Geological field excursion to the Peräpohja belt, August 2024

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The REPower-CEST "Clean Energy System Transition" project receives financial support for the sustainable and just transition of clean energy in Finland from the European Union (number 151, P5C1I2, NextGenerationEU). The project includes a diverse set of tasks related to various aspects of the clean energy transition. Geological Survey of Finland (GTK) is responsible for the raw materials package (work package 3); its task 3.2 "Exploration Concept" includes large-scale gravity and seismic surveys, 3D modelling, and a fingerprinting study of the Vähäjoki Fe-Cu-Co-Au deposit in the Peräpohja belt. More detailed information about the project can be found in a previous article by Mari Kivinen et al. in this issue.

Six GTK members involved in task 3.2 participated in a 3-day field excursion during the last week of August 2024. The plan was to visit localities of known geodynamic, geological, and metallogenic interest in the Peräpohja belt (Fig. 1), and through field observations and exchange of knowledge between experts to support the development of a holistic understanding of the mineral systems in the target area. This article gives a brief overview of our observations during our field visits. The different localities described in the text are marked in Figure 1.

Day 1: Sulfides, folds, and stromatolites

The first day started with a visit to the Kivimaa Au-Cu deposit. There, research professor **Tero Niiranen** provided us with an overview of the geological features and exploitation history of the deposit. The Kivimaa deposit was discovered in 1964 and mined during 1969–1970 for Cu and Au. The sulfide-rich and magnetite-bearing Au-Cu deposit is hosted primarily by a 350-meter-long quartz-carbonate vein, varying between 1–6 m in thickness. The vein cuts through metadolerite and subordinate mafic metavolcanic rocks. Kivimaa has been interpreted as an orogenic Au deposit. During our visit, the open pit of the deposit was filled with water so there was not much to be seen, but our team had the chance to examine in detail the sulfide-rich boulders surrounding the pit (Fig. 2). These observations were important considering that this type of Cu(-Co)-rich orogenic Au mineralization is common in the Peräpohja belt.

Next, we drove further south to the dolomite quarries of Kalkkimaa and Rantamaa, operated by SMA Mineral AB. In the office of SMA Mineral, we learned about the over 100-year-long history of the Kalkkimaa quarry and about their processing flow. Dolomite excavated from the quarry has many uses including fertilizers, animal feed, and as a filler in concrete.

The Rantamaa quarry offers a rare opportunity to observe well-preserved stromatolites in boulders (Fig. 3a) and in outcrops (Fig. 3b–c). Stromatolites are more than just pretty-looking round formations on the surface of dolomite. Not only do they provide a clear indication of shallow marine conditions during deposition of the dolomite rocks, but they also represent signs of some of the earliest forms of life on Earth. Stromatolites are essentially

