IMPLICATIONS FOR TIMESCALE OF CENTRAL PEAK FORMATION ESTIMATED BY IMPACT MELTS ON CENTRAL PEAKS OF LUNAR CRATERS. Y. Kuriyama[1,2], M. Ohtake[2], J. Haruyama[2], T. Iwata[2], and N. Hirata[3]. [1] Department of Earth and Planetary Science, The University of Tokyo, Japan (kuriyama@planeta.sci.isas.jaxa.jp), [2] Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), [3] Department of Computer Software, University of Aizu, Japan.

Introduction: Impact melts within complex impact craters have been known to be flat and smooth deposits filling the floors or wall terraces [1]. Recent studies suggest that compositionally different layers with smooth surfaces are present on the central peaks in several lunar craters, implying impact melts [2, 3]. Impact melts on the central peaks could constrain the central peak formation timescale because impact melts will flow out from slopes if peaks are uplifted faster than the time required for impact melts to cool to become more viscous and stop flowing. However, little evidence and few examples of impact melts on the central peaks were reported. This study investigates the central peaks of all 109 major lunar complex craters listed by [4] to check the presence of impact melts morphologically and compositionally.

Methods: Central peak morphologies and topographies were investigated using SELENE (Kaguya) data obtained by the Terrain Camera (TC) and Multiband Imager (MI). The spatial resolution of TC is 10 m per pixel, and that of MI is 20 m (visible) or 62 m (near-infrared) per pixel at the nominal altitude (100 km) [5]. MI spectral data also provide compositions of observed geologic units. Impact melt textures are identified by characteristic features such as cooling cracks and flowing features (lobes or levees) [6], using data from the Narrow Angle Camera (NAC, 0.5-1.2 m/pixel) abroad the Lunar Reconnaissance Orbiter (LRO) in addition to TC and MI data.

Results: At least 12 of the analyzed central peaks of lunar complex craters have distinctive melt morphologies such as cracks or flows on their peaks (Figs. 1, 2). Seventy-one craters (including the above mentioned 12 craters) have two or more compositionally different geologic units on their central peaks with melt-like textures but without the distinctive melt morphologies (Fig. 2). Among the compositionally different units on the central peaks, units with smooth surfaces exhibit low albedo and weak absorption depth similar to their floor melts. These spectral features are also observed in the distinctive melt morphologies on the 12 central peaks.

The 71 craters vary in diameter and formation age, while all the 12 distinctive melt morphologies are observed in the craters formed in Copernican period, which is the latest selenogical period. More than half of the analyzed Copernican-period complex craters have melt morphologies on their peaks.

The most significant flowing lobe morphologies were observed on the slopes at Jackson and Tycho. In these two craters, we identified that the impact melt flows are remaining on the slopes of central peaks and the all of them are parallel to their slope directions. These lobe morphologies are 10-24 m thick and 50-220 m wide on the 15-33° slopes.

Discussion: Considering melted material exhibiting low albedo and weak absorption depth [6] and having smooth surfaces [3], our spectral and morphological analysis suggests that the unique geological units on the 71 central peaks are possibly impact melt origin. Clear impact melt morphologies were not found on central peaks older than the Copernican period, so melt morphologies on the older central peaks are probably obscured by some mechanisms such as space weathering or landslides. If our interpretation is correct, it implies that it is common that impact melts did not flow out completely from the central peaks when the peaks were uplifted. This is also supported by the fact that more than half of the Copernican period craters have distinctive melt morphologies on their central peaks.

