of magnitude shorter [10]; in our case t = 2.5 to 5 Ma, that is by an order of magnitude shorter than the boulder lifetime T. If on some slope the rate of the boulders' appearance (per unit of time) is close to constant, then the ratio R of the number of boulders with tracks (N_t) to the total number of boulders (NT) should be proportional to t/T, in our case ~ 0.1.

In the above considered cases, R was found to be 98/211 = 0.46 for the Schrodinger study area and 32/249 = 0.13 for the Taurus-Littrow area. This probably means that in the Taurus-Littrow area for the latestgeologic time period (probably ~ 100 Ma [11]) the interaction between the appearance of new boulders and their destruction by surface processes was close to equilibrium, while in the Schrodinger study area some catastrophic event which provoked the appearance of many new boulders occurred recently (moonquake, meteorite impact).

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