Statistical identification of meteorites using X-ray energy spectra measured with handheld-XRF

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Landing explorations of extraterrestrial bodies give us detailed information of their surface materials. Rapid identification of the types of materials is important for planning further in-situ analysis during a remote mission, which includes selecting prime targets to yield optimal science return. Active X-ray fluorescence (XRF) is a candidate for future missions, including being a part of the payload of a surface rover [1] as well as APXS [2], for example, which can perform in-situ measurements of the composition of the surface materials. However, one of the largest problems with XRF measurement is the matrix effect. X-ray excitation intensity is highly influenced by changes in the various matrices (e.g. mineral abundance, crystallinity, and porosity). To remove this effect, fusion bead sample is used for laboratory analyses. Then to calculate quantitative values, abundant numbers of a well-known standard samples are measured to obtain a calibration curve, otherwise the bulk compositions cannot be quantitatively and accurately analyzed. Thus, we are testing whether the meteorite type can be statistically identified without matrix correction using X-ray energy spectra yielded from a hand-held XRF (Olympus Delta). We measured 20 meteorite slab samples stored at the University Museum, University of Tokyo, which include chondrite (carbonaceous and ordinary), achondrite (HED, mesosiderite, and Martian), and primitive achondrite (ureilite). Niihara et al. [3] reported that the compositional values of at least 6 elements (Si, Ti, Al, Fe, Mn, and Ca) could be measured both quantitatively and accurately using a hand-held XRF. Thus, we also perform comparative analysis among the compositional values and the X-ray energy spectra, although the quantitative values include large uncertainty due to the matrix effect; we conduct principal components analysis on both the X-ray energy spectra (10 kV and 40 kV: 40 kV can detect signals from minor to trace heavy elements) and compositional data.

On the PC1 and PC2 space, although the total number of classified types of meteorites is only six, we can distinguish almost every type of meteorite (although mesosiderites are widely distributed) utilizing every data set. Achondrites and primitive meteorites can be easily separated by PC1 for energy spectra or PC2 for compositional data. On PC2, ordinary and carbonaceous chondrites are nearly identical both in 10 kV and 40 kV energy spectra data, while indistinguishable using compositional data. Variations appear to be mainly due to the Fe, Ca, and Si components in the spectral and compositional data sets, consistent with Miyamoto et al.[4], despite the fact that 10 kV and 40 kV spectra have different elemental sensitivities. These three elements are major components of major rock-forming minerals (olivine and pyroxene) and are common in meteorite samples. Based on these result, we suggest X-ray energy spectra could be used to classify meteorites directory without any kind of correction and is useful for primary classification and targeting during future planetary surface explorations.

References: [1]Nagaoka et al., 2016. LPSC. [2]Rieder et al., 2004. Science. [3]Niihara et al., 2015 JpGU. [4]Miyamoto et al., 2016, MAPS (in press).

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