DeepBEAT project: developing applied geochemical and biogeochemical methods to detect critical raw material deposits

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The demand for critical raw materials is growing as Europe accelerates its transition toward clean energy systems, advanced manufacturing, and digital innovation. Ensuring secure and sustainable supply of these materials is a pressing challenge. The DeepBEAT (Deep Exploration Boosted by Advanced Exploration Technologies) project, funded under the Horizon Europe's research and innovations actions program (Grant Agreement No. 101177617), seeks to address this challenge through technological innovation and strong community engagement.

As Europe pushes toward its green and digital future, the demand for critical raw materials (CRMs) is skyrocketing. These resources – used in everything from renewable energy systems to advanced electronics – are projected to see demand rise by up to 500 % by 2050. Yet, Europe produces only a fraction of what it consumes. For example, 100 % of Europe's supply of heavy rare earth elements currently comes from China (European Commission 2023).

Meeting this challenge requires new thinking. Recycling and secondary sourcing will play a vital role, but they cannot meet the scale of future demand on their own. This is where DeepBEAT comes in – a Horizon Europe-funded initiative designed to unlock Europe's hidden mineral wealth through cutting-edge science and socially responsible practices. By pioneering innovative geochemical and biogeochemical exploration methods aligned with the EU's Critical Raw Materials Act, DeepBEAT aims to strengthen Europe's resource security while setting new standards for sustainable exploration.

Rethinking how we explore

Europe's long history of mining has led to the exploitation of many near-surface deposits, yet geological evidence suggests a significant potential for undiscovered resources at greater depths or beneath sediment cover (European Commission 2023). Traditionally, exploration in Europe has relied heavily on geophysical methods. Geochemical methods, while effective for near-surface deposits or drill-core analysis, have not been systematically applied to prospecting of deeper targets. Pioneering projects in Canada, Australia (CSIRO), and isolated European studies (Cameron et al. 2004; Munday 2019) show promise, but

a comprehensive approach for Europe is still missing.

DeepBEAT aims to change the concept of exploration by combining applied geochemistry, state-of-the-art technology, and community engagement into one integrated approach. In DeepBEAT, "deep" refers to blind deposits at depths up to 500 m, as well as concealed deposits under transported cover – both of which pose significant challenges for exploration. Its mission is to create a replicable, low-impact exploration workflow that not only identifies resources but also earns the trust of local communities.

DeepBEAT will advance exploration by integrating:

- **Geochemistry** to trace deep-seated signals,
- **Geophysics** to image concealed structures, and
- **3D mineral prospectivity modelling** to predict deposit potential.

This holistic approach will be tested across different mineral systems and deposit types, aiming to improve discovery rates, reduce exploration costs, and minimize environmental and social impacts.

Project overview

DeepBEAT research is conducted on three target sites located in Finland, Germany, and Czechia. Together, they represent diverse geological settings and CRM-bearing deposit types (volcanogenic massive sulphide - VMS, granite-related, alkaline metasomatite, Table 1), ensuring that the results are robust and transferable to other European and global contexts. The sites were selected based on well-characterized, drilled deep-seated ore bodies and have extensive existing datasets (geophysical, geological, geochemical), which provide a strong foundation for testing new methods. In Finland, the study site is the Saramäki Outokumpu-type VMS deposit in Polvijärvi.

Altogether 11 partners are included in the DeepBEAT project. Geological Survey of Finland (GTK) is one of the biggest part-

Table 1. Three test sites representing diverse geological settings and deposit sites of the DeepBEAT project. Here * = critical raw material and ** = critical and strategic raw material defined by EU.
Taulukko 1. Kolme valittua tutkimuskohdetta edustavat erilaisia geologisia ympäristöjä ja esiintymätyyppejä. Taulukossa * = kriittinen raaka-aine, ** kriittinen ja strateginen raaka-aine EU:n määritelmän mukaisesti.

	Saramäki	**Erzgebirge**	**Hůrky**
Country	Finland	Germany	Czechia
Ore	Volcanogenic massive sulphide (VMS)	Granite hosted Li, Sn, W	Alkaline metasomatite rare earth elements (REE)
Host Rock	Serpentinite and its alteration products within predominantly mica shists	Calcitic and siliceous metamorphic units	Shear-zone related alkaline metasomatites in granite
Commodities	Cu**, Co*, Zn, Ni**	Sn, Li*, W**, Cu**	REE**, Zr, Mo
Depth	0–700 m	0–800 m	0–400 m in the central part, deepening towards the north

Figure 1. Typical sample from the Saramäki deposit hosted by biotite- and quartz-rich tremolite skarn rock. Main ore minerals include pyrrhotite, chalcopyrite, and sphalerite. Photo: Tuulia Häkkinen.

Kuva 1. Tyypillinen näyte Saramäen mineralisaatiosta, jossa isäntäkivi on biotiitti- ja kvartsipitoinen tremoliittikarsi. Päämalmimineraaleina ovat magneettikiisu, kuparikiisu ja sinkkivälke. Kuva: Tuulia Häkkinen.

ners. Other partners from Finland are IMA Engineering Ltd Oy, University of Oulu, and FinnCobalt Oy. The project is ongoing from 2024 to 2027.

