HOKUSAI CRATER ON MERCURY AND ITS IMPACT RAYS. Zhiyong Xiao[1] and Stephanie C. Werner[1], [1]Centre for Earth Evolution and Dynamics, University of Oslo, Sem Sælands vei 2A/B, 0371 Oslo, Norway (zhiyong.xiao@geo.uio.no).

Introduction: The formation mechanism of impact rays, especially combining that of the other crater exterior deposits, is poorly known [1]. Compositional and/or maturity contrast with the background is the main reason for optical rays [2, 3], and surface roughness was the main cause for radar rays [4]. On both the Moon and Mercury, optical rays are more abundant than radar rays, suggesting that ray-formation is largely correlated with deposition of fine primary ejecta. On the other hand, not every radar ray corresponds to an optical ray, suggesting that surface disturbances occur during the formation of some (segments of) rays.

Orbital dynamic models predicted that Mercury has both the largest range of impact velocities and highest impact flux among the terrestrial planets and the Moon [5]. The areal density of impact craters that have optical rays on Mercury are at least 4 times less than those on the Moon, and it was ascribed to the larger erosion rate on Mercury so that the population of Mercurian rayed craters is younger [6, 7]. The number of craters that exhibit S- and/or P-band radar rays is much more on Mercury than the Moon, which was interpreted to be cause by the larger amount of centimeter–decimeter scale rocks excavated by the bigger secondaries within Mercurian rays [8]. These interpretations, if correct, suggest that impact craters on Mercury have a much higher efficiency in producing far-field large secondaries that are capable of producing rough surfaces (i.e., radar rays), hinting that larger ejecta and/or higher ejection velocities were produced on Mercury.

However, sizes of secondaries within impact rays were not systematically studied on Mercury or the Moon. We investigate the size–frequency distributions (SFD) and morphology of secondaries within impact rays on Mercury, and compare them with those on the Moon to better understand the formation mechanism of impact rays.

Observation: The highly elliptical orbit of the MESSENGER spacecraft obtained higher resolution images on the northern hemisphere of Mercury. We select the Hokusai crater (D=93 km; 57.77°N, 16.8°E) to systematically study the different crater populations related with this crater, considering the good image coverage, its young age, and the well-developed rays. Hokusai is *the* most obvious rayed crater on Mercury seen in optical images. Many of the rays extend at least 4500 km across the planet, reaching well beyond ~50°S. Global maturation index for Mercury derived from the ~433–996 nm reflectance spectra suggested that Hokusai had a comparable age with the Eminescu, but it was younger than both Amaral and Debussy [8]. Large uncertainties exist when comparing reflectance spectra extracted from different multiband color mosaics. Plus, the identity and physical properties (e.g., fragment sizes, reflectance) of crater ejecta deposits are not well known for Mercury. Therefore, it is not safe to compare the relative age of rayed crater on Mercury based only on reflectance spectra of crater ejecta. Based on the observations below, we find that Hokusai is perhaps one of the youngest rayed craters on Mercury: (1) the crosscutting relationship of secondaries chains within the impact rays of Hokusai, Kuiper, and Debussy suggest that Hokusai is at least not older than Debussy; (2) when high-resolution (<20 mpp) images are available, Amaral and most rayed craters >10 km on the northern hemisphere, show superposed chains /clusters of secondaries on the crater floors and continuous ejecta, but no secondaries chains are visible on neither the continuous ejecta or crater floor of Hokusai.

Wide stripes of fluidized material, which may be impact melt [9], cover a large portion of the continuous ejecta deposits and also some of the continuous secondaries field [10]. Such material had a fast emplacement velocity considering that no/little deposition occurred when flowed over/around local obstacles, even within depressions. The overlapping relationship suggests that the emplacement was at the end of the modification stage. We collect the craters that have formed on the flows, which have three potential sources considering similar features on other planetary bodies: primaries postdating Hokusai, self-secondaries of Hokusai that emplaced after the formation of the flow, and distant secondaries from other rayed craters on Mercury. We consider the second and third possibilities as unlikely, but not impossible sources, considering that almost no similar-sized craters are visible on the crater floor.

Nets of crater rays and chains/clusters of secondaries are visible almost everywhere on the planet. To precisely locate the rays of Hokusai, we select ray segments that are located on either continuous ejecta of fresh craters or very old surfaces where no other rays is visible.

Results: Two ray segments are discussed here: one on the southern ejecta of the Degas crater (~3450 km away from Hokusai), the other on the northern volcanic plain (~540 km from Hokusai). The SFD of the secondaries within the rays, secondaries on the continuous secondaries facies, and the small crater population on the flow feature on the crater rim are shown in Fig. 1.

The results show that: (1) Hokusai has a model age of less than 10 Ma by comparing to the crater isochron; (2) Both the density and SFD of secondaries within the rays of Hokusai are not the same at the two locations, as the one at the southern rim of Degas has a relative slope of ~-4 for *D*<~400 m, and the one on the northern plain has a relative slope of ~-2 for *D*<~400 m.

