TAILINGS VALORISATION TO SECURE RARE EARTH (REE) SUPPLY

Technical Research Centre of Finland
Metals and Materials Recovery Team

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Industrial Chemistry - Metals and materials recovery

3 locations:

1. Minerals processing and bench-scale lab
2. Geomicrobiology lab
3. Piloting facility

Bioruukki Hydrometallurgy Piloting Facility

Press here for visiting Flexmet

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RePower project – Thematic opening: Electricity storage and accelerating clean energy/ **Critical Raw Materials for clean energy**

Funded by the European Union NextGenerationEU. The project is part of the strategic research opening "Electric Storage" of VTT, launched with the support of the additional chapter of the RePowerEU investment and reform programme for sustainable growth in Finland.

The focus areas within CRM for clean energy are:

- Lithium iron phosphate (LFP) battery recycling
- Rare earth recovery

VTT´s photo archive, photographer Timo Kauppila

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Réka Hajdu-Rahkama, Tuomo Mäkelä, John Bacher, Ivan Korolev and Päivi Kinnunen

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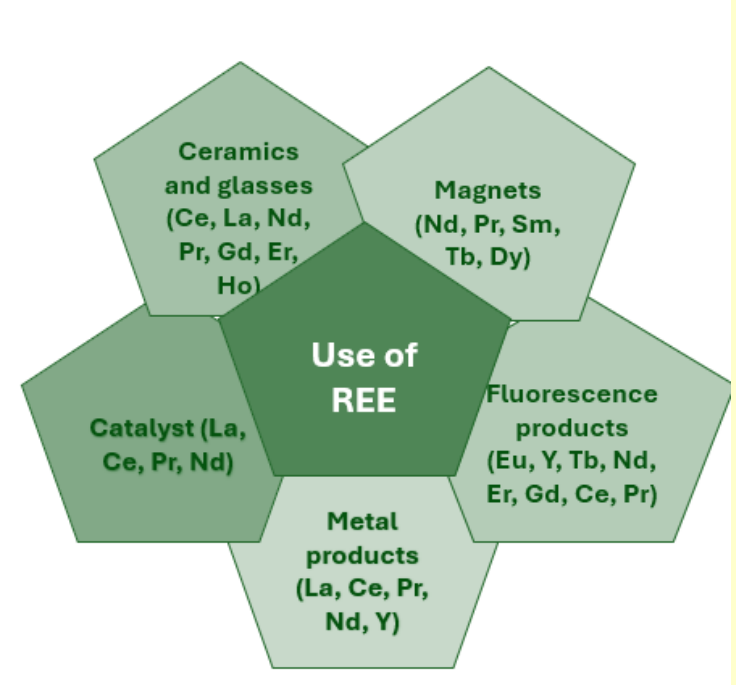

REE demand and resources

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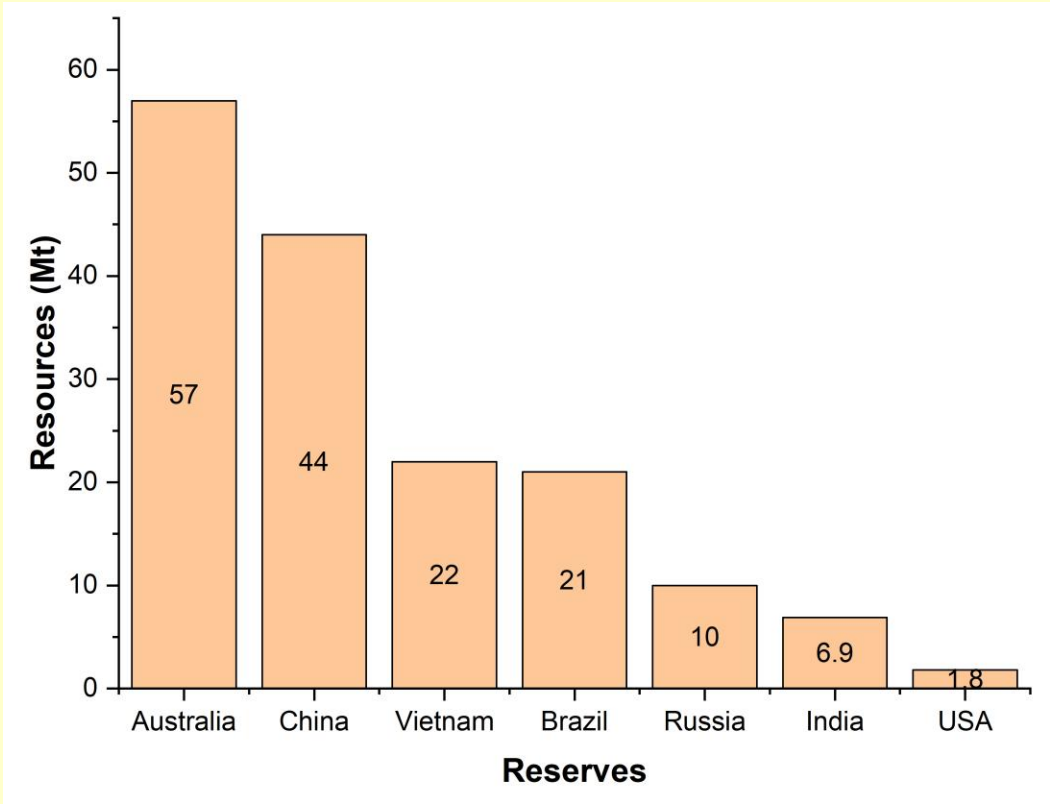
- Rare earth elements are critical raw materials (CRM) according to the International Energy Agency (IEA).
- Rapid increase of global REE demand due to their crucial role in green energy and advanced technologies.

