Elemental and mineralogical diversity of serpentine soils in East Asia

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Serpentinite is an ultrabasic rock composed of ferromagnesian minerals with extremely high concentration of Mg and transition metals. Mainly due to the anomalies, special vegetation communities called serpentine flora can be developed on serpentinite geological substrate. Because serpentine minerals are relatively unstable in ordinary temperature and pressure, they may transform or neoform into secondary silicates or oxides during soil formation process with much higher rate than other felsic minerals such as quartz, feldspars and micas. In East Asia, where it has high temperature and much precipitation, mierals in serpentine soils are weathered easier than those in soils from other regions. Thus, mineral diversity of serpentine soils is expected to be very high in East Asia depending on the climate conditions. However, there has been no comprehensive study to elucidate diversity of these soils in this region. The objective of this work is to investigate the variation of elemental and mineral composition of serpentine soils in East Asia to understand their diversity in the region.
Samples were collected from Japan (Hokkaido, Kyoto, Kochi), Malaysia (Mt. Kinabalu’ s 4 sites with different elevation) and Indonesia (Kuaro). Soil samples collected from each horizon and rock samples were collected from near respective soil sampling sites. The elemental compositions of the samples were determined by AAS or ICP-AES after wet-digestion or by XRF directly. A ratio of ferrous (Fe^{2+}) to total Fe was determined by a photochemical method using 1, 10-phenanthroline. The Fe in free oxides (Fe_d) was extracted by dithionite-citrate-bicarbonate (DCB) method. The Fe_d content was determined by ICP-AES. Mineral composition of rocks and clays fractionated from each soil sample was identified by XRD. Principal component analysis (PCA) was used to obtain basic information on difference of elemental concentrations in the samples.
The rock samples showed similar elemental composition regardless of sampling sites. Namely, sum of SiO_2, MgO and Fe_2O_3 was 96±0.8% of total weight, and their ratio was about 8: 5: 1. The ratios of ferrous to total Fe were over 0.3 in the rock samples and the Fe_d contents were 12±1.5 g kg^{-1}. In the soil samples, the SiO_2 content varied largely from 45% to 5%, which was associated with the decrease in MgO content from 40% to almost zero, while the increase in Fe_2O_3 content from 15% to 80%. Furthermore, the increase in Fe_2O_3 content was proportional to the increase in the Fe_d content from 40 to 200 g kg^{-1} and the decrease in the proportion of the ratio of ferrous to total Fe from 0.2 to 0.01. Thus, elemental composition of serpentine soil was considerably different from parent rocks. The difference in the elemental condition was more evident in soils at lower latitude with similar elevations or at lower elevation with the same latitude (i.e. Kinabalu soils). PCA revealed that the first two PCs accounted for 77% of the total variance. The contents of Si and Mg had high positive loadings and those of Fe, Ni, Cr, and Mn had high negative loadings to PC1, indicating that PC1 is associates with degree of mineral weathering. The contents of Na, K, Al, and Ti had negative loadings to PC2. Because these elements were poor in all the rock samples and were relatively abundant in surface soil in Japan, PC2 may be associated with an incorporation of exotic minerals, probably as aeolian materials. Indeed, XRD revealed that quartz and mica were present in the Japanese clay samples, although major clay components were serpentine and talc. Thus, serpentine soils in East Asia were found to have highly variable elemental and mineralogical composition, largely different from those of serpentine in most cases. Such information of elemental and mineralogical diversity would be helpful to establish land management strategies in serpentine areas in East Asia.

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