LUNAR APEX-ANTAPEX CRATERING ASYMMETRY AND ORIGIN OF IMPACTORS IN THE ERATH-MOON SYSTEM. T. Morota[1], J. Haruyama[1], and M. Furumoto[2], [1]Department of Planetary Science, Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara 229-8510, Japan (morota.tomokatsu@jaxa.jp), [2]Graduate School of Environmental Studies, Nagoya University.

Introduction: The synchronous rotation of a planetary satellite should generate a spatial variation in the crater production rate on its surface [1-9]. The production rate that has the maximum at the apex (equator, 90˚W) of the orbital motion of the satellite decreases with increase in angular distance from the apex and becomes the minimum at the antapex (equator, 90˚E).

The degree of the apex-antapex cratering asymmetry primarily depends on the mean encounter velocity of impactors with respect to the planetary system and the orbital velocity of the satellite [1-5, 9]. The ratio of the maximum rate to the minimum value increases with the decrease of the encounter velocity of impactors. This fact means that we can estimate the mean encounter velocity of impactors by observation of the apex-antapex cratering asymmetry. A validity of this technique has already been verified by Morota and Furumoto [7]. From investigation of the spatial distribution for rayed craters of the Moon, they have estimated the mean velocity of recent impactors in the Earth-Moon system to be about 15 km/s corresponding to that of near-Earth asteroids. This result is consistent with recent studies of the size-frequency distribution for near-Earth asteroids; The shape of the size distribution of near-Earth asteroids is similar to that of lunar craters of the past 3.8 Gyr [10, 11].

Terrain Camera (TC) installed on a Japanese lunar explorer, SELENE that will be launched in 2007, will take images of surface of the whole Moon with nominal spatial resolution of 10 m/pixel [e.g., 12-14]. The extensive high-resolution images are available for the statistical study of crater distribution. Therefore, it is necessary to establish the technique for presumption of the origin of impactors.

In this paper, we purpose to derive the lunar apex-antapex cratering asymmetry as functions of the mean encounter velocity of impactors and time, considering the temporal variation in the lunar orbital velocity last 4.0 Gyr.

Lunar Cratering Asymmetry and Impactor's velocity: The relationship between degree of the apex-antapex cratering asymmetry and the impactor's encounter velocity has been formulated by analytical studies and numerical simulations [2-6]. Zahnle et al. [5] have given the cratering rate as a function of the angular distance β from the apex as follows

$$\Gamma = \overline{\Gamma}\left(1 + \frac{\upsilon_{orb}}{\sqrt{2\upsilon_{orb}{}^{2} + \upsilon_{\infty}{}^{2}}}\cos\beta\right)^{2.0-1.4b} \quad (1),$$

where $\overline{\Gamma}$ is the cratering rate at $\beta = 90^{\circ}$, υ_{orb} and υ_{∞} are the orbital velocity of the satellite and the encounter velocity of impactors in the planetary frame at infinity, respectively, and b is the exponent of the mass-frequency distribution of the impactors. From Eq. (1), the ratio of cratering rate at the apex to that at the antapex is obtained as

$$\gamma = \left\{\left(1 + \upsilon_{orb} \Big/ \sqrt{2\upsilon_{orb}{}^{2} + \upsilon_{\infty}{}^{2}}\right) \Big/ \left(1 - \upsilon_{orb} \Big/ \sqrt{2\upsilon_{orb}{}^{2} + \upsilon_{\infty}{}^{2}}\right)\right\}^{2.0-1.4b} \quad (2).$$

The orbital velocity of the Moon has probably varied since the formation of the Moon in conjunction with increase in the Earth-Moon distance. To estimate the degree of the lunar apex-antapex cratering asymmetry as a function of time from Eq. (2), we assume a computed result of lunar orbital evolution by Abe and Ooe [15] (Fig. 1). We also assume $b = -0.53$ implied by the crater size-frequency distribution $N \propto D^{-1.8}$ where N is the cumulative number of craters and D is the crater diameter. The exponent of –1.8 is well fitted for size distribution of lunar craters larger than 4 km in diameter [e.g., 16].