51.4% in carbonatites

13.6% in tailings



Hajdu-Rahkama, R., & Kinnunen, P. (2025). Tailings valorisation: Opportunities to secure rare earth supply and make mining environmentally more sustainable. In *Journal of Cleaner Production* (Vol. 520). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2025.146147

Tailings valorization

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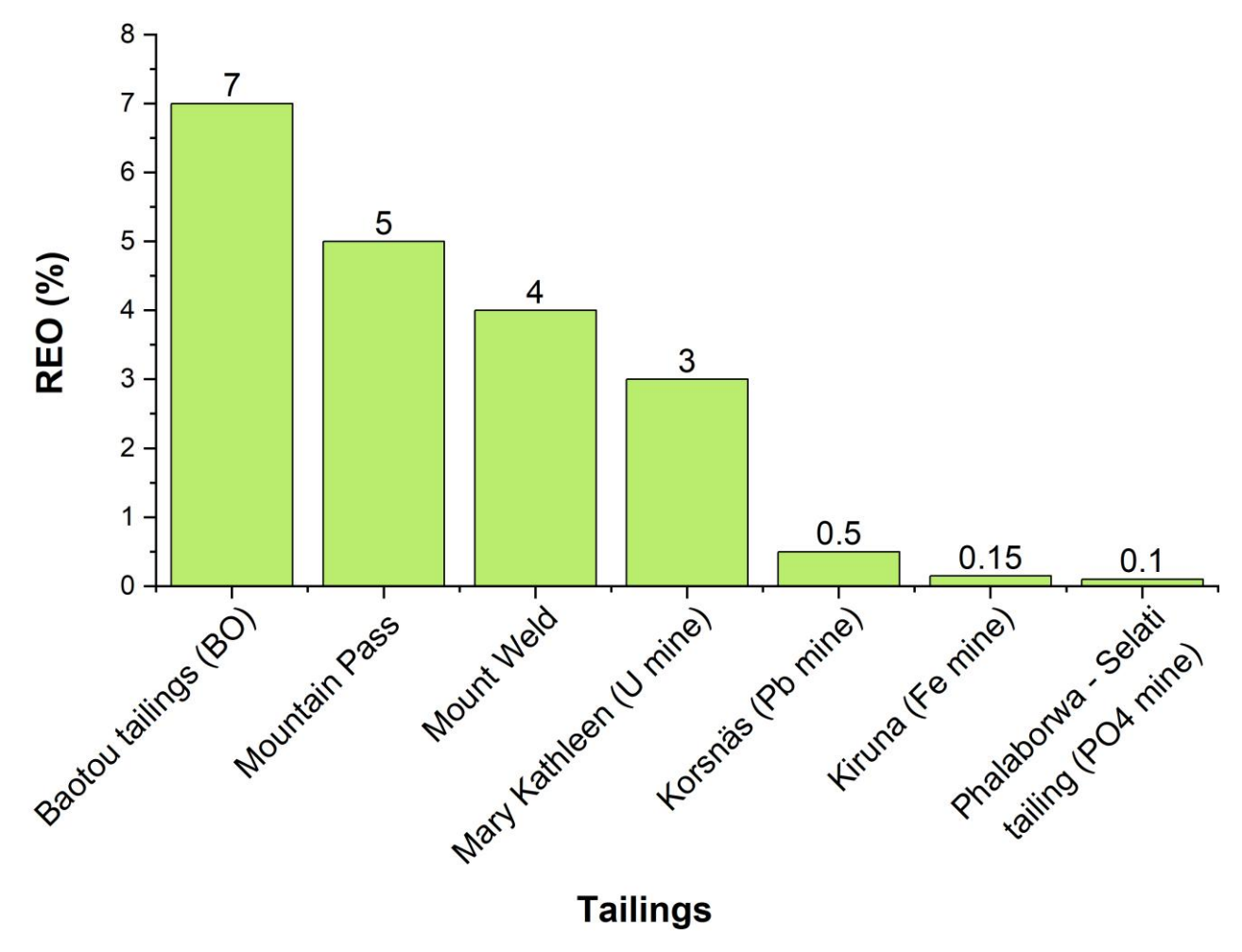

