SURVIVAL TIME OF METER-SIZED ROCK BOULDERS ON THE SURFACE OF ASTEROID ITOKAWA.

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Introduction: Recently a new approach for the estimation of survival times of meter-sized rock boulders on the lunar surface was suggested [1]. It is based on consideration of the spatial density of the boulders on the rims of small lunar craters whose age was determined by isotopic studies [e.g., 2-5] or estimated from the crater morphology and size [e.g., 6,7] (Figures 1 and 2).

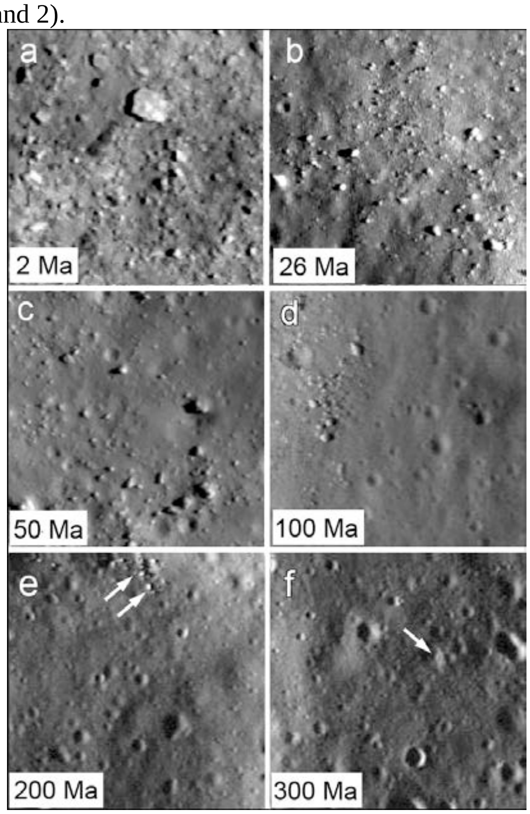

Figure 1. LROC NAC images of 100x100m areas on the rims of craters of different absolute age (lower left).NASA/ASU

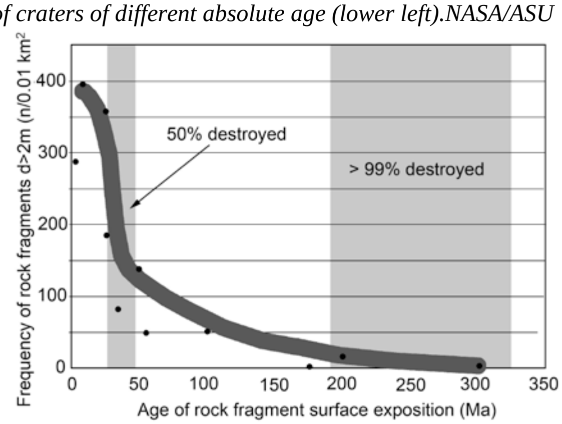

Figure 2. The rock boulder spatial density on the crater rims as a function of crater age (modified from Fig 6 of [1].

It can be seen from Figure 2 that for the time of boulder exposure on the lunar surface of a few millions of years, only a small fraction of the boulder are destroyed; for the time of several tens of million years ~ 50%, are destroyed, and for times of 200-300 m.y. ~90 to 99% of original boulder population is destroyed. As it was shown by [8] the destruction is catastrophic due to impacts of relatively small meteoroids. The role of micrometeorite abrasion is minor.

Application to Itokawa rock boulder fields: In this work we apply the new estimates of lunar boulder survival time to the boulder population on asteroid Itokawa. The latter has rocky areas which probably record the event of catastrophic destruction of the parent body and smooth areas which are apparently similar to the Eros ponds [e.g., 9, 10] (see Figure 3)

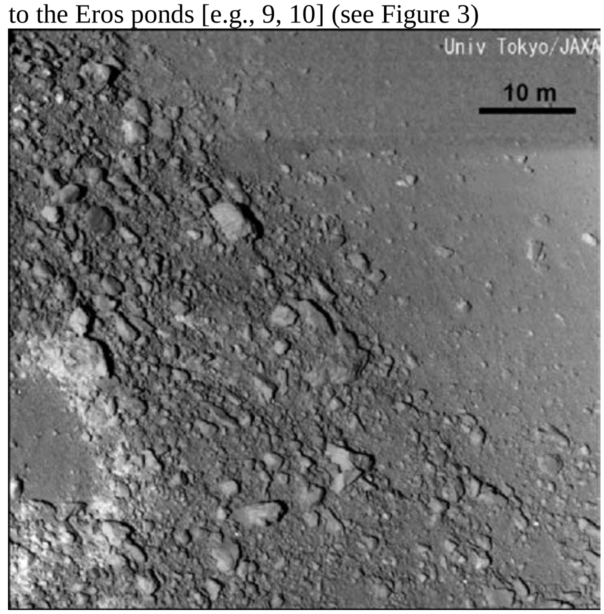

Figure 3. A Hayabusa image of a rocky area on asteroid Itokawa, where the spatial density of boulders ≥2 m was determined (see Figure 4).

We have counted rock boulders with diameters from 2 to 5 m and put the resulting size frequency distribution on the diagram where results of crater counts on the rims of the lunar craters South Ray and Cone, having ages 2 and 26 m.y. respectively, are shown (Figure 4). Our crater counts have been compiled on a rather small area, ~2000 m^2, so their representative nature may be insufficient. For higher reliability we also use the results of counts of the spatial density of blocks >6 m and >10 m done by [10] for the whole surface of the asteroid.

