Hestia Hotel Europa – 7–8 October 2024

Day 1: Monday 7th October 2024

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Time		**Title**	**Speaker**	**Organization**
10.00 - 10.30		***Registration and coffee***		
		Opening session		
		Chairs: Kathryn Goodenough (British Geological Survey) / Juha Kaija (Geological Survey of Finland)		
10.30 - 10.45	15 min	Welcome to Estonia and CRMs	Sirli Sipp Kulli	Geological Survey of Estonia
10.45 - 11.15	30 min	**KEYNOTE:** CRM importance in EU, New CRM Act	Madalina Ivanica	European Commission
		SESSION 1: CRM in Scandinavia and implications for the Baltic States (Part 1)		
		Chairs: Kathryn Goodenough (British Geological Survey) / Juha Kaija (Geological Survey of Finland)		
11.20 - 12.00	40 min	**KEYNOTE:**The Nordic part of Fennoscandia – a potential treasure trove for European critical raw material needs	Erik Jonsson	Geological Survey of Sweden
12.00 - 12.20	20 min	Re-investigation of historical drill cores - Indications for CRMs in Estonian crystalline basement	Siim Nirgi	Geological Survey of Estonia
		12.20 - 13.20 LUNCH BREAK		
		SESSION 1: CRM in Scandinavia and implications for the Baltic States (Part 2)		
		Chairs: Tapio Halkoaho (Geolological Survey of Finland) / Jakob Keiding (Geological Survey of Denmark and Greenland)		
13.20 - 13.40	20 min	GTK's scientific projects supporting CRM exploration in Finland	Tero Niiranen	Geological Survey of Finland
13.40 - 14.00	20 min	Review of the critical raw material resource potential in Greenland	Jakob Keiding	Geological Survey of Denmark and Greenland
14.00 - 14.20	20 min	Lithium pegmatites: from Africa to Europe	Kathryn Goodenough	British Geological Survey
14.20 - 14.40	20 min	The GREENPEG project toolset to explore for buried pegmatites hosting lithium, high purity quartz, and other critical raw materials	Axel Muller	University of Oslo
14.40 - 15.00	20 min	Exploration Carbonatite - TBA	Holly Elliot	British Geological Survey
		15:00 - 16:00 POSTER SESSION and COFFEE BREAK		
		SESSION 2: CRM in sedimentary basins		
		Chairs: *Lauri Joosu (Geological Survey of Estonian) / Kathryn (British Geological Survey)?*		
16.00 - 16.40	40 min	**KEYNOTE:** Sedimentary phosphorites	Lauri Joosu	Geological Survey of Estonia
16.40 - 17.00	20 min	Metal-Rich Iron-Manganese Oxyhydroxide Concretions	Martin Liira	Geological Survey of Estonia
17.00 - 17.20	20 min	Comparative Study of Phosphorite Deposits in the Tethyan Phosphogenic Province: Active Exploitation in Türkiye and Abandonment in Albania	Ana Fociro	Polytechnic University of Tirana
17.20 - 17.40	20 min	Perspectives of phosphorites deposits as REE resources	Sophie Graul	Tallinn University of Technology
17.40 - 17.45	***5 min***	***Announcements about dinner and next day***	***Kairi Põldsaar***	
		18.00 - 21.00 CONFERENCE DINNER @HESTIA HOTEL EUROPA		

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Poster Session – Monday 7th October 2024 15:00 – 16:00

POSTER SESSION - Presenters and Titles				
Number	**Related Session**	**Poster title**	**Presenter**	**Organization**
1	S2	Geochemical Processes in Estonian Graptolite Argillite: Insights into Vanadium Concentration Mechanisms	Mawo Ndiaye	Tallinn University of Technology
2	S2	Geochemistry, provenance, and tectonic setting of Paleoproterozoic metavolcanic and metasedimentary units of the alutaguse zone, Estonia, a comparative study with the	Juan David Solano Acosta	Tallinn University of Technology
3	S3	Copernicus data to boost raw materials source management: Illustrations from the RawMatCop Alliance Project	Sara Kasmaee	University of Bologna
4	S3	Let the exploration begin: helicopter-borne remote sensing a new addition to geological mapping studies	Sara Salehi	Geological Survey of Denmark and Greenland
5	S3	Harnessing Advanced Technologies for Sustainable Mineral Exploration: The AGEMERA Project	Tony Hand	Tallinn University of Technology
6	S3	Regional-scale exploration targeting of northern Finland for ultramafic-mafic intrusion hosted critical metals and its global	Malcolm Aranha	University of Oulu
7	S4	Analyzing the supply chains of critical raw materials in lithium-ion batteries: A focus on cobalt and lithium	Juan Tan	Geological Survey of Denmark and Greenland
8	S4	Recovery of Critical Elements from Estonian Phosphate Rock Using Hydrochloric Acid.	Ruhany Sheherazad Azeez	Tallinn University of Technology
9	S4	Effect of calcination on the leachability of metallic elements from Estonian graptolite-argillite in sulfuric acid	Eliise-Koidula Kivimäe	Tallinn University of Technology
10	S4	Developing non-toxic collector chemicals for the flotation of Cu and P minerals	Samuel Hartikainen	University of Oulu
11	S4	Developing continuously compressing crushing of critical minerals	Niina Paasovaara	South-Eastern Finland University of Applied Sciences
12	S4	Wet Process for Phosphorus Fertilizers and Rare Earth Elements from Estonian Phosphate Rock	Andres Trikkel	Tallinn University of Technology
13	S5	EGT-TWINN: Enhancing Research Capacity at the Geological Survey of Estonia to Accelerate the Country's Transition to Green Energy	Kairi Poldsaar	University of Tartu

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Hestia Hotel Europa – 7–8 October 2024

Day 2: Tuesday 8th October 2024

Day 2: Tuesday 8. October				
Time		**Title**	**Speaker**	**Comments**
8.30 - 9.00		***Gathering and Coffee***		
SESSION 3: New Exploration Techniques for CRM				
Chairs: *Jakob Keiding (Geological Survey of Denmark and Greenland) / Pertti Sarala (University of Oulu)*				
09.00 - 9.40	40 min	**KEYNOTE:** Utilizing Machine Learning for Mineral Prospectivity Mapping and Target Generation of Critical Raw Materials	Vesä Nykänen	Geological Survey of Finland
9.40 - 10.00	20 min	Environmentally friendly surficial geochemical exploration techniques	Pertti Sarala	University of Oulu
10.00 - 10.20	20 min	MINEYE - Earth observation techniques for mine life cycle monitoring	Saman Tavakoli	Norwegian Geotechnical Institute
10.20 - 10.40	20 min	An innovative method to image inner structure of orthomagmatic ore deposits using regional seismicity: a case study of Akanvaara Cr-V-PGE deposit in Northern Finland.	Nikita Afonin	University of Oulu
10.40 - 11.00 COFFEE BREAK				
SESSION 4: CRM Processing and Valorization				
Chairs: *Saija Luukkanen (University of Oulu)* ***/*** *Jakob Keiding (Geological Survey of Denmark and Greenland)*				
11.00 - 11.40	40 min	**KEYNOTE:** Value chain perspective in CRM extraction	Saija Luukkanen	University of Oulu
11.40 - 12.00	20 min	Developing a value chain for high strength magnets based on rare earth minerals from Europe	Arne Ratvik	SINTEF
12.00 - 12.20	20 min	Pioneering Sustainable CRM Recovery in European Mining	Fotios Konstantinidis	National Technical University of Athens
12.20 - 12.40	20 min	Sustainable mining practices: Innovative technologies on tailings management	Priyadharshini Priumal (INVITED)	University of Oulu
12.40 - 13.00	20 min	Circular solutions for mine tailings	Päivi Kinnunen (ONLINE)	Technical Research Centre of Finland
13.00 - 14.00 LUNCH BREAK				
SESSION 5: Environmental, Social, and Governance aspects of CRM				
Chairs: *Juha Kaija (Geological Survey of Finland) / Tapio Halkoaho (Geological Survey of Finland)*				
14.00 - 14.40	40 min	**Keynote 7:** The evolution and impacts of the Finnish mining-sceptical movement from the uranium debate to the green energy transition: an environmental protest wave?	Toni Eerola	Geological Survey of Finland
14.40 - 15.00	20 min	Assessing Water-Use Impacts of Critical Raw Materials Production with Life Cycle Assessment Techniques	Rowan Halkes	British Geological Survey
15.00 - 15.20	20 min	Sustainable management of abandoned mines: The REMINDNET initiative funded by COST	Ledi Moisiu	EIT Raw Materials Regional Innovation Center of Albania
15.20 - 16.00	20 min	Assessing ESG challenges for cobalt supply from new mining projects in Europe.	Stefan Horn	British Geological Survey
16.00 - 16.20	20 min	China's REE Monopoly Renders Global Exploration Efforts Futile. Lessons learned?	Per Kalvig	Geological Survey of Denmark and Greenland
16.20 - 16.30 CLOSING REMARKS + INSTRUCTION FOR EXCURSION (KATHRYN/HEIKKI)				

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Conference „Exploration and exploitation of critical raw materials“

Visit to the Geological Survey of Estonia Arbavere Research Centre
Only for participants who signed up during the registration

October 9th, 2024

TIME	AGENDA	
09.00	*Bus leaving from the Hestia Europe hotel to EGT Arbavere Research Centre*	
10.15 – 10.45	*Arrival and welcome coffee*	
10.45 – 11.15	Overview of the Arbavere Research Centre	**Jaak Jürgenson**
11.15 – 12.00	Introduction to drill cores in two groups: - CRMs in Estonian phosphorite - CRM indications in Estonian crystalline basement rocks	**Lauri Joosu** **Siim Nirgi**
12.00 – 13.00	*Buffee lunch*	
13.00 – 13.45	Introduction to drill cores in two groups: - CRM indications in Estonian crystalline basement rocks - CRMs in Estonian phosphorite	**Siim Nirgi** **Lauri Joosu**
13.45 – 15.00	*Return to Tallinn*	

Brief overview of the EGT Arbavere Research Centre: EGT Arbavere Research Centre

Photo: L. Maala

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Abstracts

Session 1: Critical Raw Materials in Scandinavia and implications for the Baltic States – Monday 7th October 2024 (11.20 – 15.00)

