Preliminary Unsupervised Classification of the Mercury's Surface using Multiband Reflectance Data Obtained by MESSENGER/MDIS. Makoto Hareyama[1], Yoshiaki Ishihara[2], Chikatoshi Honda[3], Makiko Ohtake[2], [1]St. Marianna University School of Medicine (m-hareyama@marianna-u.ac.jp), [2]Japan Aerospace Exploration Agency, [3]University of Aizu.

Introduction: The final goal of our study is to create a global geologic map of Mercury to approach Mercurian crustal evolution. For that purpose, we decide geological unit of Mercury's surface by using automatic classification methods for different physical quantities such as reflectance spectrum, element concentration, and elevation acquired by US Mercury Explorer "MESSENGER".

It has been clarified recently that volatile elements such as carbon, sulfur and chlorine exist on Mercury's surface due to X-ray and γ-ray spectroscopy on MESSENGER [1, 2]. Such volatiles are largely related to the process of magma ocean differentiation, crustal formation and volcanic activity. For example, the presence of carbon was imaged as a dark region in a visible-infrared spectroscopic camera and many of which were observed in large impact craters and their ejecta. This result was suggested as lower crust origin that was consistent with the formation of the graphite crust floated from the early magma ocean [3]. However, previous studies have been done in local areas where they were interested, and there is no global classification map of Mercury's reflectance spectrum under unified classifying criteria.

For a first step to build the Mercury's geological map, this work shows a classification map of visible-infrared reflectance spectra obtained by MESSENGER MDIS by using automatic classification method.

Data and Method: The analysis data classified was 8 bands cubed global mosaic data called 8 color (MDR) of MESSENGER/MDIS [4]. Wavelengths of the bands are 433.2, 479.9, 558.9, 628.8, 748.7, 828.4, 898.8 and 996.2 nm (Fig.1). Though the original spatial resolution is 64 pixels per degree, the data was picked up every 0.5 degrees grid to reduce calculation time after removing unsuitable data for automatic classification. Analysis region is within ±65.5 deg. of latitude.

Unsuitable data for automatic classification was detected by RXD (Reed-Xiaoli Detector) algorithm [5], and pixels having RXD index over 200 were removed from the original data. Then, principal component analysis (PCA) was applied to the mosaic data, because an automatic classification result of raw reflectance data was almost classified by absolute value of reflectance. The first, second, third and sixth primary component (PC) were recognized as signal. After histograms of these PCs's intensity were normalized each standard deviation to become 1, the four signal components were classified by K-means of unsupervised classification method [6]. As K-means was need numbers of class to divide, this work gave it from one to ten to test this method.

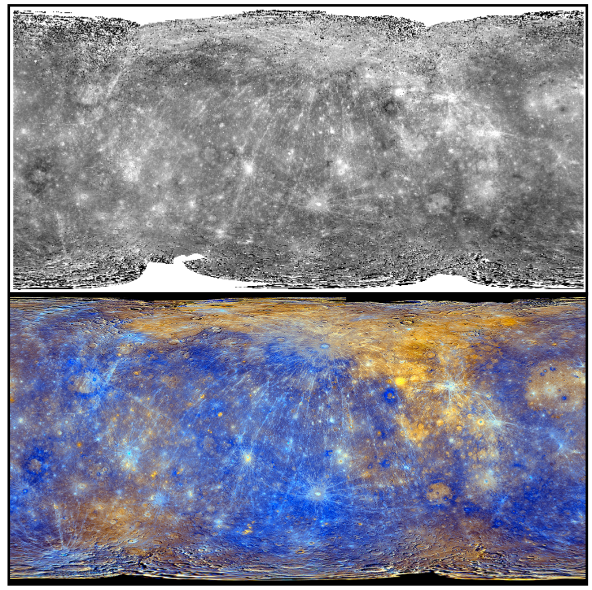

Fig.1 8 color (MDR) 750 nm image of Mercury (top) [4] and enhanced color mosaic of 3 color (MP3) (red : PC2, green: PC1, blue: 430 nm/1000 nm ratio) of MDIS (bottom) (NASA / Johns Hopkins University Applied Physics Laboratory / Carnegie Institute of Washington).

Furthermore, in order to test whether this method is correctly classified, the same classification method was applied to the reflectance data of the Moon. For the Moon, since a cubed average absorption hyper spectrum (160 bands from 530 nm to 1600 nm) called SP-Cube Depth was classified successfully by K-means and ISODATA [7, 8], this work can be compared to that and the result can be evaluated. The data for the Moon was analysis the similar wavelength range, which was 7 bands (512.6, 560.5, 632.7, 752.8, 830.8, 902.7 and 1003.6 nm) picked from a cubed average reflectance hyper spectrum called SP-Cube [7, 8]. PC1, PC2, PC3, and PC4 were selected to classify by K-means.

