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## Introduction

Rare earth elements (REE) are used in a variety of high technology devices, for instance hybrid cars, smartphones and permanent magnets. They are typically and historically extracted from the conventional minerals monazite ( $\text{REEPO}_4$ ) and bastnaesite ( $\text{REECO}_3(\text{F}, \text{OH})$ ) which contain considerable amounts of radioactive elements and have only relatively low concentrations of the more valuable heavy rare earth elements (HREE, Gadolinium – Lutetium). These are currently almost exclusively supplied by the Ion Adsorption Clay (IAC) deposits of southern China (Chi and Tian 2008). This study presents a geo- and hydrometallurgical investigation of a potential Ion Adsorption Clay material and its parental rocks from outside China.

## Geochemistry & Mineralogy

The parental rocks can be discriminated into  $\text{SiO}_2$  undersaturated (foiid-bearing diorite and syenite) and  $\text{SiO}_2$  rich specimen (Fig. 1). Whereas the former have a relatively low average REE concentration (~300 ppm), the latter are highly enriched in REE (average ~11000 ppm) and radioactive components Th (~1700 ppm) and U (~170 ppm). Additional valuable elements are Nb (~2600 ppm) and Zr (~10000 ppm). XRD analysis and Rietveld quantification of laterite samples revealed a high abundance of clay minerals with predominantly kaolinite (~22-80 wt.%). Quartz contents (~4-40 wt.%) are highly variable depending on the sample origin. Iron (hydr-) oxides occur in terms of goethite (~0-19 wt.%) and hematite (~0-3 wt.%). The lateritic Ion Adsorption Clay samples have an average REE concentration of ~500 ppm with a maximum of ~1200 ppm and a minimum of ~150 ppm. The Light vs. Heavy Rare Earth Element (LREE vs. HREE) ratio is approximately 5:1.

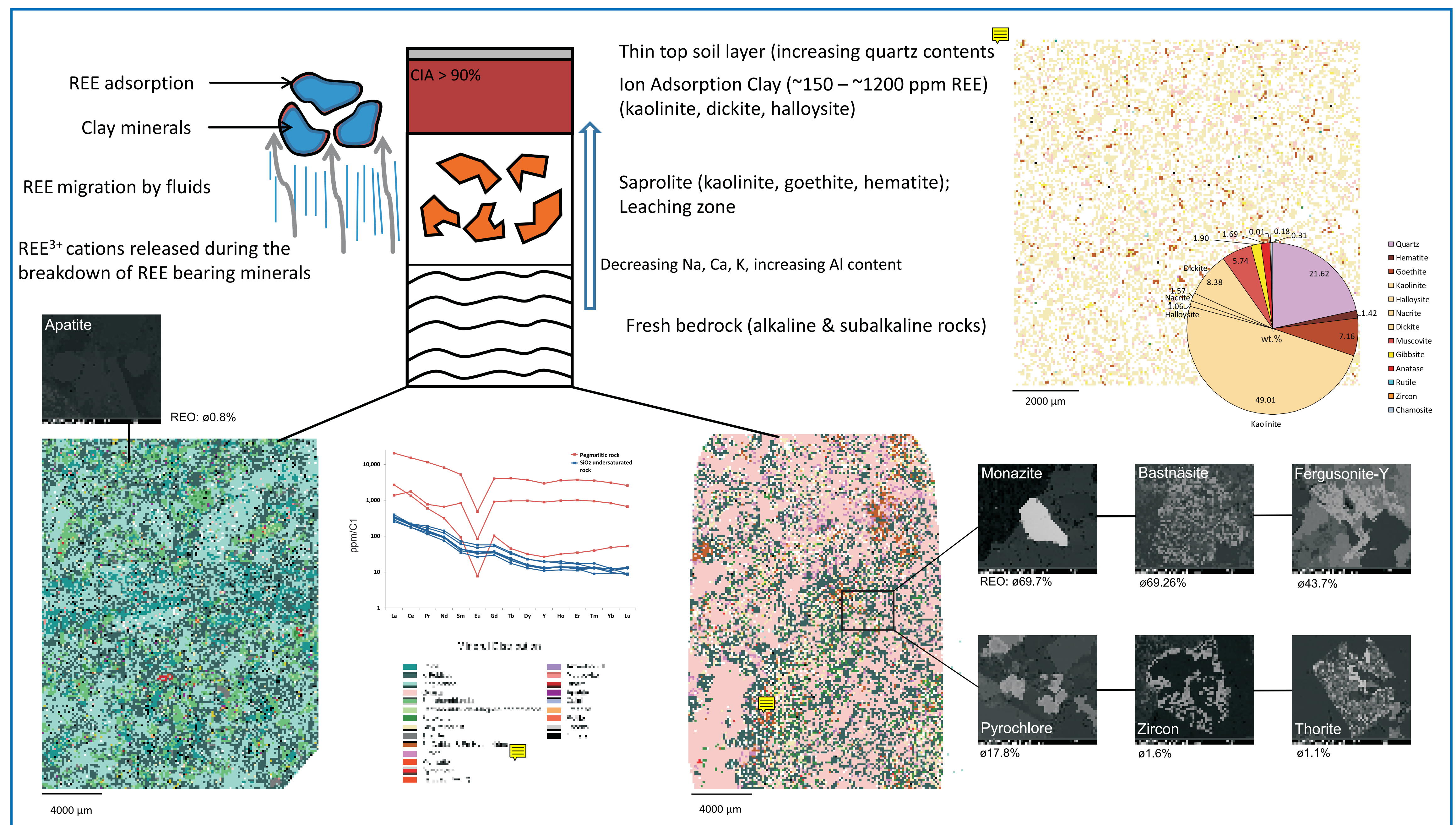


Figure 1 Geochemical and mineralogical inventory of Ion Adsorption Clay material and associated parental rocks

