FURROWS ON GANYMEDE INDICATE GLOBAL-SCALE MULTI-RING STRUCTURES FORMED BY AN ANCIENT GIANT IMPACT.

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Introduction: The oldest recognizable surface feature on Ganymede is sets of tectonic troughs in the dark terrain, called furrows [1]. Numerous blocks classified into the dark terrain are ubiquitously distributed over the surface of Ganymede, and most of these blocks include furrows (Fig. 1A). Furrows are crosscut by any recognizable impact craters exceeding 10 km in diameter, and therefore regarded as the oldest features on Ganymede [8]. Voyager images show that a hemispherical-scale furrow system exists in Galileo and Marius Regios, and the system has a concentric pattern centered at 20°S 180°W [2,3]. It is proposed that the system is fragments of multi-ring structures formed by the collapse of the transient crater when the excavation depth is comparable to the thickness of the planetary lithosphere, as in the case of the outer rings around Valhalla and Asgard basins (Fig 1C) [1,4,5], although tectonics induced by the internal convection have been proposed alternatively [6]. Galileo images reveal furrows in the dark terrain which were not imaged by Voyager. For example, the furrows in the west portion of Nicholson Regio approximately parallels the trend of most of the dark fractured unit in the area, which is in contrast to ones in Galileo Regio (Fig. 1B) [7].

Analysis: We analyzed the distribution of furrows utilizing Voyager and Galileo images. We developed azimuthal equidistant projection maps centered at 20°S 180°W (Marius-Galileo hemisphere) shown in Fig. 2A, and its exactly opposite hemisphere (Perrine-Nicholson hemisphere) shown in Fig 2B. As reported by the previous work [3], we confirmed that almost all of the furrows on the MG hemisphere are aligned with concentric circles centered at 20°S 180°W (Fig. 2A). Some of blocks of the dark terrain, such as Melotte Regio, include few furrows, which is, we guess, mainly because the resolution, illumination, and/or emission of images were not suitable for detecting furrows. Otherwise, a lateral resurfacing process, such as impacts, may erase furrows. Interestingly, we found that furrows on PN hemisphere are also aligned with concentric circles centered at 20°S 180°W (Fig. 2B). This means that not only in the MG hemisphere but the entire surface of Ganymede, furrows have concentric pattern centered at the same point.

Result and Discussion: Although the dark terrain covers only about one-third of the current surface, Ganymede considerably used to have a global-scale multi-ring system before the formation of the bright terrain.

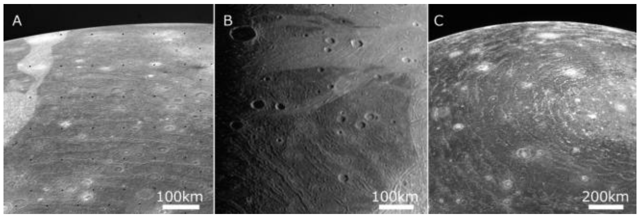

Fig. 1. Furrows on Ganymede (A, B) and Valhalla ring system on Callisto (C).

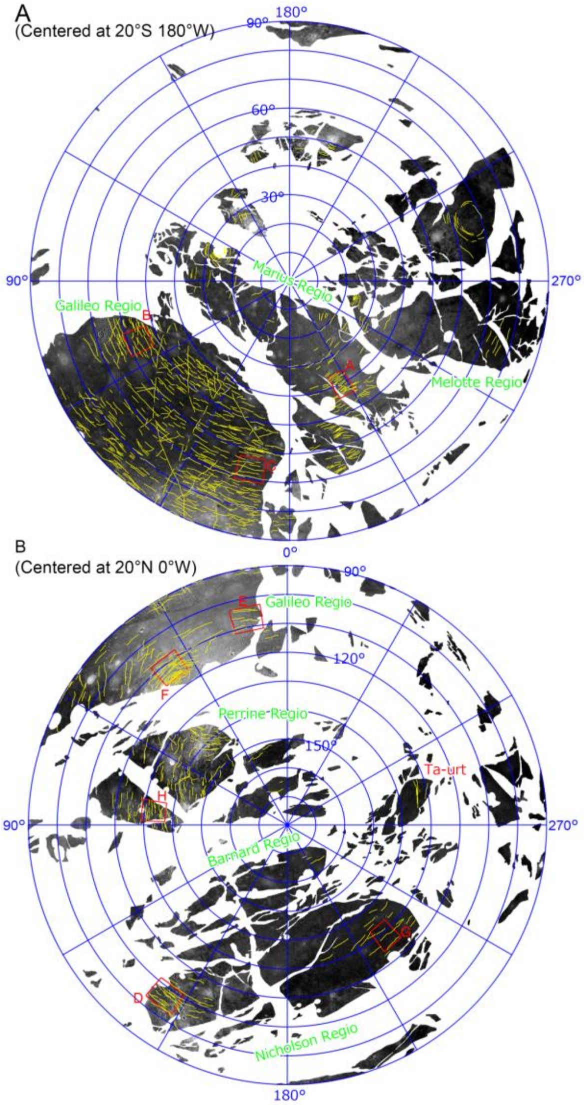

Fig. 2. Yellow lines indicate furrows. These maps are projected in azimuthal equidistant centered at 20°S and 180°W (A) and its exactly opposite point, 20°N, 0°W (B).