11.20 – 12.00 Keynote: *The Nordic part of Fennoscandia – a potential treasure trove for European critical raw material needs*

Erik Jonsson (Geological Survey of Sweden)

The Nordic countries, not least if one includes Greenland, represent one of the most relevant regions of Europe (sensu lato) today with regards to mineral exploration. Specifically, and more strictly European, the Nordic part of the Fennoscandian Shield, or Fennoscandia, is both one of the most important current mining regions in Europe and comprise promising targets for near-future, intra-EU production of critical raw materials (CRM) featuring a multitude of known mineralisation types and extensive remaining exploration potential (e.g., Jonsson et al. 2023). This is certainly not least due to the diverse geology of the shield and its younger cover units, representing >2500 Ma of geological evolution, with associated variable processes of ore formation over time and vastly contrasting P-T-X-conditions. While mining has traditionally been focused on base and ferrous metals together with noble metals, increasing efforts are focused on the development of exploration and production of critical metals and minerals such as cobalt, graphite, fluorspar, lithium, phosphorus, platinum-group metals (PGM), high-purity quartz for silicon metal production, rare earth elements (REE) and vanadium, among others. Indeed, some CRM deposits have already been in production for a significant time and include cobalt, phosphorus and PGM production from Finland and graphite and titanium production from Norway. Of these, several of these commodities represent the majority or all of current European mine production. Large question-marks, however, concern the so-called by-product metals (e.g., Bi, Co, Ga, Ge, Sb…), for which relatively little is known of their overall distribution in different types of deposits in Fennoscandia. This also goes for rare and exotic metals such as scandium, with notable exceptions. Highlighting the nearest-future CRM potential of Sweden, significant projects encompass, e.g., graphite, fluorspar, lithium, phosphorus and the REE. The present Swedish NI-43-101-classified REE projects at Norra Kärr and Olserum (both in southern Sweden) together with potential by-product REE and phosphorus from apatite-iron oxide ores (Kiruna-type deposits) stand out significantly in a context of Europe proper. With regards to, a.o., the recently CRM-classified semi-metal arsenic, Sweden hosts significant deposits. As in the rest of Fennoscandia, the exploration potential for CRMs is extensive, while secondary accumulations associated with previous mining and extraction may be relevant, particularly if processed in conjunction with primary mining.

Reference: Jonsson, E., Törmänen, T., Keiding, J. K., Bjerkgård, T., Eilu, P., Pokki, J., Gautneb, H., Reginiussen, H., Rosa, D., Sadeghi, M., Sandstad, J. S. & Stendal, H. 2023: Critical metals and minerals in the Nordic countries of Europe: diversity of mineralisation and green energy potential. Geological Society of London, Special Publication 526, 95-152.

12:00 – 12.20 *Re-investigation of historical drill cores - Indications for CRMs in Estonian crystalline basement*

Siim Nirgi (Geological Survey of Estonia)

Over the past century, more than 500 boreholes have been drilled to explore the crystalline basement of Estonia, with core samples preserved at the Arbavere research center. As technology has advanced and the list of critical raw materials has expanded, reassessing these cores has become increasingly important. This project utilized a modern automated scanning technique with the Geotek MSCL-XYZ station to detect critical raw materials and associated elements in selected drill cores from the Estonian Geological Survey's archive. The study focused on 22 promising cores, selected based on historical geochemical analysis involving over 25,540 samples from 41 different rock types, to collect comprehensive geochemical, mineralogical, and petrophysical data. The analysis identified element associations linked to critical raw materials, including Ni-Co-Cr, Mo-W-Bi, Sn-Zn-Cd, Cu-Ni, Nb-Y-P, K-Sn-Rb-Ga, and Au-Ag-As-Sb-Bi-W-Se-Sn, and revealed significant heterogeneity in the drill cores, uncovering previously unrecognized geochemical variations within rock units and their contact zones. These element associations suggest the potential presence of critical raw materials in Estonia's crystalline basement, offering new opportunities for resource exploration. The main goal of this project was to identify specific depth intervals with mineral potential that should be studied in more detail to verify the observed anomalies and understand possible mineralization processes. These steps will help focus future exploration efforts and enhance our understanding of where critical raw materials might be located in Estonia.

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13.20 – 13.40 *GTK's scientific projects supporting CRM exploration in Finland*
Tero Niiranen (Geological Survey of Finland)

Finland has proven potential for several critical (CRM) and strategic raw materials (SRM) listed by the EU. The EU's Critical Raw Materials Act requires the development of a national exploration program aimed at increasing the production of primary CRMs within the EU to 10% by 2030. A key strategic goal for GTK during the current strategy period is to significantly enhance the discovery potential of SRMs in Finland. This is done increasing effort in SRM related mineral potential mapping and research in GTK. The mineral potential mapping is done applying mineral systems approach, where critical components of relevant mineral systems are identified and mapped in 2D and 3D space. This process involves geophysical and geochemical surveys, geological fieldwork and novel data integration and interpretation work. The mappable mineral system components are subsequently used generation of predictive maps through GIS-based prospectivity modeling. In parallel, the goal is to develop new methods for each stage of the process, including the use of innovative geochemical and geophysical techniques, 3D modeling workflows, and prospectivity modeling tools. This approach aligns closely with the EU's requirements for a national exploration program and is being applied in GTK's ongoing and upcoming scientific projects related to CRM exploration in Finland.

Key ongoing and upcoming CRM-related projects at GTK include the EU Horizon-funded Exploration Information Systems (EIS) project, the EU Recovery and Resilience Plan for Finland-funded Repower-CEST project, and the EU Horizon-funded UNDERCOVER project. The EIS project (2022-2025) is a Pan-European initiative involving 17 partners across the EU, with additional partners from South Africa and Brazil. Its key objectives include developing mineral systems models for CRM-bearing Iron oxide-Cu-Au, Co-bearing VMS, and Li-bearing LCT pegmatite systems, as well as creating spatial data analysis tools for mineral exploration. The Repower-CEST project (2024-2027) is a national collaboration involving SYKE, GTK, and VTT. One of its primary goals is to test the national mineral exploration concept by assessing the Co and Cu potential of the Peräpohja Schist Belt (PSB). This will be done through geophysical surveys, 3D geomodeling of critical components in the PSB epigenetic Au-Co ± Fe-Cu-REE mineral system, deposit-scale fingerprinting, and predictive mapping. The UNDERCOVER project (2025-2028) includes 16 partners and aims to integrate lithospheric to deposit-scale geophysical surveys with geological, geochemical, and geochronological data. The goal is to create 4D mineral systems models from test sites in Finland, Portugal, and Namibia. In Finland, the project focuses on the Kuusamo Schist Belt, targeting polymetallic Co-Cu-Au-REE mineral systems known in the area.

13.40 – 14.00 *Review of the critical raw material resource potential in Greenland*
Jakob Keiding (Geological Survey of Denmark and Greenland)

Europe heavily relies on imported critical raw materials (CRMs) for its industry, especially those essential for emerging green energy technologies. The soaring demand for these specific metals and minerals has prompted Europe to reassess its sourcing strategies. In this context the Geological Survey of Denmark and Greenland (GEUS) has reviewed the CRM resource potential of Greenland. This assessment has highlighted the Gardar alkaline province in South Greenland as an exceptional accumulation of CRMs. This is documented by the known rare earth element deposits, some also hosting very significant lithium, fluorite, tantalum, niobium, hafnium and/or zirconium resources, namely the very large deposits at Kvanefjeld/Kuannersuit, Kringlerne/Killavaat Alannguat and Motzfeldt. East Greenland stands out by hosting the very large Malmbjerg molybdenum deposit and the large platinum group metals, titanium and vanadium Skaergaard deposit, both related to Palaeogene intrusions, as well as the very large evaporitic Karstryggen strontium deposit. Additionally, and due to its relatively underexplored status, East Greenland can be considered to still hold a significant potential for yet undiscovered deposits of these commodities. Furthermore, this area also holds a significant potential for granite-related tungsten, tin, and antimony, as well as sedimentary copper mineralisation. The West Greenland Palaeogene Province is thought to hold a significant potential for conduit-type Ni-Cu-Co-PGM mineralisation. The Palaeoproterozoic terranes in West, South and East Greenland, have a potential for hosting undiscovered deposits of graphite, exemplified by the large Amitsoq deposit in South Greenland. The Thule black sands province, in North-West Greenland, holds a significant titanium endowment, illustrated by the Moriusaq deposit. Finally, the Palaeozoic Franklinian Basin of North Greenland has a very significant potential for zinc and lead deposits, from which gallium and germanium can be possible by-products. The quantified resources are significant for many CRMs in Greenland, often even in a global context. However, it is important to recognize that most of the resource estimates for individual deposits are based on historical, non-compliant assessments. As a result, the estimated CRM tonnages come with considerable uncertainties and require further validation through resource evaluations that meet modern standards. Overall, we conclude that the exploration potential for most CRMs is significant in Greenland.

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14.00 – 14.20 *Lithium pegmatites: from Africa to Europe*
Kathryn Goodenough (British Geological Survey)

Lithium is a key critical raw material for the energy transition, required for batteries in electric vehicles and energy storage. Globally, lithium comes from two deposit types: brines, chiefly extracted from the salars of South America; and hard-rock deposits (granites and pegmatites) which occur worldwide. Growing demand for lithium in recent years has driven significant growth in both exploration and production. However, exploration models for hard-rock lithium deposits remain under-developed. The 'classic' model for generation of lithium pegmatites involves the most evolved melts from a parental granite pluton being ejected to form pegmatites. However, more recent models have drawn on the concept of vertically extensive trans-crustal magmatic systems in collisional belts, where thickened crust undergoes partial melting and small batches of melt develop from varying sources. These melts can become increasingly evolved as they move upwards through the crust, typically following major structural pathways. In this model, the development of lithium-mineralised granites and pegmatites depends on enrichment of lithium in the original source that melted, as well as the melting and subsequent evolutionary processes. Making the link between source and pegmatite can be very difficult, because the pegmatite may be emplaced into the crust several kilometres above the melting zone. However, our work across the African continent has shown that different collisional belts may have slightly different pegmatite 'fingerprints', depending on the types of sources that were available to melt. In general, two features that are common to the main lithium pegmatite fields are the availability of a suitable metasedimentary source for melting, and also a major structure such as a shear zone that represents a pathway for melts to ascend into the crust. In Northern Europe, the major known economic lithium pegmatites occur in the Svecofennian belt of Finland and Sweden. Where rocks of this age form the basement to the Baltic countries, it is very likely that lithium pegmatites may also occur, and a mineral systems approach can be applied to identify prospective areas.

