

### Rare Earth Element Ion Adsorption Clay Deposits: A Mineral Systems Approach for Exploration

**Samantha Russo**<sup>1,2</sup>, Ignacio González-Álvarez<sup>2,3,4</sup>, Helen A. Cocker<sup>2</sup>, Alex J. McCoy-West<sup>1,2</sup>

<sup>1</sup>IsoTropics Geochemistry Laboratory, Earth and Environmental Science, James Cook University, Townsville, Australia, <sup>2</sup>Economic Geology Research Centre, James Cook University, Townsville, Australia, <sup>3</sup>CSIRO, Mineral Resources, Discovery Program, Perth, Australia, <sup>4</sup>University of Western Australia, Perth, Australia

The transition to a 'green energy' future requires increased production of critical elements, such as rare earth elements (REE). REE Ion Adsorption Deposits (IACD) have sparked international interest as a heavy rare earths (HREE) source, supplying ~80% of global HREE. Therefore, a mineral systems approach is applied herein to constrain REE source, mobility, deposition, and preservation required for IACD formation. REE IACD are formed through intense weathering, where REE are liberated from REE-bearing minerals (e.g., REE-(fluoro)carbonates and REE-phosphates) and mobilised within the weathering profile before adsorbing onto clay minerals (e.g., kaolinite and halloysite). Granitic rocks are common IACD source rocks, however, other igneous, metamorphic, and sedimentary rocks, as well as REE-rich fluids and brines, are potential REE sources for in-situ and/or transported weathering required for IACD formation.

Once liberated, REE are mobilised within the weathering profile as complexes with ligands (e.g., F<sup>-</sup>, CO<sub>3</sub><sup>2-</sup>, SO<sub>4</sub><sup>2-</sup>, PO<sub>4</sub><sup>3-</sup>) or existing as hydrated REE species. REE complexation and fractionation are strongly controlled by pH, where non-fractionating complexes dominate under acidic to circumneutral conditions (e.g., hydrated REE mineral species and REE-sulfate complexes) and fractionating complexes dominate under circumneutral to alkaline conditions (e.g., REE-carbonate and -phosphate complexes). Therefore, pH and REE complexation control REE adsorption onto clay minerals, and relative light REE (LREE)- and HREE-enrichments throughout the weathering profile. REE adsorption is most favourable at circumneutral pH, where competition with H<sup>+</sup> ions is minimal, and hydrolysis is limited. REE adsorption, and therefore IACD, are preserved under low erosional settings. Climates with excessive rainfall (e.g., tropical humid climates) are problematic for preservation, where excessive rainfall promotes clay dissolution. The conceptual model based on a mineral systems approach provided herein presents a framework to be built upon in the coming years as our knowledge and global exploration of IACD continue.