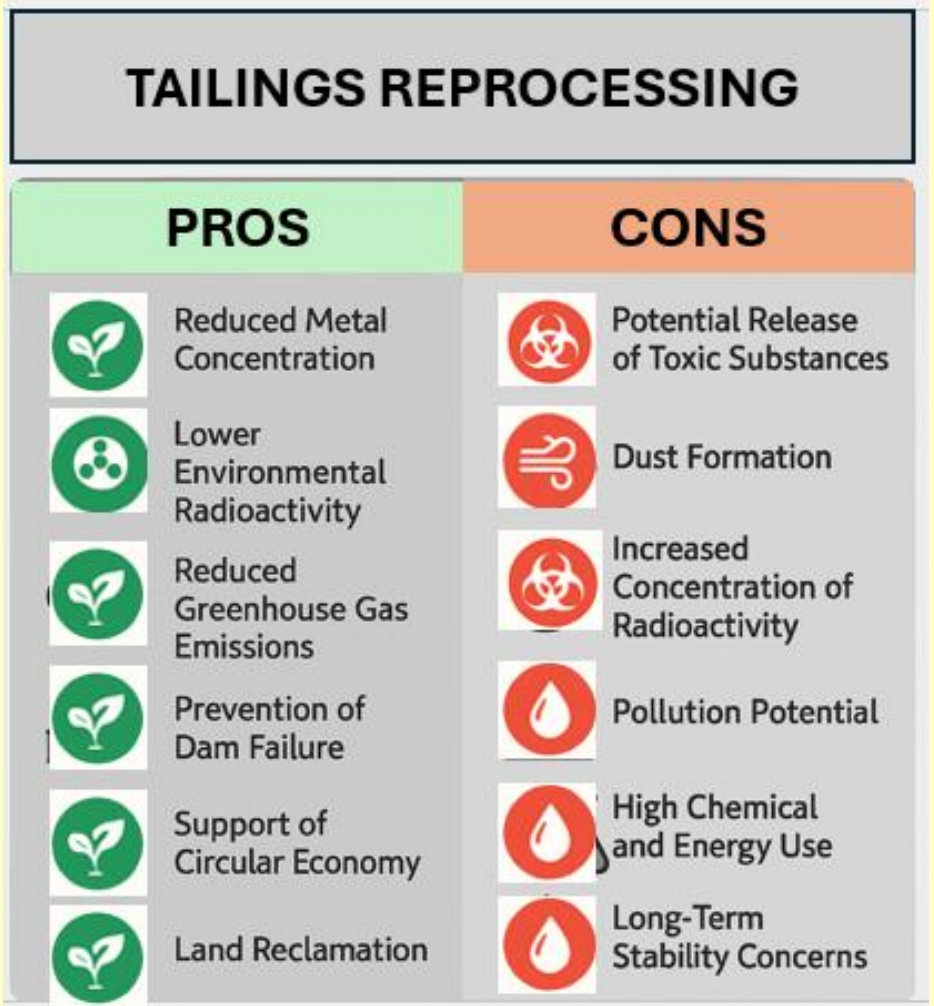

Hajdu-Rahkama, R., & Kinnunen, P. (2025)

