PDC 2019
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The boulders on asteroid Ryugu: clues to the formation history of the top-shaped morphology

Bin Cheng[a,*], Yang Yu[b], Hexi Baoyin[a]

[a]*School of Aerospace Engineering, Tsinghua University, Haidian, Beijing, 100084, China*
[b]*School of Aeronautics Science and Engineering, Beihang University, Haidian, Beijing, 100191, China*

Keywords: Asteroids dynamics, Asteroids rotation, Geological process

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On June 27th, 2018, the *Hayabusa2* spacecraft arrived at the target asteroid Ryugu, showing us its surface morphology in unprecedented detail. One of the most curious characteristics is the presence of large boulders particularly around the poles [1]. Boulder size measurements indicate that they are too large to be impact ejecta from observed craters, suggesting that they may be direct fragments from Ryugu's parent body [2]. We therefore believes the boulders should have recorded the geological evolution of the surface regolith, and may provide important clues regarding the formation process of the top-shaped asteroid Ryugu, despite their motion history during the YORP acceleration has not been identified yet. In this study, we investigate the creep evolution of the boulders on granular regolith during the spin-up of asteroid Ryugu. The asteroid body is represented as a rigid polyhedron subjected to rotational acceleration, and a granular layer (about 40 m in thickness) consisting of 1,603,021 particles is used to simulate the surface regolith. Boulders of various sizes initially distribute on the surface of the regolith layer. A soft-sphere discrete element model (SSDEM) [3] capable of simulating granular system in quasi-static states is implemented in order to track this quasi-static spin-up procedure. We systematically explored the effect of the mechanical properties of the regolith particles, including the friction and cohesive strength. The results show that the progenitor turns to an oblate shape as the spin rate approaches the critical limit, in parallel with regolith mass moving from the poles to the equator [4]. During this granular migration, the boulders are transported to low-latitude by creeping grains underneath. Simultaneously, the strength of the force network supporting the boulder is weakened due to the creep deformation, thus the boulder sinks into regolith layer in a gradual manner until buried by surrounding deposition. These results explains the deficiency of large boulders at the equatorial area, and will serve as direct evidence of the formation processes of the top-shaped morphology.

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*Corresponding author
Email addresses: chengb16@mails.tsinghua.edu.cn (Bin Cheng), yuyang.thu@gmail.com (Yang Yu), baoyin@tsinghua.edu.cn (Hexi Baoyin)

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