EIS Final Event:

Shaping the Future of Sustainable Mineral Exploration

EIS
Exploration
Information
System

Funded by
the European Union

Advancing mineral exploration through innovative technologies

11:00 – 12:30

EIS
Exploration
Information
System

Moderator
Imad Audi
(LGI)

Malcolm Aranha
(HZDR-HIF)

Tony Hand
(TalTech)

Lucija Dujmovic
(HZDR-HIF)

Juha Kaija
(GTK)

27/10/2025

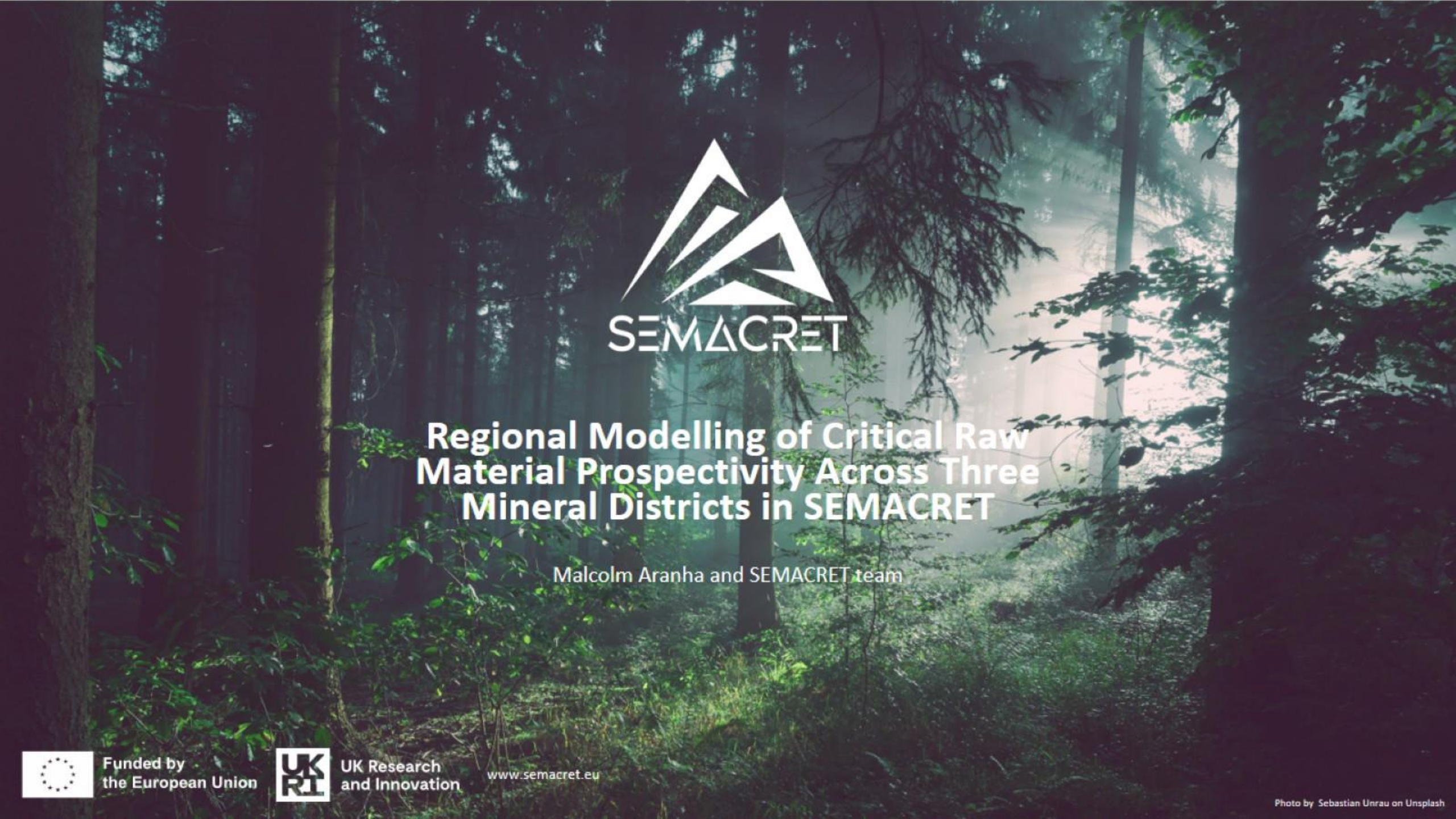
EIS
Exploration
Information
System

Malcolm Aranha (HZDR-HIF)

SEMACRET

Clustering session: Advancing mineral exploration through innovative technologies

11:00 – 12:15



SEMACRET

Regional Modelling of Critical Raw Material Prospectivity Across Three Mineral Districts in SEMACRET