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Materials and Methods

Sampling and characterization

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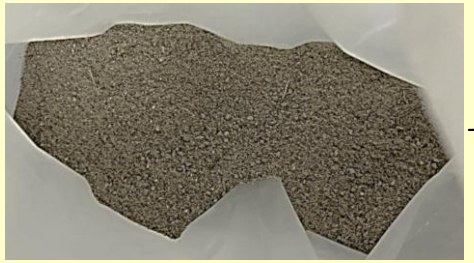
Closed Pb-REE mine

0.5-2 m

Drying & homogenization

PSD, XRD, ICP-OES, SEM, ignition loss

REE-concentration



sieving
≤ 1000 µm

Low intensity magnetic separation

Iron oxides

sieving

>125 µm

heavy

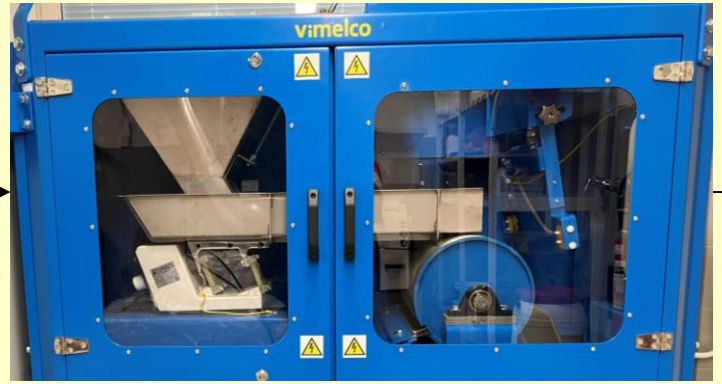
≤125 µm

heavy

Concentrate

light

63-1000 µm



non-cond. + middling

Concentrate

conductive

Analytics: ICP-OES

Acid baking & water leaching

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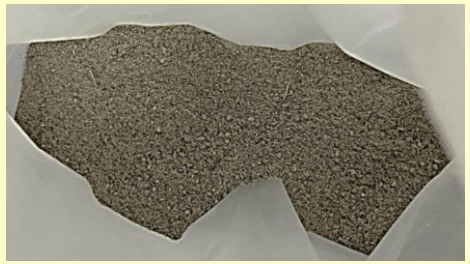
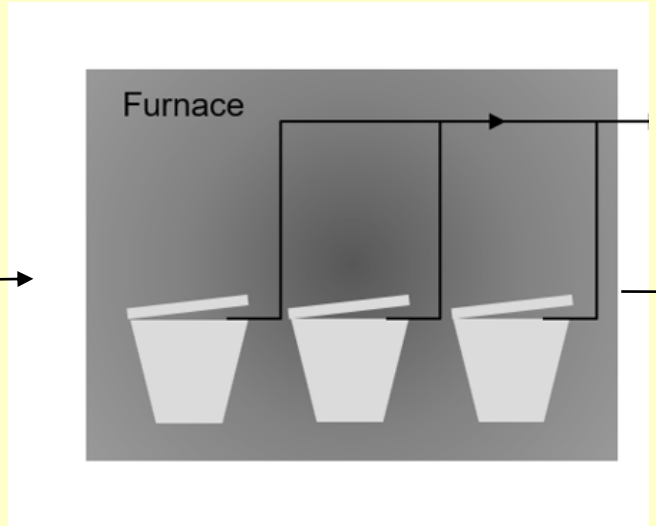


≤1 mm

$+H_2SO_4$

mixing



200-270°C, 2-4h
S/L: 0.5-1.4

Water leaching (1h, 10 wt%)

