



Estonian Paleozoic shelly phosphorites: a continent-scale resource for phosphorus and potential for rare earth elements

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What is Estonian phosphorite?



Chem. composition (n=12):

P_2O_5 – 37.11%

MgO – 0.67%

Fe_2O_3 – 1.17%

FeS_2 – 0.21%

P_2O_5 citric acid – 11.06%

Chem. composition (n=6):

P_2O_5 – 35.37%

MgO – 0.63%

Fe_2O_3 – 3.15%

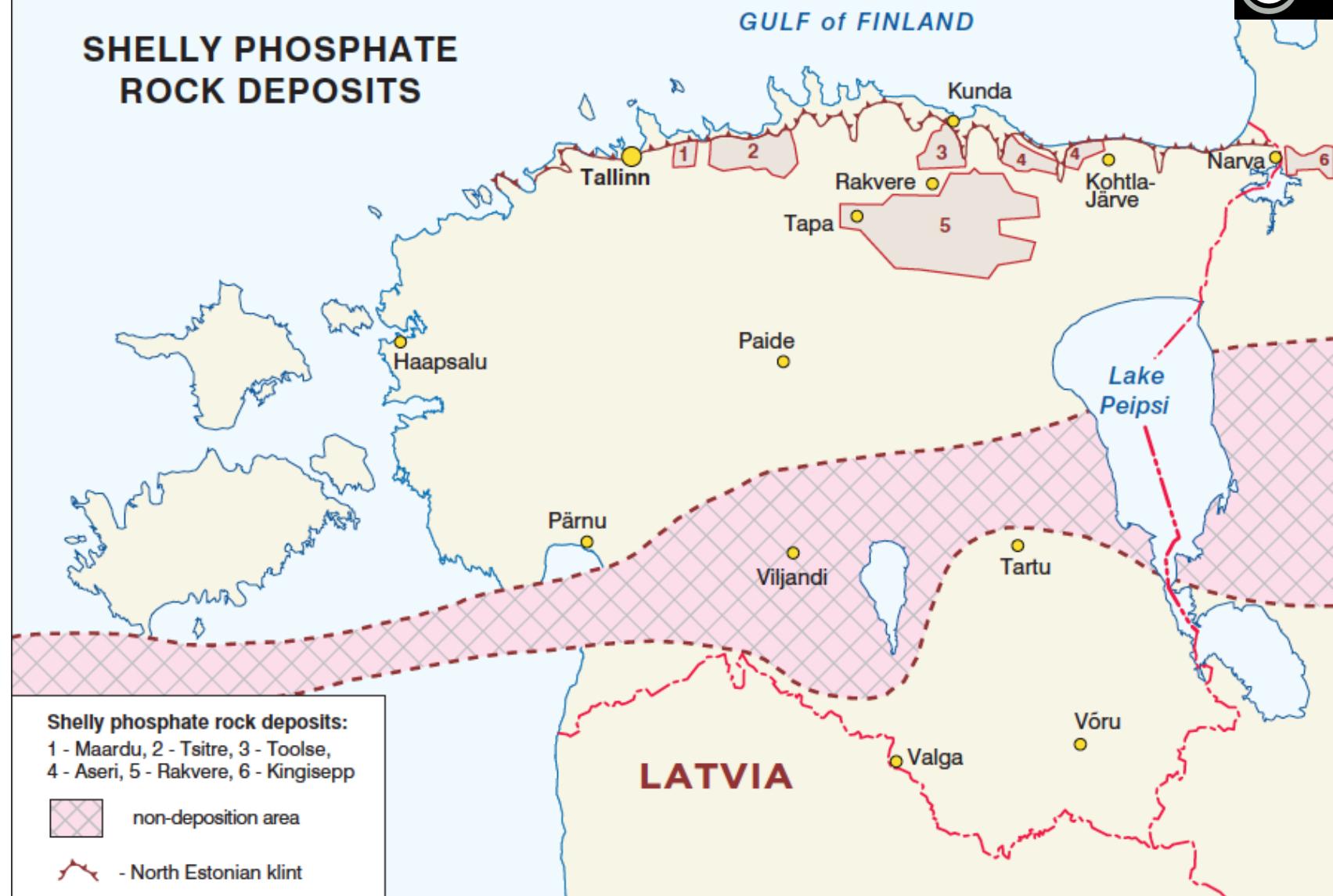
FeS_2 – 3.36%

P_2O_5 citric acid – 10.39%

Estonian phosphorite is a sedimentary rock, which contains Lingula valves and detritus, rich in phosphorus.

