Geomorphological characteristics of asteroid Ryugu and its preliminary geologic map. H. Miyamoto1, R. Hemmi1, H. Kikuchi1, G. Komatsu2, C. Honda3, T. Michikami2, T. Morota3, Y. Cho1, O. S. Barnouin4, S. Sasak2, N. Hirata4, N. Honda5, S. Kameda11, E. Tatsumi1, Y. Yokota12, T. Kouyama13, H. Suzuki14, M. Yamada15, N. Sakatani12, M. Hayakawa12, K. Yoshioka1, M. Matsuoka12, M. Hirabayashi9, H. Sawada12, S. Sugita1 1Dept Systems Innovation, University of Tokyo, Tokyo, Bunkyo, Japan (hm@sys.t.u-tokyo.ac.jp). 2IRPS, Pescala, Italy. 3Aizu University, Aizu, Japan. 4Kinki University, Hiroshima, Japan. 5Nagoya university, Nagoya, Japan. 6Johns Hopkins Univ, Laurel, MD, United States. 7Osaka Univ, Osaka, Japan. 8Kobe Univ, Kobe, Japan. 9Auburn University, Auburn, AL, United States. 10Kouchi Univ, Kochi, Japan. 11Rikkyo Univ, Tokyo, Japan. 12ISAS/JAXA, Sagamihara, Japan. 13AIST, Tsukuba, Japan. 14Meiji Univ, Tokyo, Japan. 15Chiba Tech, Narashino, Japan.

Introduction: Observations by Hayabusa 2 spacecraft indicate that Ryugu, a C-type near-Earth asteroid, is highly porous (>50% porosity) [1]. The surface is covered by numerous boulders [2], and thus the high porosity is explained by a rubble-pile nature [1].

Interestingly, Itokawa, the only other similarly-sized rubble-pile asteroid closely observed by spacecraft, is different from Ryugu in many aspects. For example, while Ryugu shows a top-shape [1], Itokawa is somehow elongated cigar-like asteroid. Though Ryugu is generally homogeneous in terms of roughness [2], Itokawa has two distinctive areas such as smooth and rough terrains. Ryugu has an almost continuous equatorial ridge, though Itokawa does not have such a large-scale topographic feature.

These differences may come from the difference in evolutional processes; a top-shape of rubble pile asteroid is believed to be resulted from rotationally induced deformation [3, 4, 5] or from reaccumulation [6]. Or the differences may come from variations in mechanical properties of asteroid forming materials.

We are investigating geological characteristics of Ryugu, which may hold clues for these aspects. We report initial results of geological investigations mostly using visible images obtained by the Optical Navigation Camera (ONC) onboard the Hayabusa2 spacecraft.

Global characteristics: Ryugu has a diamond-like overall profile with a perfect north-south and a west-east symmetrical silhouette when viewed from the equatorial plane. However, when viewed from either pole, Ryugu shows an almost perfect circular profile due to the existence of the equatorial circular ridge (Ryuujin Dorsum). The ridge is generally continuous with some exceptions, which are mostly depressions including craters with relatively distinct rims. For example, Urashima crater, the largest (290m in diameter) crater on Ryugu, clearly cut the Ryuujin Dorsum, which is thus formed before the Urashima crater.

We developed several types of equidistant cylindrical projection maps including orthographic image, digital elevation model, and shaded relief map based on the numerical shape model [1], which are used to map out geomorphological features in two dimensions by using ArcGIS software. At the same time, we also map them on a three-dimensional shape model by using the SBMT software [7] depending on the purpose of mapping. Results of mapping by these approaches are combined into the map of ArcGIS for illustrous purposes as shown in Fig.

As detailed by [8], about 30 circular depressions >20m in diameter have been identified [2], which is based on the detailed study of images to identify ~70 crater candidates >10m in diameter [8]. Numerous boulders are identified all over the surface of Ryugu, whose sizes range from less than a meter to more than 100m [9]. The number density of boulders is larger than other small bodies [2].

Dichotomy and the western bulge: Using these geomorphological maps of Ryugu, we evaluate the spatial distributions of geological features. Importantly, distributions of craters and boulders are not uniform over the surface of Ryugu [2, 8, 9]; for example, craters are relatively enriched in the eastern side of Ryugu and near the equatorial region[8]. Eastern side of Ryugu has relatively higher number densities of boulders as well compared to the western side [2, 9]. These imply that Ryugu has at least two mappable units, which is also supported by subtle but non-negligible color and brightness variations [2].

We identify large trough-systems, Horai Fossa and Tokoyo Fossa, in the southern hemisphere. The profile of these trough systems indicate that they are generally steeper near the bottom and their depth/width ratios are shallower than fresh craters on Ryugu. These likely indicates that trough systems are not chains of craters. The locations of the trough systems are identical to the boundaries between eastern/western dichotomy discussed above. In fact, the western side of Ryugu is basically a bulge centered by the Brabo crater and divided by the trough systems. Thus, we propose to call the bulge in the western side of Ryugu as the Western Bulge. The trough systems seemingly affect the circularity of the Ryuujin Dorsum (equatorial ridge) [10]. Though the effect is small, if we assume the effect is not negligible, one possible interpretation is that the formation of Ryuujin Dorsum predates the formation of Horai and Tokoyo Fossae.
Mass wasting: Different from Itokawa, features indicating mass wasting on Ryugu is limited. One example is along both sides of the equatorial ridge (Ryujin Dorsum), which shows characteristics of imbricated boulders. Asymmetric depositions of finer particles on larger boulders are found at several locations implying downslope motion of regolith particles. These can be seen, for example, in the areas immediately east and west of the Brabo crater in the Western Bulge, where the possible directions of gravel migrations indicated by morphologies are consistent with the direction of the current topographic profiles. Mass wasting during the formation of equatorial ridge may explain the lower boulder number density in the equatorial region than higher latitudes [1]. Slumping of some boulders along crater walls are also found in some craters, which indicate existence of unconsolidated particles.

Conclusive remark: Current version of geological mapping of the body is still insufficient to clarify the evolulational history of the body. However, we can suggest that Ryujin Dorsum, the most outstanding feature of Ryugu, is formed earlier in the history of Ryugu. Some large craters, including Urashima, the largest crater, is formed after the formation of Ryujin Dorsum. The formation of Ryujin Dorsum may predate the formations of Horai and Tokoyo Fossae, but could continue even after the Horai and Tokoyo Fossae formations.