Filtration

PLS

Analytics: ICP-OES, pH, ORP

HCl leaching

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≤1 mm

HCl solution

mixing

170 rpm, 35°C, 2h, 0.05-1.5M HCl, 5 wt.%

~170 rpm, 35 and 75°C, 2h, 1.5M

Filtration

Analytics: ICP-OES, pH, ORP

Bioleaching

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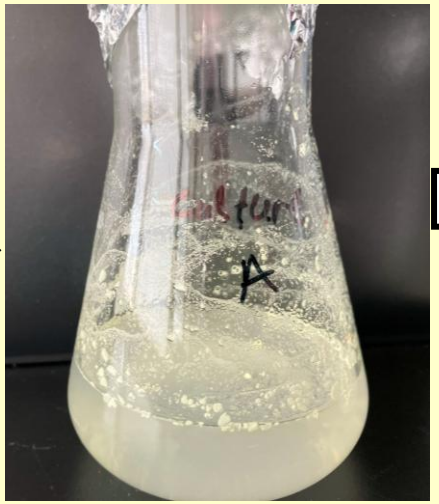
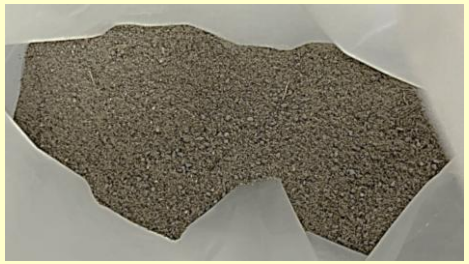
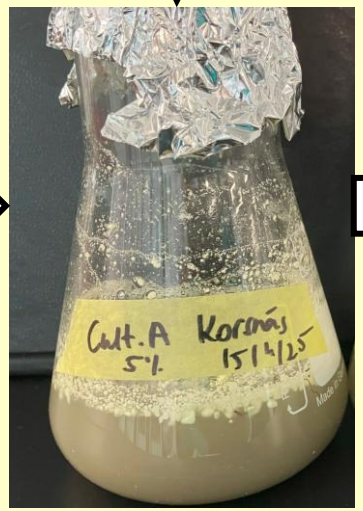
S-oxidizing enrichment