Malcolm Aranha and SEMACRET team

Funded by the European Union

UK Research and Innovation

www.semacret.eu

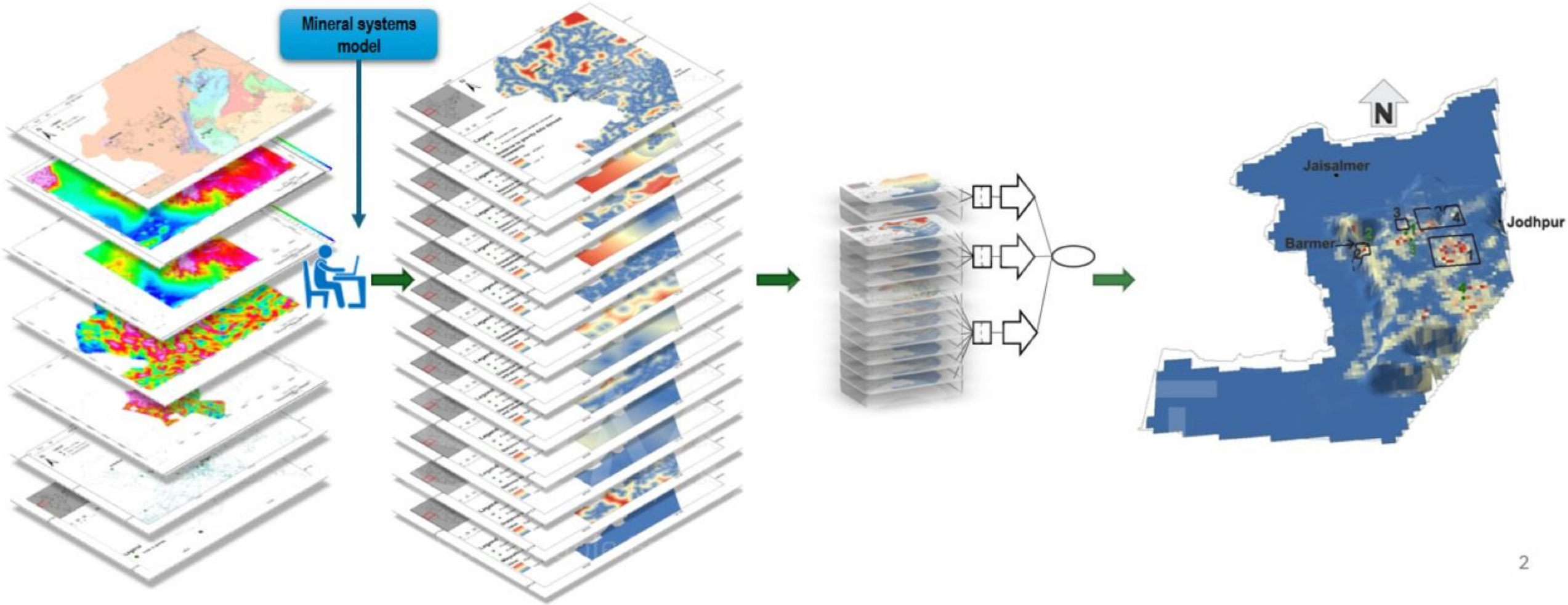
Prospectivity modelling workflow

PRIMARY DATASETS

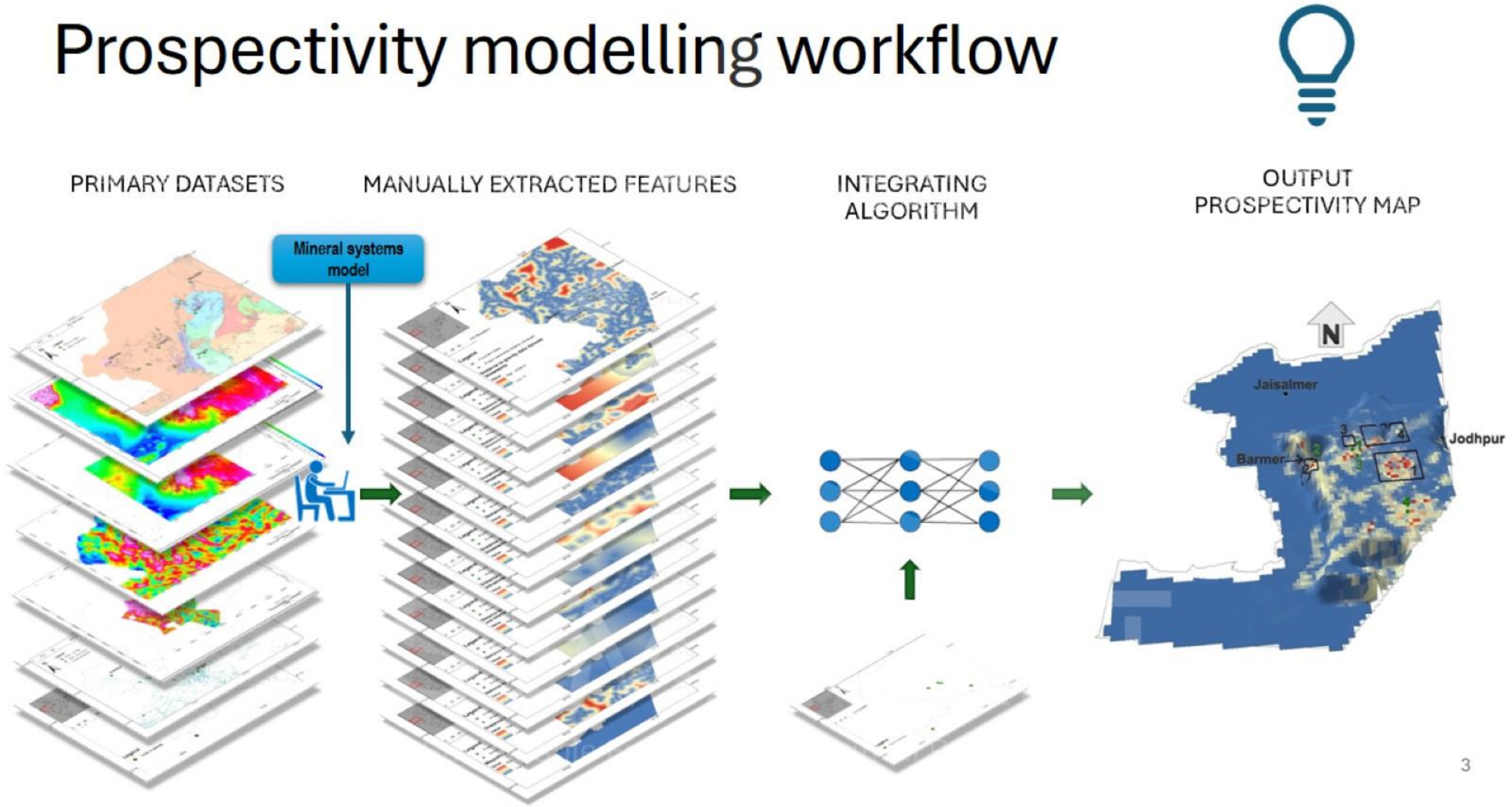
MANUALLY EXTRACTED FEATURES

INTEGRATING ALGORITHM

OUTPUT PROSPECTIVITY MAP



Prospectivity modelling workflow



Prospectivity modelling workflow

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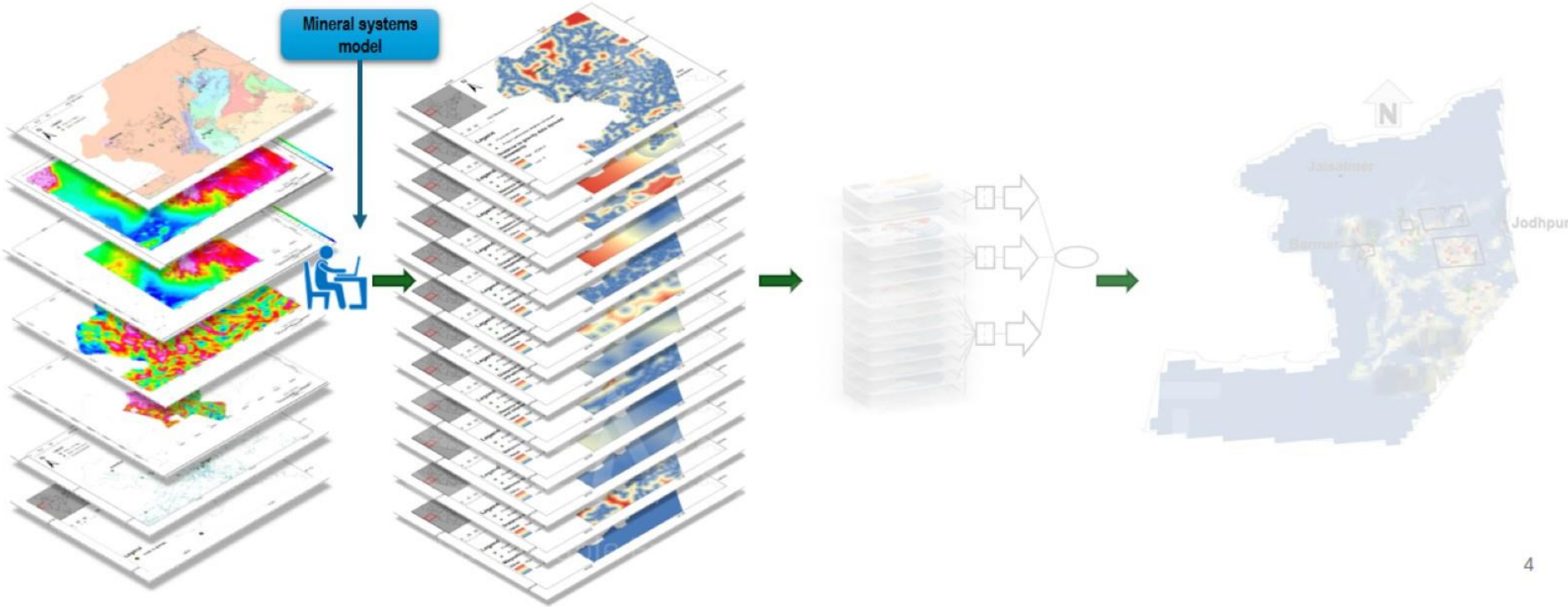
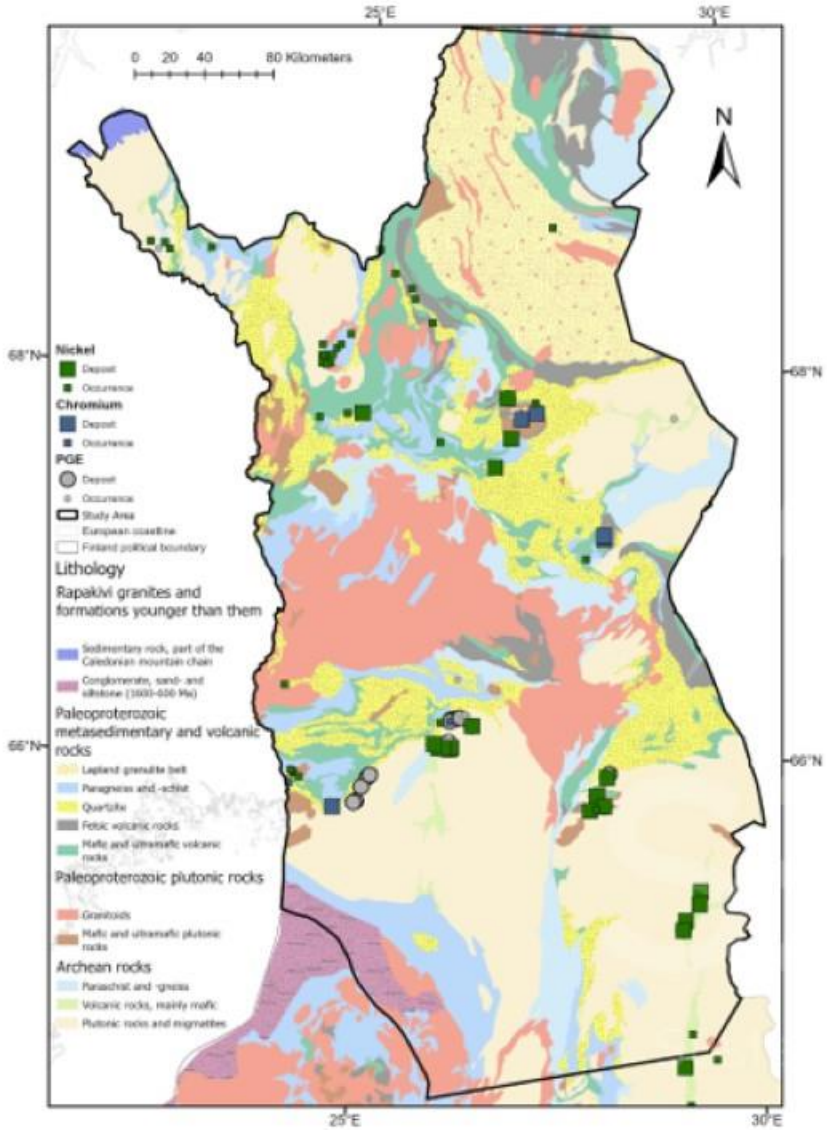


Site 1: Northern Finland



Eastern Fennoscandian Shield

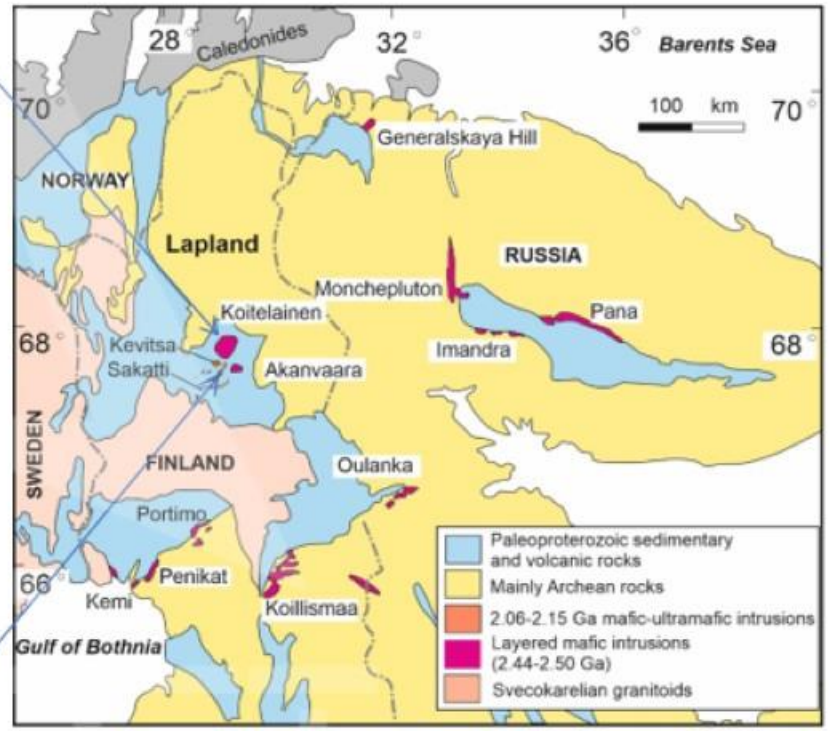
2.45 Ga dike swarms
- connected with layered intrusions; two magma types
  - (1) boninite–norite dikes (high MgO, SiO_2, Cr, Ni, and LREE, low TiO_2 and Zr), NE-trend
  - (2) gabbronorite dikes (low TiO_2, Cr, and Zr), NW-trend
  - (3) low-Ti tholeiitic (NW-trend) and
  - (4) Fe-tholeiitic dikes (E-trend), continental type
  - (5) orthopyroxene-plagioclase-phyric dikes (high SiO_2, LREE; calc-alkaline aff.), E-trend