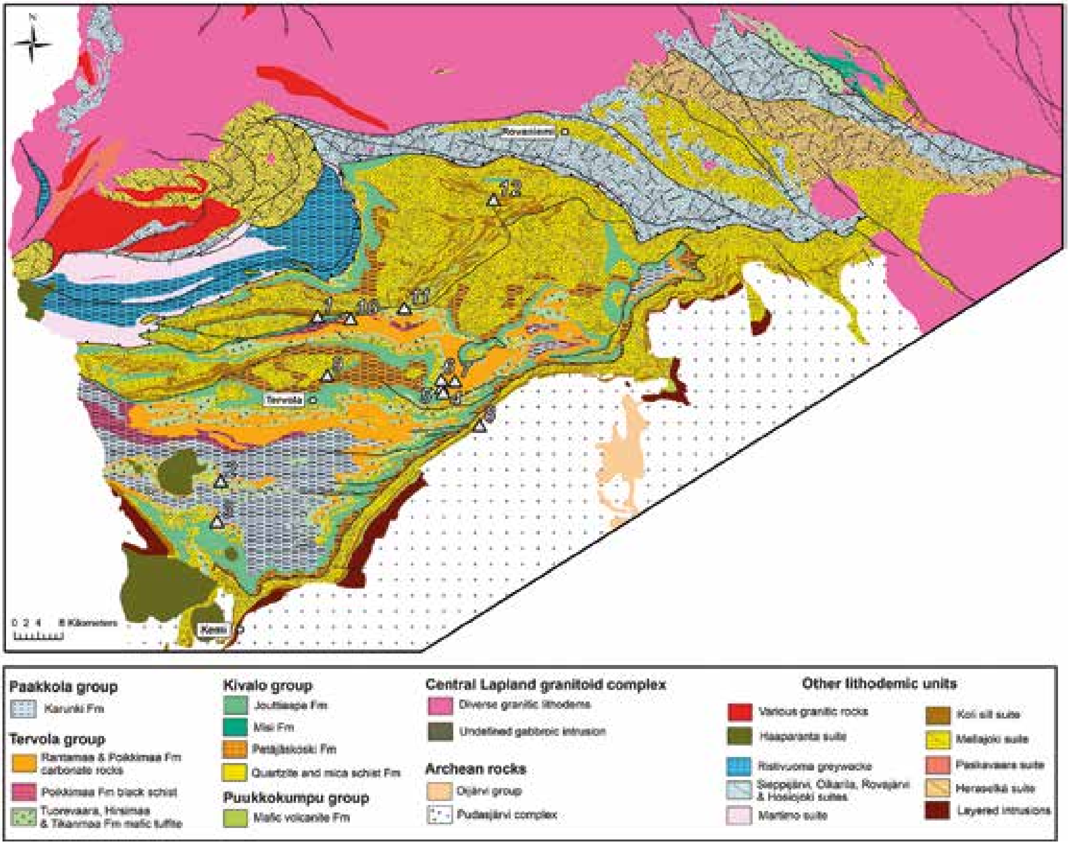

Figure 1. Simplified geological map of the Peräpohja belt. Silver triangles mark the field stops of the excursion: 1) Kivimaa deposit; 2) Rantamaa quarry; 3) Kalkkimaa quarry; 4) Vähäjoki deposit, Torpankangas area; 5) Vähäjoki deposit, Mutka area; 6) Vähäjoki deposit, Kalliomaa area; 7) Näre location, approximately 2 km east of Vähäjoki; 8) Runkausvaara; 9) Varevaara; 10) Ahvenlampi quarry; 11) Pukinselkä quarry; 12) Giant's kettles of Sukulanraka. Background map: modified bedrock of Finland 1:200,000, GTK open licence CC BY 4.0.

Kuva 1. Yksinkertaistettu Peräpohjan liuskealueen kartta. Ekskursion kohteet on merkitty harmailla kolmioilla: 1) Kivimaan esiintymä; 2) Rantamaan louhos; 3) Kalkkimaan louhos; 4) Vähäjoen esiintymä, Torpankangas; 5) Vähäjoen esiintymä, Mutka; 6) Vähäjoen esiintymä, Kalliomaa; 7) Näreen alue, noin 2 km itään Vähäjoen esiintymästä; 8) Runkausvaara; 9) Varevaara; 10) Ahvenlammen louhos; 11) Pukinselän louhos; 12) Sukulanrakan hiidenkirnut. Taustakartta: muokattu bedrock of Finland 1:200 000, GTK avoin lisenssi CC BY 4.0.

microbial reefs created by the activity of cyanobacteria and thus can be classified as trace fossils. Rantamaa quarry is one of the best locations to observe stromatolites in Finland. Fun fact: stromatolites are not just a window to the past but are still forming, as you read this, in parts of the Bahamas and the Shark Bay area of Western Australia.

Back in the Kalkkimaa quarry, we got the opportunity to study large-scale structures from two pit walls. The studied cross-sections include stunning folding patterns that can be readily distinguished due to interchange of light-coloured dolomite and dark phyllitic interlayers (Fig. 4a–c). Our group studied the folds in detail and correlated our observations

Figure 2. Sulfidized dolerite boulder above the Kivimaa open pit. Photo: Mikael Vasilopoulos.

Kuva 2. Runsaasti sulfideja sisältävä doleriittilohkare Kivimaan avolouhoksen yläpuolella. Kuva: Mikael Vasilopoulos.

with the different deformation stages of the Peräpohja belt. Other interesting observations included the local presence of sulfides in dolomite and its interlayers, and the recognition of ripple marks in one part of the quarry. To balance out the geological excitement, one of our cars got a flat tire in the quarry. Thankfully, task lead **Jonna Tirroniemi** managed to secure a replacement, so we could continue our excursion as planned. This was a good time to call it a day.

Day 2: You betcha, it's a breccia!