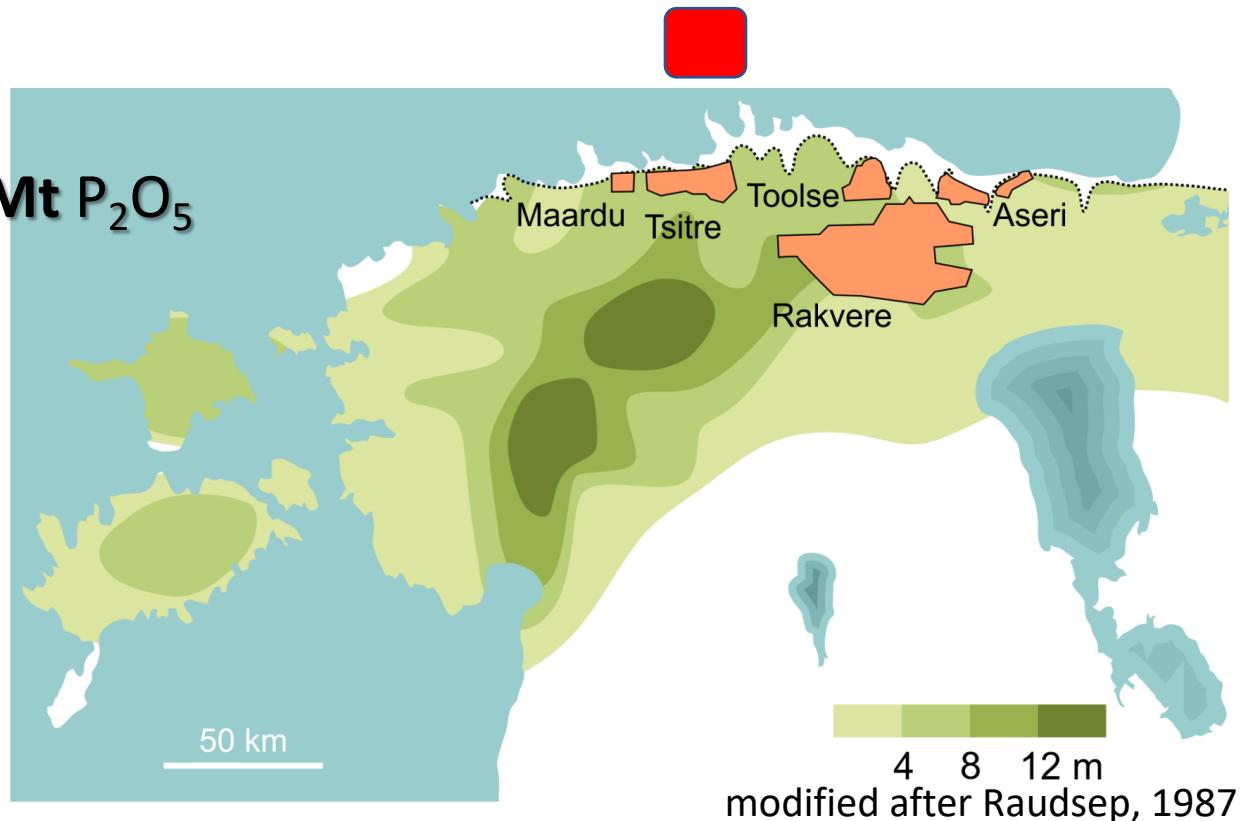


SHELLY PHOSPHATE ROCK DEPOSITS

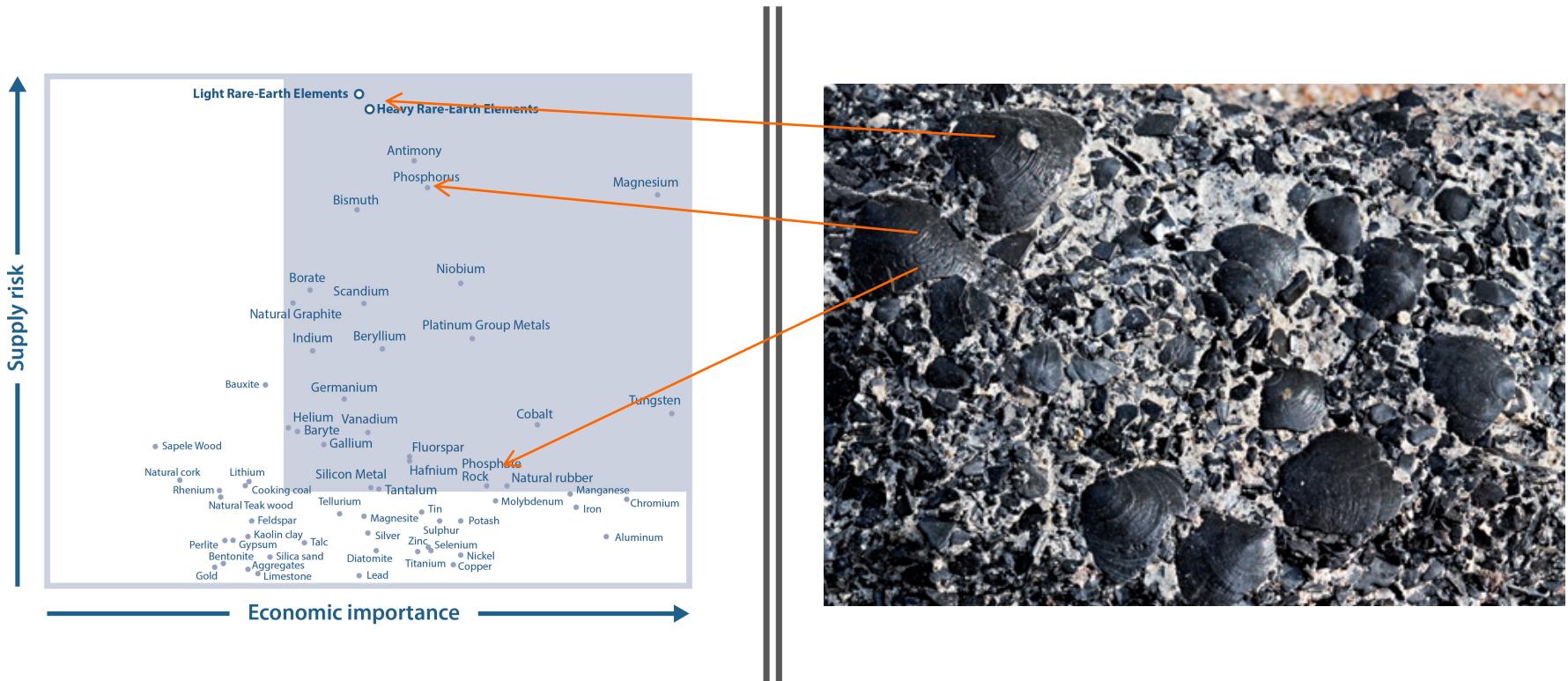


Estonian Deposits (Millions tons of P₂O₅)

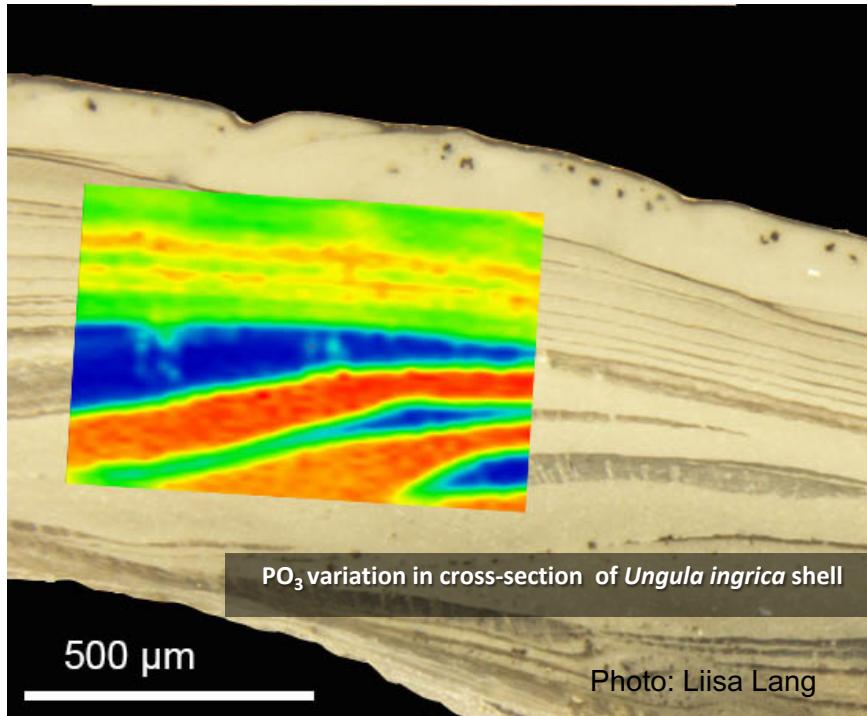
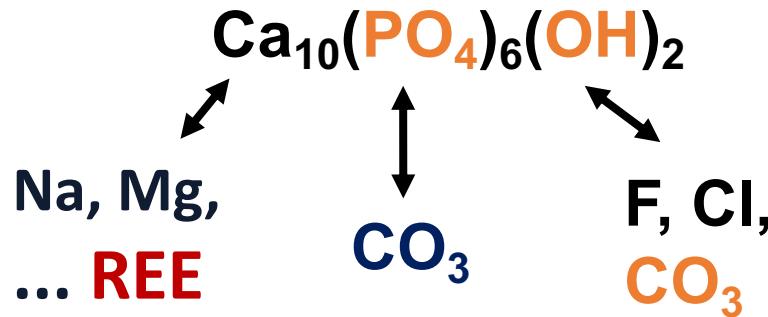
- Maardu - ca 3.4 Mt (not in registry)
- Tsitre - 4.1 Mt
- Aseri - 22.5 Mt
- Toolse - 27.4 Mt
- **Rakvere** - ca 735 Mt P₂O₅



