REE abundances and ion-exchangeable REE fraction are high for intermediately weathered granite by formation of outer-sphere complex

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Ion-adsorption type ore of rare earth elements (REE) is found in weathered granite, from which we can readily extract REE using ammonium solution by ion-exchange reaction. Previous studies of the ion-adsorption type ore have been limited to China and Southeast Asia, but few for the weathered granite in Japan. In addition, there are no studies to clarify the relationship between the ion-exchangeable REE fraction (F_{REEex}) and REE species at molecular level. Thus, the aim of this study is (i) to clarify the relationship between F_{REEex} in the weathered granite and REE species at the molecular level using XAFS method and (ii) to study the dependence of abundance and F_{REEex} on the degree of weathering of the granitic rocks.

In this study, we analyzed granite or weathered granite samples collected in Japan (Hiroshima, Shimane, and Tottori), Sri-Lanka, and Myanmar. The collection of the samples from various sites are strongly needed to cover granitic rocks with various degrees of weathering.

The results showed that REE in the samples with CIA (Chemical Index of Alteration) between 65 and 80 can be readily extracted, in which REE species suggested by Y K-edge EXAFS was outer-sphere complex adsorbed weakly in the weathered granite. The μ-XRF-XAFS and SEM analyses suggested that REE was mainly adsorbed on phyllosilicates such as halloysite and weathered biotite. On the other hand, F_{REEex} in the samples with CIA < 65 are low, since REE is incorporated possibly into primary minerals or phosphate. The ratio of REE outer-sphere complex to total REE determined by EXAFS was positively correlated with that of F_{REEex}. However, strongly weathered granite samples with CIA > 85 did not show high REE abundance and F_{REEex}. Mineralogy of the samples is dominated by kaolinite and gibbsite, which suggests that the fraction of REE adsorbed on clay minerals is minimal for the strongly weathered granites compared with intermediately weathered granitic rocks with CIA value around 70. Thus, we can conclude that intermediately weathering characterized by the presence of vermiculate/smectite/weathered biotite with CIA value around 70 is an important limiting factor to establish the weathered granite sample as the ion-adsorption type REE ore.