The second field day had a clear focus and an immediate connection to the fingerprinting study of REPower-CEST task 3.2 as most of our day was spent in the area of the Vähäjoki Fe-Cu-Co-Au deposit. The Vähäjoki deposit is situated c. 20 km east of the town of Tervola, and it was already discovered during the late 1930s and drilled during the 1940s. Through the decades, several models have been

Figure 3. Stromatolites visible in a boulder located in the Rantamaa open pit (a). Stromatolites in an outcrop on top of the Rantamaa pit (b). Specialist Jonna Tirroniemi, senior specialist Irmeli Huovinen, and postdoctoral researcher Mikael Vasilopoulos (from left to right) documenting stromatolite occurrences at an outcrop on top of the Rantamaa pit (c). Photos: Mikael Vasilopoulos (a–b), Tero Niiranen (c).

Kuva 3. Stromatoliitteja lohkareessa Rantamaan louhoksella (a). Stromatoliitteja paljastumassa Rantamaan louhoksen yläpuolella (b). Asiantuntija Jonna Tirroniemi, erikoisasiantuntija Irmeli Huovinen ja postdoc-tutkija Mikael Vasilopoulos (kuvassa vasemmalta oikealle) dokumentoimassa stromatoliitteja paljastumasta Rantamaan louhoksen yläpuolella (c). Kuvat: Mikael Vasilopoulos (a–b), Tero Niiranen (c).

proposed for the genesis of the magnetite- and sulfide-rich mineralization. The aim of the fingerprinting study under the REPower-CEST project is to utilize modern geochemical methods combined with geological and mineralogical observations with a purpose of uncovering the sequence of ore-forming events in the deposit. An additional aim of the study is to confidently identify the genetic type of the deposit. Outcrops in the Vähäjoki area are moss-covered and scarce, and they are situated in a lush forest area. However, some of the outcrops provide a great opportunity to observe brecciated and mineralized rocks displaying textures and structures similar to the mineralized parts of drillholes. The field visit to the Vähäjoki area was led by senior specialist **Irmeli Huovinen** and me, as the two of us had already conducted field work there earlier in the summer.

Figure 4. An overview of the folded rocks in one of the Kalkkimaa quarry pit walls (a). Research professor Tero Niiranen and senior scientists Juha Köykkä and Tuomo Karinen pondering the geodynamic evolution of the Peräpohja belt while looking at the folded rocks in one of the Kalkkimaa pits. Colors in this photograph have been slightly edited and a touch of vignette was also added (b). Unedited close-up of the beautiful, folded rocks depicted in Fig. 4b (c). Photos: Mikael Vasilopoulos (a–b), Tero Niiranen (c).

Kuva 4. Yleiskatsaus Kalkkimaan louhoksen poimuttuneista kivistä (a). Tutkimusprofessori Tero Niiranen sekä erikoistutkijat Juha Köykkä ja Tuomo Karinen katsomassa Kalkkimaan louhoksen poimuttuneita kiviä ja pohtimassa Peräpohjan liuskealueen geodynaamista kehitystä. Tämän kuvan värejä on hieman editoitu ja kuvan reunoja on tummennettu aavistus (b). Lähikuva kuvan 4b kauniista poimuttuneista kivistä ilman minkäänlaista editointia (c). Kuvat: Mikael Vasilopoulos (a–b), Tero Niiranen (c).

Figure 5. GTK group admiring an outcrop with brecciated dolomite in the Mutka location of the Vähäjoki deposit. Photo: Mikael Vasilopoulos.

Kuva 5. GTK:n seurue ihailemassa breksioitunutta dolomiittipaljastumaa Vähäjoen Mutkassa. Kuva: Mikael Vasilopoulos.

The first stop in the Vähäjoki area was in the "Torpankangas" location, which represents the southern part of the deposit. In this part, most outcrops comprise unaltered dolomite, which locally shows some light degree of brecciation related to ore-forming activity. This was a good opportunity to see what the host rocks look like in more distal parts of the deposit. Our next stop was at the "Mutka" location at the heart of the Vähäjoki deposit. Outcrops here show clear signs of brecciation, which typically characterizes the mineralized parts of Vähäjoki: small- to medium-sized dolomite fragments of different shape floating in a chlorite- and magnetite-rich, and locally sulfide-containing, matrix (Fig. 5). Subsequently, our team continued to the "Kalliomaa" location in the northern part of the Vähäjoki area. There are several outcrops that show clear ore-related textures in this area, similar to the previous stop; especially one outcrop hosts a particularly impressive example of the typical ore-related brecciation, with dolomite fragments reaching up to several tens of cm in diameter (cf. cover photo). The excursion in the Vähäjoki area was concluded by examining outcrops outside the known extent of the deposit, where some signs of sulfide-bearing and amphibole-rich rocks that resemble parts of the Vähäjoki ore were recognized c. 2 km east of the known borders of the Vähäjoki deposit.