35°C, 150 rpm, S°



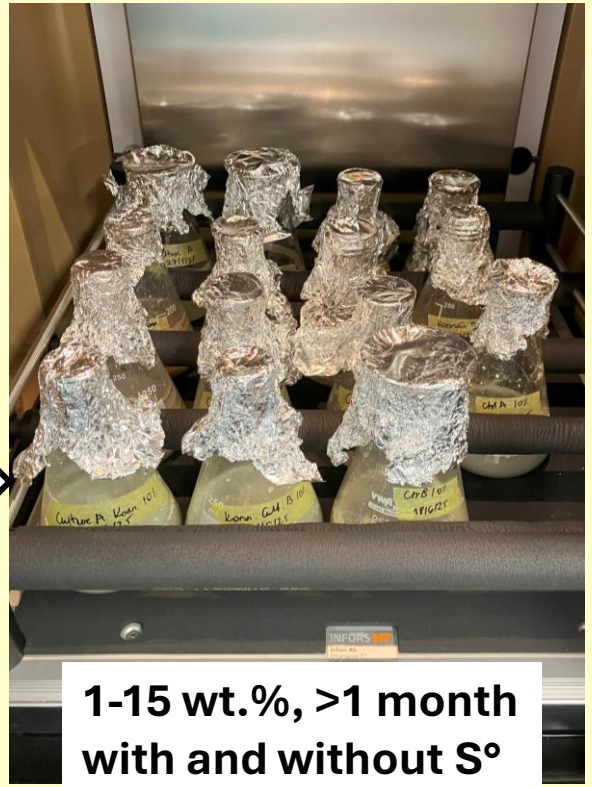
Activation/inoculation





Tailings adapted culture

Analytics: ICP-OES, pH, ORP



1-15 wt.%, >1 month with and without S°

Bioleaching experimentation

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Results

Characterization

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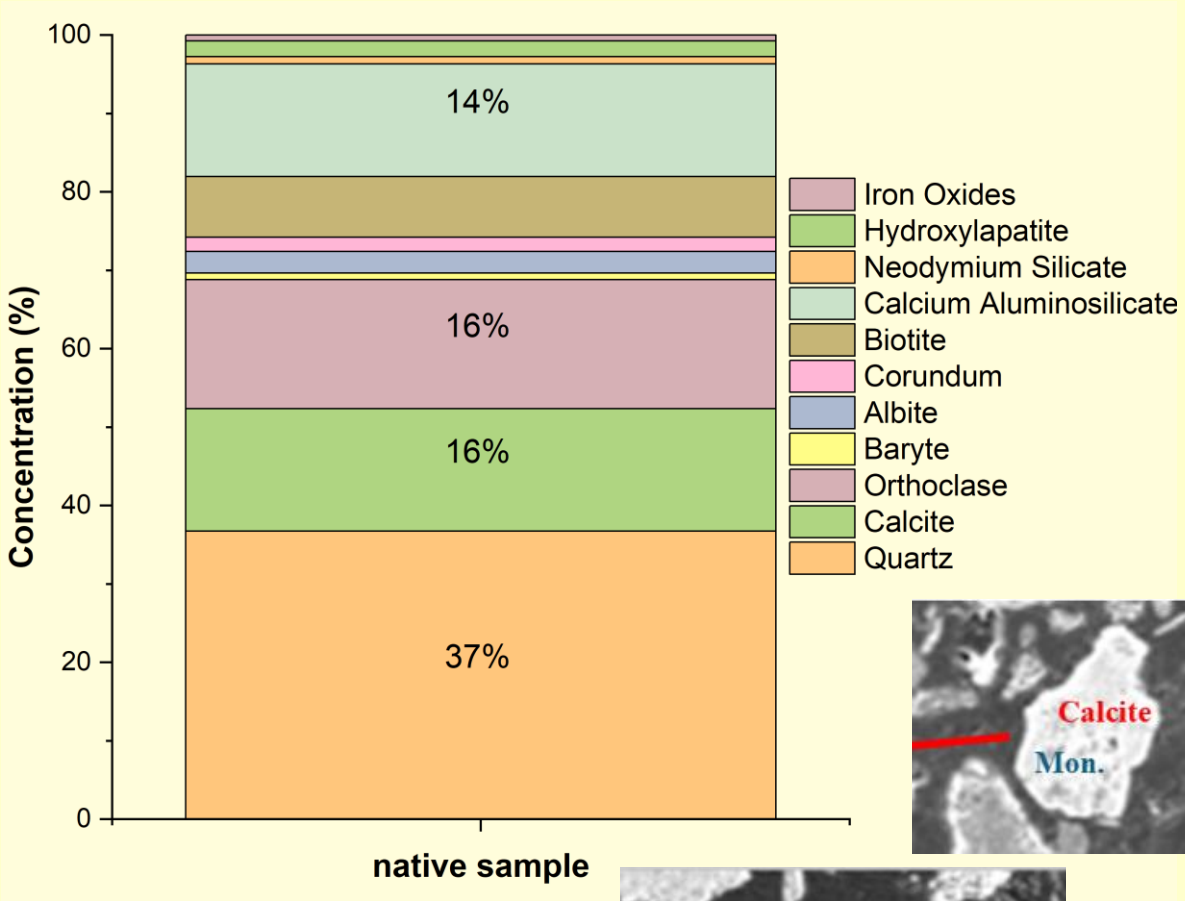
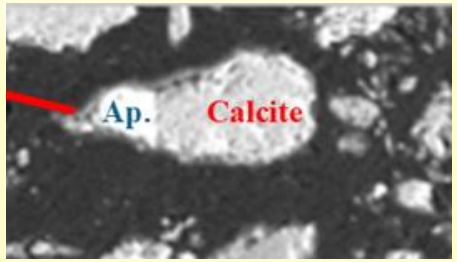
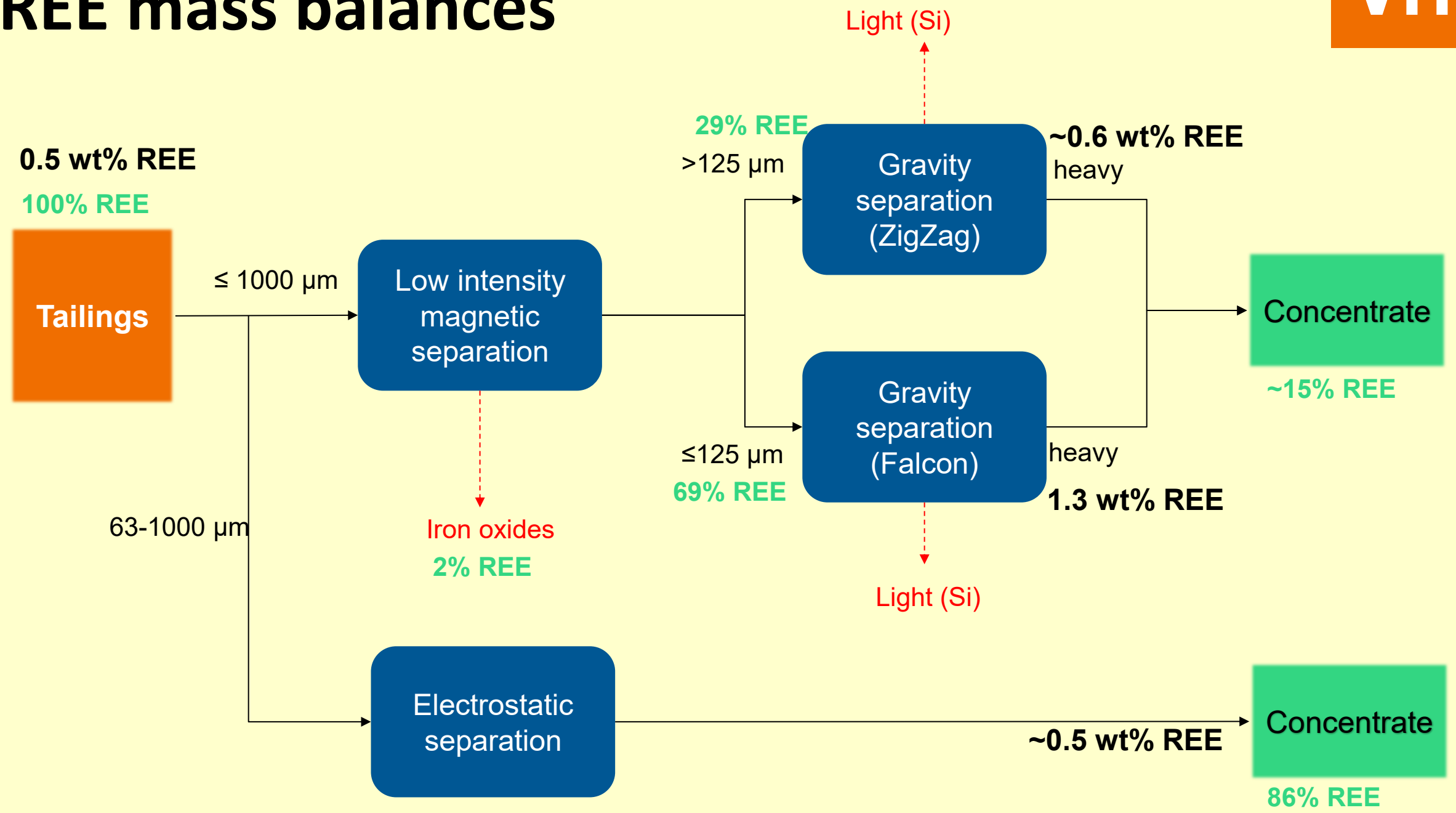




