Modeling Bennu's Crater Development

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Introduction

Several hundred craters have been identified and mapped on Bennu [1]. Their spectral properties have been studied using data from the MapCam instrument onboard the OSIRIS-REx spacecraft [2]. The crater frequency versus spectral slope across the wavelength range of 0.550 µm (v band) to 0.860 µm (x band) shows a skewed distribution varying from the median spectral slope of –0.17 micron^{-1} (x/v = 0.948) to a neutral or flat slope (x/v = 1.0). DellaGiustina et al. [2] attribute this trend to space weathering. They suggest that freshly formed craters are red, and as they age, they evolve to the bluish slope seen across the asteroidal surface. This abstract presents the results of an age model of Bennu's craters in the size range of 1 to 10 m. Craters in this size range were selected as having likely been formed during the time that Bennu has orbited in near-Earth space. Larger craters on Bennu are thought to have formed during its long history in the main asteroid belt [3].

Elements of the Crater Model

Our model covers three stages in the evolution of craters. First, a creation function produces a small number of craters randomly selected for size according to a power law distribution. These craters appear each time step. Because the modeled crater distribution will be compared to the measured one, an uncertainty is introduced into the color slope. In other words, at each time step, craters form with an x/v of 1.0±0.01 and with sizes randomly drawn from a power law distribution (radius^{-3}).

Once a crater is created, it is tracked throughout its evolution. With each time step, the crater weathers toward a bluish slope. The number of time steps required is determined through an exponential function whose 1/e time is a variable in the model. The slope decreases rapidly at first but approaches the final Bennu slope asymptotically. This is the final destination for stages one and two.

The third stage is the erasure of craters. This can occur through mass wasting that is either gravitationally forced or caused by impact-driven seismic shaking [4]. OSIRIS-REx has observed particles thrown off into orbit that return to the surface, which may also contribute to erasure [5]. Because of the limited observational data concerning these processes, they are modeled together in a linear fashion such that the smaller craters have shorter lifetimes than the larger ones. The slope of this fill-in rate is a variable in the model.

The code runs time step by time step, and all craters are tracked throughout their lifetime. The variables are optimized so that the spectral slope distribution matches that observed.

Model Results

Figure 1 illustrates a typical output of the model. The variables are set in the following manner: The 1/e time for weathering is 50 time steps. The erasure algorithm starts eliminating the smallest craters after an age of 160 time steps and will eliminate all craters <10 m after 1600 time steps. The final part of this exercise is estimating the length of a time step.

Judging from [6], 26 impacts/year with a typical crater diameter of 14 cm could have produced the observed particles leaving Bennu. Putting this observed flux onto a size distribution power law curve suggests that a time step on the order of 1000 years would produce several 1-m craters. Therefore, using a time step of 1000 years, the weathering time for all craters is about 150,000 years (3 times the 1/e value). The erasure rates are size-dependent: 1-m craters "live" about 160,000 years; 10 m craters ~~live~~ survive about 1.6 million years. New craters are always forming ~~to~~ replacinge the ones that have been erased.

These values are meant to be illustrative rather than accurate. They show a pathway for the creation of a skewed size distribution where we observe that the freshest-looking craters are reddish while the older ones match Bennu's average blue slope.