Estonian sedimentary shelly phosphate rock – a multi-resource of P and REE



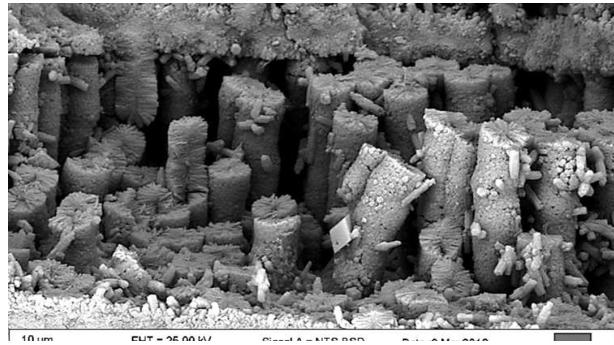
Rare Earth Elements in apatite as an additional value to phosphorite?



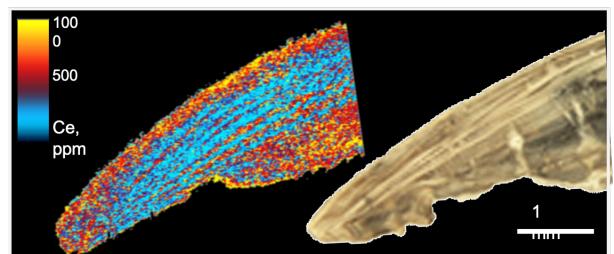
ionic radii of Ca and REEs is similar, and as the result REEs are concentrated in apatite