2.32 Ga Fe-tholeiitic dike swarm and intrusions
- few dikes and intrusions identified
- E-trend?

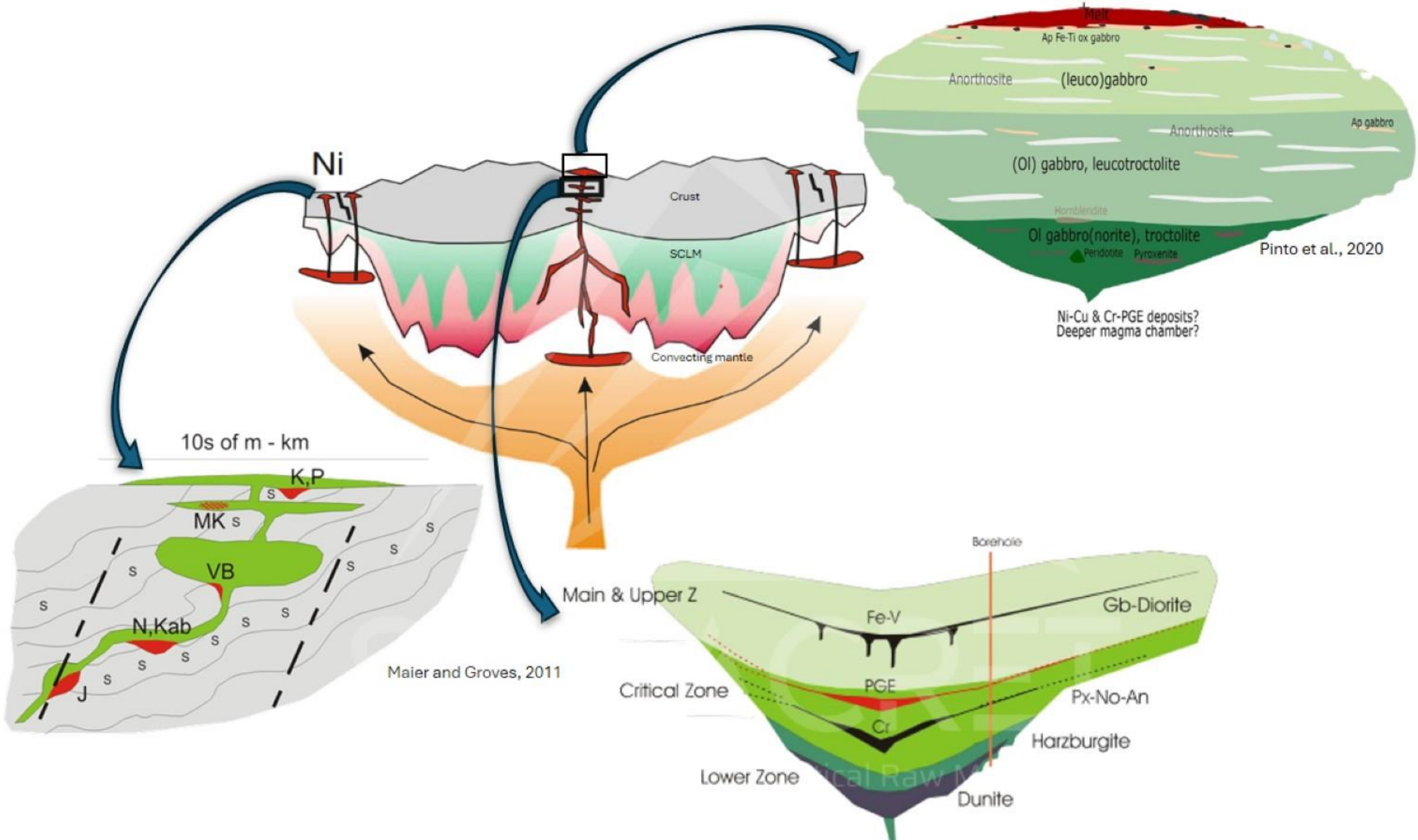
2.2 Ga low-Al tholeiitic (karjalitic) layered sills
- layered intrusions/sills (max. length 150 km) and minor dikes
- wehrlite–clinopyroxenite–gabbro–granophyre
- widespread in eastern and northern Finland

~2.1 Ga Fe-tholeiitic dike swarm
- includes several pulses between 2.13 Ga to 2.05 Ga
- continental tholeiitic type
- mainly E-trend (Kuhmo block) and minor NW-trend

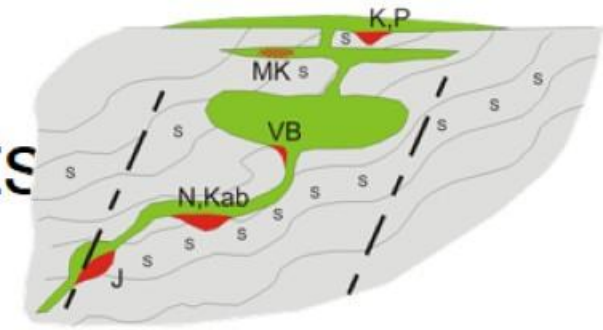
~1.98 Ga Fe-tholeiitic–tholeiitic dike swarm
- predates 1.95 Ga ophiolites
- NW-trend (Kuhmo block), continental tholeiitic to IAT type
- mainly unaltered (plagioclase and pyroxenes)



Vuollo and Huhma, 2005


Ni
Crust
SCLM
Convecting mantle
Melt
Ap Fe-Ti ox gabbro
Anorthosite
(leuco)gabbro
Anorthosite
Ap gabbro
(Ol) gabbro, leucotroctolite
Hornblendite
Ol gabbro(norite), troctolite
Peridotite
Pyroxenite
Pinto et al., 2020
Ni-Cu & Cr-PGE deposits?
Deeper magma chamber?
10s of m - km
K,P
MK
VB
N,Kab
J
Maier and Groves, 2011
Main & Upper Z
Borehole
Fe-V
Gb-Diorite
Critical Zone
PGE
Px-No-An
Cr
Harzburgite
Lower Zone
Dunite

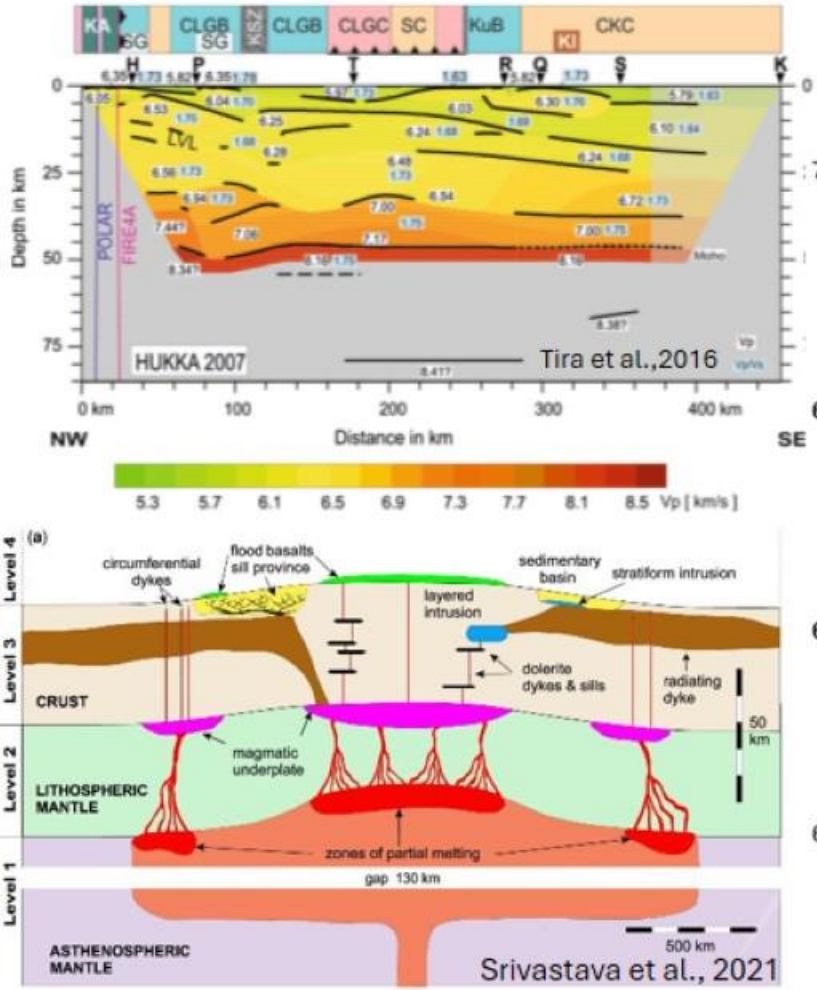
Mineral systems model for Ni-Cu conduit deposits