14.20 – 14.40 *The GREENPEG project toolset to explore for buried pegmatites hosting lithium, high purity quartz, and other critical raw materials*
Axel Muller (Natural History Museum, University of Oslo)

The GREENPEG toolset is the first to set out a comprehensive guide to exploration for all types of granitic pegmatites, including especially cases where they are buried. Its importance lies in the urgent need to identify new deposits of green energy transition and high-tech commodities such as Li for electric vehicle batteries and high purity quartz for the Si metal needed to produce photovoltaics. The toolset is based on four years' (2020-2024), EU-funded work by the GREENPEG consortium, which has been drawn from 13 academic, industry and government organizations across Europe. The result is an integrated, multi-method exploration toolset ranging from remote sensing, geological, and numerous geophysical and geochemical techniques equipping small and medium scale companies getting started or progressing in their activities for pegmatite exploration. Besides tailored conventional and newly developed exploration methods, the toolset comprises novel workflows and data processing approaches, three new geophysical exploration systems and two specialized databases, all designed and optimized from knowledge, experience and innovations developed during the GREENPEG project. The application of the toolset aims to maximize the success of subsequent and generally more costly techniques such as drilling. Apart from the technical methods of mineral exploration, GREENPEG has also integrated ESG practices and considerations into this toolset. The accurate application of the toolset will minimize social and environment impacts of the applied exploration activities employing today's ESG standards.

14.40 – 15.00 *Fertility indicators for carbonatite-hosted rare earth element deposits*
Holly Elliot (British Geological Survey)

Carbonatite and alkaline-silicate rocks are the most important source of global rare earth element (REE) supply. Their unique properties make REE key constituents in many portable, medical, and defence technologies [1]. The demand for permanent magnets to be used in carbon reducing technologies, such as electric cars and wind turbines, is also increasing dramatically [2]. Therefore, pressure is mounting to develop new global supply chains outside of Chinese dominance to meet growing REE requirements. Geophysical exploration methods and best practices are well-established for carbonatites and alkaline-silicate rocks and databases of global localities exist [3]. However, finding a carbonatite does not equate to discovering a REE deposit and exploration drilling is expensive. Therefore, there is a need to develop REE fertility indicators that can determine the potential for REE mineralisation early in project development. The same geological processes that enrich REE in carbonatite and alkaline-silicate rocks also enrich iron and radioactive elements. Multiple stages of magmatism within a complex with iron-rich carbonatites can indicate a more evolved system with greater potential for REE-enrichment. A strong positive correlation between REE enrichment and radioactive element concentration [4] means that positive Th anomalies on radiometric surveys can be used as a

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proxy for REE deposits. Cooling carbonatite magmas release alkali-rich fluids which metasomatise the surrounding country rock during a process called fenitisation [5]. These fenite alteration aureoles consist of an inner potassic zone and outer sodic zone which can extend >1km from the source intrusion. Fenite can be used as a vectoring exploration tool in a similar manner to porphyry copper alteration. Anions in fenitising fluids complex with REE, enhancing their solubility and mobilising them into the surrounding fenite. REE micro-mineral assemblages precipitated in the fenite can therefore indicate a REE-enriched source intrusion, whilst the zoning of fenite apatite crystals observed under cold cathodoluminescence record the evolution of carbonatite systems and can indicate the potential for REE mineralisation. Fenite alteration patterns therefore have great potential to be used as exploration tools, in addition to indicators of fertility and the potential for REE mineralisation.

Session 2: Critical Raw Materials in Sedimentary basins – Monday 7th October 2024 (16:00 – 17.40)

16:00 – 16:40 Keynote: *Sedimentary phosphorites*
Lauri Joosu (Geological Survey of Estonia)

Phosphorus (P) is primarily used in the production of fertilizers, with significant implications for global food security. The European Union recognizes P as a critical raw material due to its irreplaceable role in agriculture as well as emerging technologies. In addition to fertilizers, phosphorus has numerous additional uses, such as phosphoric acid in the food industry or lithium iron phosphate batteries, but on a global scale, these volumes are low. Currently, there is only one phosphate mine in Europe (Siilinjärvi in Finland), which covers about 15-20% of EU P demand. Phosphorus compounds are imported mainly from Morocco. Phosphorus ores are predominantly found in sedimentary rocks formed commonly through upwelling processes that deliver phosphorus-rich waters to shallow marine environments. On continental shelves influenced by upwelling, redox boundary fluctuations in the upper few cm of the sediment result in high P concentrations in pore water, leading to the precipitation of phosphate-mineral apatite. Apatite is prone to chemical substitutions in the crystal lattice. This allows Rare Earth Element (REE) enrichment in apatite during diagenetic processes. REEs are widely used in electronics and have a crucial role in the EU economy. REEs are listed as critical raw materials similar to phosphorus. With its substantial phosphorite deposits, Estonia has the potential to play a significant role in the EU's phosphorus security. The origin of Estonian phosphate deposits is unique. The main P-carriers are shells of ancient animals – brachiopods that were deposited in near-shore to beach environments and later concentrated by winnowing. Estonian P deposits have been known for decades and heavily explored from the 1950s to the late 1980s, followed by a ca 30 years of standstill. The Geological Survey of Estonia is taking a fresh look at these deposits and conducting a research and exploration project to better understand the economic potential and environmental implications of utilizing these deposits.

16:40 – 17:00 *Metal-Rich Iron-Manganese Oxyhydroxide Concretions*
Martin Liira (Geological Survey of Estonia)

This study examines the distribution and geological implications of iron-manganese (Fe-Mn) oxyhydroxide precipitates on the seafloor of the Gulf of Finland, emphasizing the critical raw material aspects. Found in areas without modern sediment deposition, these formations reveal exposures of late glacial clays, glacial tills, or bedrock. Pockmarks, up to 3 meters deep and 30-60 meters wide, coexist with Fe-Mn concretions, indicating active fluid seepage from underlying strata. Globally distributed Fe-Mn concretions, primarily composed of iron and manganese compounds, form through redox-driven processes in seabed environments, accelerated by microbial activity. This study identifies two types of Fe-Mn concretions in the Gulf of Finland—concentric and crust-like—each with varied compositions, suggesting diverse formation mechanisms. Notably, these concretions contain elevated concentrations of different metals, highlighting their potential industrial applications. They also provide insights into sedimentary processes and environmental changes over time. However, the genetic types of Fe-Mn concretions in Estonian sea areas remain unclear, necessitating further research. Recent international expeditions to the central Gulf of Finland aimed to understand the relationships between fluid seepage, Fe-Mn concretions, and seafloor features. These efforts collected materials focusing on groundwater discharge, mineral precipitation, and microbial processes. Preliminary results offer insights into the geological processes influencing seafloor features. In conclusion, this study enhances our understanding of Fe-Mn precipitates' distribution and genetic characteristics in the Gulf of Finland. The findings underscore the importance of further research to clarify the genetic types of Fe-Mn concretions and the dynamic interactions between fluid seepage, mineral precipitation, and microbial processes on the seafloor."

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17.00 – 17.20 *Comparative Study of Phosphorite Deposits in the Tethyan Phosphogenic Province: Active Exploitation in Türkiye and Abandonment in Albania*
Ana Fociro (Polytechnic University of Tirana)

The Tethyan Phosphogenic Province, marks a significant period of phosphate deposition during the Upper Cretaceous-Eocene era. This study aims to compare the phosphorite deposits from two contrasting regions along the Neo-Tethyan Ocean: the Şemikan deposits in Türkiye, which are actively exploited, and the Gusmari deposits in Albania, now representing an abandoned mine. The investigation focuses on their depositional environments, mineralogical compositions, and geochemical characteristics, with an emphasis on the economic implications based on their CRM status. In Türkiye, the Şemikan phosphorites are primarily cream-coloured (CCP) with occasional reddish phosphorites (RP), forming lenses or concordant blankets within high-grade deposits. Microscopic analysis reveals CCP's composition of phosphatic pellets, intraclasts, bioclasts (including fossilized shark teeth and ostracods), and non-phosphatic components, indicative of a shallow marine environment with textures ranging from wackestone to packstone. Mineralogical examination shows CCP contains carbonate-rich fluorapatite, minor calcite, and quartz, while RP comprises carbonate-rich fluorapatite, hydroxyapatite, montmorillonite, and minor quartz. Geochemically, CCP has a mean P2O5 content of 29%, with both RP and LP at 14%, lower than other global deposits. High CaO content and trace element scarcity is noted, likely due to rapid sedimentation and high burial rates. The active exploitation of these phosphorites underscores their economic value despite their lower phosphate content. Conversely, the Albanian Gusmari phosphorites, deposited in higher latitudes and colder climates, exhibit laminated phosphorites (LP) with a mudstone/wackestone texture and planktonic foraminifera Globotruncanidae. These phosphorites feature alternating laminae of phosphate and pelagic carbonate. SEM-EDS analysis reveals 5µm crystals of uranium ore (UO2) in LP for the first time. Mineralogical analysis indicates LP primarily consists of calcite, carbonate-rich fluorapatite, hydroxyapatite, and trace quartz. Geochemically, LP shares the lower P2O5 content and high CaO levels seen in Turkish deposits, with similar trace element scarcity due to rapid sedimentation. Albanian phosphorites of Early Jurassic age present two distinct types of U-bearing deposits, with the younger stratigraphic layers showing significant gamma radiation and uranium content. Despite their geological significance, the abandonment of these mines reflects the economic challenges and potential hazards associated with uranium content and the region's mining infrastructure. This comparative study highlights the diverse depositional environments and geochemical profiles of phosphorites within the Tethyan Phosphogenic Province. It also underscores the impact of current exploitation practices in Türkiye versus the abandonment in Albania, providing insights into the geological processes and economic factors influencing the development and utilization of these significant phosphate deposits.