sedimentary phosphates are considered as REE ores

Soesoo & Kirsimäe, 2020: Estonian Paleozoic shelly phosphorites...; EGU 2020

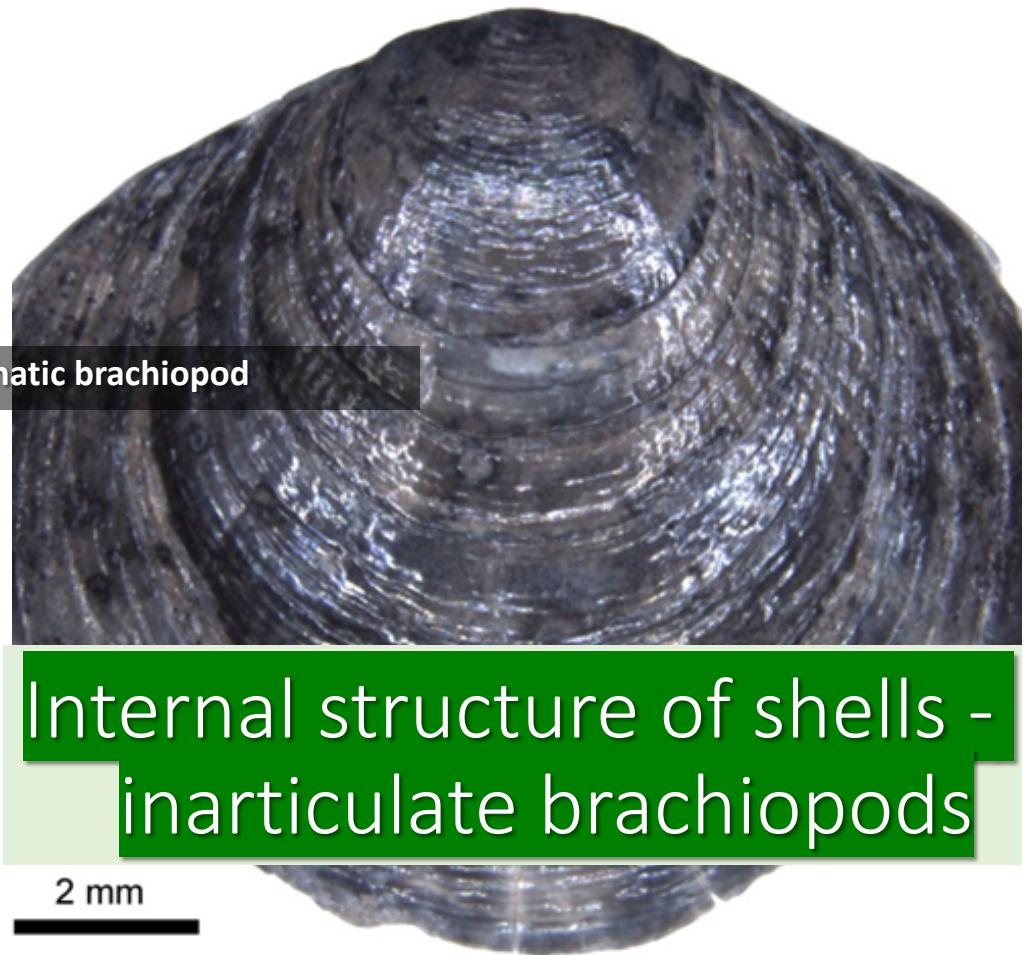


apatite crystal aggregates in phosphatic brachiopod

