Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SRD043-01 Room:201A Time:May 22 09:00-09:15

Geochemical and mineralogical characteristics of ion-adsorption type REE mineralization: A case of Phuket, Thailand

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Ion-adsorption type rare earths (REE) deposits are composed of weathered granite formed in warm and moist climate, providing both light REE (LREE) and heavy REE (HREE) resources. As REE are chemically adsorbed onto weathering products such as clays, they can be extracted by ion exchange reaction with electrolyte solutions. The REE deposits have been mined only in southern China and similar mineralization is locally identified outside China. In order to elucidate the genesis of ion-adsorption type deposits, particularly the transportation and adsorption of REE in the process of weathering, we studied geochemical behavior of REE and occurrences of REE-bearing minerals in weathered crust on the Kata Beach Granite in Phuket Island, Thailand.

The Kata Beach Granite is ilmenite-series biotite granite with transitional characteristics from I-type to S-type (ASI = 1.01), and is abundant in REE (595 ppm). REE are contained in fluorocarbonate and subordinate allanite and titanite with lesser amounts of apatite and zircon. Chondrite-normalized REE pattern of the parent granite indicates the enrichment of LREE relative to HREE and without Ce anomaly. The upper part of the weathering profile from the surface to 4.5 m deep are mostly characterized by positive Ce anomaly, showing lower REE contents ranging from 174 to 548 ppm and lower percentages of adsorbed REE (adsorbed REE / whole-rock REE x 100) from 34 to 68 %. In contrast, the lower part of the profile from 4.5 to 12 m deep are characterized by negative Ce anomaly, showing higher REE contents ranging from 578 to 1084 ppm and higher percentages from 53 to 85 %. These REE contents, percentages of adsorbed REE and thickness of weathered crust are comparable to those of ion-adsorption type REE deposits in China. The upper part of the weathering profile is a leached zone in which Ce^{4+} is immobilized as CeO_2 in an oxidizing condition and REE with the depletion of Ce are dissolved in acidic soil water. The lower part of the profile is an accumulation zone in which REE with the depletion of Ce transported from the upper part of the profile are adsorbed onto weathering products or are distributed into the structure of secondary minerals such as rhabdophane. The immobilization of REE results from the increase of pH due to the contact with higher-pH groundwater. In ion-adsorption type ores (weathered granite with $>$50 % adsorbed REE) the majority of REE is present in the ion-adsorption phase with negative Ce anomaly, not in mineral structures, leading to the negative Ce anomaly of whole-rock geochemical data. Thus, the percentages of adsorbed REE are positively correlated with whole-rock negative Ce anomaly. Fractionation between LREE and HREE is not simply explained because it is controlled by occurrences of REE-bearing minerals and adsorption affinity. However, La/Yb ratios indicate that LREE tend to be more adsorbed onto weathering products than HREE.

The result of this study suggests that the occurrence of easily-soluble REE fluorocarbonate is important for formation of ion-adsorption type REE deposits. Whole-rock negative Ce anomaly of weathered granite suggests the ion-adsorption type mineralization and is a useful geochemical indicator for exploration of the deposits. As LREE tend to be more adsorbed than HREE in the process of weathering, identification of HREE-rich parent rocks is required to explore HREE-rich ion-adsorption type deposits.

Keywords: REE, granite, weathering, adsorption, mineralization, Phuket