17.20 – 17.40 *Perspectives of phosphorites deposits as REE resources*
Sophie Graul (Tallinn University of Technology)

"Rare earth elements (REE) are among the EU's most critical raw materials (CRM), as they are widely used in high-tech industries and are especially needed for low-carbon energy components. The growing demand for green technology and the scarcity or availability of conventional resources have spurred interest in exploring unconventional deposits. Unconventional REE resources include a wide range of low-grade, high-tonnage mineral bodies. Sedimentary phosphorites are considered among the most prospective ore types for the EU regarding REE and P2O5 sourcing. However, these ores are highly diverse regarding ΣREE content, distribution, and nature of phosphatic materials. Assessing the economic potential of phosphate deposits and their characteristics and understanding the geological history of REE accumulations is thus essential for exploration and processing. Estonian shelly phosphorites are among Europe's most extensive phosphate rock reserves, with a tonnage of approximately three billion tonnes. The ore consists of sandstone rich in apatite-mineralised shell fragments deposited in a shallow marine environment during the Ordovician period, and multiple REE uptake stages in the porewater drove the ore enrichment during the diagenesis. Investigations are currently being carried out in the Rakvere region, focusing on the Toolse and Aseri deposits.The average shelly phosphorites model showed homogenous REE-distribution patterns, with an MREE enriched up to 15-fold compared to the average shale and positive Y and Ce anomalies indicative of a progressive digenetic overprint. The median apatite grade is 27%, with a ∑REE of ±700ppm; the most enriched sections are found in the lower part of the ore, where the apatite grade reaches 60% and the ∑REE ±1200ppm. In-situ textural survey further explored apatite variability. Shell showed chemical variation related to the diagenetic overprint extent. In Toolse, apatites demonstrated less recrystallisation and low REE-enriched zones. The calculated ∑REE was 1850±880ppm. In Aseri, apatites revealed intense recrystallisation and altered edges, indicative of a second diagenetic alteration-driven uptake. Average ∑REE was 2440±460ppm while edges presented a ΣREE up to 7020ppm. Based on these findings, apatite composition could be modelled. Despite differences in enrichment level, the two deposits' REE distributions are similar. The main REEs are Ce (33%), Y (21%), La (12%), Nd (16%) and Dy (3%). On average, U concentrations are 92ppm in Aseri and 31ppm in Toolse, and toxic elements are found in trace amounts. To determine ore prospectivity, the mineralisation prospectivity outlook coefficient (Koutl) was calculated. Based on this approach, both deposits fall in the range of 'promising for

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economic development' (33% ≤ REEdef ≤ 50; 0.9 ≤ Koutl ≤3.1). Therefore, the ratio of valuable REEs is relatively high, and Estonian phosphorites are potential REE sources with low toxic element contents and predictable contents."

Poster Session: Monday 7th October 15:00 – 16:00

Posters related to Session 2: Critical Raw Materials in Sedimentary Basins

(1) *Geochemical Processes in Estonian Graptolite Argillite: Insights into Vanadium Concentration Mechanisms* (Related to Session 2)

Mawo Ndiaye (Tallinn University of Technology)

"Estonian Tremadocian black shale, known under the local name ‘graptolite argillite’, is a rich but complex source of polymetallic resources such as vanadium, molybdenum, and uranium. These sedimentary rocks, formed under anoxic conditions, are notable for their high organic matter content and the presence of various trace metals, making them promising yet challenging targets for resource extraction. This study aims to unravel the processes driving metal enrichment in these shales and to identify the primary carriers of vanadium within their intricate matrix. Thus, the investigations of potential vanadium carriers in the different grain size fractions of the graptolite argillite revealed that the finest grain fractions, which include clays and organic matter, contain the highest concentrations of vanadium, reaching up to 5000 ppm. Additionally, textural analyses using transmission electron microscopy (TEM) and scanning electron microscopy (SEM) identified two distinct types of amorphous organic matter: Type I, forming clumped aggregates that contain vanadium, and Type II, appearing as flakes or filaments but showing no evidence of vanadium presence. The results confirmed that vanadium is predominantly associated with the fine-grained fractions of clay minerals and amorphous organic matter. These findings underscore the pivotal role that these fine-grained materials play in the retention and concentration of vanadium within black shales) [1]. This research enhances our understanding of the geochemical and sedimentary processes involved in forming Estonian black shales, providing crucial insights that could help develop future strategies for resource extraction from these unconventional and complex ore deposits.

References: [1] Ndiaye, M. et al. (2023) Chem Geol 624: 121583"

(2) *Geochemistry, provenance, and tectonic setting of Paleoproterozoic metavolcanic and metasedimentary units of the alutaguse zone, Estonia, a comparative study with the south Svecofennian zones*

Juan David Solano Acosta (Tallinn University of Technology)

The research delved into the geochemistry of Paleoproterozoic metasedimentary and metavolcanic units in North Estonian Alutaguse and South Svecofennian (SS) zones (i.e. Ladoga, Saimaa, Häme Belt, Uusimaa Belt zones), uncovering the Svecofennian Orogeny's tectonic evolution in Eastern Fennoscandia. Metasedimentary units comprise micaceous gneisses (± Grt ± Crd ± Sil) and metavolcanics as amphibolites and pyroxenic gneisses. Using historical and new data, High-SiO_2 (> 63.wt%) metasediments matched litharenites, while Low-SiO_2 (≤ 63.wt%) aligned with graywackes and shales. Weathering indices CIA, PIA, CIW, ICV were applied to metasediments; AI, CCPI, WIP, SI to metavolcanics. High-SiO_2 metasediments had felsic origins, confirmed by A–CN–K plots and K-Rb, resembling UCC. Low-SiO_2 indicated mafic-intermediate origins, similar to PAAS, with TiO_2–Ni emphasising sedimentary trends for Alutaguse and magmatic for SS. Discriminant-function diagrams associated both regions to continental rift zones majorly. TAS classified metavolcanics as sub-alkaline, and La/Yb vs. Zr/Nb and La/Sm vs. Sm/Yb relations, crossing the spinel-lherzolite trend, closest to the Primitive mantle (PM) reference. From Th/Nb and Th/Zr relations, the basaltic magma sources revealed asthenospheric mantle origins for Alutaguse and subducted oceanic crust for SS. Tectonic affinities from Y/15-La/10-Nb/8 and TiO_2–10(MnO)-10(P_2O_5) showed oceanic arc tendencies preferably across all zones. High CaO and MnO concentrations in Alutaguse and Uusimaa metasediments suggest a genetic link, positioning Alutaguse as a 1.90 - 1.89 Ga back-arc of Uusimaa belt at Bergslagen's north, followed by Uusimaa and Häme belt accretion at 1.87 Ga, marking the Svecofennian ocean's closure.

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Posters related to Session 3: New Exploration Techniques for CRMs

(3) Copernicus data to boost raw materials source management: Illustrations from the RawMatCop Alliance Project

Sara Kasmaee (University of Bologna)

Abstract: A crucial challenge for the transition to a carbon neutral economy is the high demand for mineral resources. In addition, embracing circularity and reducing the environmental impacts lead to focus on developing and using advanced tools to improve the mineral resource management, both technologically and economically. Earth observation (EO) can come into play, and specifically the Sentinel satellites of the Copernicus program. Many satellite sensor types (multispectral and hyperspectral) are commonly used in different sectors such as agriculture and climate. However, utilization in mineral resource exploration and management is less well developed. The reason is partly linked to that EO techniques are not an integral part of geoscience and engineering education at many universities. RawMatCop Alliance has the ambition to become the pertinent kit to transform the advanced scientific knowledge integrated with the industrial expertise to fill this gap. The course modules' cover the whole mining life cycle, including exploration and new source prospecting mapping using machine learning and geological feature extraction studies; acid-mine drainage detection and time-series monitoring; mine monitoring using SAR imaging and ground deformation mapping. The adoption of the methods with free-access data, (e.g. Copernicus data) will inspire various stakeholders to uptake the satellite technology, within and beyond the raw materials industries.

(4) Let the exploration begin: helicopter-borne remote sensing a new addition to geological mapping studies

Sara Salehi (Geological Survey of Denmark and Greenland)

Remote-sensing techniques play an important role in the geological surveys for mapping and mineral prospecting and are particularly well adapted for the investigation of remote and inaccessible areas, either for preparing field work or for supporting thematic mapping in the field. Satellite images allow for the discrimination of rock units in the broader region and help in effectively defining the best initial targets for regional exploration. Unmanned aerial systems (UAS) are particularly attractive to investigate potential deposits in difficult or environmentally sensitive areas but are limited to small-to-medium-sized survey areas, i.e. tens of square kilometers. Using a fixed-wing aircraft or helicopter, aerial surveys can provide information in a rapid, non-invasive manner on areas conducive to mineralization that may be otherwise difficult to access from the ground. Fixed-wing aircrafts are useful for large-scale and/or lower-resolution surveys, while helicopter surveys are excellent for defining smaller to medium sized targets at higher resolution and can be flown at both lower ground clearance and speed in terrains that would be impossible to follow in a fixed-wing aircraft. To address scaling issues and the accessibility in the field, and to provide low altitude data from targets identified using space-borne dataset a helicopter has been utilized as a versatile means of acquiring remote sensing data emphasizing both spatial and spectral information domains using a novel sensors system setup. The focus lies hereby on the integration of digital photogrammetry with helicopter-borne hyperspectral imaging to gather high-resolution geometric data as well as quantitative information about mineral variations in the outcrop. The method is tested in North-East Greenland, where stereo images and hyperspectral data cubes have been collected simultaneously and from both nadir and off-nadir viewing angles. The highly variable terrain leads to strong illumination and atmospheric absorption variations which must be accounted for in the hyperspectral data processing. A precondition for such correction is an accurate geo-rectification which is done by the PARGE software. Retrieving the unbiased ground reflectance is solved by a physical based atmospheric correction with the ATCOR software. The study demonstrates the potential of using helicopters to help understanding the geology in poorly accessible areas and to provide information that may help in the future exploration and geological mapping activities.