Preliminary result and discussion: The classification result by this work for the Moon was compared to those of SP-Cube Depth in Fig.2. The top panel shows the result of SP-Cube Depth by K-means (K = 7 classes) and the bottom panel shows that of selected bands of SP-Cube by this work (K = 8 classes). The 7 classes of K-means for SP-Cube Depth were 2 classes of high calcium pyroxene dominant (HCP) spectrum (mainly mare region), 1 class of low calcium pyroxene (LCP) dominant spectrum (mainly SPA and highland near Mare Frigoris), 2 classes of featureless spectrum (mainly highland) and 2 classes of those mixtures. The 8 classes map by this work showed similar to the previous map. As the HCP dominant spectrum is characterized by absorption of wavelength around 1.1 ~ 1.2µm, this work could not classify HCP dominant spectrum. However, since mare had relatively high iron content characterized by absorption of wavelength around 1µm, this work can divide mare region clearly. Also, since LCP dominant spectra showed absorption around 0.9µm, SPA and northern highland area of Mare Frigoris, and this tendency can been seen in the classification of SP-Cube Depth too.

Fig.3 shows classification result of K-means for the Mercury with number of classes set as 3 (top panel) and 6 (bottom panel). The classification map is similar to the enhanced color mosaic map of Fig.2. For case of 3 classes, northern part of the Coloris basin, which is the largest basin in the Mercury, the Shakespeare (H3) and eastern area of the Debussy(H13) were divided into the same class as red, and these areas corresponds to yellow area of the Enhanced color map of Fig.1. It seems that the blue class is corresponds to craters and those ejecta. For case of 6 classes, the Coloris basin and the Debussy(H13) were classed into green, while the Shakespeare (H3) was divided into an another independent class. Small amount of the red class were appeared in center of the Debussy(H13). This fact may relate to formation history of the Mercury crust. This work indicates that the Mercury can be classified by adopting K-means of unsupervised classification to 8 band spectrum between 430 and 1000nm. However, K-means needs to be given a number of classes by users. Actually, nobody knows how many classes the Mercury is divided. For the Moon, ISODATA[6], which is a fully unsupervised classification method without giving numbers of class, was adopted to the SP-Cube Depth, and the Moon was classified into 66 classes finally[7, 8]. The same method will be adopted to full resolution data of 8 color (MDS) of the Mercury.

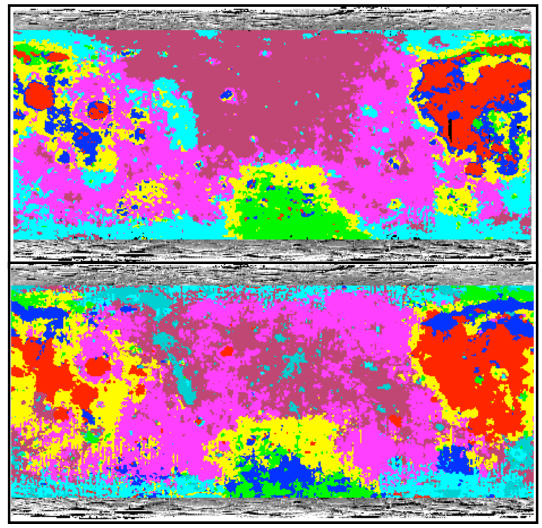

Fig. 2 Classification map for the Moon. Top panel: classification for absorption spectrum of SP-Cube Depth by K-means (K = 7) [7, 8]. Bottom panel: classification for reflectance spectrum of this work by selected PCs + K-means (K = 8).

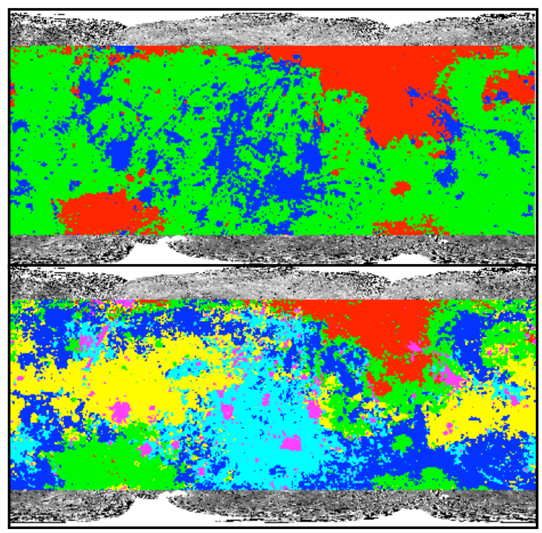

Fig. 3 Classification map of 8 color (MDS) of the Mercury. Top: The number of classes given to K-means is 3 (top) and 6 (bottom), respectively.

References: [1] Weider, S.Z. et al. (2016), *Geophys. Res. Lett.*, *43*, 3653-3661. [2] Evans, L.G. et al. (2015) *Icarus, 57*, 417-427. [3] Peplowski, P.N. et. al. (2016) *Nature Geosci. 9*, 273–276. [4] http://messenger.jhuapl.edu/Explore/Images.html#global-mosaics. [5] Reed I. S. and X. Yu (1990) *IEEE Trans. Acoustics, Speech and Signal Proc. 38*, 1760-1770. [6] Tou J.T. and Gonzalez R.C., (1974) *Pattern Recognition Principles, Addison-Wesley Publishing Company, Reading, Massachusetts.* [7] Hareyama M. et al. (2016) *LPS XLVII,* Abstract #1390. [8] Hareyama M. et al. (2017) *LPS XLVIII,* Abstract #1706.

Acknowledgements: This study is supported by JSPS KAKENHI (Grant-in-Aid for Scientific Research(C)) Grant Number 17K05641 (P.I.: Makoto Hareyama).