Saramäki study site

The Saramäki deposit is located some 25 km NE of the town of Outokumpu. The semi-massive to massive sulphide deposit is hosted by an E-SE dipping sheet composed of black schists, tremolite skarns and chlorite schists with minor serpentinite-soapstone and quartz rocks, representing a typical Outokumpu ophiolite assemblage (Fig. 1). Deposit thickness varies from 1 to 10 meters with typical Cu grades varying from 0.4 to 2.5 %, Zn, Co and Ni grades being much lower (Kontinen et al. 2006).

Field work on and around Saramäki is conducted during the field seasons 2025 and 2026. Main sample materials are till and different types of biogeochemical sampling media (Fig. 2).

Plant material such as tree canopy, bark, resin, and mushrooms will be collected and analysed: attention will be paid to overall chemistry, but also isotopic compositions will be analysed and advanced data analytical techniques will be developed. In addition, multi-sensor scanning techniques will be developed. The analysis will be done in co-operation with the DeepBEAT partners.

Why it matters

The goals of the project align directly with the EU Critical Raw Materials Act (Regulation (EU) 2024/1252) which seeks to strengthen Europe's supply security and reduce import dependency. Beyond technology, DeepBEAT emphasizes community engagement, recognising that responsible exploration must earn the trust of local stakeholders. DeepBEAT directly contributes to these priorities by:

- Expanding exploration capacity with innovative geochemical and biogeochemical methods tailored to detect deep and concealed deposits in Europe.
- Reducing environmental footprint through low-impact sampling tech-

Figure 2. In DeepBEAT project, till and biogeochemical sample material is tested to discover suitability for detection of the deep-seated Saramäki VMS deposit. Upper canopy samples are acquired with a sampling device carried by the drone. Photos: Sari Romppanen and Maarit Middleton.

Kuva 2. DeepBEAT-hakkeessa moreenia ja biogeokemiallista näytemateriaalia hyödynnetään syvällä esiintyvän Saramäen VMS-esiintymän tunnistamisen selvittämisessä. Ylälatvusnäytteitä kerätään drooniin kiinnitetyllä näytteenottimella. Kuvat: Sari Romppanen ja Maarit Middleton.

niques, UAV-assisted workflows which utilizes drones to collect samples and the map terrain, and advanced data modelling.

- Accelerating discovery with AI-supported 3D mineral prospectivity tools that shorten exploration timelines.
- Building social acceptance by engaging communities early, ensuring transparent communication, and demonstrating environmentally responsible practices.

Shaping the future of exploration

DeepBEAT represents a major step forward in sustainable raw material exploration. By fostering innovation, enhancing exploration capacity, and prioritizing community engagement, the project sets a benchmark

for responsible practices in the sector. As it progresses toward 2027, DeepBEAT is expected to generate valuable knowledge, tools, and models that will shape the future of mineral exploration in Europe and beyond. More about DeepBEAT: https://deepbeat.eu/

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Tiivistelmä

DeepBEAT-hankkeessa kehitetään geokemiallisia ja biogeokemiallisia menetelmiä kriittisten raaka-aineiden etsintään

Kriittisten raaka-aineiden kysyntä kasvaa, ja niiden luotettavan ja kestävän saannin varmistaminen on haasteellista. Perinteisesti uusien esiintymien etsintätoimet Euroopassa ovat nojanneet vahvasti geofysikaalisiin menetelmiin. Geokemiallisia menetelmiä ei ole systemaattisesti sovellettu etenkään syvempien kohteiden etsinnässä. Horisontti Eurooppa -ohjelman rahoittamassa DeepBEAT-hankkeessa kehitetään geokemiallisia menetelmiä nimenomaan syvämalminetsintään. Lisäksi hankkeessa hyödynnetään myös geofysikaalisia menetelmiä ja 3D-mineraaliprospektiivisuusmallinnusta.

DeepBEAT-hankkeessa maastotutkimuksia tehdään kolmessa kohteessa, jotka sijaitsevat Suomessa, Saksassa ja Tšekissä. Kohteet edustavat erilaisia geologisia ympäristöjä ja esiintymätyyppejä (taulukko 1). Suomessa tutkimuskohteena on Saramäen VMS-esiintymä, joka sijaitsee 25 km Outokummusta koilliseen. Hankkeeseen osallistuu yhteensä 11 partneria, joista Geologian tutkimuskeskus (GTK) on yksi suurimmista. Lisäksi Suomesta on mukana IMA Engineering Ltd Oy, Oulun yliopisto ja FinnCobalt Oy. Hanke toteutetaan 2024–2027. Kenttätöitä tehdään Saramäessä kesinä 2025 ja 2026. Pääasiassa kerätään moreeninäytteitä ja erilaisia biogeokemiallisia näytemateriaaleja (kuva 2).

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