(5) Harnessing Advanced Technologies for Sustainable Mineral Exploration: The AGEMERA Project

Tony Hand (Tallinn University of Technology)

The EU's Critical Raw Materials Act, passed on May 23, 2024, aims to secure a sustainable supply of critical raw materials, reduce import dependency, enhance supply chain resilience and emphasise investment in research, innovation, and skills to promote sustainability. Already complementing these efforts, the AGEMERA project, funded by Horizon Europe, focuses on innovative and responsible mineral exploration across Europe by employing advanced technologies to analyse information from European target sites. The project prioritises environmentally and socially responsible exploration and engages with local communities, while also raising awareness about critical raw materials through educational initiatives. These priorities are vital in gaining a social licence to explore (SLE) and a social licence to operate (SLO). Key technology contributors to AGEMERA include Radai Oy, Muon Solutions, Lithica SCCL, and OPT/NET. Radai Oy provides advanced drone-based multi-sensor systems for aerial surveys. These systems can measure magnetic, radiometric, and electromagnetic properties, enabling detailed and efficient mapping of large areas.

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Their fleet includes custom-made composite planes with payloads up to 3 kg, large-hull delta-wing planes for heavy payloads and long flight times, quadcopters for low-cost extreme condition flights, and high-endurance hexacopters for valuable payloads. This technology is cost-effective and non-invasive, reducing the need for extensive groundbased exploration and minimising environmental impact.Muon Solutions enables non-invasive, deep subsurface imaging up to 1000 meters, which is crucial for identifying critical raw materials without extensive drilling. Muography reveals rock structures by tracking how cosmic ray muons scatter through different materials. Denser materials absorb or scatter more muons, creating a "muon shadow," while less dense areas allow more muons to pass through, appearing as bright spots. This contrast helps map the internal structure and density of rocks that are otherwise difficult to image. Lithica SCCL uses passive seismic methods to improve geological understanding. This non-invasive technique observes natural rock vibrations to assess bedrock hardness and identify rock-type boundaries. It provides detailed subsurface insights, aiding in identifying critical raw materials, and reduces the need for extensive drilling operations. OPT/NET provides an advanced AI platform that accelerates data processing, modelling, and training with minimal human input. This technology enables efficient analysis of large datasets, which is crucial for identifying critical raw materials. By integrating AI-driven data processing, OPT/NET helps streamline exploration activities, making them more effective and less time-consuming. OPT/NET uses Radai Oy, Muon Solutions, and Lithica SCCL data to enhance the AGEMERA project by integrating and processing this information through their advanced AI platform. By combining aerial survey data from Radai Oy, subsurface imaging from Muon Solutions, and geological insights from Lithica SCCL, OPT/NET's AI can create comprehensive and accurate geological models. Together, they advance AGEMERA's goal of sustainable and responsible mineral exploration across Europe.

(6) Regional-scale exploration targeting of northern Finland for ultramafic-mafic intrusion hosted critical metals and its global implication

Malcolm Aranha (University of Oulu)

Orthomagmatic mafic and ultramafic intrusions are critical sources of raw materials such as nickel (Ni), cobalt (Co), platinum group metals (PGMs), vanadium (V), and copper (Cu), which are essential for modern industries and prioritised by the European Union. In Northern Finland, part of the ancient Baltica craton, these critical raw materials (CRMs) are hosted in two main types of intrusions: conduit-type deposits rich in Ni-Cu-(PGM)-(Co) sulfides and layered mafic intrusions containing PGM-Cr-V-(Co)-(Ni)-(Cu) with relatively lower sulfide content. This study utilises Fuzzy Inference Systems (FIS), an AI-driven technique, for prospectivity analysis of the conduit-type deposit. The FIS models are based on generalised mineral systems models tailored to each deposit type. For conduit-type deposits, the model includes: (1) Primitive, mantle-derived ultramafic and mafic rocks as metal sources; (2) trans-lithospheric faults and chonoliths acting as magma pathways, influenced by extensional tectonic regimes within the craton; and (3) dilatational zones with high permeability and sulfur-rich crustal rocks serving as chemical traps. Spatial proxies representing these critical processes were derived from various geoscientific datasets, including innovative use of seismic models, and integrated into the FIS models to generate prospectivity maps. The results highlight promising exploration targets. At the time of mineralisation, northern Finland was part of Kenorland that underwent protracted fragmentation between 2.48 and 2.10 Ga, driven by plume driven rifting. The plume magmatism triggered several episodes of Magmatism across Kenorland, implying that mineral deposits are likely to occur beyond northern Finland. The paleogeography of the cratons therefore becomes crucial in the context of mineral prospectivity. This study uses the reconstruction of ancient plate configurations and helps refine exploration strategies within the context of global tectonics. This work is co-funded by the European Union and UKRI (SEMACRET, GA101057741).

Posters related to Session 4: CRM Processing and Valorisation

(7) Analyzing the supply chains of critical raw materials in lithium-ion batteries: A focus on cobalt and lithium

Juan Tan (Geological Survey of Denmark and Greenland)

Battery technology is essential for the clean energy shift, but rising battery demand could lead to shortages of key materials like cobalt and lithium, crucial for lithium-ion batteries (LIB) used in electrical vehicles and energy storage systems. We mapped the global flows of cobalt and lithium and analyzed their supply risks using materials flow analysis (MFA) methodology, considering the entire value chains of these materials, from exploration to waste management, and considered various supply and demand scenarios for 2030. Global resources of lithium and cobalt are substantial, with estimated reserves of 17 Mt of lithium and 6.5 Mt of cobalt in 2019. However, production is heavily concentrated in specific regions, with the top 10 producers controlling around 80% of the market share in mining and refining. Cobalt is mainly sourced from the Democratic Republic of Congo, while lithium is predominantly extracted from South America and Australia. China plays a key role in refining these materials, accounting for over half of the global refining capacity for both cobalt and lithium. This concentration of supply raises concerns about security, leading major consumer nations to invest in foreign mining operations to ensure access to these critical materials. As demand for LIB grows, the need

for cobalt and lithium is expected to increase significantly, potentially resulting in supply shortages already by 2030. To mitigate potential supply bottlenecks, urgent investments are needed across the supply chain, especially in mining, which takes years to scale. Expanding refining capacity is also important but less urgent, as refineries can be developed more quickly. Recycling plays a crucial role to supply raw materials for LIB, with recycled batteries potentially meeting up to 10% of global cobalt demand by 2030 in the best-case scenario. Although lithium recovery from secondary sources is currently minimal, it is expected to rise significantly due to advancements in recycling technologies and stricter environmental regulations. For both metals efforts are needed to scale up recycling processes requiring new technologies and infrastructure investments. Vertical integration, where companies expand their operations across the supply chain, may potentially decrease supply chain concentration. Many upstream companies engage in vertical integration to enhance business value, whereas downstream companies invest in mining or refining operations for a reliable supply. However, vertical integration requires significant investment and expertise, and it may pose challenges to trade transparency. Securing cobalt and lithium supply chains requires a comprehensive approach that includes investing in primary sources, developing secondary sources, advancing battery technologies, ensuring responsible sourcing, and promoting transparency in global trade. Such efforts are crucial for sustaining the clean energy transition and achieving a low-carbon future.

(8) Recovery of Critical Elements from Estonian Phosphate Rock Using Hydrochloric Acid
Ruhany Sheherazad Azeez (Tallinn University of Technology)

In 2024, the European Council recognized phosphate rock and rare earth elements (REEs) as critical raw materials (CRMs) that are essential to the European economy. The common method of producing phosphate fertilizers from phosphate rock, the wet acid process using H2SO4, is plagued with serious issues. Therefore, waste-free methods of the recovery of phosphorus and REEs from phosphate ore have gained increasing prominence. This study focused on the simultaneous recovery of P-fertilizers and REEs from Estonian phosphate rock using HCl. The study investigated the influence of particle size, acid concentration, and dosage of acid on the dissolution rates of phosphorus and REEs, followed by selective separation by precipitation.The results showed that phosphorus solubility reached 94-100% for fine samples (median size = 118 μm) and 82-99% for coarse samples (median size = 1697 μm) in 60 min at the HCl/Ca mole ratio of 2.1 across the entire studied HCl concentration range of 0.5 to 1.5 M. The time to reach a steady-state pH decreased with higher acid concentrations and smaller particle sizes. Incongruent dissolution and etch pit formation were confirmed by surface analysis. The CaF2 precipitation was observed at the surface of insoluble particles detected by XPS and EDX analysis. Dissolution kinetics followed the shrinking core model, involving chemical reaction, diffusion, and interfacial transfer in sequence for coarse particles, and taking place simultaneously for finer fractions. REEs solubility rate was also dependent on acid dosage (phosphorus content in a solution) and the pH value of the forming slurry. REEs solubility above 95% was achieved at HCl/Ca ≥ 2.6 and pH below 1.5.The calcium (Ca) and phosphorus (P) solubility limits in the system govern the REEs leaching efficiency. The instant and saturation concentrations of Ca and P were used to model the kinetics of REEs dissolution. The dissolution rate constants (k) rise as the initial acid concentration increases. After the removal of insoluble part, REEs were precipitated by neutralization. The efficiency was influenced by calcium content in the solution and final pH. Adjusting the pH to 2.9–3.0 optimized REEs recovery with minimal calcium orthophosphate co-precipitation. The precipitation of FePO4 and CaF2 alongside the REEs requires further separation. After that, CaHPO4 could be extracted from the solution.