- Particle size distribution (PSD): Dv(50)= 140 µm; Dv(90)= 390 µm
- Mineralogy: monazite and apatite as REE-bearing mineral (0.7% <45 µm) + REE-silicates
- TREE: 0.6 wt%, Pr-Nd enriched
- Gangue: 19% Si, 7% Ca, 5% Al, 3% Fe
- Highest REE concentration (0.9 wt%) at <32 µm

REE mass balances



Extraction

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Table 1: Highest yields by different extraction means tested

Extraction mean	TREE leaching yield (%)	Parameters
Acid baking + water leaching	>90	1 (w/w)*, 250°C, 2h + 1h
HCl leaching	~60	1.5M (0.3, w/w)*, 75°C, 170-300 rpm, 1h
Bioleaching	~30	10 (w/w)**, 35°C, 150 rpm, 28d

*w/w is tail/acid; ** w/w is tail/S°

Conclusions

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- Tailings can be locally available sources of REE.
- REE concentration increases by particle size reduction.
- Concentrating the tailings is challenging due to the complex mineralogy, with the highest concentration ratio of 2.3 achieved through density separation.
- The highest leaching yield is obtained through sulfuric acid baking followed by water leaching.
- High acid consumption during acid baking and HCl leaching due to low grade of material.
- Improving concentration is essential to decrease processing costs.
- Bioleaching offers an energy-efficient and low-chemical alternative but requires longer leaching times and results in lower yields.

beyond

the obvious

Thank you!

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