Advanced extraction methods of metal deposit-induced information from multispectral satellite imagery with middle spatial resolution

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Remote sensing optical sensors onboard satellites have been used effectively in geological fields to identify minerals related to occurrence of metal deposits. Multispectral satellite images, represented by Landsat series and Terra ASTER, have covered all land areas for a long time and vast data have been accumulated. Spatial resolution of these images is relatively high, but more advanced image analysis methods are indispensable under a present situation that detection of new deposits becomes difficult. This study aims to develop the following two methods for precisely detecting the Earth information related to metal deposits from multispectral satellite images and verify their effectivenss.

The first is a development of a geobotanical remote sensing method to explore mineral deposits in areas covered by thick vegetation. For this, a new vegetation index (VI) was proposed using reflectance data from five bands in the visible green to shortwave infrared region (Hede et al., 2015). This index, VIGS (Vegetation Index considering Greenness and Shortwave infrared) was developed so that the VI can accurately detect vegetation stress caused by metal contamination of soils. The VIGS is examined for a mineralized area containing hydrothermal copper deposits in central Sumatra, Indonesia. Using one Landsat ETM+ scene image after atmospheric correction, the effectiveness of VIGS was proven by this case study, because VIGS anomalies appeared in high-content zones common to Cu, Pb, and Zn. Another case study was the Hokuroku district, northern Japan, recognized for rich ore deposits (kuroko and vein types). The reflectance spectra of Landsat ETM+ images acquired in summer and autumn were used to calculate VIGS. A key variable to detect the anomalies is a variation of VIGS with time at each pixel. Difference in variation is enlarged by a sequence of image enhancement methods for the detection. We find that the vegetation anomalies, defined by the large ratios, correspond well to the high potential zones of ore deposits and known major deposits.

The second method is a transformation of multispectral imagery to hyperspectral imagery. Hyperspectral remote sensing is superior to traditional multispectral remote sensing in detailed spectral information but has limited spatial and temporal coverage. Then, a new method, Pseudo-Hyperspectral Image Transformation Algorithm (PHITA) was developed using correlations between multispectral and hyperspectral band reflectance data, which could be defined as a multiple linear regression model selected through Bayesian model averaging. By choosing a part of the Cuprite hydrothermal alteration area and the Fish Lake Valley geothermal prospect area in the western United States for study, the pseudo-Hyperion images produced from the TM, ETM+, OLI, and ALI images by PHITA were confirmed to be applicable to mineral mapping. An advantage of the pseudo-image is clarified, in which the identification and mapping accuracies of metal deposit-related minerals were high even in areas outside the original Hyperion scene. Featured absorptions were reconstructed in pseudo-reflectance spectra of the typical minerals in these areas. For example, using a reference map as the truth, three main minerals (muscovite and chlorite mixture, opal, and calcite) were identified with high overall accuracies from the pseudo-images.

Keywords: Optical sensor satellite image, Metal deposit, Vegetation index, Hyperspectral image, Hydrothermal alteration mineral