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The Importance of Rare Earth Element Ion Adsorption Deposits: Their Significance, Genesis, Global Distribution and Their Environmental Impact

SAMANTHA CHE RUSSO[1,2], IGNACIO GONZÁLEZ-ÁLVAREZ[2,3] AND DR. YUAN MEI[4]

[1]James Cook University
[2]Commonwealth Scientific and Industrial Research Organisation (CSIRO)
[3]Centre for Exploration Targeting, University of Western Australia
[4]CSIRO

Presenting Author: samantha.russo@my.jcu.edu.au

Rare earth elements (REEs) are critical elements for green energy technologies, with REE ion adsorption deposits (IADs) significantly contributing to their production, in particular Heavy REEs (HREEs). But supply concerns prevail alongside geopolitical tensions. IADs are generated by natural weathering processes and allow for efficient extraction via leachates, such as traditionally used ammonium sulfate. However, concerns regarding eutrophication have recently emerged. Motives towards using safer leachates (e.g., HEH(EHP) and HDEHP) better align with environmental precautions and optimise production.

This study has undertaken a comprehensive literature review of IADs to understand the global distribution and criteria of these deposits. Grades of IADs range up to 5400 ppm REE (e.g., Tantalus, Madagascar) [1], whilst resource estimates are generally scarce. Ratios displayed in IADs, such as La/Yb, LREE/HREE, Ce/Ce* and Eu/Eu*, represent fractionation of REEs, and conditions such as redox and pH, throughout the weathered profile. Globally, these ratios have ranged from 0.10-121.00, 0.08-23.20, 0.02-3.32 and 0.02-1.02, respectively.

Most IADs are linked to deeply weathered terranes with granitic source rocks. These source rocks contain 'source minerals', generally feldspars and micas, which are weathered into clays, such as kaolinite and halloysite, and facilitate REE adsorption. IADs result from acidic surface water percolating down the weathering profile, mobilising REEs from the source minerals and transporting them until mixed with an alkaline fluid, typically groundwater. This pH change results in deposition of the REEs onto clays. Fluid-mineral interactions may also facilitate this pH change. Dissolution, mobility and adsorption are controlled via pH, Eh, T, ionic strength, ligands and cation exchange capacity of the clays. Other constraints on IADs include that of equilibrium through time, climate, groundwater table and topography. The relationship between climate and localities is exhibited in *Simplified Global Distribution of REE Ion Adsorption Deposits and Potential REE Ion Adsorption Deposits*, whereby the climatic map was derived from [2]. As shown, REE ion adsorption deposits are commonly found today in tropical and subtropical regions, such as China, highlighting potential exploration space for undetected IADs.

[1] Estrade et al. (2019), *Ore Geology Reviews 112*, 103027
[2] Sayre et al. (2020), *Global Ecology and Conservation, 21*, e00860

Simplified Global Distribution of REE Ion Adsorption Deposits and Potential REE Ion Adsorption Deposits