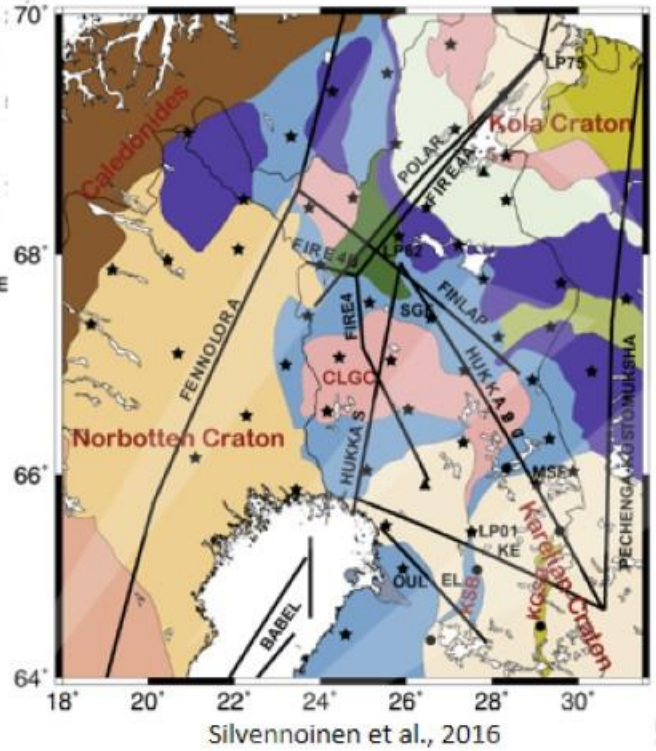


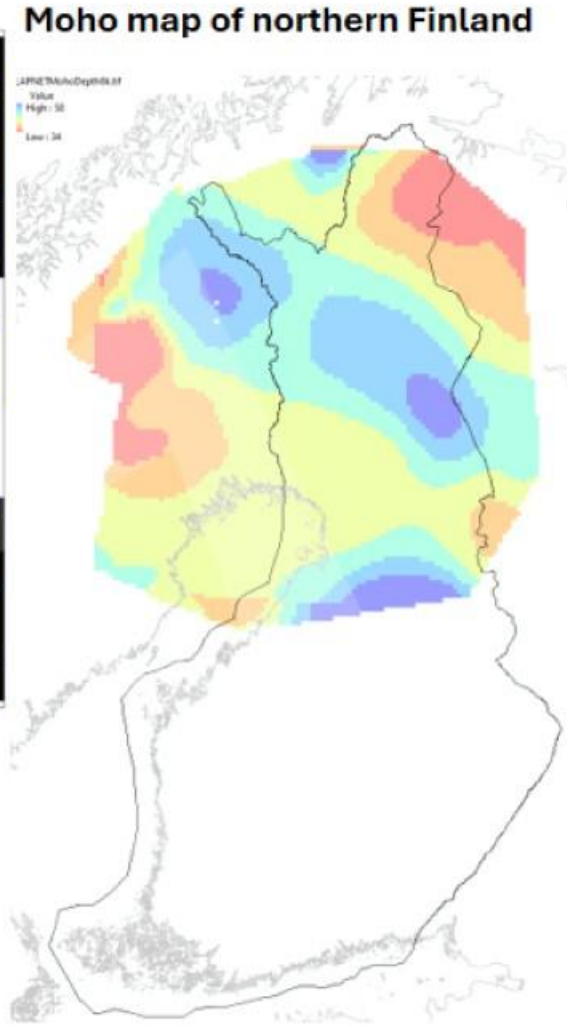
Process	Primary data	Predictor map
Source		
Convecting mantle and the lithospheric mantle	Magnetotelluric, tomography survey	Depth to mantle
Olivine is the main reservoir of nickel and the higher the MgO abundance of a mafic–ultramafic suite, the higher its Ni content can be, hence the highest its potential to host magmatic sulphides is. The MgO/(MgO + FeO) value of mafic and ultramafic suites reflects the amount of crystalized olivine (Le Bas (2000)).	Geochemistry	MgO/(MgO + FeO) ratio map
Mantle plume?		
Pathways		
Trans-crustal fault	Major gravity/magnetic breaks Seismic reflectors Change of conductivity (Magneto [illegible])	Distance to trans-crustal fault
Chonoliths (or lava channel in mafic intrusion) host Ni–Cu deposits	Geology Geophysics	Distance to chonoliths
Magma conduits like dyke host magmatic sulphides and further support the Ni mineralisation.	Geolo[illegible]ng [illegible]agnetic interpretation	Distance to dyke
Rifts?	S[illegible]ctu[illegible]dat[illegible]/Geophysics	Distance to rifts
Paleocraton margin	t[illegible]atur[illegible]Geophysics	Distance to paleaocratonic margin
Traps		
Damage zone indicates a higher degree of structural intricacy and greater availability of space, resulting [illegible] structural traps.	Structural data from geology magnetic and gravity	Structure density map
Mafic suite and chrome content	Geochemistry Geological mapping	Distance to ultramafic and mafic rocks Chrome content, Sc/Cr ratio
Chalcophile enrichment?	Geochemistry	Au,
Mafic-ultramafic rocks are dense and have a significant response to gr[illegible]	Bouguer anomaly data	Density anomalies
Abundance of metals and Fe rich minerals cause magnetic a[illegible]	High altitude aeromagnetic anomaly data	Magnetic anomalies
Ni deposits are often associated with Cu, C[illegible]GEs, C[illegible]	Geochemistry	Pt, Pd, Cr, Ni, Cu content maps
Conduit geometry: Basal segregations of N[illegible]hides are formed through the emplacement of S-undersaturated, Ni-bearing tholeiitic magmas into crustal rocks. This leads to rapi[illegible]ation via [illegible] contamination, mixing of different magma compositions, or a quick decrease in temperature (Li and Nald[illegible] 1993; [illegible]000; Lesher et al., 1998, 2000; Ripley et al., 1999). *The Cu/Pd ratio serves as an indicator: a high ratio suggests a p[illegible]ntial [illegible]o low [illegible]dicates Ni stripping and downstream NiS accumulation, and a normal ratio suggests being in the feed[illegible]or no s[illegible]*	Geochemistry	Cu/Pd, Cu/Zr
Crustal contamination: S-saturation occurs when external S is added due to devolatisation, partial melting, or assimilation of S-rich upper continental crustal rocks (Lesher and Campbell, 1993), which are usually enriched in incompatible elements. Anomalous values of the ratios of incompatible elements in the ultramafic-mafic suites indicators of crustal contamination and therefore S-saturation (e.g., Naldrett, 1997).	Geology Magneto telluric Geochemistry	Distance to sulphur rich lithologies (e.g., Black shales, Gypsum/Anhydrite), High conductance. S content maps, S isotope maps. La/Sm, La/Yb, La/Nb, Th/Yb, Th/Nb, La/Y and Rb/Cs

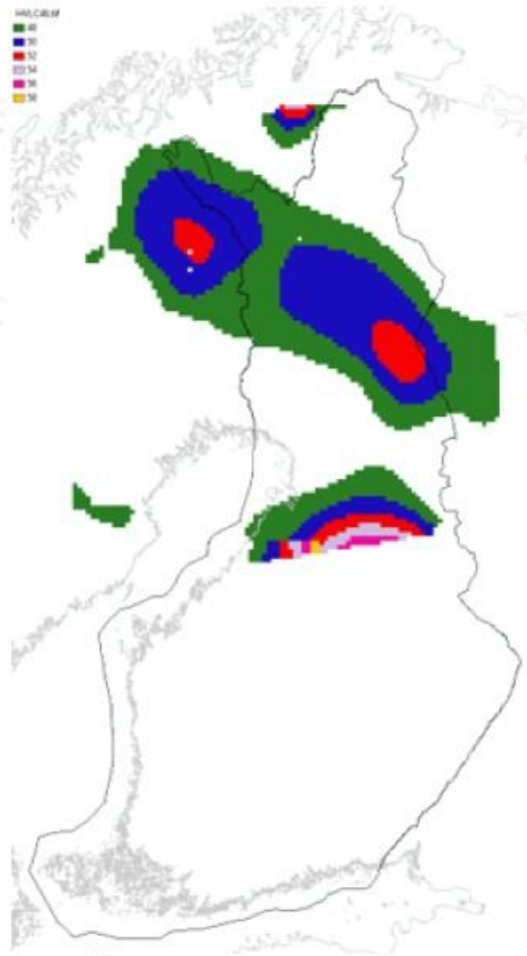
List of crucial ore-forming processes

Magma reservoirs





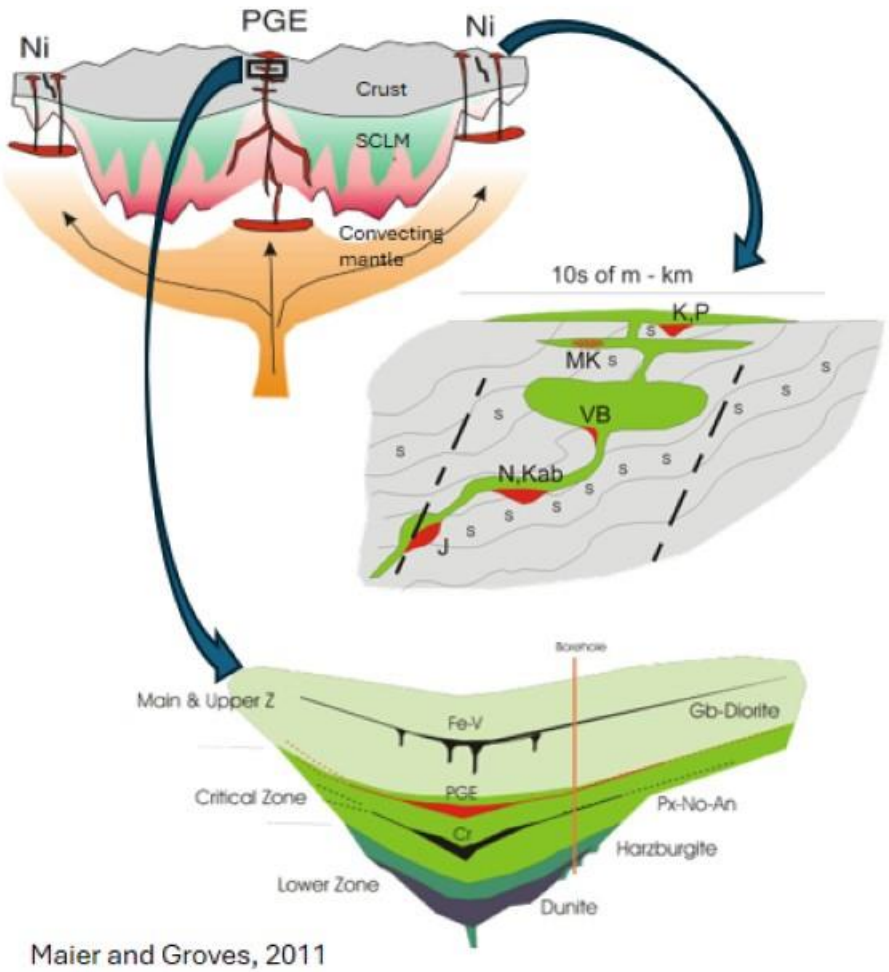




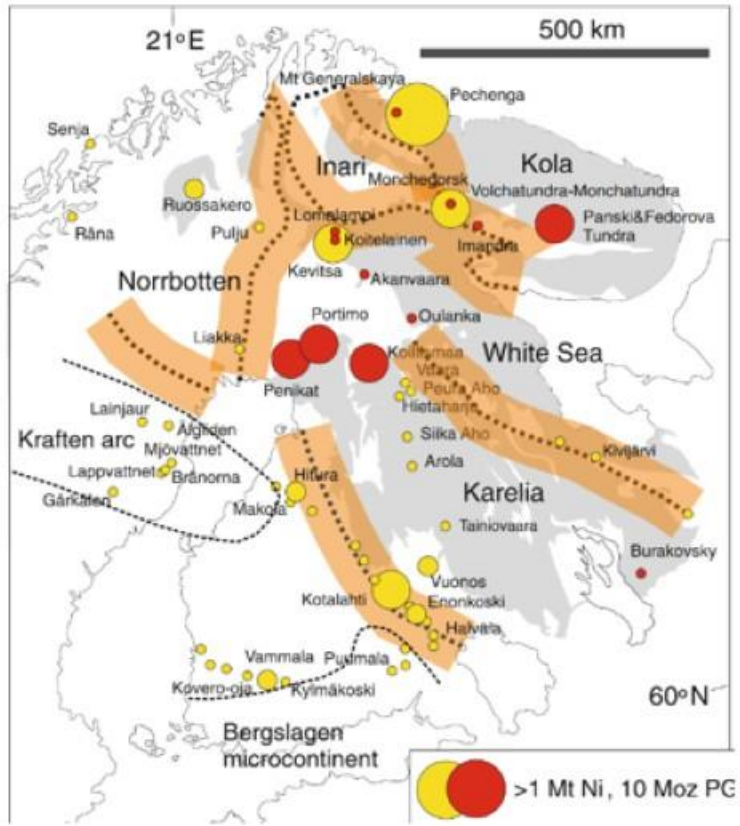
Deep crust indicative of intermittent magma chambers

- Thicker crust, corresponding to high velocity zone at lower crust, in CLGB
- Probably magma underplating, and **deep magma reservior**