The Vähäjoki deposit took up most of our day, but there was still room for other adventures. We drove to the Runkausvaara

Figure 6. A brecciated dolomite boulder from the Ahvenlampi quarry. Photo: Mikael Vasilopoulos.

Kuva 6. Breksioitunut dolomiittilohkare Ahvenlammen louhokselta. Kuva: Mikael Vasilopoulos.

hill, approximately 10 km SE of Vähäjoki, to study the Archean gneiss forming the basement of the Peräpohja belt, and the basaltic rocks of the Runkaus formation that overlie the basement. There, GTK senior scientists **Juha Köykkä** and **Tuomo Karinen** described the textures in the outcrops and helped us to understand the correlation of these formations to their equivalents in the Kuusamo and Central Lapland belts of northern Finland. Our last stop of the day was at the Varevaara hill, 5 km NE of the town of Tervola, where we studied sedimentary textures in quartzite boulders and outcrops. There, we also stumbled upon a boulder with quartz-carbonate veining and signs of oxidation, another indication as to how widespread hydrothermal activity has been in the Peräpohja belt.

Day 3: Precious railways and Giant's kettles

The third day of our excursion started with a visit to the old dolomite quarry at Ahvenlampi. Our intention was to investigate the rocks in the quarry and to search for indications of hydrothermal activity in the rocks belonging to the same dolomite formation hosting the Vähäjoki deposit. Some of the excavated boulders in the quarry contained quartz veins, ranging from individual veinlets to groups of veins resembling a stockwork network; locally, some of the veins also contained green oxidized patches indicating presence of copper-bearing minerals. The biggest find of our visit, which came as a surprise to some of us, was the recognition of clear brecciation in some of the dolomite boulders (Fig. 6). Fragments varied in size and shape even within the same boulder, but the matrix did not contain any visible signs of sulfidation nor was it magnetic. This type of brittle deformation in the dolomite would be favorable as a local structural trap for metal deposition, if extensive amounts of hydrothermal fluids would have circulated through the rocks. This recognition of the 'right' kind of deformation, despite missing the final touches for ore deposition, would imply that similar rocks in more favorable locations closer to large pathways allowing fluid circulation and more favorable large-scale structural traps, like in the Vähäjoki deposit, would have an increased potential for metal enrichment. Perhaps the Rantamaa formation dolomites still hide other Vähäjoki-type occurences waiting to be discovered.

Our next stop was at the Pukinselkä dolerite quarry, 15 km NNE of Tervola. Rocks in the pit walls of the quarry are folded and sheared, and different deformation stages could be studied and compared to our observations from the Kalkkimaa quarry. The opportunity to study structures was by itself very rewarding, but there is also a golden secret hidden in the Pukinselkä quarry: it is the location of a small orogenic Au occurrence, similar to the Kivimaa deposit. The occurence is hosted in the dolerite, and especially in a prominent quartz vein and its alteration halo. As the Pukinselkä dolerite has been exploited as rock material that was also used in railway maintenance, it is fair to say that the railways around the Tervola area are especially precious!

The final stop of the day was at the Giant's kettles of Sukulanrakka, approximately 25 km south of Rovaniemi. Some of the kettles are among the biggest in Finland, going as deep as 15.4 m, and they were formed c. 11,000 years ago. The kettles were impressive to say the least, and the well-exposed cordierite-anthophyllite rocks that tower through the surrounding area provide a panoramic view. This seemed like a nice place to end the excursion, and our day ended with our party heading to the GTK facilities in Rovaniemi and storing our gathered rock samples.

Afterwords

This field excursion was a valuable opportunity for GTK experts to further develop our understanding of the geodynamic and metallogenic development of the Peräpohja belt. The observations and exchange of ideas that took place in the field provided a knowledge foundation that has benefited the research tasks included in the REPower-CEST project. We would like to thank SMA Mineral AB for their hospitality and for allowing us the opportunity to study the rocks in the Kalkkimaa and Rantamaa quarries.