Our observation indicates that impact melts have flown along the slopes, and some of them have stopped on the slopes before they reached the floors, suggesting that impact melts already had relatively high viscosity but were not completely solidified when central peaks were uplifted. Based on our measurements and by following previous studies, we can roughly estimate the timescale for melt cooling to stop the flow. According to [7] and [8], impact melt can be considered as a Bingham fluid, and we can estimate yield strength (τ_y) of an impact melt flow, which is related to the bulk effective viscosity when melt stopped flowing. Two equations are used to calculate the yield strength from lobe measurement:

$$\tau_y = \rho g sin\theta H$$

$$\tau_y = \rho g H^2 / w_f$$

In these equations, ρ is the density of the melt (taken to be roughly 2600 kg/m^3 [9]), g is the surface acceleration of gravity (1.62 m/s^2), θ is the downhill slope in degrees, H is the thickness of the lobe, and w_f is the flow width. From impact melt lobes on the central peaks of Jackson and Tycho, the yield strength was calculated to range of ~1.2-5.5×10^4 Pa. This range of yield strength corresponds to a viscosity (η) from 3.7 ×10^6 to 1.4×10^8 (Pa･s) based on the empirical formula $\eta = 6 \cdot 10^{-4} \tau_y^{2.4}$ [10]. Based on the relationship of lunar impact melt between viscosity and temperature calculated by [8], our estimated viscosity implies that the impact melts stopped flowing on the central peaks when melts cooled down to about 1000-1100 °C, assuming the melts are anorthositic composition including 30 vol.% clasts. It is reported [11, 12] that regardless to their chemical composition impact melt cools rapidly down to 1000-1100 °C, which is similar to our temperature estimation when the melt flow stopped, in the order of first 100 seconds by local temperature equilibrium between the melt and clast (fragment) of target rocks, and after that, thermal conductivity controls the melt cooling for thousands of years. Therefore, the impact melts on the slopes of the central peaks of Jackson and Tycho are estimated to have stopped flowing in the order of 100 seconds. This implies that the two central peaks were uplifted on a timescale of 100 seconds because impact melts could flow along the slope directions during peak formation (uplift) but stopped in the first 100 seconds before reaching the crater floors. It is possible that other central peaks with impact melts on their slopes were also formed on a similar timescale based on impact melts being commonly observed on the central peaks of complex lunar craters, suggesting impact melts did not completely flow out from the central peaks when the peaks were uplifted.

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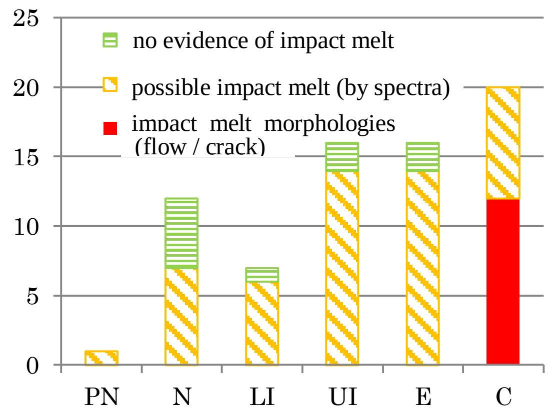

Fig. 1: Number of central peaks with impact melt morphologies or spectral melt-like materials in each selenogical period. Age of abbreviations: PN = Pre-Nectarian, N = Nectarian, LI = Lower Imbrian, UI = Upper Imbrian, E = Eratosthenian, and C = Copernican.

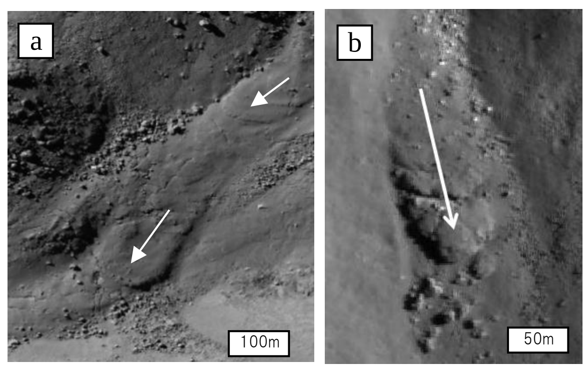

Fig. 2: LROC NAC images of the melt flow morphologies on the central peak of Tycho (a) and Jackson (b). (a) is extracted from frame ID M183595624LC, and (b), from M103223791LC. North is upward in (a), and downward in (b).