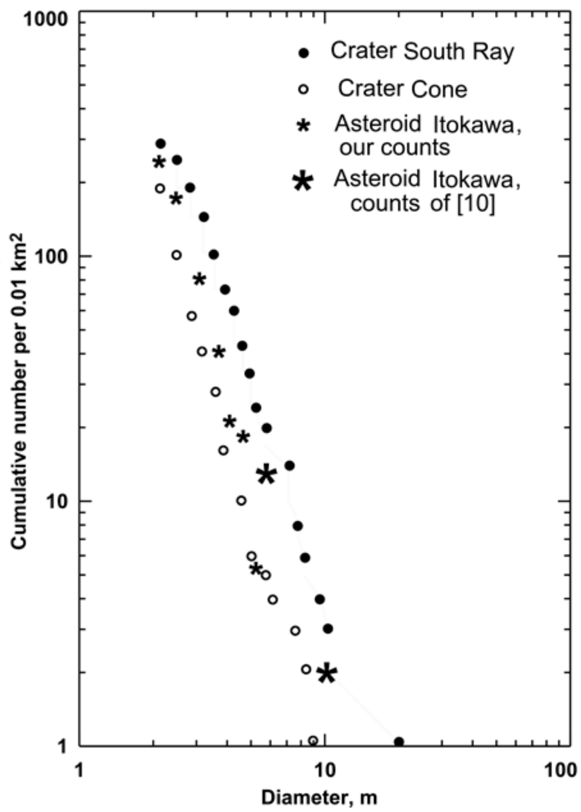

Figure 4. A diagram showing cumulative frequency of rock boulders on the rims of lunar craters South Ray (Apollo 16 site) and Cone (Apollo 14 site), ina relatively small rocky area on asteroid Itokawa and on the whole surface of this asteroid [10].

It is seen in Figure 4 that the rock boulder frequencies on asteroid Itokawa are close to those for the rocky surfaces of very young lunar craters. If we assume that rock boulders on Itokawa are being destroyed by the same process as lunar boulders are (by catastrophic rupture of boulders by small meteorite impacts), then we may use the observed boulder frequencies on Itokawa to estimate the time of their exposition to meteorite impacts.

For that we need to compare the effectiveness of such catastrophic rupture on the Moon and Itokawa. This effectiveness depends on the meteorite flux and on meteorite impact velocities. These issues were discussed by [11] who considered the Mars/Moon crater production rate ratio, averaged over time, and found that the meteorite flux in the vicinity of Mars is about twice higher than in the vicinity of the Moon (for impactors originating in the asteroid belt that are responsible for craters larger than a few tens of meters [12]). Later work [13] generally confirms this value. The orbit of asteroid Itokawa in its perihelion is inside the orbit of Mars while in its aphelion extends beyond Mars orbit and the mean orbital speed of Itokawa is 25.37 km/s while this parameter for Mars is 24.007 km/s. The latter similarity means that the meteorite flux on Itokawa is close to that in the vicinity of Mars and is twice higher than on the Moon.

To consider another factor, velocity of impacts, we computed meteor impact velocities in the vicinity of the Earth's orbit, the orbit of Mars and at the semimajor axis of Itokawa. From these three sets of intersections we computed a mean velocity that combines all intersection inclinations. Lastly, we combined the mean velocities for each region of space and compensated for the percentage of the time that Itokawa orbits in that space. Our calculations showed that a mean meteor impact velocity for Itokawa is 6.8 km/s. For the Moon according to [11] the mean meteorite impact velocity is 16.2 km/s, a factor 2.38 times higher than that for Itokawa.

So, the meteorite flux on Itokawa is about a factor of 2 higher than on the Moon but the mean meteorite impact velocity on Itokawa is a factor of 2.38 lower than on the Moon; this means that the energy of meteorite impacts on Itokawa is $(2.38)^2 = 5.7$ times lower than that on the Moon. So in total, the effectiveness of boulder rupture by meteorite impacts on Itokawa should be about 2.5-3 times lower than on the Moon. This means that the survival times of meter-sized boulders on Itokawa should be longer than those for the lunar boulders by a factor of 2.5-3. These comparisons are valid if one considers boulder destruction only by meteorite impacts. There is another potential factor of boulder destruction: sharp day-night changes of surface temperature. The effectiveness of this factor on Itokawa and the Moon is unclear.

Summary: The meter-sized boulders on Itokawa should have a survival time 2.5-3 times longer comparing to similar boulders on the lunar surface. Thus, the observed frequency of Itokawa boulders, which is in between the frequency of boulders observed on the rims of craters of 2 and 26 m.y. old, may suggest that the Itokawa rock fields are not older than 5 to 75 m.y. ago and this may be the time of break-up of the Itokawa parental body.

References: [1] Basilevsky A.T. et al. (2013) *Planet. Space Sci., 89,* 118-126. [2] Turner et al. (1971) *Earth Planet. Sci. Lett., 12,* 19–35. [3] Kirsten et al. (1973) *Earth Planet. Sci. Lett., 20,* 125–130. [4] Arvidson et al. (1975) *The Moon, 13,* 255–276. [5] Eugster O. (1999). *Meteoritics Planet. Sci., 34,* 385–391. [6] Basilevsky A.T. (1976) Proc. 7th Lunar Sci. Conf., 1005–1020. [7] Basilevsky, A.T. and Head, J.W. (2012). *Planet. Space Sci.,* 73, 302–309. [8] Horz F. (1975) *The Moon, 13,* 235–238. [9] Fujiwara a. et al. (2006) *Science, 312.* 1330-1334. [10] Mazrouei S. (2014) *Icarus, 229.* 181–189. [11] Ivanov B.A. (2001) *Space Science Reviews, 96,* 87–104. [12] Hartmann W.K. and Neukum G. (2001) *Space Science Reviews, 96,* 165–194. [13] Ivanov B.A. *The 3rd Moscow Solar System Symposium,* abs. 3MS3-MR-09.