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The role of clay minerals in formation of the regolith-hosted heavy rare earth element deposits

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Abstract

Rare earth elements (REEs) have become increasingly important to our modern society due to their strategical significance and numerous high technological applications. Regolith-hosted heavy rare earth element (HREE) deposits in South China are currently the main source of the HREEs, but the ore-forming processes are poorly understood. In these deposits, the REEs are postulated to accumulate in regolith through adsorption on clay minerals. In the Zudong deposit, the world's largest regolith-hosted HREE deposit, clay minerals are dominated by short, stubby, nanometer-scale halloysite tubes (either 10 or 7 Å) and microcrystalline kaolinite in the saprolite and lower pedolith and micrometer-sized vermicular kaolinite in the humic layer and upper pedolith. A critical transformation of the clay minerals in the upper pedolith is coalescence and unrolling of halloysite to form vermicular kaolinite. Microcrystalline kaolinite also transformed to large, well-crystalline vermicular kaolinite. This transformation could result in significant changes in different physicochemical properties of the clay assemblages. Halloysite-abundant clay assemblages in the deep regolith have specific surface area and porosity significantly higher than the kaolinite-dominant clay assemblages in the shallow soils. The crystallinity of clay minerals also increased, exemplified by decrease in Fe contents of the kaolinite group minerals (from ~1.2 wt% in the lower saprolite to ~0.35 wt% in the upper pedolith), thereby indicative of less availability of various types of adsorption sites. Hence, halloysite-abundant clay minerals of high adsorption capacity in deep regolith could efficiently retain the REEs released from weathering of the parent granite. Reduction in adsorption capacity during the clay transformation in shallow depth partially leads to REE desorption, and the released REEs would be subsequently transported to and adsorbed at deeper part of the soil profile. Hence, the clay-adsorbed REE concentration in the lower pedolith and saprolite (~2500 ppm on average) is much higher than the uppermost soils (~400 ppm on average). Therefore, weathering environments that favor the release of the REEs in the shallow soils but preservation of halloysite in the deep regolith can continuously adsorb REEs in the clay minerals to form economically valuable deposits.

Keywords: Rare earth elements (REEs), REE adsorption, halloysite, kaolinite, regolith-hosted REE deposits, weathering