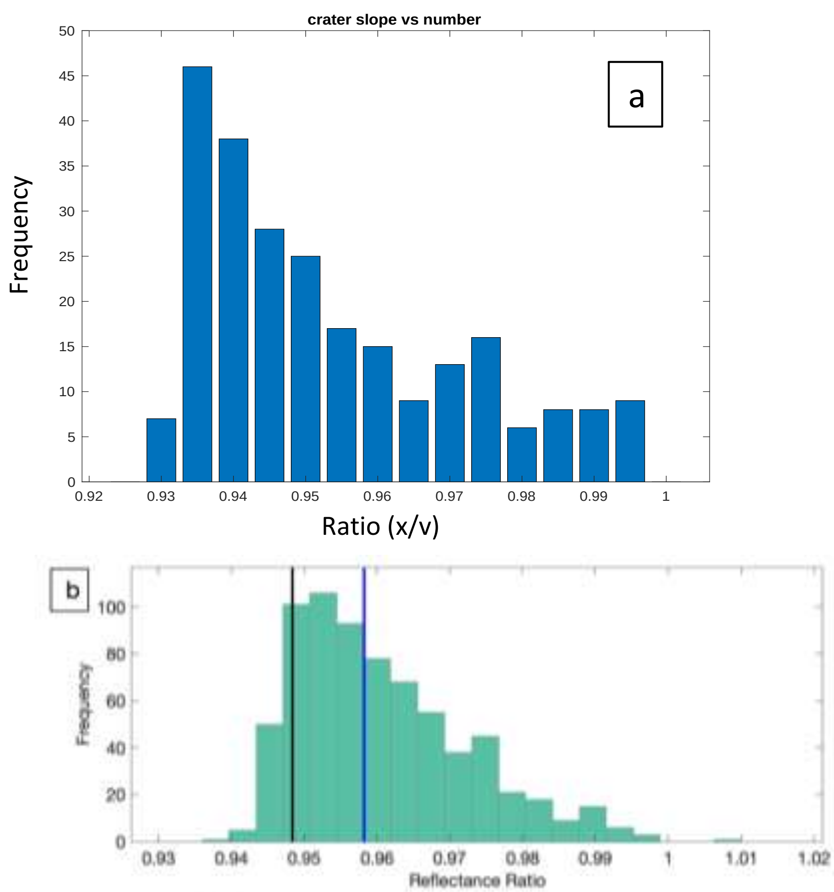
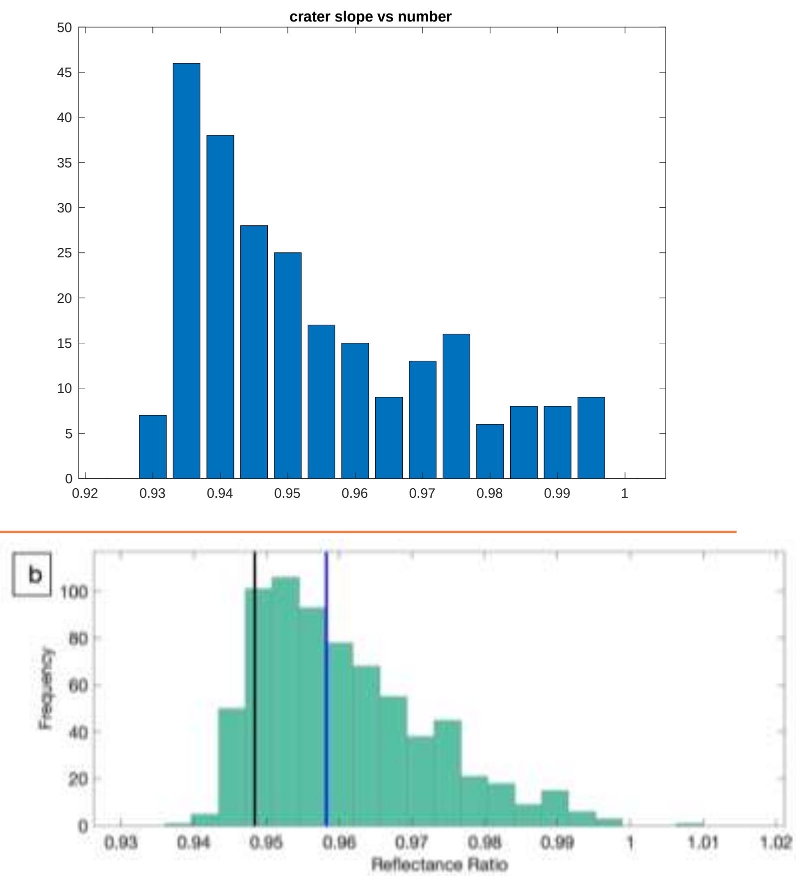


Figure 1. (a) Frequency for the model is plotted against crater spectral slope (x/v). (b) Measured values. Notice that both distributions are skewed in a similar way.



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References

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