Craton boundaries

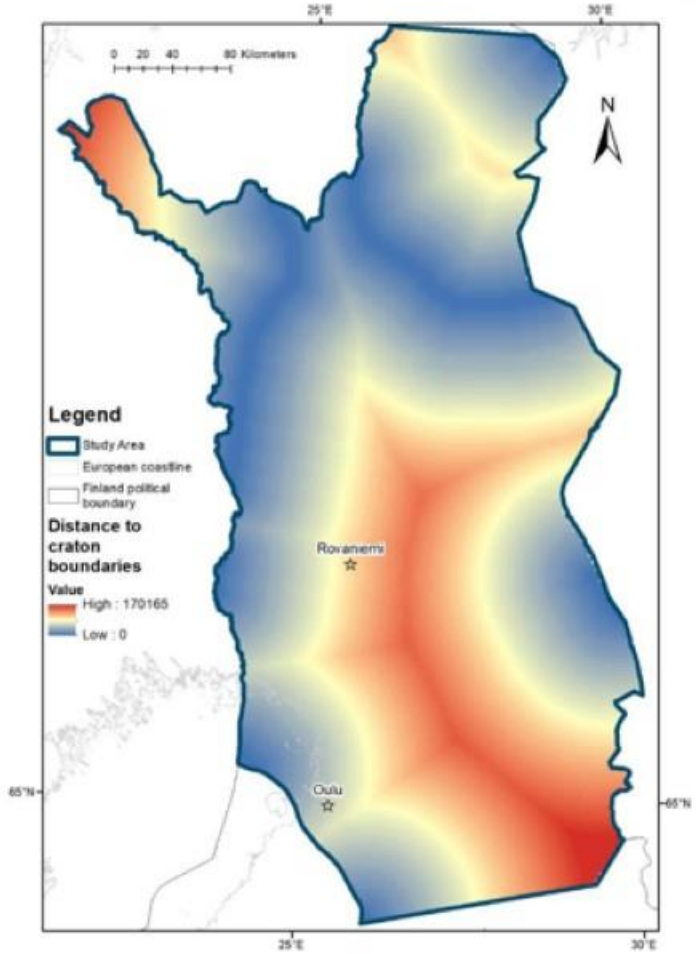


Maier and Groves, 2011



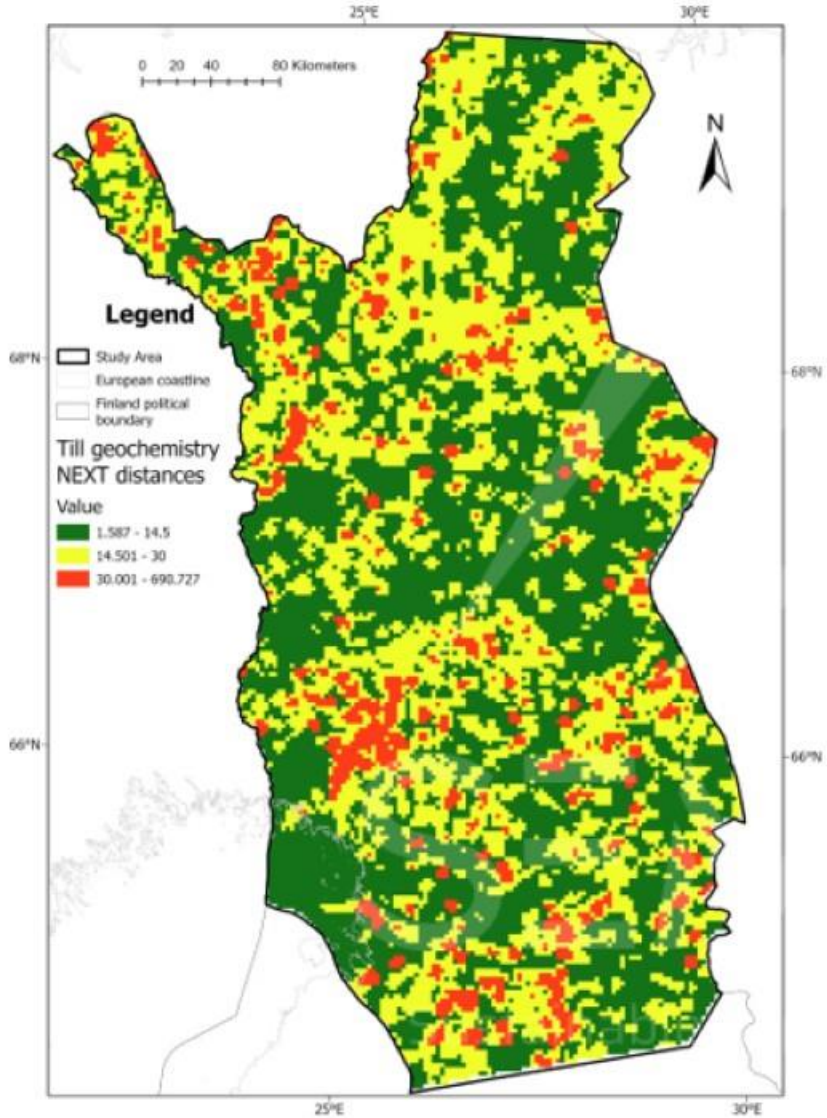
Processed data

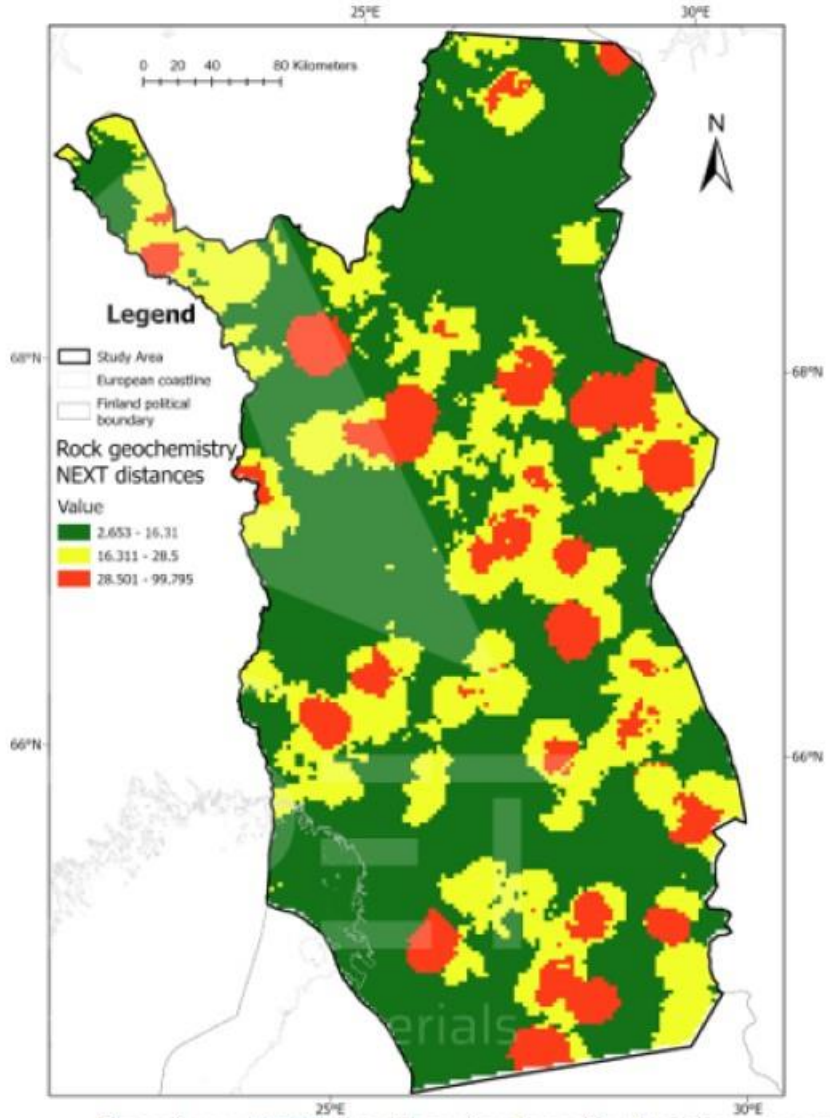
Distance to craton boundary



Craton boundary may provide channel to concentrate magma at **greater depth**

Geochemical outliers

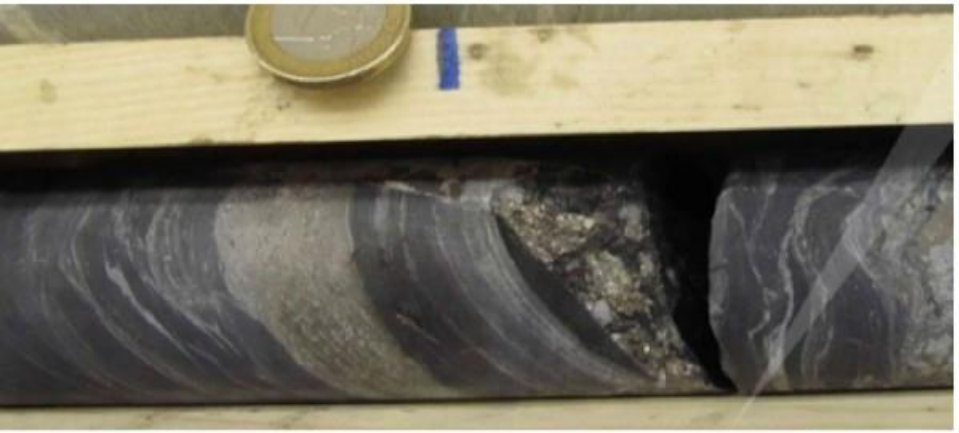




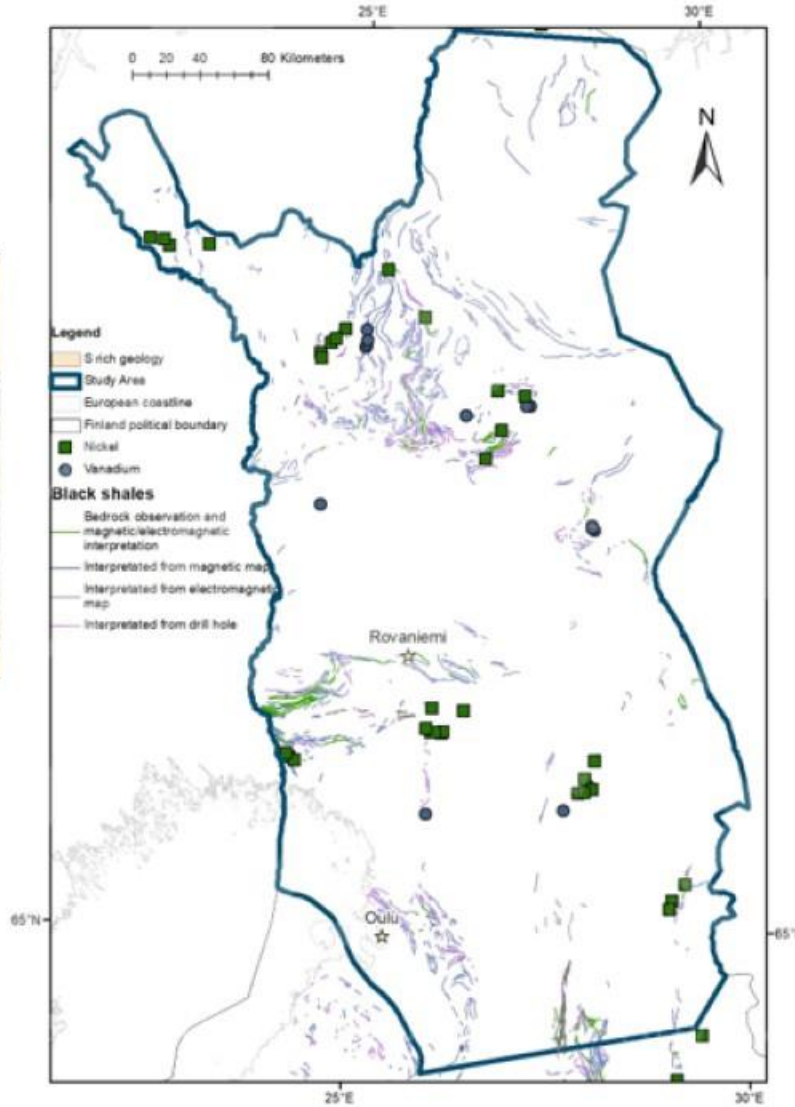
Based on ssMRCD algorithm developed by Puchhammer and Filzmoser, (2023)

External sulphur...

