LUNAR CRATERS EVOLUTION AND METEOROIDAL FLUX
IN PRE–MARE AND POST–MARE TIMES

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Abstract. In order to study the geomorphic evolution and lifetimes of lunar craters, data were collected from (i) 32 mare and terra provinces of the nearside of the Moon using the L.P.L. catalog; (ii) a mare area in Sinus Medii, using direct observations of Lunar Orbiter photos, and (iii) a terra area on the farside using direct observations of Zond-8 photos. The theory presented in a previous publication is expanded and applied to the data.

The following conclusions are obtained. (1) Steady-state conditions occur on the studied mare surfaces for craters of diameter up to approximately 220 m, and on the studied terra surfaces for craters of diameter up to at least 50 km. (2) The average lifetime of a crater, in addition of being a function of the meteoroidal flux, is a steep function of the diameter of the crater. (3) The correlation is good between a geomorphic classification of craters based on visual comparison with standard craters and a classification of craters based on their depth-diameter ratio, resulting in a coefficient of rank correlation of 0.64. (4) When craters are classified as young, mature, and old, the time of spent as young is less than a few percent of the total lifetime of the crater; the time spent as mature is 10 to 30%; and as much as 80% is spent as an old crater. Within the error of the calculations, these values are independent of crater diameter and apply to both pre-mare and post-mare craters, indicating that they are also independent of the intensity of the meteoroidal flux. (5) The average lifetime of a 50 km crater in pre-mare times is estimated to be less than 0.3 × 10⁹ years. (6) The average lifetime of a 50 km crater in post-mare times is estimated to be between 3 × 10¹¹ and 10¹⁴ years. (7) The average meteoroidal flux in pre-mare times is estimated to be three to six orders of magnitude more intense than in post-mare times.

1. Introduction

Craters are the predominant landforms on the Moon and cratering was the leading geological process both in pre-mare and post-mare time. The pre-mare crater population is well-preserved on the lunar terrae, where the craters larger than 1 or 2 km are predominantly of pre-mare age. The post-mare craters on the terrae are relatively so few in number that they can be ignored in first-approximation considerations. Cratering is of importance not only in lunar geology, but in the study of the early stages of the Earth and in general planetology.
Our study is not concerned with the formation and development of any individual impact crater but with the behavior of the population of craters as a whole. The nature of cratering is such that it displays a prominent stochastic character, this differing from most of the geological processes on Earth. Our approach consists of developing theoretical models, comparing them with observational data, and reading interpretations in terms of the model processes. This approach is not new in lunar studies and was applied with success by some investigators (for example, Chapman et al., 1970).

In our study, besides the widely used parameter of crater density (number of craters per unit area), we have used the geomorphological classes of craters. The existence of several geomorphological stages of degradation in craters is well established. The principal reason for these stages stems from the nature of the impact cratering process. The formation of a new crater is likely to be accompanied by the damaging or obliteration of one or more pre-existing craters. Because the formation of a small crater is always more common than the formation of a large crater, it follows that the damage to pre-existing craters is more common than their complete obliteration. Other processes, like downslope creep due to temperature variations, may be responsible for the progressive crater damage. All this means that only rarely is a clearly visible crater suddenly eliminated. More commonly craters become progressively eroded to more subdued forms. Most craters, like old soldiers, do not die but fade away. For this reason, the number of old craters is often a function of the angle of illumination and of the experience of the observer.

The degree of geomorphological degradation can be used to classify craters as belonging to class 1 (fresh) through class 5 (highly eroded), as in the Catalog of the Lunar and Planetary Laboratory of the University of Arizona (Arthur et al., 1963, 1964, 1965, 1966), or to class A (fresh) through class C (highly eroded), as done by the Laboratory of Comparative Planetology of the Vernadsky Institute (Florensky and Taborko, 1972; Basilevsky, 1974). Different systems have been used (for example, Pohn and Offield, 1970). The general concept, however, remains the same.

Another method used to define geomorphological classes is to measure the depth-diameter ratio of the craters. Intuitively this ratio should decrease as the crater becomes degraded. This is confirmed by measurements (Florensky et al., 1972, Pike, 1976).

The purpose of this paper is to investigate these basic processes of cratering: Presence or absence of a steady state; the total lifetime spent in the youthful, mature and old geomorphological stage. The study is based on an analysis of some craters listed in the Lunar and Planetary Catalog and on a large amount of crater data obtained from studies of Lunar Orbiter and Zond-8 photographs. The theoretical models used were discussed in detail in a previous publication (Basilevsky et al., 1980).

2. The Growth and Destruction of Craters – Theoretical Considerations

A previous publication (Basilevsky et al., 1980) presented an analytical method to describe the behavior in time of the number of craters on a lunar surface. The development and arguments are long and will not be repeated here. It was concluded that, for periods