On the basis of the Voyager data, Schenk and Mckinnon [3] pointed out that furrows in east portion of Nicholson Regio may also align with this system. Our present work supports their insifhtful view. If we assume furrows to be impact origin as in the previous works [1,4,5], this must be the largest impact structure in our solar system.

The divergence (angle formed by furrows and equidistant circle) is mostly small (not greater than 15 degrees) as shown in Fig. 3. Considering that the divergence of the furrows of Galileo Region studied by Schenk and Mckinnon [3] is 16 degree at the maximum, the divergence of furrows of the other dark terrain blocks could be simply explained by the coincidence of faulting. This also implies that relative locations of block of the dark terrain were not moved much (i.e. lateral crustal movements were small), despite the tectonically modified surface of Ganymede.

Estimating the impactor diameter forming the furrow system is complicated because of the deficiency of an identifiable clear rim. No clear rim itself is not unusual because Valhalla or Asgard ring systems also lack a clear rim [9]. Although their transient crater rims likely have been collapsed or did not form, their diameters are estimaged to be equivalent to 1000 km for Valhalla and 675 km for Asgard based on the mapping of ejecta and secondaries [10]. Following the simple pi-scale low, we can estimate the impactor diameters to be 115 km for Valhalla and 70 km for Asgard. Numerical simulation to model a Valhalla-like basin using iSALE shows that an impactor with 100 km in diameter can produce a central melt pool with ~600 km in diameter, which is consistent with the size of the central smooth region of Valhalla (even though ejecta may be responsible for the central smooth region) [11]. Also, the furrow system on Ganymede has a central region with neither ridge nor trough (r < 1380 km) and global-scale outer ring zone (1380 km < r < 7800 km). Note that it does not include an inner ridge zone. If the central zone in Marius Regio is equivalent to the central smooth zone of Valhalla, the impactor forming furrows may be as large as D~500km. On the other hand, if we assume the central region is ejecta origin, crater rims would be one-third or half of the central smooth region, extrapolated from the comparison between the diameters of palimpsest and crater rim[12]. Then, the transient crater diameter becomes ~1000 km, which could be produced by an impactor with D~100km. We are currently working on a numerical simulation using iSALE for modeling of the formation of furrows to estimate more plausible impactor diameter.

Although Callisto is similar to Ganymede in size and composition, Ganymiede is differentiated while the differentiation of Callisto is incomplete. This is known as the Ganymede-Callisto dichotomy. To explain this, Barr and Canup [13] proposed that impacts during the late heavy bombardment have been sufficiently energetic to lead to differentiation in Ganymede, but not in Callisto. If the impactor that formed the furrow system on Ganymede is 500 km in dimameter, it would be sufficiently massive to differentiate the interior of Ganymede, and may be thus responsible for the dichotomy in the internal structure of Ganymede and Callisto.

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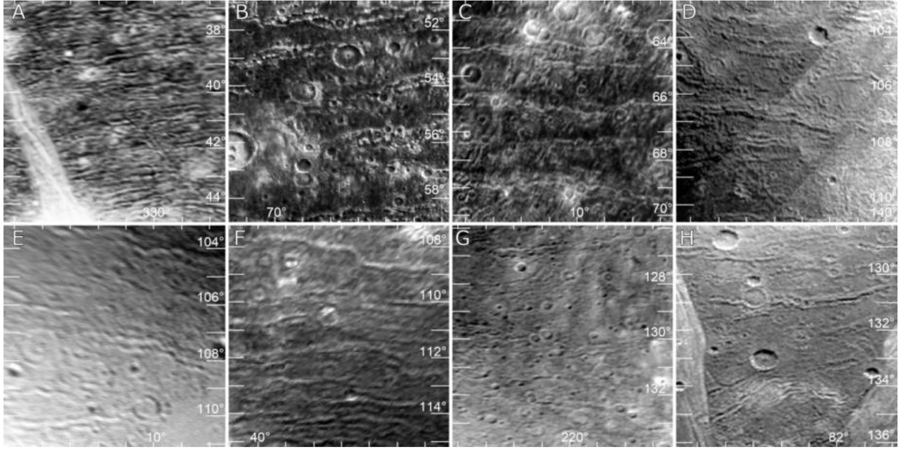

Fig.3. Close up views of the transects. Vertical value represents the angle measured from 20°S and 180°W and horizontal represents longitude of the oblique cylinder. These images shows Marius Regio (A), Galileo Regio (B, C, E, F), Nicholson Regio (D, G), and Perrine Regio (H).