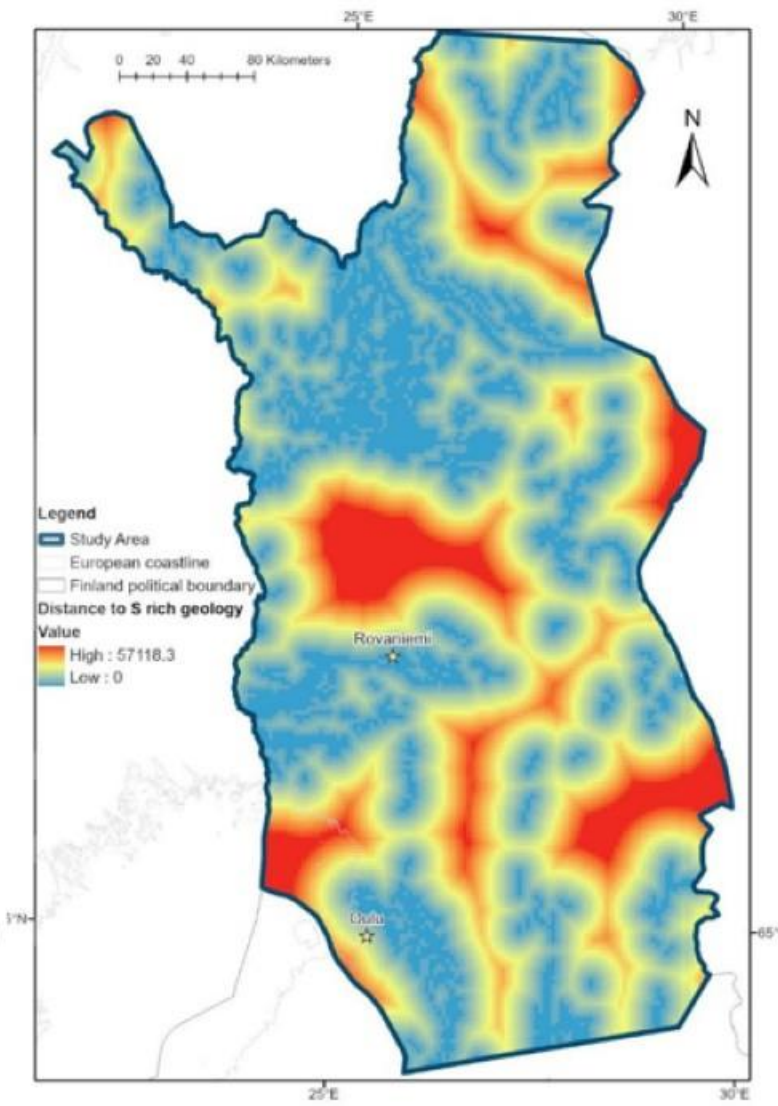
S-rich lithological units such as black shales, gypsum anhydrite, may provide external sulphur to form magmatic sulphide deposits



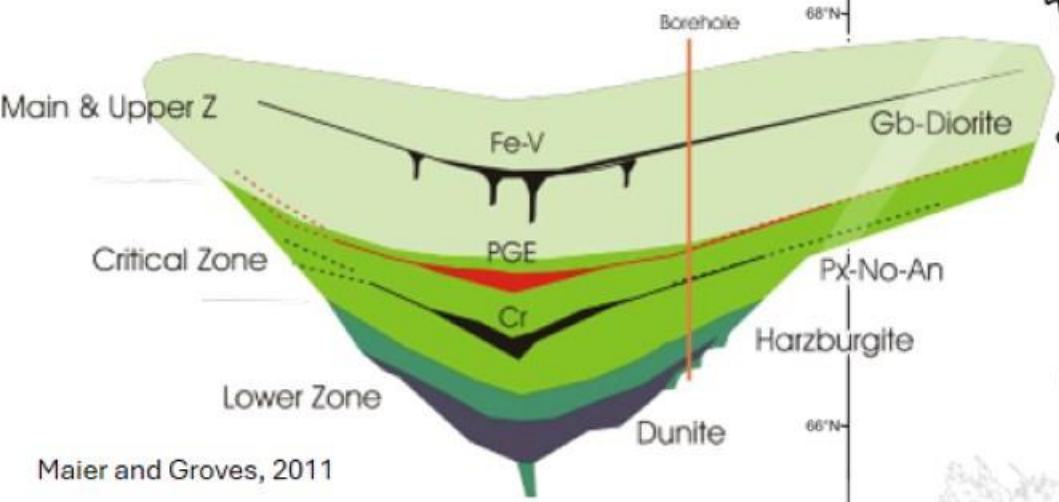
Mapped sulphur-rich geology and black shales from geophysical data



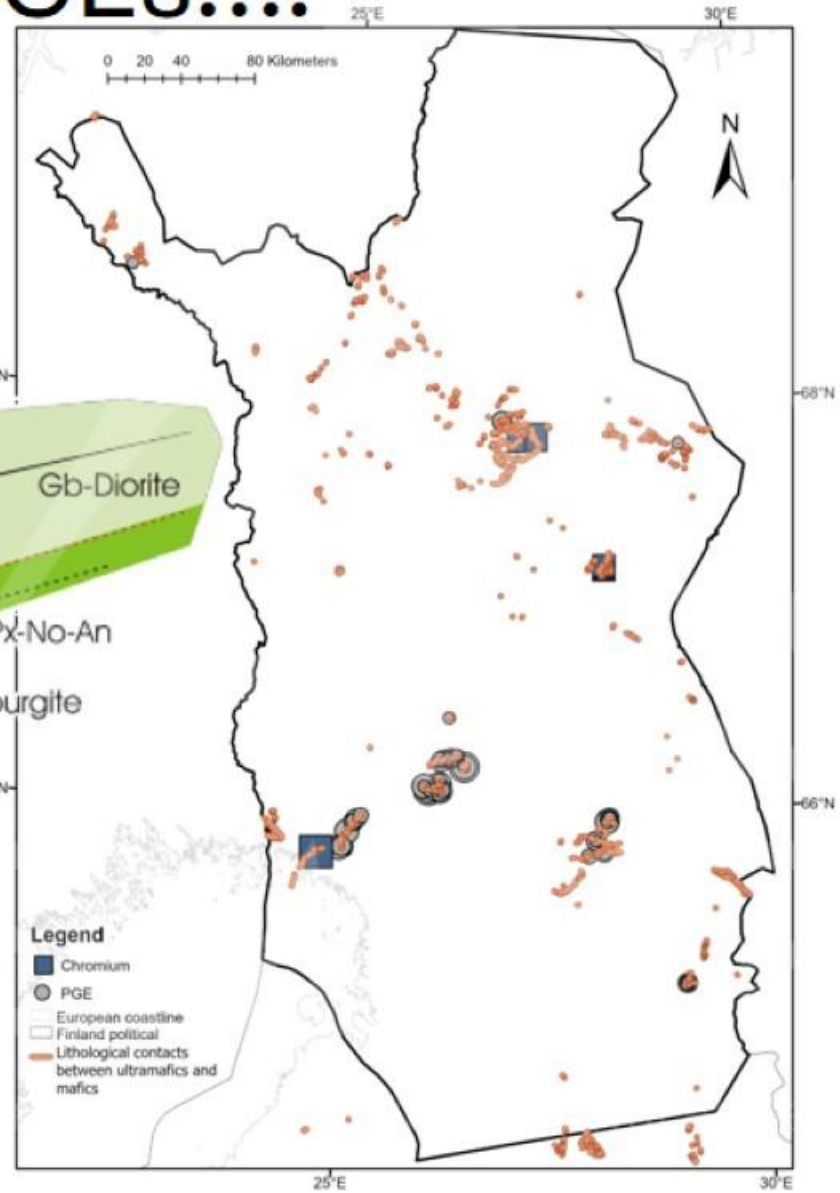
Distance to Sulphur-rich geology

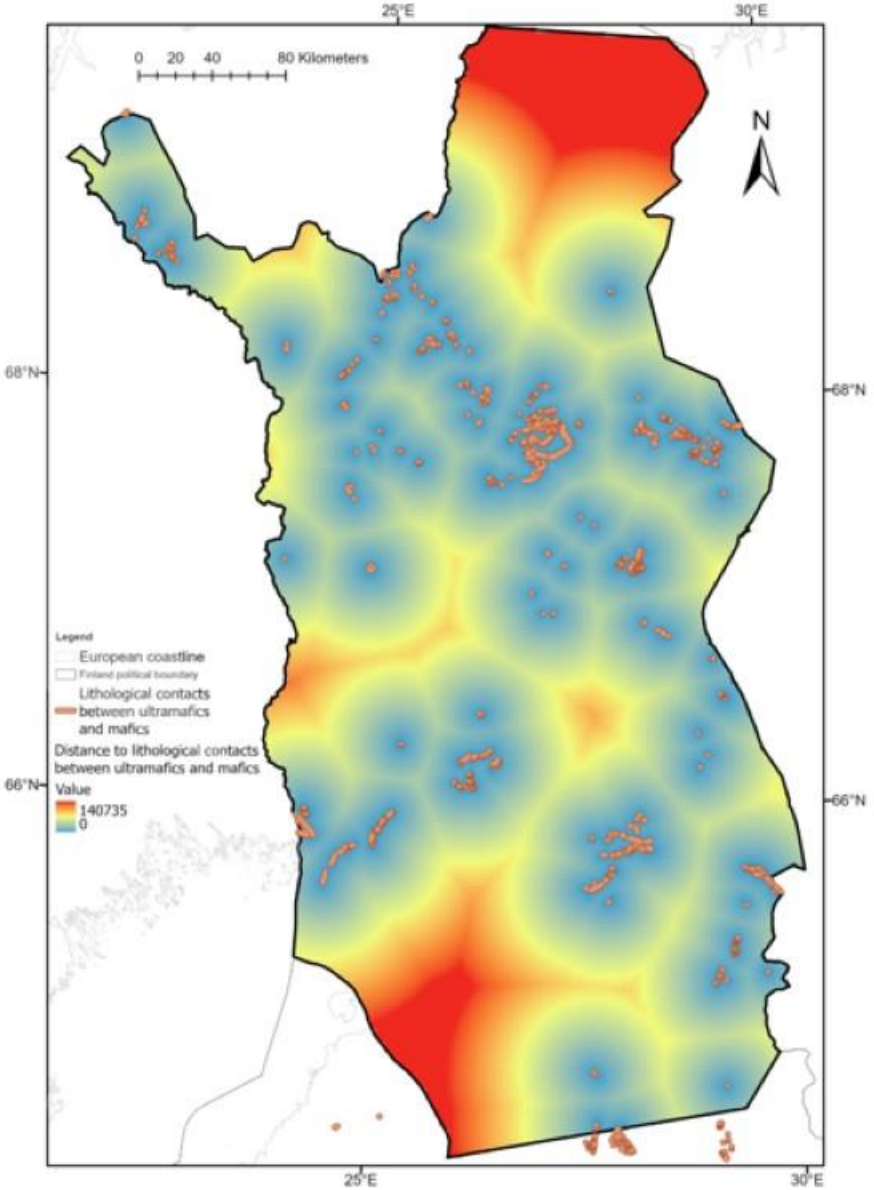


Layering for PGEs....