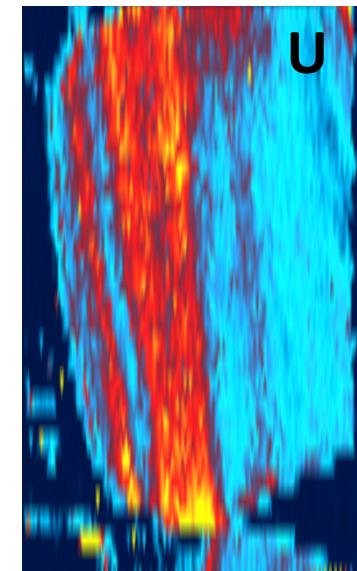
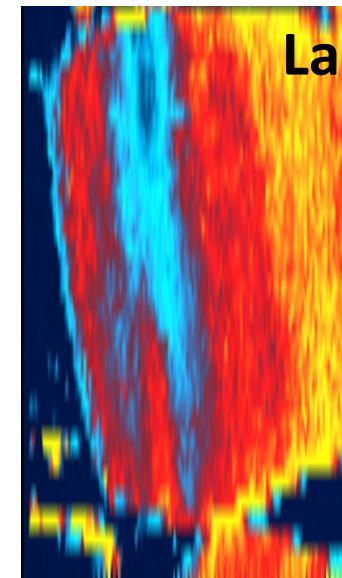
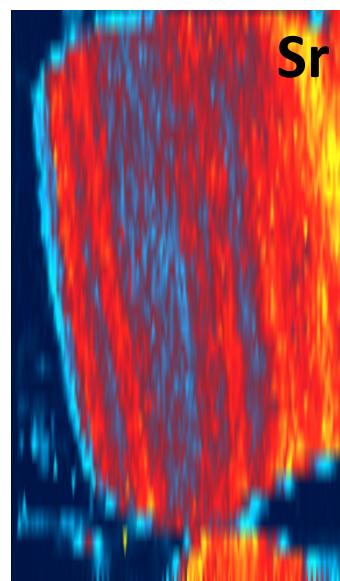
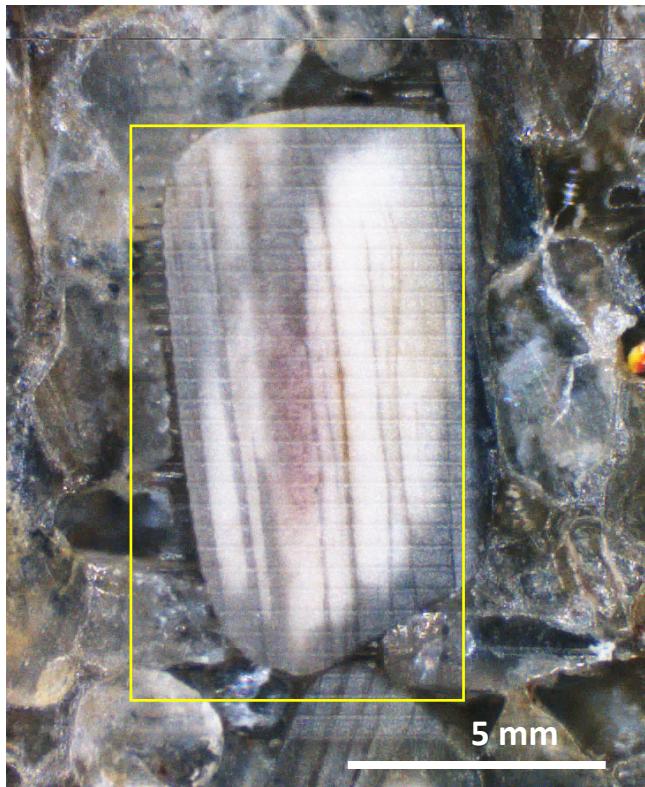
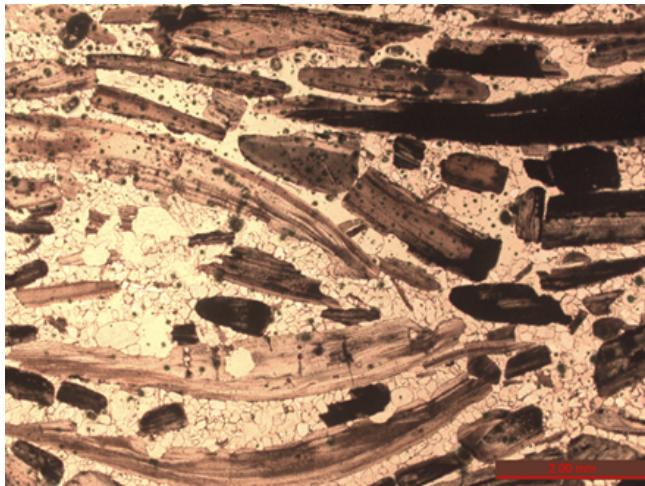