(9) Effect of calcination on the leachability of metallic elements from Estonian graptolite-argillite in sulfuric acid
Eliise-Koidula Kivimäe (Tallinn University of Technology)

Graptolite-argillites (GA) or black shales are viewed as a potential future source of different metallic elements like V, Mo, Cu, Pb, Zn, REEs and others, for which the demand is growing with the advancement of various high-technology areas. The effect of calcination, with or without additives like Na2CO3 and/or K2SO4, on the solubility of metallic elements from Estonian GA samples from Pakri peninsula and Toolse drill core in sulfuric acid was investigated. The mineral part of both samples mainly contain quartz, orthoclase, muscovite and pyrite, and, in addition jarosite in Pakri GA, and dolomite in Toolse GA. The content of organic carbon in Pakri GA sample was 12.6%, while in the Toolse GA sample it was 9.3%. Thermal analysis was performed using Setram Labsys 1600 thermal analyzer coupled with Pfeiffer OmniStar mass spectrometer. The initial GA samples as well as the products of calcination were studied with XRD and SEM, and the specific surface area was determined by nitrogen adsorption method. Leaching experiments were carried out in 10% H2SO4 at 90oC for 3h with S/L ratio of 0.75:50 and the solutions were analyzed for V, Mo, Mg, Fe, K and Al with Agilent 4210 microwave plasma atomic emission spectrometer. The results of thermal analysis indicated emission of hygroscopic and physically bound water up to 110oC, which was followed by the thermo-oxidative decomposition of organic matter up to 550°C with the emissions of H2O, CO2, SO2 and various hydrocarbons. Decomposition of pyrite initiates at around 500oC, dehydroxylation of muscovite and chlorite, as well as decomposition of jarosite, dolomite, and

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unreacted Na2CO3 residue, takes place between 400-900oC. Results of XRD analysis confirm decomposition of pyrite, dolomite, jarosite and, additionally, indicate the formation of two different forms of orthoclase – K-sanidine and microcline. Calcination of GA samples in the presence of Na2CO3 additive alters the parameters of K-sanidine and orthoclase indicating the formation of K-Na-feldspar from V-bearing muscovite which enables the bonds between Al(V)–O to break and liberate V from the lattice. Analysis of the leaching solutions showed that calcination of GA samples, especially with additives, significantly increased the solubility of metallic elements in sulfuric acid. For example, the solubility of V and Mo increased from 33-40% and 60-70%, respectively, up to 70-80% without additives, and up to 90-95% with additives. Therefore, based on the results obtained, the calcination of Estonian GA samples, with or without Na2CO3 and/or K2SO4 additives, could be a promising method for increasing the solubility of various metallic elements from GA using sulfuric acid.

(10) Developing non-toxic collector chemicals for the flotation of Cu and P minerals – Towards the sustainable beneficiation of critical raw materials

Samuel Hartikainen (University of Oulu)

Green flotation chemicals, as well as energy and water saving technologies, are needed to ensure the cleanliness of green energy transition in the mining sector. While ore exploring technologies and the recycling of mining wastes have been developing rapidly in last few years, mineral processing is still a critical bottleneck of sustainable mining value chain. Many methods and chemicals used in mineral processing are more than 100 years old and have not been developed on a sustainable basis originally. Moreover, the ore contents of the mined deposits have been decreasing and the extraction of valuable minerals from them is very challenging nowadays. Valuable minerals are now found in more complex geological and mineralogical formations, which also makes their processing challenging. This means that larger volumes of mining and mineral processing are needed, with the consequence that more energy, water, and chemicals are consumed, thus increasing waste generation and environmental pollution in mining. Our aim is to develop non-toxic collector chemicals for froth flotation of sulphide minerals and industrial minerals. These minerals include many critical metals, e.g., copper, nickel, cobalt, PGMs, and REEs. In this study, non-toxic synthesized bisphosphonate was used as a highly selective collector in froth flotation of massive Cu-Zn-Fe sulphide ore. The average total recoveries for copper from the flotation tests (n = 10) with bisphosphonate collector were 91.9 % Cu for CuRC (Hartikainen et al., 2023). Flotation tests were carried out with 1 kg ore samples by using Outotec GTK LabCell™ flotation device. A non-toxic bisphosphonate collector was tested successfully also in the reverse flotation of Estonian shelly phosphorite. The average total recovery for phosphorus from the flotation tests (n = 3) was 82 % P for rougher concentrate. It is notable that coarser particles are favoured in the reverse flotation of Estonian phosphorites (Yang et al., 2021). This indicates that the flotation of Estonian phosphorites would benefit from a new continuously compressing crushing (CCC), which will produce less overgrinded particles compared to conventional crushing and grinding methods (Paasovaara et al., 2024).

(11) Developing continuously compressing crushing of critical minerals – Towards the sustainable comminution of critical raw materials

Niina Paasovaara (South-Eastern Finland University of Applied Sciences)

Various climate technologies, such as solar panels, electric vehicles, and wind turbines, are being built faster than ever in the world, making a sustainable supply of critical raw materials such as lithium, cobalt, nickel, copper, phosphorus and rare earth elements crucial for the clean energy transition. However, many crushing and grinding methods used in mineral enrichment are more than 100 years old and were not originally developed on a sustainable basis. More sustainable and controlled separation methods are becoming the next cutting-edge technology of interest to the mining and process industries. These alternative technologies need to be explored to ensure an adequate and sustainable supply of critical materials, as the clean energy transition should also mean cleaner mining and mineral processing. This is due to the requirements of the clean transition to develop mineral processing methods that consume less water, energy, and chemicals. Our aim is to develop Continuously Compressing Crushing (CCC) method, which is based on the theory of free crushing. In free crushing, the rate of feed is such that the crushed material passes freely through the crushing unit without contact between liberated particles. This prevents the formation of overfine particles and reduces energy consumption. During the free crushing in CCC method, microcracks are formed at the natural boundaries of mineral crystals resulting in the liberation of cleaner mineral particles with larger surface area. This can be utilized in the more sustainable comminution and beneficiation processes of ores, especially in dry physical separation, froth flotation, chemical leaching, and bioleaching. In this study, the CCC method was successfully tested for the dry separation of coarse-grained graphite flakes, which are favored in the battery industry (Paasovaara et al., 2024). The CCC method produces a rougher and cleaner crushing product, and less overgrinded particles, which in many ways facilitates next steps of beneficiation of valuable mineral and produces less fine and ultrafine particles waste. This study is also linked to an ongoing green chemistry research, which uses new green flotation chemicals to concentrate valuable minerals (Hartikainen et al., 2023). Together with the new flotation chemicals, the CCC method will aim to the cleanliness of green energy transition in the whole ore beneficiation process.

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References: Paasovaara N., Hartikainen S., Peräniemi S., Kuopanportti H.,Yang S. (2024). Continuously compressing crushing towards a dry processing method, a testing for graphite ore. Minerals Engineering, 212, 108713. https://doi.org/10.1016/j.mineng.2024.108713 ; Hartikainen S, Paasovaara N, Peltoniemi M, Vepsäläinen J, Peräniemi S, Yang S (2023). Synthesized bisphosphonates as non-toxic collectors in the flotation of massive Cu-Zn-Fe sulphide ore. In: The 11th International Flotation Conference (Flotation '23), November 6 – 9, 2023, Cape Town, South Africa."

(12) Wet Process for Phosphorus Fertilizers and Rare Earth Elements from Estonian Phosphate Rock

Andres Trikkel (Tallinn University of Technology)

The European Council has recognized phosphate rock (PR) and rare earth elements (REEs) as critical raw materials (CRMs). Estonia holds the largest unexploited sedimentary PR reserves in the EU, totaling approximately 800 million tons of P2O5. The phosphate in Estonian shelly phosphorite is predominantly composed of the fluorcarbonate apatite mineral phase. The P2O5 content in the samples ranges between 6–22%; however, brachiopod shells and detritus can contain up to 35–37% of P2O5. Additionally, Estonian phosphorite contains valuable REEs, with their total content in tested concentrates reaching up to 1500–2000 ppm on average. To expand the resource base of these CRMs, new sustainable and potentially waste-free methods for valorizing Estonian PR are needed. The common wet process using sulfuric acid has several drawbacks, including the loss of phosphorus and REEs during enrichment and, particularly, through phosphogypsum. This study focuses on an alternative wet process using hydrochloric acid. By treating PR with hydrochloric acid, phosphorus and REEs can be separated, along with valuable by-products like pure gypsum and quartz sand. The study investigated the influence of particle size, acid concentration, and dosage of acid on the dissolution rates of phosphorus and REEs, followed by selective separation by precipitation. It was shown on lab-scale that effective processing of Estonian PR with hydrochloric acid can be carried out at room temperature using raw material without enrichment. Almost complete dissolution of P was achieved at HCl/Ca mole ratio (acid dosage) 2.2 during 30 min at 23°C. The optimum HCl concentration to achieve 98% P dissolution rate was determined to be 4.5%. Acid dosage over 2.1–2.2 (stoichiometric 2.0) had minor effect on the dissolution rate and increasing acid concentration increases dissolution rate of FeS2 and dolomite. The solution obtained is neutralized to precipitate REEs, CaF2 and FeS2. At pH = 3, up to 90–99% of REEs can be precipitated as REE-PO4. At that also 97–99% of F and 95–98% of Fe can be removed from the solution in solid form. The precipitate (so called REE concentrate) contains about 1% of REEs and can be further processed to separate REEs from CaF2 and FeS2. Increasing the pH of the remaining solution of phosphates up to 6–7 enables to precipitate pure CaHPO4 that can be processed to get phosphorus fertilizers or H3PO4. Over 99% of P in solution was precipitated. Hydrochloric acid can be recycled using H2SO4. The results obtained so far showed that up to 80–90% of initial P can be precipitated as CaHPO4 and 70–98% of initial REEs were separated with the REE concentrate depending on the sample."

(13) EGT-TWINN: Enhancing Research Capacity at the Geological Survey of Estonia to Accelerate the Country's Transition to Green Energy

Kairi Poldsaar (University of Tartu)

The successful completion of the first half of the EGT-TWINN project signifies a significant milestone for the Geological Survey of Estonia (EGT). This Horizon-funded initiative spans three years (2023-2025) and aims to elevate geological research capabilities at EGT while fostering international collaborations. During the project's first half phase (January 2023 until October 2024), all activities progressed according to schedule, showcasing efficient resource utilization and excellent collaboration among partners committed to achieving project objectives. The project's management strategy, characterized by clearly defined responsibilities and open communication, facilitated overall project smoothness. The Finnish Geological Survey (GTK), British Geological Survey (UKRI/BGS), Geological Survey of Denmark and Greenland (GEUS), and the University of Oulu (UOULU) collaborated closely with EGT, providing high-level specialized training to EGT staff and facilitating knowledge exchange. The trainings covered diverse areas such as geological mapping, database development, 3D modeling practices, specialized geological methodologies, and exploration in geothermal studies. These courses involved site visits, hands-on activities, and theoretical learning, significantly enhancing the existing expertise of EGT geologists. The project's first half resulted in many mandatory reports, including a project management handbook, a comprehensive overview of EGT's digital infrastructure and data repositories, training guides, a communication plan, and a data management plan, some of which are publicly available on the project's website. Noteworthy achievement are the organising of two international conferences including the Conference on Exploration and Exploitation of Critical Raw Materials (October 7-8, 2024, in Tallinn) and the Conference on Urban Geochemical Baseline Survey in Estonia (September 10-11, 2024). The project's online presence, comprising a website and social

media channels, continues to serve as an engaging information hub for thousands of visitors. Looking ahead, the EGT-TWINN project anticipates another dynamic year filled with numerous training sessions, seminars, lectures, and international conferences as it progresses towards its three-year completion. For more information about the project and related events, visit the official project website: https://egt-twinn.voog.com/.

