Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-P19 Room:Poster Time:April 28 18:15-19:30

Grooves on Phobos: Spatial distributions and their implications to the formational mechanism

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Grooves are roughly-defined as trough-like depressions commonly found on asteroids and small satellites. Among the various features categorized as grooves, the most typical are considered as those found on the surface of Phobos. Grooves on Phobos are the most extensively-existing geological features on the satellite, and thus are documented and discussed for years. However, their formational processes remain controversial. Previously-proposed hypotheses are (1) grooves are some kind of intentional fractures and (2) they are results of impacts caused likely by linearly-aligned impactors ejected from Mars.

Former hypothesis has difficulty in explaining the geographical distribution of grooves (Murray 2011). In fact, because of this difficulty, Murray (2011) concluded that the latter (i.e., secondary impactors derived from Mars) could only be the reasonable explanation for the observed characteristics of grooves on Phobos, including their morphological features, distributions, and hemispheric coverage. Nevertheless, Ramsley and Head (2013) recently showed that, in order to form grooves well organized as those found on Phobos, each of fragments ejected from Mars should have no relative velocity, which is difficult to be achieved for ejecta from Mars. They also showed that most grooves on the northern hemisphere cannot be formed as secondary impacts from Mars because the impactors ejected from Mars do not impact in the directions normal to the equatorial plane of Phobos. Therefore, neither hypothesis remains satisfactory to explain the observational facts.

We carefully reevaluate previous hypothesis based on recently-acquired data, which are partly not available at the time of previous studies. We scrutinize all of the high-resolution images obtained so far to map them out on a numerical shape model. As a result, we identify 488 grooves, whose spatial distributions are precisely mapped three dimensionally. We newly find that each of grooves is always aligned on a certain plain even though it sometimes appears to be an undulating curved depression. We consider this strongly indicates that a groove is a result of a series of impacts of aligned fragments.

We statistically study the angle between the equatorial plane of Phobos and the plane, which contain each groove and find that the distributions of the angles have three peaks at 25, 90 and 155 degrees (hereafter we call A, B, and C type, respectively). Most of the B type grooves exist on the northern hemisphere.

To explain our mapping results, we propose a new hypothesis for the formation of Phobos as follows: (1) An asteroid of a collection of smaller fragments held together by self-gravity in the form of a rubble-pile is pulled apart and stretched straightly by tides during a close approach to Mars; (2) The asteroid (now separates into a train of fragments) is caught by the Mars gravity and revolves around Mars; (3) Every time it revolves around Mars, a part of the fragments hit Phobos and form a lineated depression, which is observed as a type A or C groove; (4) When the eccentricity of the impartor becomes low until the overlapping the trajectory of Phobos, type B grooves are formed.

Our hypothesis is along the idea that grooves are formed by aligned impactors as proposed by Murray (2011) but essentially different in the origin of the fragments, which can resolve the difficulty pointed out by Ramsley and Head (2013). Not only that, our hypothesis has advantage of completely satisfying both the morphological and geographical characteristics of grooves on Phobos. Furthermore, our hypothesis can also explain the deficiency of grooves on Deimos.

Reference

[1]Murray, J.B., Iliffe, J.C., 2011. Geomorphology. Geol, Soc, Spec, Publ., London, pp.21-41
[2]Ramslay, K.R., James, W. H., 2013. Planetary and Space Science, 69-95

Keywords: Phobos, groove, Mars, tidal-disruption, impact