Internal structure of shells -
inarticulate brachiopods

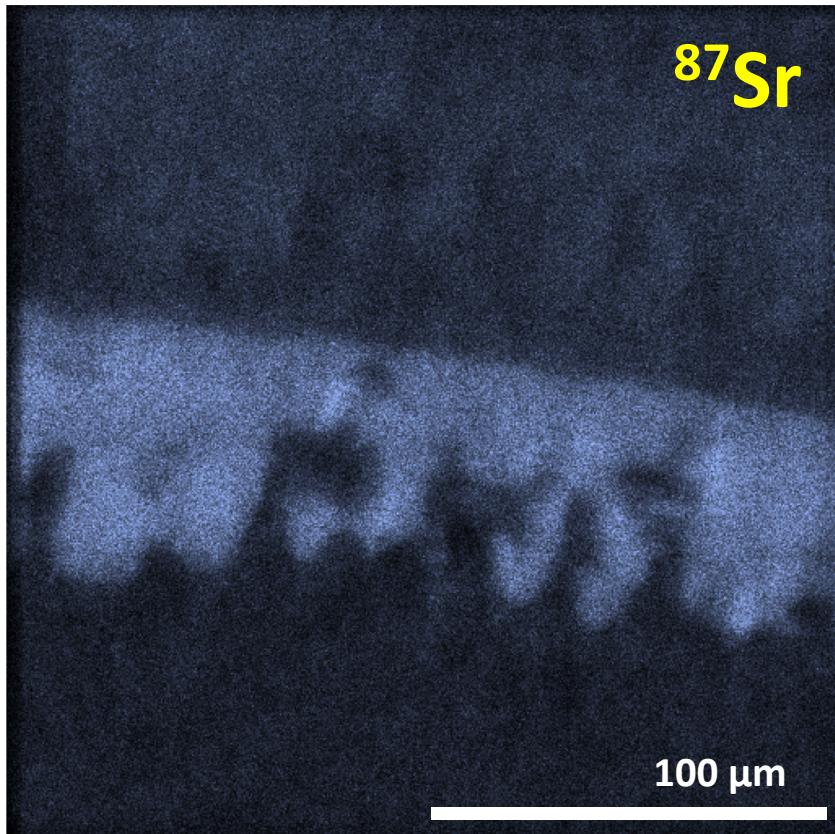
2 mm



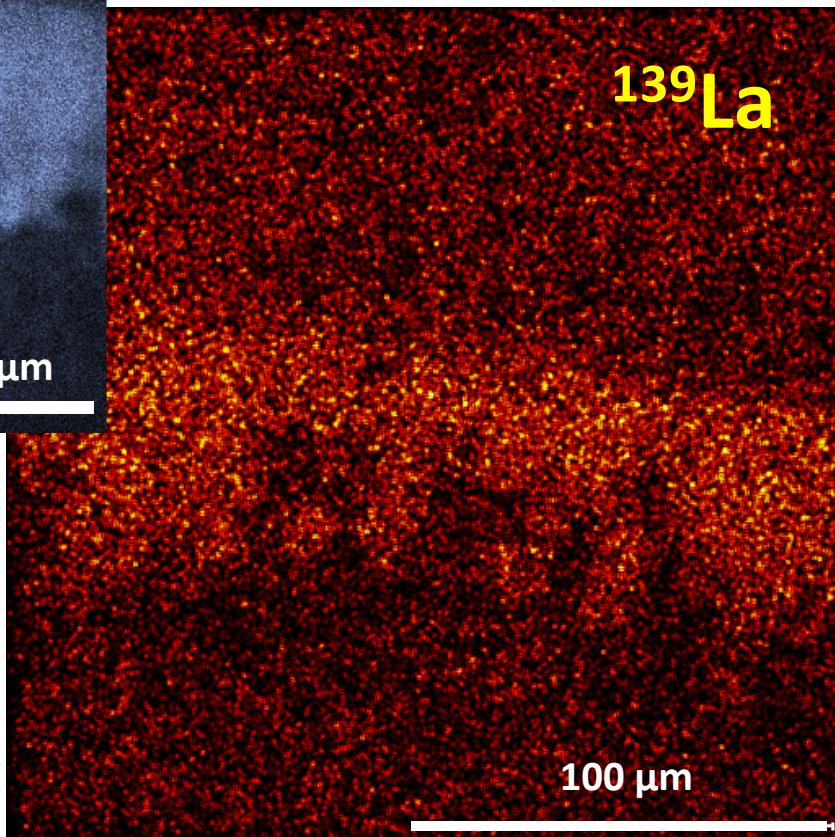
Element distribution within shells



Distribution of Trace and REE elements?

