Cratering asymmetry and the lunar evolution

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The synchronous rotation of the satellite ought to cause a spatial variation in the cratering rate over its surface. The cratering rate should be maximum at the apex (0, 90) of the orbital motion of the satellite, decreases with increasing of the angular distance from the apex, and becomes minimum at the antapex (0, 90). Degree of the apex-antapex asymmetry in the cratering rate depends on the encounter velocity of impactors and the orbital velocity of the satellite [e.g., Horedt & Neukum, Icarus, 60, 710-717, 1984; Zahnle et al., Icarus, 153, 111-129, 2001]. The large asymmetry can be generated in case that the orbital velocity of the satellite is comparable with the encounter velocity of the impactors. On the contrary, a condition that the encounter velocity of the impactors is very large compared to the satellite's velocity cannot provoke the cratering asymmetry.

On the Moon, the recent cratering rate at the apex is estimated to be about 1.5 times higher than that at the antapex [Morota & Furumoto, EPSL, 206, 315-323, 2003; Morota et al., Icarus, 2005, in press]. Since the Morota & Furumoto [2003] investigate the spatial distribution of craters with bright rays, the observed asymmetry has been generated in the Copernican period (i.e., in the last 1.1 Gyr). It is expected that the cratering of the early Moon was more asymmetrical. The Earth-Moon distance of the time was about one twentieth of the present that and then the lunar orbital velocity was extremely high. Such a condition provides a heavy asymmetrical bombardment on the early Moon. For example, at that time the cratering rate at the apex is estimated to be about 10 times higher than that at the antapex for impactors with encounter velocities of 10 km/s. Even if the Moon had moved out to a half of present distance from the Earth within 100 Myr, the apex-antapex ratio would have been approximately 3.0. The heavy asymmetrical bombardment should have undoubtedly effects on the lunar evolution. In this study, we discuss influences of the asymmetrical bombardment on early Moon.

The preferential bombardments thinned the crust of the leading hemisphere and thickened that of the trailing hemisphere [Wood, The Moon, 8, 73-103,1973]. As a consequence of the redistribution of crustal materials, the axis of the minimum principal moment of inertia shifted westwards. The Moon was reoriented eastwards to make the new minimum axis along the Earth-Moon line. The sequential actions operated continuously on the early Moon, so that the Moon was gradually rotated eastwards. The record of the lunar continuous reorientation is descried as a longitudinal variation in the distributions of the impact basins and the crustal thickness. The rotational history is summarized as follows: The present trailing hemisphere was on the front of orbital motion on one occasion in the pre-Nectarian period. The Moon rotated eastwards concurrently with the formation of the pre-Nectarian basins. The present trailing hemisphere looked toward the Earth, and the present nearside looked ahead at the beginning of the Nectarian period. The Moon reoriented further concurrently with the formation of the Nectarian and Imbrian basins. The gradual reorientation continued until the main phase of mare basalt volcanism coinciding with the end of the heavy bombardment.