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Tiivistelmä

Geologinen ekskursio Peräpohjan liuskealueelle elokuussa 2024

Elokuussa 2024 kuusi Geologian tutkimuskeskuksen (GTK) asiantuntijaa osallistui kolmipäiväiseen geologiseen ekskursioon Peräpohjan liuskealueella osana Euroopan unionin rahoittamaa REPower-CEST-projektia. Ensimmäinen päivä alkoi Kivimaan esiintymän avolouhokselta, jossa seurue pääsi tutkimaan runsaasti sulfideja sisältäviä lohkareita ja keskusteli esiintymän historiasta. Päivä jatkui SMA Mineral -yrityksen hallinnoimilla Kalkkimaan ja Rantamaan dolomiittilouhok-

silla, joissa saimme tilaisuuden tutustua stromatoliitteihin ja näyttäviin poimurakenteisiin. Kenttävierailut jatkuivat toisena päivänä Vähäjoen Fe-Cu-Co-Au-esiintymän alueella, noin 20 km itään Tervolasta. Siellä tutkimme breksioituneita ja mineralisoituneita dolomiittipaljastumia kolmessa eri paikassa. Päivä jatkui Runkausvaarassa, jossa tehtiin havaintoja arkeeisesta gneissistä ja sen päällä esiintyvästä basaltista. Toinen ekskursiopäivä päättyi Varevaaran kvartsiitissa esiintyviä tekstuureja tutkien. Viimeinen kenttäpäivä alkoi käynnillä Ahvenlammen dolomiittilouhokselle, jossa löysimme kvartsijuonia ja breksioituneita lohkareita. Päivä jatkui tutustumisella Pukinselän doleriittilouhokseen: siellä tutkimme poimuttuneita kiviä ja teimme havaintoja pienestä orogeenisesta kultaesiintymästä. Louhoksen kiviainesta on käytetty mm. Tervolan rautateiden kunnossapitoon, joten totesimme, että Tervolassa on kullanarvoiset rautatiet! Päivä päättyi käynnillä Sukulanrakan hiidenkirnuilla, jonka jälkeen veimme kerätyt näytteet GTK:n näytevarastoon Rovaniemelle. Tällä ekskursiolla tehdyistä havainnoista ja niiden pohjalta syntyvistä keskusteluista on ollut paljon hyötyä REPower-CEST-projektin Peräpohjan liuskealueeseen kohdistuneissa tutkimuksissa.

Kaivannaisjätealueet kriittisten raaka-aineiden lähteinä – FutuRaM-projekti ja tapaus Otanmäki

TEEMU KARLSSON, JANNE HOKKA JA TUOMAS LESKELÄ

Kriittisten raaka-aineiden tarve kasvaa vihreän siirtymän myötä, erityisesti aurinkopaneelien, tuuliturbiinien ja sähköajoneuvojen yleistyessä. Euroopan unionin (EU) uusi raaka-aineasetus (European Comission 2024) edellyttää, että vuoteen 2030 mennessä vähintään 15 % kriittisten raaka-aineiden kulutuksesta katetaan kierrätyksellä. Tämä on lisännyt kiinnostusta myös sekundäärisiin lähteisiin, kuten kaivosten jätealueisiin, joista toivotaan löytyvän merkittäviä raaka-ainevarantoja.

Suomessa Geologian tutkimuskeskus (GTK) osallistuu nelivuotiseen (2022–2026) Horizon Europe -ohjelman rahoittamaan FuTuRaM-projektiin (*The Future Availability of Secondary Raw Materials*), jonka tavoitteena on mm. luoda tietokanta sekundääristen raaka-aineiden saatavuudesta ja hyödynnettävyydestä EU:ssa. Osana projektia arvioitiin suomalaisten suljettujen kaivannaisjätealueiden raaka-ainepotentiaalia erityisesti EU:n kriittisiksi määrittelemien raaka-aineiden osalta. Lisäksi projektissa tutkittiin tarkemmin Otanmäen rikastushiekka-alueen sisältämän ilmeniitin ($FeTiO_3$) resurssipotentiaalia.

Kaivannaisjätteet Suomessa

Suomessa syntyy vuosittain noin 100 miljoonaa tonnia (Mt) kaivannaisjätettä, pääosin rikastushiekkaa (kuva 1) ja sivukiveä. Tämä vastaa 74 % kaikista tuotetuista jätevirroista. Kaivostoiminnan historian aikana (1500-lu-