## Sequential Extraction & Hydrometallurgy

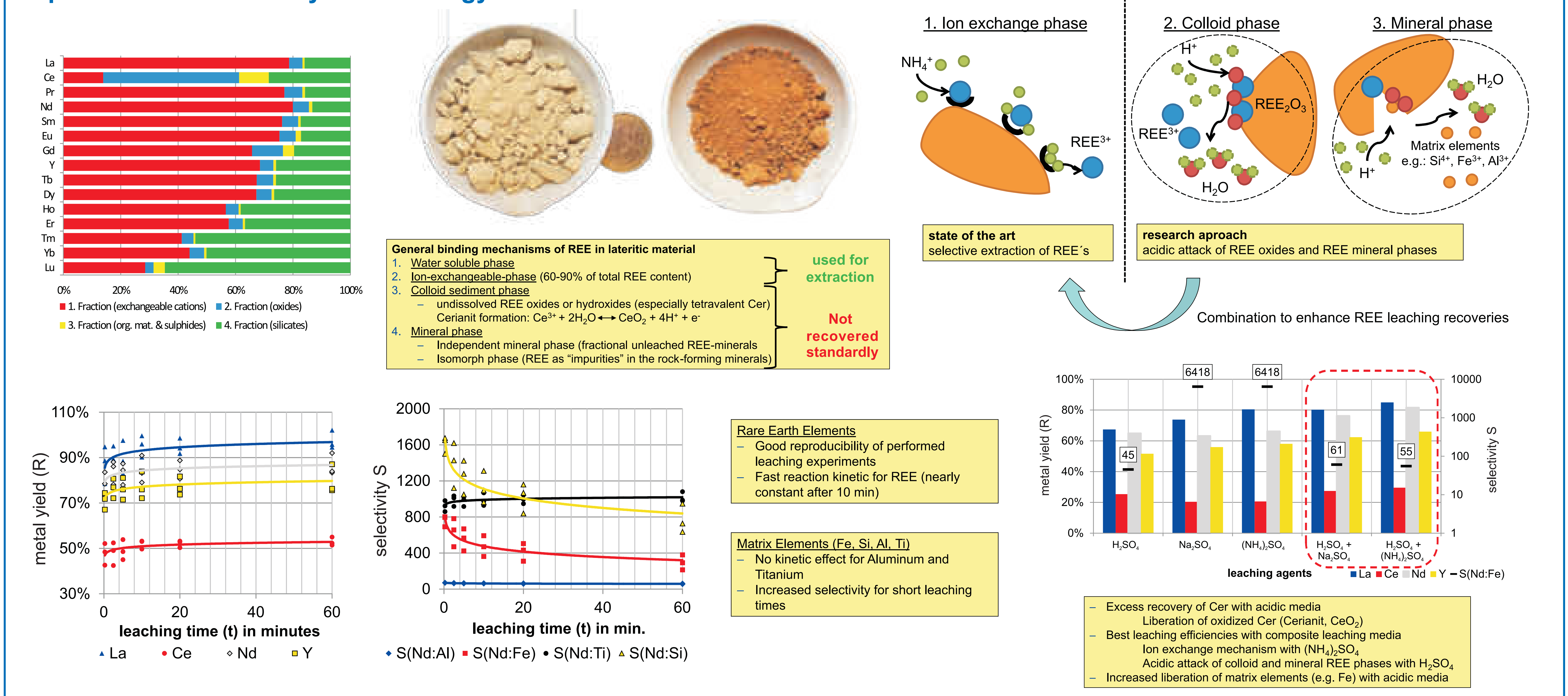


Figure 2 Results of sequential extraction and hydrometallurgical treatment of Ion Adsorption Clay material

## Conclusion

Ion Adsorption Clays are formed under lateritic weathering in tropical to semi-tropical climates from parental rocks with at least partially high abundances of labile REE minerals. Investigated lateritic samples were derived from  $\text{SiO}_2$  undersaturated and REE poor rocks as well as pegmatitic rocks with high REE concentrations due to the presence of REE minerals such as monazite (Ce, La), bastnaesite (Ce, La), pyrochlore and fergusonite (Y). During the breakdown of these minerals, REE<sup>3+</sup> ions are released and attached onto clay mineral surfaces. The lateritic samples show a consistent mature weathering status and high abundances of clay minerals, mainly kaolinite. REE variations within the ore body (~150 – ~1200 ppm) should have no distinct economic impact on mining due to a relatively easy and cost-efficient excavation process of lateritic material in general. In terms of beneficiation, low and high grade material can be mixed. However, matter with low non clay mineral content (e.g. quartz) is preferred. The results of sequential extraction analyses indicate that the majority of LREE are present in the exchangeable fraction, thus adsorbed onto clay mineral and Fe-/Al-(hydr-)oxide surfaces. With increasing atomic number, REE are progressively located within the residual fraction (silicates). Performed leaching experiments with the investigated IACs demonstrate an economic advantage based on increased REE recovery rates with minor addition of mineral acids to state of the art salt solutions. In comparison to chloride and nitrate based systems, the best leaching efficiencies could be achieved with sulfate based systems, particularly using a mixture of H<sub>2</sub>SO<sub>4</sub> and (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>. Short leaching times are favorable to prevent an excessive liberation of matrix elements especially Fe and Si. Further investigations will be focused on these impurities in the following purifying steps, implemented in the state of the art, with respect to the REE product quality.

## Reference

[1] Chi R, Tian, J (2008) Weathered Crust Elution-deposited Rare Earth Ores. Nova Science Publishers, New York, p 288