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Characterization of lunar blocks fragmented in situ: implications for impacts and solar-induced thermal stresses

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Abstract

We characterized the morphology, morphometry and abundance of in situ fractured blocks as a function of surface exposure age on the Moon. We find that in situ fractured blocks are due to meteoroid impacts with possibly a minor contribution by non-uniform diurnal solar heating and associated thermal stresses. In situ fractured blocks provide insights into regolith formation on the Moon and other airless bodies.

1. Introduction

In order to understand the process of block breakdown and regolith development, we characterized populations of blocks at the rim of 6 large craters. These craters have been previously dated with the crater size-frequency distribution technique [e.g., 1]: the youngest crater is ~4 Ma, the oldest is ~1 Ga. Because all blocks on the rim of these craters were emplaced during crater formation, the surface residence age of the blocks populations is known. In situ fractured blocks in each population were characterized in terms of morphology, morphometry and abundance. We refer to in situ fractured blocks to instances of disruption without dispersion, i.e., to splitting of a block without significant movements of the fragments [2,3].

2. Methods and Results

We present a representative set of in situ fractured blocks in Figure 1. A range from highly to weakly fractured blocks is observed. In morphological terms, this range can be represented with the ratio of the area of the largest fragment to the area of the cluster of all fragments. We find that this morphological continuum is present in all populations, independently of their surface exposure age. The abundance of fractured blocks relative to the total number of blocks in a population increases with time (Figure 2). This trend implies that fragmentation occurs mostly *after* block emplacement and that fragmentation *during* landing of ejecta block plays a minor role. In order to disentangle fragmentation by meteoroid impacts from the suggested influence of non-uniform solar heating [e.g., 4], we estimate the flux and size frequency distribution of the putative projectiles that are responsible for fragmentation. Here we assume that each fragmented block has been disrupted by a *single* projectile of energy ~Q^*_s. This value corresponds to the energy required to disrupt a body such that the mass of the largest fragment is half the mass of the parent body [e.g., 5,6]. We compare the flux and size frequency distribution of putative projectiles with that of known meteoroids [7,8]. We find that both the estimated flux and size frequency distributions are consistent, within uncertainties, with the expected meteoroids impacting the Moon. This implies that impacts are the dominant process disrupting blocks, as previously suggested [e.g., 9]. In order to identify the possible influence of non-uniform solar irradiation, we performed azimuth measurements of cracks on blocks, as previously done on blocks on Earth deserts and on Mars [e.g., 10,11]. We find a preferred orientation of cracks in the youngest population, consistent with thermal stresses originating from non-uniform solar irradiation.

3. Conclusions

The study of in situ fragmented blocks allows to characterize the processes responsible for regolith formation. On the Moon, where disruption is dominated by impacts, in situ fragmented blocks enable the study of projectiles at small diameters and provide complementary information in addition to study of impact craters. These results might be useful for the interpretation of block-rich surfaces on other airless planetary bodies.

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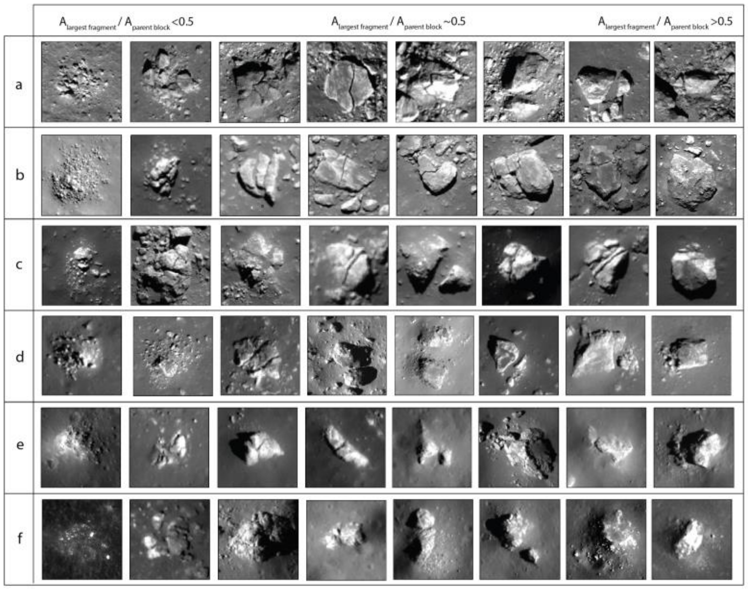

Figure 1: Typical examples of in situ fractured blocks in the size range 20-100 m, shown from highly (left) to weakly (right) fractured. The surface exposure time of the blocks increases from top to bottom. (a) Giordano Bruno, (b) Byrgius A, (c) Tycho, (d) Aristarchus, (e) Copernicus, and (f) King craters, ~4 Ma, ~47 Ma, ~85 Ma, ~175 Ma, ~800 Ma, ~1 Ga, respectively.

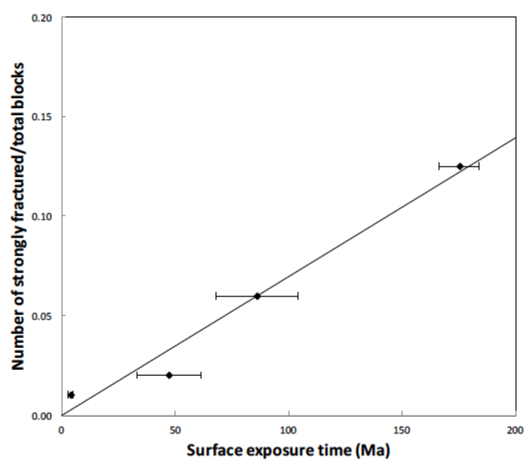

Figure 2: Relationship between the relative abundance of highly fractured blocks in a block population and the surface exposure time. The number of measured blocks in each population is >500 and their size range is 8-60 meters.