The apex/antapex ratio of the cratering rates is calculated for various encounter velocities of impactors υ_{∞}. Figure 2 shows the calculated result.

Discussion: The use of Fig. 2 allows us to estimate the impactor's velocity from investigation of the spatial distribution of craters. For example, Morota and Furumto [7] identified rayed craters with Clementine UVVIS images and estimated the apex/antapex ratio of rayed craters to be 1.5±0.09. The observed asymmetry is shown in Fig. 2. The apex/antapex ratio corresponds to impactor's velocity of about 15 km/s. Furthermore, it is possible to infer the origin of impactors form the velocity, because the encounter velocities are difference among kinds of impactors. The mean encounter velocity of near-Earth asteroids is 15-20 km/s, while those of short- and long-period comets are larger than 25 km/s.

We will target on the detection of possible changes of the origin of impactors by the TC image data, investigating the history of the lunar cratering asymmetry. The identification of crater ages is necessary to investigate the asymmetrical cratering history. Absolute ages of individual lunar craters can be roughly determined from the degradation state of crater morphology and density of superposed small craters [e.g., 17-20], although those have large errors. However, those dating methods are based on an assumption that the cratering rate is spatially uniform on the whole Moon. Therefore, we must improve those dating methods with the investigation of the asymmetrical cratering history.

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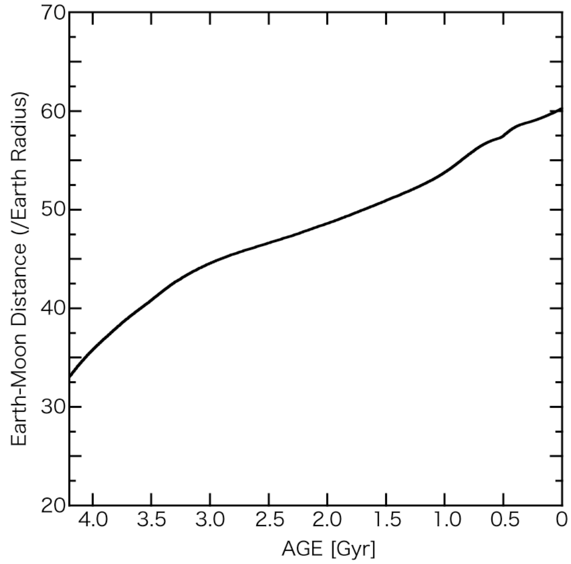

Figure 1. Lunar orbital evolution calculated by Abe and Ooe [15].

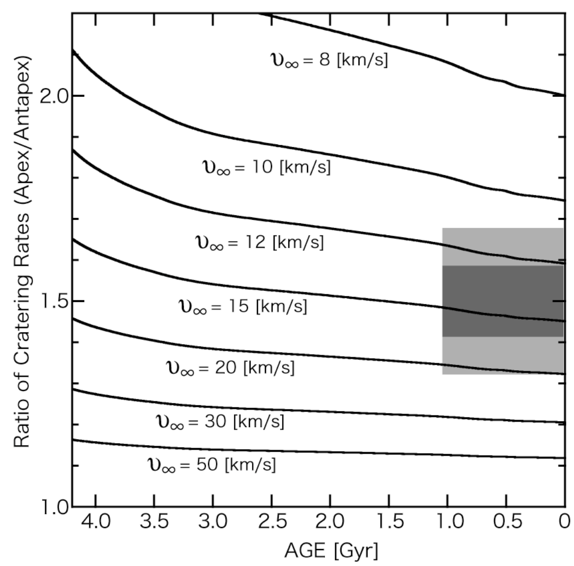

Figure 2. Lunar cratering asymmetry calculated from Eq. (2). Here we assume that $b = -0.53$. The observed asymmetry for rayed craters [7, 8] is also represented by the dark gray zone ($\pm 1\sigma$) and the light gray zone ($\pm 2\sigma$). The observed asymmetry is average in the Copernican period (about last 1 Gyr).