Session 3: New Exploration Techniques for CRMs – Tuesday 8th October 2024 (09:00 – 10.40)

09.00 - 9.40 Keynote: *Utilizing Machine Learning for Mineral Prospectivity Mapping and Target Generation of Critical Raw Materials*
Vesä Nykänen (Geological Survey of Finland)

The objective of mineral prospectivity mapping (MPM) is to identify regions likely to contain specific types of mineral deposits. This identification can be achieved through either an empirical or data-driven approach, which leverages existing data, or a conceptual or knowledge-driven approach, which converts expert insights into mathematical models. Machine learning (ML) techniques, capable of both supervised and unsupervised learning, enhance these approaches by applying advanced algorithms that learn from data to improve predictions. Geographical information systems (GIS) serve as an ideal framework for MPM, enabling the automation and development of complex models that predict optimal locations for mineral exploration. This keynote explores the application of machine learning in MPM across various stages, illustrated through examples from recent and ongoing research and innovation projects.

9.40 - 10.00 *Environmentally friendly surficial geochemical exploration techniques*
Pertti Sarala (University of Oulu)

Advanced surface geochemical sampling and analysis techniques offer a cost-effective and environmentally friendly set of ore prospecting methods for glaciated areas. In traditionally glaciated areas, conventional methods based on the secondary transport of the glacier have been used to determine the origin of surface boulders, heavy minerals and till geochemistry. Due to the variable glacial history, directions of glaciers' movement, and the complex stratigraphy, tracing the origin can be difficult. Instead, surface geochemical techniques based on the elements' composition of different surficial sample media such as upper sediments and organic materials provide a direct signal of underlying sediment-covered or deep-seated mineralization. Techniques which are based on the so called mobile metal ion theory, i.e., migration of mobile metal ions from mineralization in the bedrock through the top of the bedrock and the sedimentary cover to the upper soil horizons can be used in exploration for all type of elements and their associations. Great benefit is that practically all type of materials, i.e., mineral and organic sediments, plants and even snow are suitable sample media. Easy sampling and sample processing procedure with relative low analytical costs make these techniques effective in mineral exploration. Experiences have been good in the areas of transported cover such as in the glaciated terrains, where secondary transport distances of surface sediments can be long and complex making conventional tracing of mineralized rock sources difficult.

10.00 - 10.20 *MINEYE - Earth observation techniques for mine life cycle monitoring*
Saman Tavakoli (Norwegian Geotechnical Institute)

The MINEYE project's overall ambition is to increase access to critical and strategic minerals and metals in Europe with full consideration of environmental and social aspects, by providing the mining industry with proven and validated solutions for the uptake of Earth Observation data and technology. MINEYE aims to develop innovative and competitive technologies for the mineral exploration, operational, closure, and post-closure stages. Pilot sites. The technologies will be demonstrated at pilot sites in Europe, in a variety of mining contexts, from greenfield to brownfield, to secondary deposits, and at different phases of the mining life cycle. The MINEYE pilot sites include: Iberian Pyrite Belt, Spain; Norrbotten ore province, Sweden;; Ternove Chromium mine in Albania. Preliminary exploration results for Rare earth Elements (REE) from Norrbotten will be presented.

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10.20 - 10.40 An innovative method to image inner structure of orthomagmatic ore deposits using regional seismicity: a case study of Akanvaara Cr-V-PGE deposit in Northern Finland.
Nikita Afonin (University of Oulu)

Orthomagmatic mineral systems include mafic layered intrusions and conduit-type sulphide deposits, which host many of the critical raw materials such as platinum-group metals (PGM), nickel (Ni), cobalt (Co), vanadium (V), copper (Cu). This study is a part of the SEMACRET project ("Sustainable exploration for orthomagmatic (critical) raw materials in the EU: Charting the road to the green energy transition") where one of the goals is to develop environmentally friendly methods to explore the structure of orthomagmatic ore deposits. Such deposits are, for example, mafic layered intrusion, where often the ore is hosted in layers. Therefore, constraining the internal layering of these intrusions can provide critical information about the locations and extent of the ore layers. Application of non-invasive geophysical techniques, like controlled source seismic (CSS), is challenging, as mineralization is often confined to near-vertical relatively thin layers. Delineation of such boundaries by traditional ground-based controlled-source seismic profiling with one-component sensors is problematic because of the absence of reflected arrivals from such boundaries on seismograms. In this study, we try to solve this problem using passive seismic methods, based on the use of regional seismic events (earthquakes and mining blasts). For this, we utilised the theoretical background and principles of the receiver function method, teleseismic coda wave interferometry and autocorrelation of teleseismic P-wave coda which have been widely used to study the deep structure of the Earth's crust and upper mantle. Based on the theory of seismic wave propagation in layered medium, the above-mentioned methods and the results of numerical simulations conducted in this study, we propose a new method to study the inner structure of ore deposits. This method was tested on the seismic data recorded during a high-resolution passive seismic experiment in the Akanvaara layered intrusion in northern Finland. With this method, it was possible to detect the extent of the mafic intrusion as well as the Cr and V mineralization layers inside the intrusion. A comparison of our results with petrophysical and drillhole data shows a good correlation. Therefore this method can be used as an effective and environmentally friendly tool for brownfield exploration of orthomagmatic mineral deposits, in which mineralised bodies often lack clear electromagnetic response.

Session 4: CRM Processing and Valorization – Tuesdau 8th October 2024 (11:00 – 13.00)

11.00 - 11.40 Keynote: *Value chain perspective in CRM extraction*
Saija Luukkanen (University of Oulu)

The availability of raw materials is highly adversely affected by challenges related to the efficient use of the resources, including high energy and water consumption, high CO2 emissions, high risks of environmental contamination, and social resistance. The easiest-to-mine ores have already been exploited and the rest are typically complex, low grade ores. Due to the decrease in ore grades, larger tonnages are needed to be mined and for the same production, more inputs are needed in the form of energy, water, capital and labor, and at the same time larger volumes of waste are generated. To meet the increased demand for raw materials, it is necessary to maximize resource use efficiency, not only by extracting maximum value from mined products, but by increasing recovery of metals and minerals from the secondary sources, such as mine tailings. In order to optimize resource efficiency, reduce technical risks and environmental impacts of processing, it is extremely important to understand the variability of the feed material of the process; regardless of whether the ore is from primary or secondary sources. Comprehensive knowledge of ore characteristics connected with the integrated value chain of mining-mineral processing-metallurgical processes is crucial for the optimized feed to downstream processing and best metallurgical performance. Multidisciplinary research, new methods and holistic, innovative solutions, as well as sharing of best practices are required to respond to various challenges and enable sustainable mining in the current global situation.

11.40 - 12.00 Developing a value chain for high strength magnets based on rare earth minerals from Europe
Samuel Senanu (SINTEF)

The SUPREEMO project (SUstainable EuroPean Rare Earth Elements production value chain from priMary Ores) funded by the EU Commission and UKRI target the development of an integrated value chain from minerals to magnets. SUPREEMO comprises 11 partners from 10 European countries. The main objective is to develop a sustainable and secure supply of critical rare earth elements for Europe from mine to magnets. The main mineral source for the SUPREEMO project is the Fen deposit in Norway, currently considered the largest mineral resource for light rare earth elements in Europe. The project aims are focusing on beneficiation, froth flotation, efficient hydrometallurgical cracking to separate the rare earth elements before electrowinning and alloy production for high strength rare earth magnets.

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12.00 - 12.20 Pioneering Sustainable CRM Recovery in European Mining
Fotios Konstantinidis (National Technical University of Athens)

The OPTIMINER & MASTERMINE projects aims to sustainably recover Critical Raw Materials (CRMs) from complex ores in Europe through five key initiatives: REMINER, which uses advanced technologies like smart ore sorters and bioleaching; DIGIMINER, a digital platform for smart monitoring and control; ECOMINER, which enhances sustainability with tools for optimizing energy, water use, and waste valorization; DEMOMINER, which showcases pilot CRM recovery lines in multiple countries; and GLOBEMINER, which promotes awareness and market uptake, particularly through EU-Chile cooperation.

12.20 - 12.40 Sustainable mining practices: Innovative technologies on tailings management
Priyadharshini Priumal (University of Oulu)

Mining industries play a crucial role in the industrialization and advancement of human civilization. However, the significant amount of secondary waste generated during the mining process cannot be overlooked. While it is essential to recognize both the benefits and drawbacks of mining, it is even more important to pursue technological progress in a way that minimizes environmental harm. A circular and sustainable approach to mine design, where secondary residues are repurposed as resources for various applications, particularly within the mine site or nearby areas, would be a more effective and environmentally friendly option. At the same time, the construction industry faces challenges in finding new resources to meet growing infrastructure demands while addressing the climate change concerns associated with raw material procurement. This talk will be about encouraging practices that minimize environmental impact by utilizing materials efficiently, reducing waste, and promoting recycling and reuse. The focus is on creating a significant and lasting effect on the industry's sustainability and resource management practices. Specifically, the discussion will focus on case studies involving mining residues, exploring their potential as alternative raw materials for creating circularity within mining and construction industries.

12.40 - 13.00 *Circular solutions for mine tailings*
Päivi Kinnunen (ONLINE) (Technical Research Centre of Finland)

Circular economy practices have the potential to turn mining waste into valuable products. Many critical metals and minerals are present in tailings. Not only one single circular solution, but a combination of several different circular economy approaches (reduce, reprocess, upcycle, downcycle and dispose for future) are needed to manage the waste streams. Typically, the management strategies of tailings have focused on downcycling, but there are possibilities for transforming the tailings into higher value products. Remining projects need to look at by-products in addition to the conventional target metals. Technologies which recover critical metals from the tailings and use mineral residues in high-value products are highlighted in the presentation. The results from experimental studies show the economic and environmental potential to recover critical valuables from mining waste streams such as tailings.

