

Deciphering Molecular-Scale Mechanisms Governing Scandium Dynamics in the Critical Zone

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When rare-metals' supply emerged as a priority issue in many countries, Georges foresaw the potential of molecular-scale approaches to understand the processes forming critical-metal deposits. Among these elements, scandium (Sc) attracted his attention due to its emerging role in high-technology and energy transition-related applications. Recent discoveries of lateritic deposits in Australia represent a potential revolution in Sc supply but its mineralogy and geochemistry in this context were almost untouched. Laterites thus constituted strategic targets to study Sc speciation and deduce the concentration processes, demonstrating the potential of the proposed approaches in the perspective of improving the sustainability of critical-metals supply.

We have now made significant progress in understanding Sc dynamics in laterites, and more broadly in the critical zone. We show that the initial reservoir of Sc contained in exceptional parent rock[1] is preserved under reducing conditions in the lowest horizons of lateritic profiles. Scandium is subsequently trapped in the lateritic duricrust by goethite[2]. Scandium mobilisation then increases upward due to the dissolution of goethite, possibly assisted by dissolved organic matter, and the precipitation of hematite. We demonstrate that changes in speciation govern Sc concentration, with substitution in smectitic clays and adsorption on iron oxyhydroxides playing a crucial role. The higher affinity of Sc for goethite relative to hematite drives Sc mobilisation and concentration downward in the profile. These successive processes illustrate how the unique complexity of the critical zone leads to Sc concentrations forming new types of world-class Sc deposits.

In summary, we show how multi-scale mineralogical approaches complemented by theoretical modelling[3] allows us to decipher the mechanisms and conditions favouring rare-metals concentration, from the regional geological context down to the molecular level.

[1] Chassé *et al.* (2018), *Lithos* 310-311, 409-421. [2] Chassé *et al.* (2017), *Geochem. Perspect. Lett.* 3, 105-114. [3] Chassé *et al.* (2018) *Phys. Chem. Chem. Phys.* 20, 23903.