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Genesis of ion-adsorption type REE ores in Thailand

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Ion-adsorption type REE deposits, which have been economically mined only in southern China, are predominant supply sources for HREE in the world. The ore bodies consist of weathered granites called ion-adsorption ores. The majority of REE (>50 %) are electrostatically adsorbed onto weathering products in the ores and they can be extracted by ion exchange using an electrolyte solution (e.g., ammonium sulfate solution). Recently the occurrences of ion-adsorption ores have been reported in Indochina, SE Asia. In this study, we discuss geochemical and mineralogical characteristics of parent granites and weathered granites in Thailand in order to reveal the genesis of ion-adsorption ores.

Permo-Triassic and Cretaceous-Paleogene granite plutons are distributed from northern Thailand to western Indonesia through eastern Myanmar and Peninsular Malaysia. They are mostly ilmenite-series calcalkaline biotite or hornblende-biotite granites. REE contents of the granites range from 60 to 600 ppm and they are relatively high in Peninsula Thailand. REE-bearing minerals consist mainly of apatite, zircon, allanite, titanite, monazite and xenotime. Some I-type granites contain REE fluorocarbonate (probably synchysite-(Ce)) in cavities and cracks in feldspars and it is the dominant source of REE for ion-adsorption ores because the fluorocarbonate is easily soluble during weathering. In contrast, insoluble monazite and xenotime are not preferable for ion-adsorption ores although they are common ore minerals of placer REE deposits.

Weathered granites show REE contents ranging from 60 to 1100 ppm in Thailand because REE are relatively immobile compared with mobile elements (e.g., Na, K, Ca). In the weathered granites, REE are contained in residual minerals and secondary minerals and are adsorbed onto the surface of weathering products. A weathering profile of granite with ion-adsorption type mineralization can be divided into upper and lower parts based on REE enrichment and Ce anomalies reflecting a redox condition during weathering. The upper part of the profile is a leached zone characterized by positive Ce anomaly and lower REE contents compared with the parent granite. This indicates that acidic soil water in an oxidizing condition immobilized Ce^{4+} as CeO_2 and transported REE^{3+} downward. In contrast, the lower part of the profile is an accumulation zone characterized by negative Ce anomaly and higher REE contents. This indicates that the transported REE^{3+} (depleted in Ce) were adsorbed onto weathering products and/or distributed into secondary minerals such as rhabdophane. This immobilization of REE results from the increase of pH and subsequent decrease of REE solubility due to the contact with higher pH groundwater. Percentages of adsorbed REE to whole-rock REE are also higher in the accumulation zone than in the leached zone. As the majority of REE in the weathered granites are present in the ion-adsorption phase with negative Ce anomaly, the percentages of adsorbed REE are positively correlated with the whole-rock negative Ce anomaly. Although fractionation of LREE/HREE is controlled by the occurrences of REE-bearing minerals and adsorption by weathering products, the ion-adsorption phase tends to be enriched in LREE relative to whole-rock compositions of weathered granites.