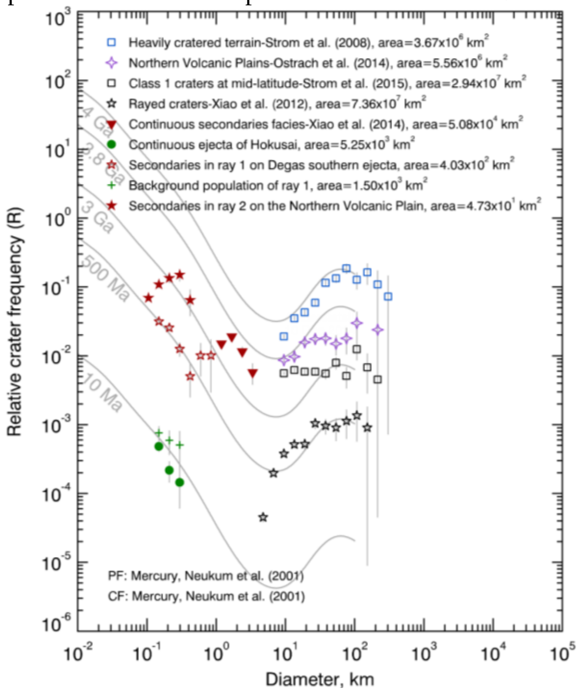

Fig. 1. SFD of different crater populations on Mercury. No obvious secondaries clusters or chains are visible on the western continuous ejecta of Degas, so that craters on this facies are selected as the background crater for the Ray 1 secondaries counted on the southern ejecta of Degas. The crater populations on the heavily cratered terrains and northern volcanic plains are compared with the Ray 2 secondaries.

The Tycho crater (*D*=85 km; 348.8°E, 34.3°S) has the longest impact rays on the Moon (~2500 km). It is one of the few lunar rayed craters that several of its rays are visivle in radar images [8]. Interestingly, its transient crater has the same size with that of Hokusai [10]. Assuming a constant ejection angle of 45°, ejecta on the Moon travel 2 times further than those with same velocities on Mercury. We compare the morphology of secondaries within the rays of Hokusai and Tycho that have comparable trajectory distances (Fig. 2). The secondaries of Hokusai are more circular in shape and are more easily recognizable due to their relatively circular shape. Similar morphological differences are visible for secondaries within other rays(segments) of Tycho and Hokusai. The highly irregular shapes of the lunar ray-secondaries were suggested to be caused by the downrange surging effect caused by the large horizontal momentum of the ejecta [11]. Many complex craters on Mercury also have similar circular secondaries on the continuous secondaries facies, which were ascribed to the larger ejection angles [10]. It is possible that ejecta forming the rays on Mercury also have larger ejection angles, but the effect of both ejecta and target properties was not included in the discussion.

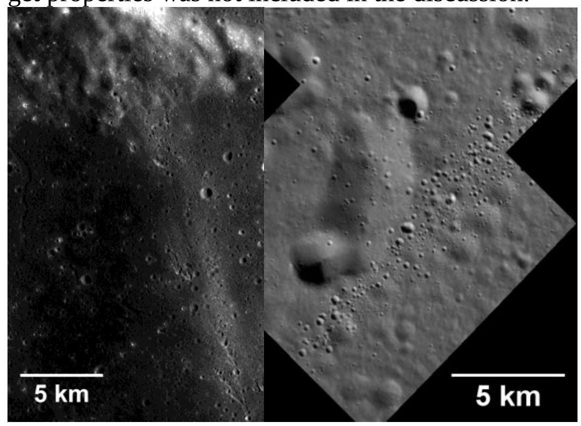

Fig. 2. Comparison between ray-secondaries of the Tycho (left) and Hokusai (right). The rays are both visible in S-band radar image [8], and they have comparable ejection velocity.

Implications: Some of the ray-secondaries of Hokusai is the first secondary crater population that does not have ≤-4 relative slope. The special morphology of ray-secondaries possibly indicate larger ejection angles if material properties are not the major cause. For a given crater, secondaries within a same patch/segment of impact ray likely have the same landing velocity (i.e., launch velocity for the ejecta). Therefore, the SFD of ray-secondaries can reveal that of the ejecta, at least in a relative sense. Secondaries within different segments of a single ray should be launched from the same angular position, but different radial distance from the impact point [12]. Ray-secondaries that travel the farthest should have both the largest ejection angles and velocities among those within a same ray, and vice versa. Therefore, by systematically study the SFD of secondaries within several long impact rays of Hokusai, the SFD of ejecta that form the rays could potentially be recovered as a function of ejection velocity.

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References: [1] Shuvalov V. (2012) *Meteoritics & Planet. Sci.*, *47*, 262–267. [2] Hawke B. R. et al. (2004) *JGR*, *170*, 1–16. [3] Werner S. C. and Medvedev S. (2010) *Earth Planet. Sci. Lett.*, *295*, 147–158. [4] Harmon J. K. (2007) *Space Sci. Rev.*, *132*, 307–349. [5] Le Feuvre M. and Wieczorek, M. A. (2008) *Icarus*, *197*, 291–306. [6] Xiao Z. et al. (2012) 43rd, Abstract #2143. [7] Braden S. E. and Robinson M. S. (2013) *JGR,118*, 1903–1914. [8] Neish C. D. et al. (2013) *118*, 2247–2261. [9] Osinski G. et al. (2011), *Earth Planet. Sci. Lett.*, *310*, 167–181. [10] Xiao Z. et al. (2014) *Icarus*, *228*, 260–275. [11] Dundas C. M. and McEwen A. S. (2007) *Icarus*, *186*, 31–40. [12] Melosh H. J. (1989), Impact cratering: a geologic process, Oxford University Press, 245pp.