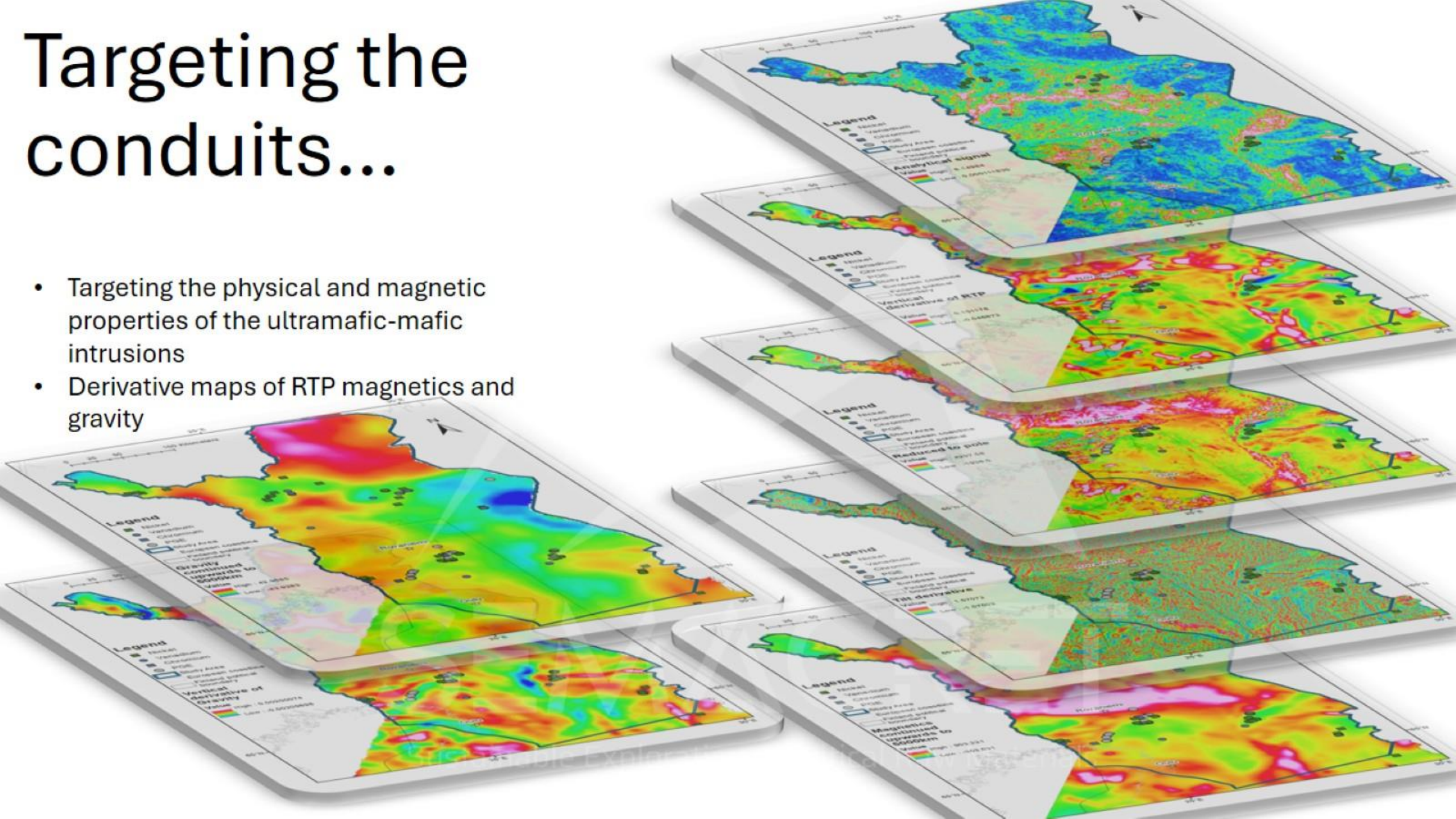
Maier and Groves, 2011





Targeting the conduits...

- Targeting the physical and magnetic properties of the ultramafic-mafic intrusions
- Derivative maps of RTP magnetics and gravity



