EJECTA AND SECONDARY CRATER DISTRIBUTIONS OF TYCHO CRATER: EFFECTS OF AN OBLIQUE IMPACT. N. Hirata[1], A. M. Nakamura[1], and K. Saiki[2], [1]Graduate School of Science and Technology, Kobe University, Nada, Kobe 657-8501, JAPAN, [2]Research Institute of Materials and Resources, Faculty of Engineering and Resource Science, Akita University, Correspondence author's e-mail address: narunaru@kobe-u.ac.jp.

Introduction: Although it is well known that most impact events on planetary surfaces are oblique to some degree, our understandings on oblique impacts are not enough in past decades because of difficulties in theoretical modeling and laboratory experiments of oblique impacts. Recently, however, more improved works on oblique impact cratering with both theoretical and experimental methods make it possible to reveal the effects of impact angle on the cratering process [1-3].

In an attempt to verify the recent results of theoretical and experimental studies, we have undertaken a new analysis on a lunar crater Tycho using remote sensing data. Tycho (85 km in diameter) is located on the southern nearside of the Moon (43°S, 349°E), and is one of the most typical craters formed by an oblique impact. The suggested impact angle is less than 30°, based on the asymmetric ejecta distribution and a subtle uprange offset of the central peak [4].

Data sets: A set of mosaics was produced from Clementine UVVIS images. The spatial resolution of the mosaic is 100 m/pixel. The data set includes a 750-nm albedo image, a color ratio image, and an optical maturity parameter (OMAT) image As the illumination angle of Clementine images at the Tycho region is low, they are useful for photogeological studies as well as Lunar Orbiter photographs. The color ratio image is used to identify compositional and maturity variations. The OMAT is another optical maturity index with only weakly coupling to material composition [5]. In the OMAT image, immature (fresher) materials such as ejecta of young crater are indicated as brighter tone. The OMAT is also used as an index of existence of glassy deposits of impact melt, as which exhibits low value of the OMAT index.

Telescopic spectra are also powerful tools for identification of lunar surface materials. We use telescopic spectra data of a new telescopic imaging spectrometer named as "Akita Lunar Imaging Spectrometer (ALIS)". The spectral coverage of ALIS-VIS is from 380 nm to 1060 nm with 5 nm steps, and the spatial resolution is about 10 km/pixel for lunar observation. A calibration procedure of the ALIS data is still under development, so we use the ALIS data as subsidiary in this study. A detailed description on ALIS is presented in [6].

Results: A brief summary of current analysis is shown in this abstract. We divide Tycho ejecta and related features into the following units: blocky ejecta, continuous ejecta, dark ring, fresh ejecta, and glassy ejecta at downrange. The distributions of several units are mapped in Fig. 1.

Blocky ejecta. Blocky ejecta is an innermost unit of the Tycho ejecta, and a part of the continuous ejecta. The blocky ejecta region is characterized by small angular hummocks [7,8]. The blocky ejecta material has a large OMAT value. It develops adjacent to the northeast and southeast rim of Tycho. Their typical extent from the rim is about 10 km, and the maximum one is 25 km.

Continuous ejecta. We refine the limit of the continuous ejecta of Tycho based on secondary crater distribution (a white line of Fig. 1). The continuous ejecta extends outward 50 to 110 km, which are corresponding to 1.2 to 2.6 crater radius from the crater rim. The most extensive directions of the continuous ejecta are northeast and southeast. The surface textures within the ejecta are dictated by radial lineation [7,8].

Dark ring. There is a ring of mature halo of glassy melt material just outside of the rim. Based on the OMAT image analysis, the dark ring extends 50 to 70 km, corresponding to 1.2 to 1.6 crater radius from the rim. This result is in agreement with an analysis that used a ratio image [9]. It is noted that the distribution field of the dark ring material is roughly in accordance with that of the continuous ejecta, with the exception of blocky ejecta near the crater rim.

Fresh ejecta. It is easier to discern the existence and the extent of immature ejecta in the OMAT image in contrast with using a single band image or a ratio image. A line profile of OMAT illustrates a trend that OMAT decreases with a distance from the crater rim, and fades out into the background [10]. Fig. 1 shows a bright fan-shape fresh ejecta distribution. Red lines are OMAT contours of 0.19. The extents of the region within the contours are 140 km in west, 200 km in east, and 260 km in northeast and southeast from the rim, corresponding to 3.3, 4.7 and 6.1 crater radius respectively.

Laboratory experiments revealed asymmetric nature and time evolution of ejecta curtains at oblique impacts [3,4]. The uprange ejecta are faster and dense, and have shallower ejection angle than the downrange ejecta at the initial stage, but the curtain becomes more symmetrical with time. These experimental results are consistent with our observational results that the distributions of the ejecta farther from the crater rim are more asymmetric. Secondary craters are more dense and more elliptical in shape in downrange. This result also agrees well with the experimental results.

Glassy ejecta at downrange. In addition to the dark ring around the crater rim, another low OMAT unit with a fun-shape is distributed on the eastern area of Tycho (blue dotted lines in Fig. 1). The low OMAT unit merges to the dark ring at the eastern limit of the continuous ejecta. The five-point spectra and the ALIS spectra of this unit are identical to those of the dark ring, especially the east half of the ring. It is suggested that a glassy material is extensively distributed to the downrange direction, even beyond the continuous ejecta region. A numerical modeling on a terrestrial crater, Ries in southern Germany shows a fan like distribution of impact melts in the downrange direction of oblique impact [2]. Although the atmospheric effects must be taken into account in a comparison between the terrestrial model and the lunar crater, the observed trend of the material transportation is in good agreement with the result of the numerical simulation.

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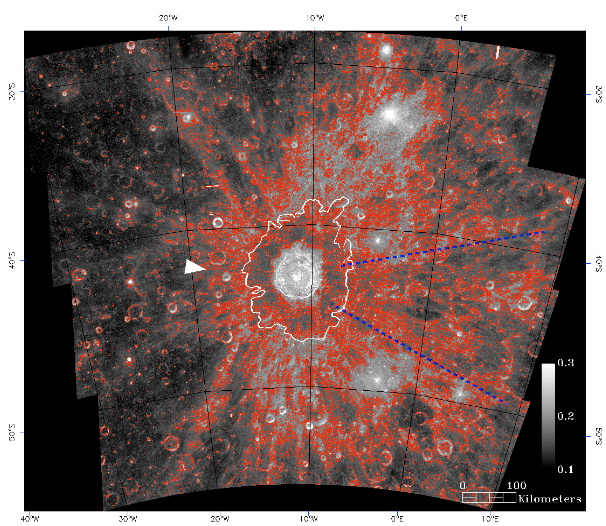

Fig. 1 OMAT image of Tycho and environs. Azimuthal equidistant projection centered at the center of Tycho. A white line is a limit of the continuous ejecta. Red lines are OMAT contours of 0.19. Blue dotted lines indicate glassy ejecta at downrange. The inferred impact direction is indicated by an arrow.