Session 5: Environmental, Social, and Governance aspects of CRMs – Tuesday 8th October 2024 (14.00 – 16.20)

14.00 - 14.40 Keynote: The evolution and impacts of the Finnish mining-sceptical movement from the uranium debate to the green energy transition: an environmental protest wave?
Toni Eerola (Geological Survey of Finland)

The evolution of the Finnish mining-sceptical movement is described and situated within the context of Finnish environmental protest waves. This evolution occurred through the uranium debate (2005–) and mining debate (2010–ongoing). These stages are described and compared with the characteristics of the Finnish environmental protest waves. The purpose is to determine whether the evolution of the mining-sceptical movement represents a new environmental protest wave in Finland. Five environmental protest waves have been reported to have occurred in Finland. After the end of the last wave (Global Justice Movement) at the beginning of 2000s, the Finnish environmental movement lost its impetus, followed by a swell/latency. At the same time, the climate change debate returned nuclear energy to the agenda and raised the uranium spot price in the global market. China's economic growth increased demand for mineral raw materials which expanded mining and mineral exploration and related conflicts all over the world. Finland was not an exception. Together with the rebirth of the Finnish mining industry resulting from foreign companies, uranium exploration restarted in Finland in 2005, which raised opposition. The uranium debate revitalized the national environmental movement and opened spaces for local resistance in the countryside. Even though uranium exploration ended in Finland, the uranium debate continued as attention shifted towards mining projects associated with

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uranium. The environmental problems in one of them (Talvivaara) increased opposition and directed the following mining debate also towards other commodities. After that, the green energy transition with its battery minerals (nickel, lithium, graphite, cobalt) boom expanded opposition and several local mining-sceptical movements were created and they formed a nation-wide mobilization with international networking. The Extinction Rebellion also extended its activities towards mining. Therefore, the climate change debate has been crucial for generation of the uranium and mining debates which contributed for evolution of the mining-sceptical movement. Association with uranium is still one of the issues that generates opposition and one of the sensitive contexts prone to mining and mineral exploration disputes in Finland. Other sensitive contexts are related to land use: reindeer herding, second homes along waters, protected areas, indigenous Sámi homeland, and tourism destinations. The uranium and mining debates represent two decades of evolution of the Finnish mining-sceptical movement. It has impacted the Finnish society in many ways. The Finnish mining-sceptical movement shares many characteristics with the previous Finnish environmental protest waves. In fact, because of its duration, impacts, and importance, the evolution of the mining-sceptical movement is suggested to form the sixth Finnish environmental protest wave together with the coeval climate change debate.

14.40 - 15.00 Assessing Water-Use Impacts of Critical Raw Materials Production with Life Cycle Assessment Techniques

Rowan Halkes (British Geological Survey)

Global decarbonisation will drive unprecedented demand for critical raw materials, even with advancements in efficiency and recycling(1). The required rapid scale-up of critical raw materials production, such as lithium, poses significant environmental, social, and governance (ESG) challenges(2). While reducing emissions remains a primary focus, it is crucial to consider other environmental factors, particularly impacts related to water use(3). Life Cycle Assessment (LCA) has emerged as a crucial tool for quantitative evaluation of the environmental impacts of products or processes across multiple impact categories, including global warming potential and water scarcity footprints(2). LCA enables the identification of environmental 'hotspots' and is increasingly utilised in sustainability assessments of critical raw materials(2,4). However, our recent work on assessing the water-use related impacts of lithium production from salars in South America has revealed limitations in current LCA methodologies(5). Although Northern Europe is not water-scarce, the insights from this research have broad implications for improving LCA-based water-use impact assessments globally. Furthermore, as Europe will rely on critical raw materials from regions with water scarcity challenges, these aspects must be considered when assessing the environmental footprints of supply chains. This presentation will cover a) the limitations of assessing water-use impacts of critical raw material production with current LCA methodologies; b) potential improvements and development of alternative techniques; c) how LCA can enhance the assessment of impacts in critical raw material production, contributing to more responsible practices and supply chains. References 1: Giurco, D., et al., 2019. Achieving the Paris Climate Agreement Goals. pp. 437–457 2: Pell, R., et al., 2021. Nat Rev Earth Environ 2, 665–679. 3: Gilsbach, L., et al., 2019. Water Resources and Industry 22, 100118. 4: Chordia, M., et al., 2022. Resources, Conservation and Recycling 187, 106634. 5: Halkes, R.T., et al., 2024. Resources, Conservation and Recycling 207, 107554.

15.00 - 15.20 Sustainable management of abandoned mines: The REMINDNET initiative funded by COST

Ledi Moisiu (EIT Raw Materials Regional Innovation Center of Albania)

The REMINDNET network, funded by COST - The European Cooperation in Science and Technology, addresses the pressing issue of managing abandoned mines across Europe. Historically, mining activities have left behind significant environmental legacies such as tailings, waste dumps, and contaminated water, necessitating effective closure and post-closure strategies. This network Focused on legislation, governance, financing, and rehabilitation techniques, REMINDNET aims to harmonize best practices and standards for sustainable management of mining legacies. Key objectives include establishing a European mining legacy database, assessing legal frameworks and governance structures, and providing guidance to mine authorities and regulators. The project emphasizes comprehensive environmental monitoring, risk management, and capacity building through specialized working groups. comprises 74 experts from over 50 organizations across 32 EU countries, spanning disciplines from geology and engineering to economics and law.Through collaborative efforts across its five working groups—Government and management practices, Socio-economic aspects and financing, Environmental monitoring and risk management, Training and capacity building, and Dissemination and communication—the network seeks to consolidate knowledge, promote mutual exchange among researchers, and disseminate findings through an open access visualization platform. Ultimately, REMINDNET endeavors to enhance the social and environmental sustainability of mining legacies across Europe.

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15.20 - 16.00 Assessing ESG challenges for cobalt supply from new mining projects in Europe. Stefan Horn (British Geological Survey)

Despite the abundance of cobalt-bearing deposits in Europe and the goal to increase domestic cobalt supply, only Finland and Turkey are currently extracting cobalt. This study investigates the challenges for new sustainable cobalt mine development in Europe by comparing seven exploration projects and two cobalt-producing mines in Finland, Norway, Sweden, and Turkey. The selected projects include a range of deposit types focused on different main commodities (nickel, copper, palladium, and gold). A new multicriteria analysis framework has been developed to assess four different domains, which are environmental (E), social (S), political and legal (G), and economic (EC). Each domain includes five to six indicators that rank each project. The results indicate complex interactions between the different indicators used, their scale of influence (e.g. national, local) and their impact on a project. Finland, Norway, and Sweden have well-established mineral governance. However, several of the assessed projects may affect the livelihood of local communities, for example the Sàmi indigenous people and their reindeer herding pastures. In addition, new mines may add environmental stress to the Arctic, which is one of the most vulnerable regions to climate change in Europe. Other common issues include land use conflicts due to projects being investigated in nature protected areas, or where other economic activities are prominent. In contrast to the projects in the North, The Çaldağ nickel-cobalt laterite deposit in Turkey has promising cobalt resources and the planned processing route suggests higher recoveries of up to approximately 94 % Co. However, the environmental footprint from energy and chemicals use is high and competing demands of land and water can cause conflicts with agriculture and forestry. Moreover, Turkey lacks a clear governance framework for sustainable mining, that well established in the Nordic countries. In all projects, conflicts could be mitigated with improvements in early community participation and engagement to gain the social license to operate, but unfortunately this is not always practiced appropriately. While the multicriteria analysis has been tailored towards cobalt exploration projects in Europe, the framework can be adapted for use in other regions and for other target commodities.

16.00 - 16.20 China's REE Monopoly Renders Global Exploration Efforts Futile. Lessons learned? Per Kalvig (Geological Survey of Denmark and Greenland)

Rare earth elements (REE) have been utilized in industrial applications for several decades, with a significant surge in demand emerging around 2005. This increase was driven by rapidly expanding markets, particularly those for raw materials used in wind turbines, e-transportation, and electronics, where China established itself as the dominant full-chain supplier. A serious political conflict between China and Japan in 2010 exposed the vulnerabilities of REE supply chains, leading many nations to classify REEs as critical raw materials (CRMs). The bilateral conflict resulted in a dramatic rise in REE prices between 2011 and 2013, spurring a boom in new exploration projects and prompting dedicated national investments in downstream industry development. By 2020, approximately 1,000 REE-occurrences, including mines and exploration projects, were identified, hosting around 14 million tons of total rare earth oxide (TREO) measured resources and 93 million tons of TREO indicated resources, sufficient for more than 100 years. Heavy mineral deposits and carbonatites comprised over 50 % of these projects. Of these occurrences, 105 were in production, and seven under construction. The global REE-resources were. Status in 2024: Global TREO production has doubled since 2010, and more countries are now involved in primary REE production. However, most of these resources continue to be exported to and consumed by China. Despite fourteen years of dedicated efforts to break the Chinese dominance, Western nations remain entirely dependent on China for REE-embedded manufactured goods, and the supply risk has not been mitigated. Several factors have contributed to this disappointing outcome, the most significant of which include: (i) The technical challenges and intellectual property protections associated to the development of the necessary industrial infrastructure for converting REE minerals into e.g. NdFeB magnets and other commercial REE products remain politically unrecognized. (ii) Prohibitive long-term low-price scenarios hinder the development of viable business plans for the development. (iii) No western market/demand for midstream and downstream products; and (iv) China's strategic instruments for maintaining its monopoly on REEs. Conclusion: From both societal and investor perspectives, REE exploration projects have largely failed to achieve their intended goals, and so have the attempts to establish independent Western supply chains. This call for the question: Can lessons learned from REE be useful in reducing Chinas dominance on other critical raw materials (CRMs), and as well lead to more fruitful exploration projects? Kalvig, Per (2022): Rare Earth Elements (REE). Geology, technologies, and forecasts (MiMa rapport No. 1, Vol 2022; 253 pp) (https://pub.geus.dk/en/publications/rare-earth-elements-ree-geology-technologies-and-forecasts)

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