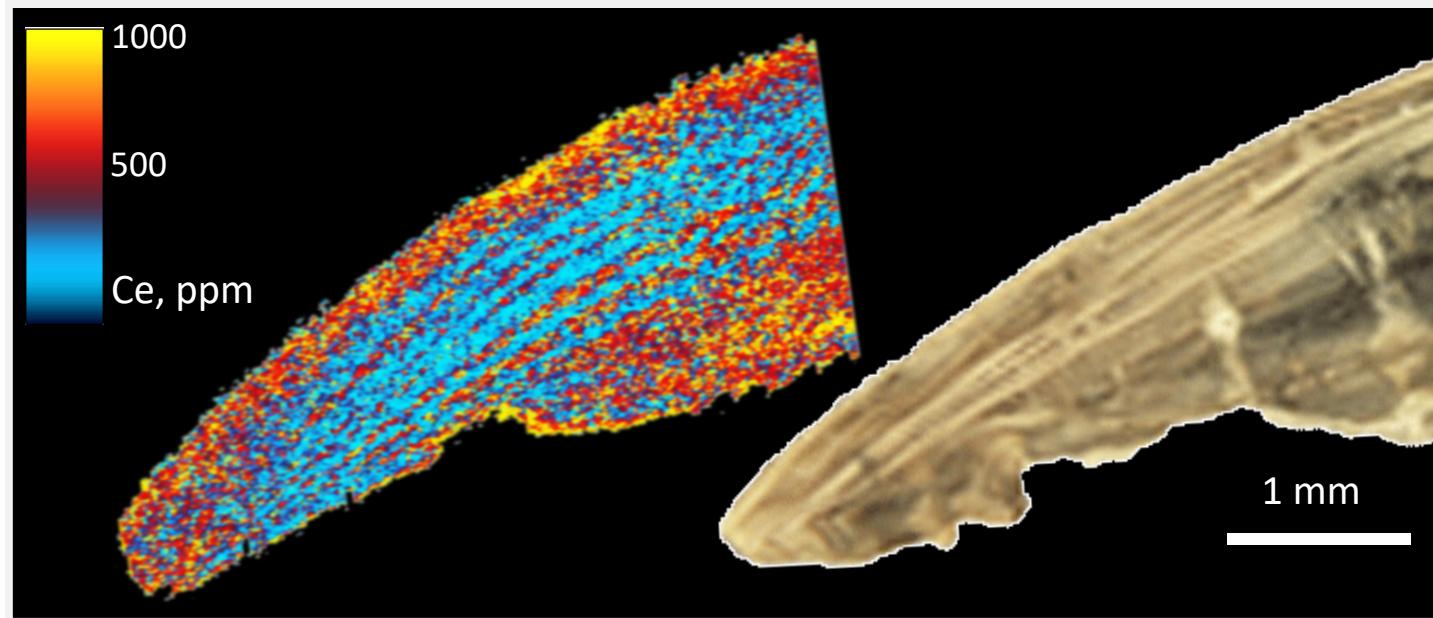


TOF-SIMS
elemental mapping of
shell structures



Soesoo & Kirsimäe, 2020: Estonian Paleozoic
shelly phosphorites...; EGU 2020

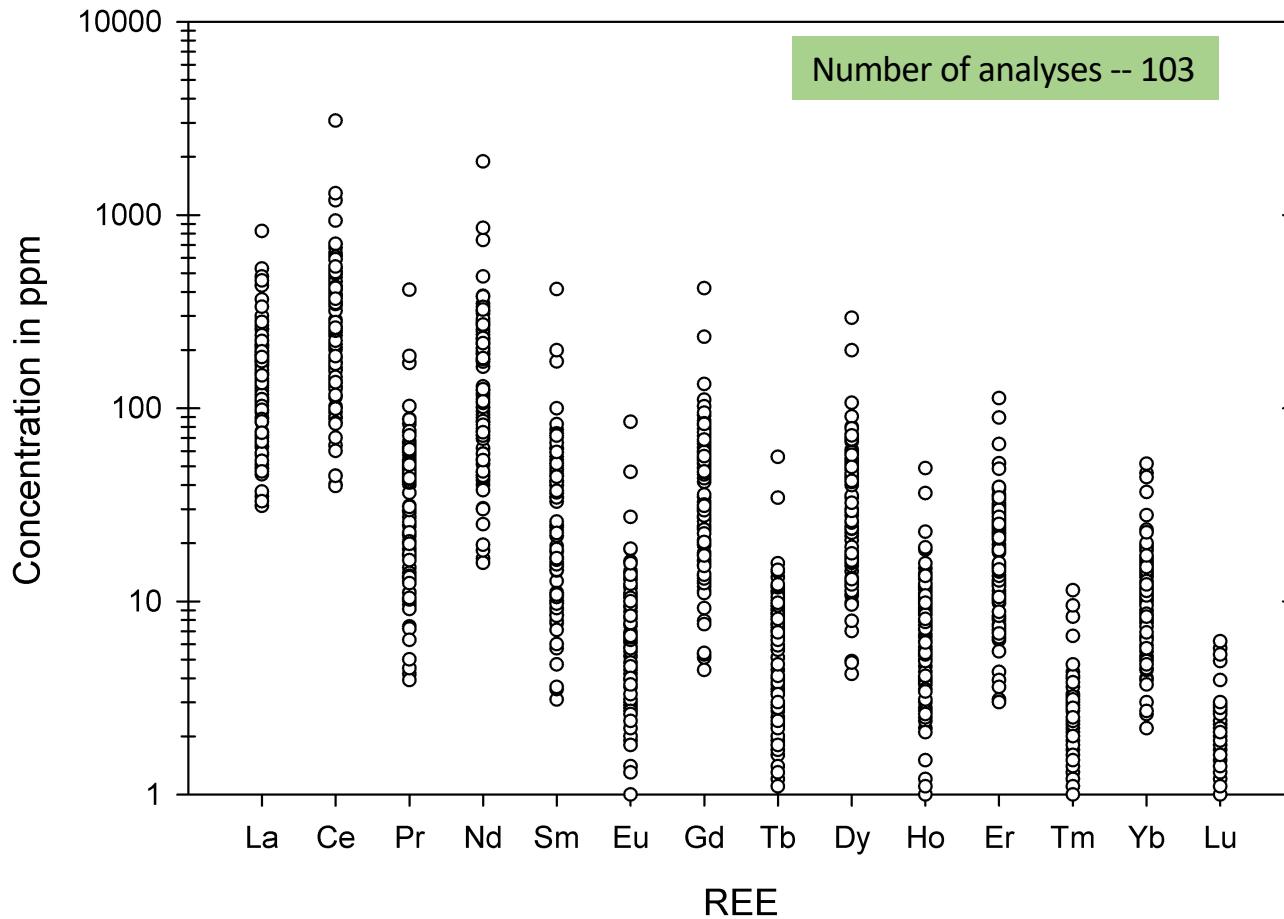
Ce distribution in shells



REE distributions “copy” an internal structure of the shell

• REE elements in shelly apatite?

REE concentration in single shell



Why Estonian phophorite is in good quality?

Weak cementation



Simple enrichment and processing technology

Low content of heavy metals - Cd <0.5 ppm (in shells)

3-165 ppm in Moroccan phosphate rock (>300 ppm in apatite phase)

Low to moderate content of U <<70 ppm (in shells)

100-300 (600) ppm in Moroccan phosphate deposits

Mar & Okazaki, 2012

The calculation!

- Take annual mining (raw) – 5 Mt
- P @ 12%  600 000 t P₂O₅
- _{tot}REE – 1200 ppm  720 t
- _{tot}REE – 1500 ppm  900 t
- REE recovery – 50% **360-450 t total REEs**



Conclusions

- Estonian phosphorite reserves – the biggest in EU?
- Open pit and underground mining possible
- REEs – as a co-product of phosphorites; the size is meaningful
- Historical knowledge on technologies, REE plant in Estonia
- Technologically easy & good infrastructure (railway, seaports)
- Willingness to be developed
- Knowledge-based society



THANK YOU FOR YOUR ATTENTION!

REE & P

REE & P

Quartz sand