FORMATION OF IRREGULAR CRATERS ON THE MOON; H. R. Aggarwal, Univ. of Santa Clara, Care of NASA-Ames Research Center, Moffett Field, CA 94035; and V. R. Oberbeck, NASA-Ames Research Center, Moffett Field, CA 94035

It has long been known that impact craters occur in clusters on the Earth's surface. Nonrandom distribution of Martian craters is common, and there is evidence that members of crater pairs have been produced by simultaneous impact of bodies near one another.(1) Large irregular, and compound craters also exist on the surface of the Moon. One example is Schiller, a large oblong crater. Another is the Messier and Messier A belonging to a complex whose origin has always been a mystery. Similar albedo of Messier and Messier A suggests that these craters are similar in age and this together with the ray system suggests a simultaneous impact for their origin. If the large irregularly shaped craters on the Moon are due to multiple primary impact craters, then a mechanism is required to supply bodies to impact against the surface in clusters. In this paper, we test the hypothesis that multiple impact due to tidal fission of weak bodies such as comets is responsible for production of lunar craters like Schiller and the Messier complex.

The analysis is accomplished by first determining the candidate craters formed under tidal fission. This is done by studying the circularity index of the lunar craters on the Moon and employs statistical measures for this purpose. The circularity of some lunar craters is shown in Fig. 1, which categorizes Schiller and Messier as highly irregular craters. The circularity study is further aided by photogeologic analyses of craters to determine the probable craters in a cluster that are formed by tidal fragments. Next, the scaling equation for the relationship between the crater size and kinetic energy is used to calculate the size of the fragments required to form the crater or craters. The size of the parent body is determined by summation of the fragment masses and it in turn is used to calculate the breakup altitude of the body for an assumed tensile strength by using the recently published Aggarwal and Oberbeck tidal fission theory.(2) Equation of motion of the fission products then give the distance apart between the craters thus produced as a function of the impact angle. Iterative calculations provide a range of impact conditions for tidal fission formation of observed irregular or compound craters.

We applied our analysis to Schiller and to the Messier complex. A photogeologic analysis of the Messier complex shows that Messier and Messier A were probably formed simultaneously and that the body producing Messier A impacted on or near the rim of a pre-existing crater. Our conclusion is based on the fact that the albedo of Messier is similar to that of Messier A and that the albedo of Messier A is much higher than that of the crater pre-existing Messier A. Figure 2 shows the calculated separation distance between the fragments at impact time that produced Messier and Messier A for different assumed impact velocities, V (km/sec), and impact angles θ, measured from the normal for parent bodies. Figure 3 shows a similar plot for Schiller. The dotted lines in these figures represent the actual

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separating distance (km) observed between Messier and Messier A and the two craters supposed to be forming Schiller. Based on these figures, our conclusions are that Messier and Messier A may not have been formed as a result of tidal fission since it takes a very weak body (tensile strength 10^4 dynes/cm^2) to form these craters; that Schiller, however, may have been formed by the tidal fission of a weak body (tensile strength 10^6 dynes/cm^2) like a comet or a highly fractured meteorite under impact conditions which range as:

$$2.4 \leq V < 10 \text{ km/sec} \; ; \; 67° \leq \theta < 80°$$

It is possible that Messier and Messier A, because of their small size, are basin secondaries. There are innumerable widely spread basin secondaries on the lunar surface due to large number of basins and the low gravity field of the Moon. Oberbeck, et al.,(3) have pointed to an area near and around Nicolai crater in the lunar highlands least influenced by basin ejecta and deficient in irregular, clustered and chain craters $\leq$ 40 km which are believed to be basin secondaries. This and similar evidence from Mars and Mercury have led them(3) to propose that there was a deficiency in small bodies required to form primary craters smaller than $\sim$ 30 km in the late heavy bombardment of the Moon. The deficiency of small size bodies is consistent with the tidal fission hypothesis for fragments of the late bombardment.(4)

References

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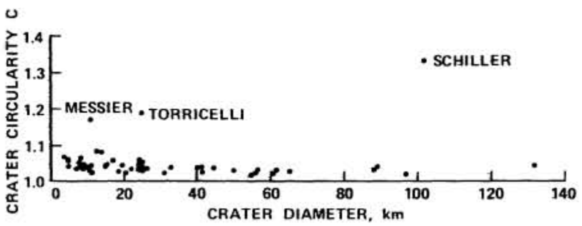

Fig. 1 Circularity of lunar craters.

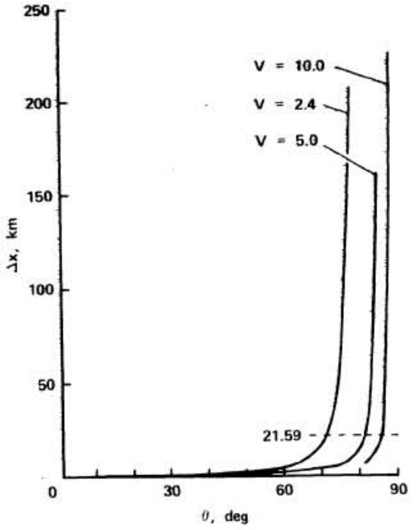

Fig. 2 Formation of Messier, $T = 10^4$ dynes/cm^2.

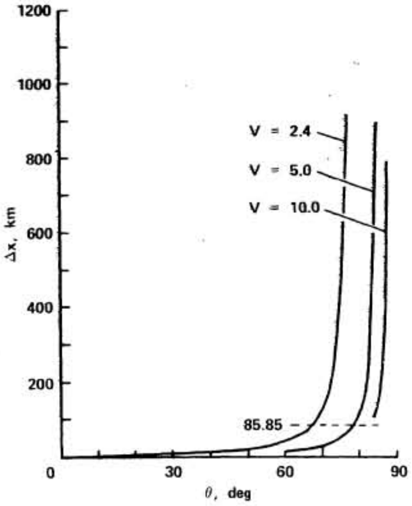

Fig. 3 Formation of Shiller, $T = 10^6$ dynes/cm^2.

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