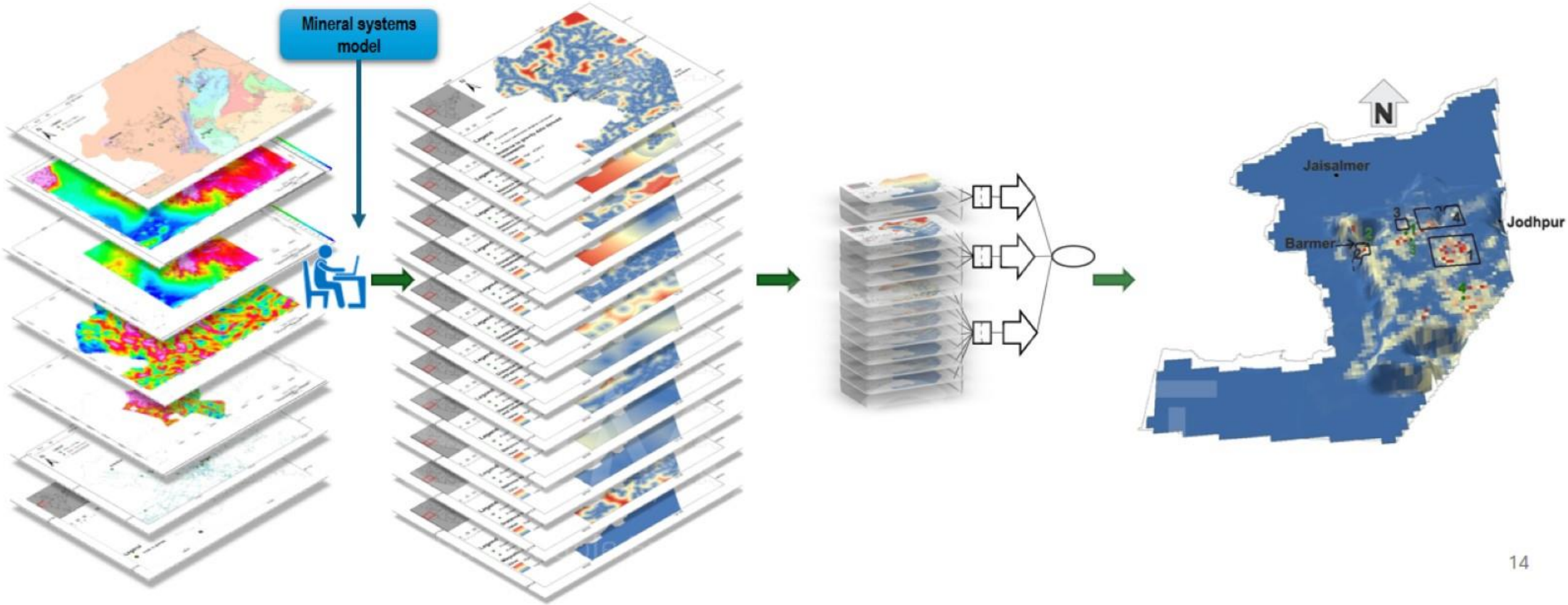
Prospectivity modelling workflow

PRIMARY DATASETS

MANUALLY EXTRACTED FEATURES

INTEGRATING ALGORITHM

OUTPUT PROSPECTIVITY MAP



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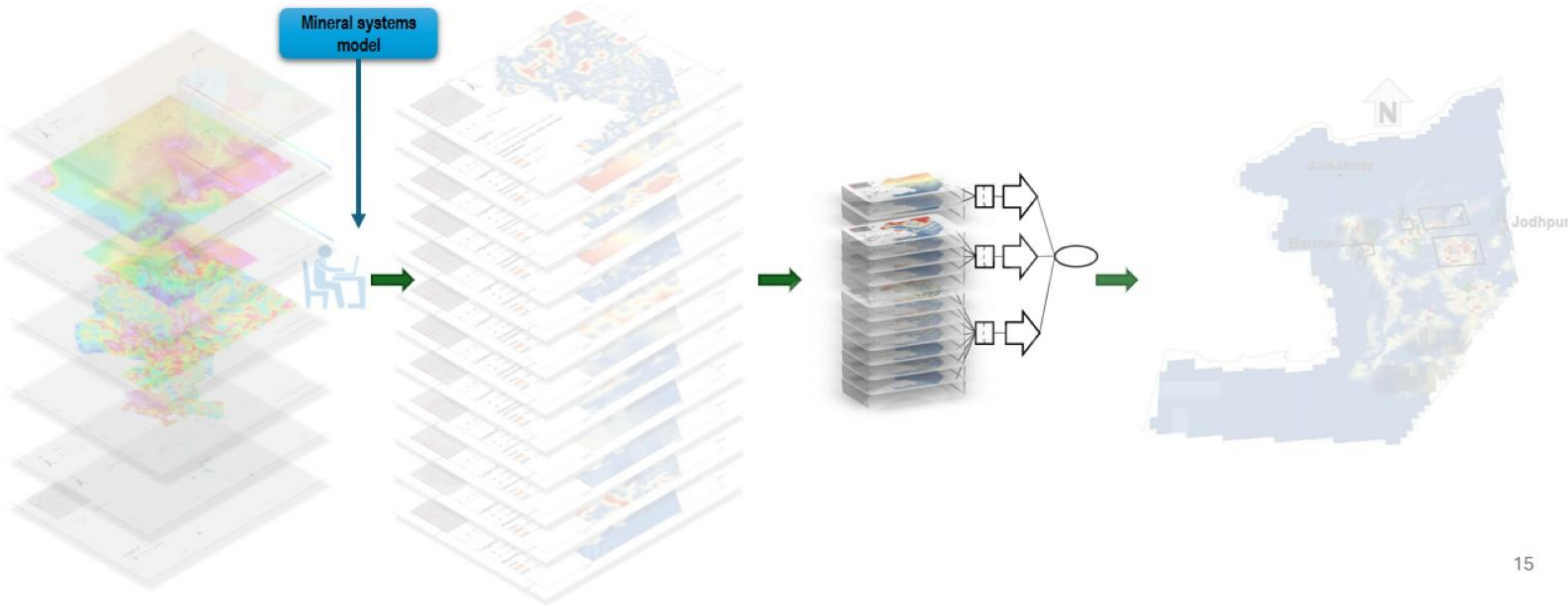
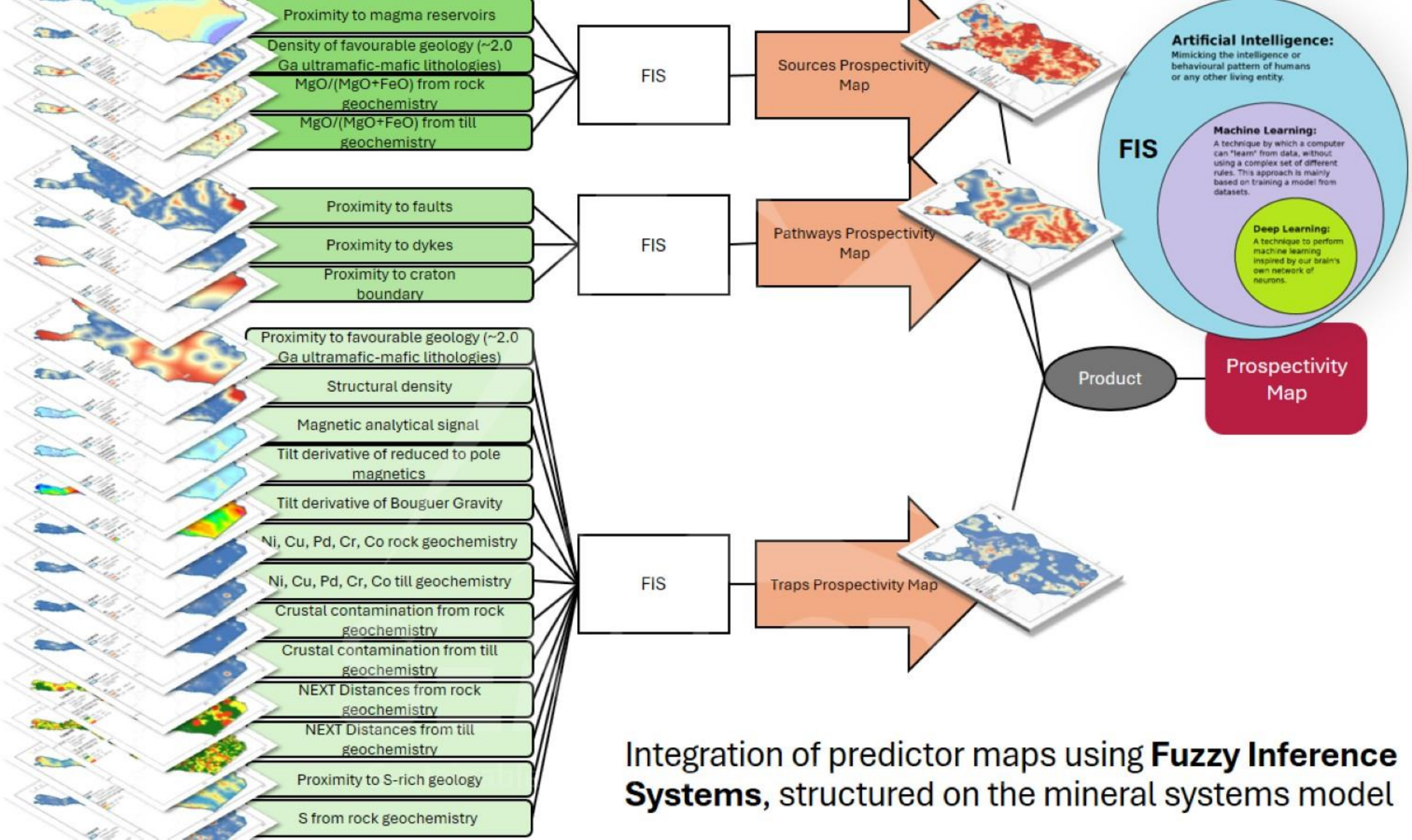
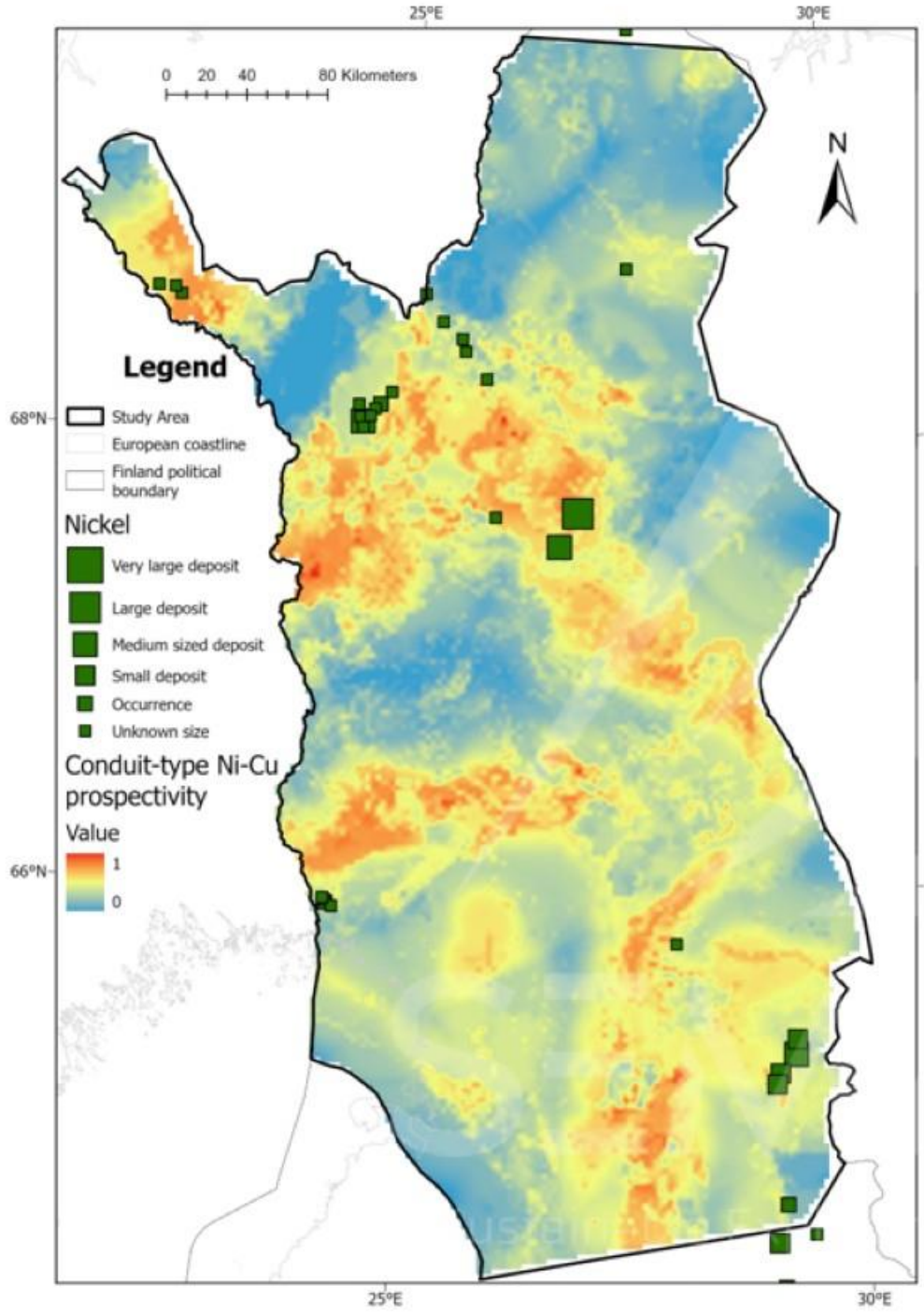
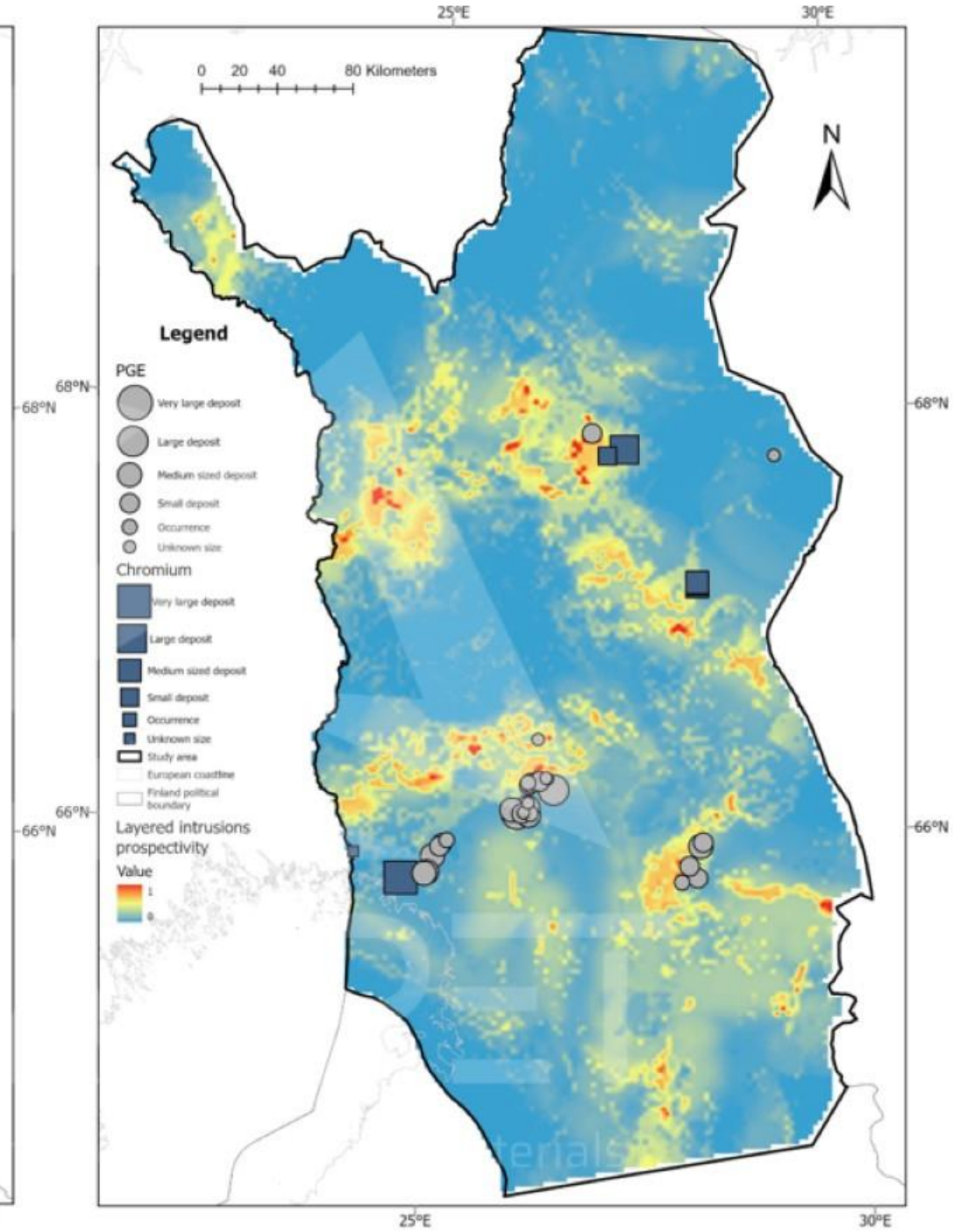


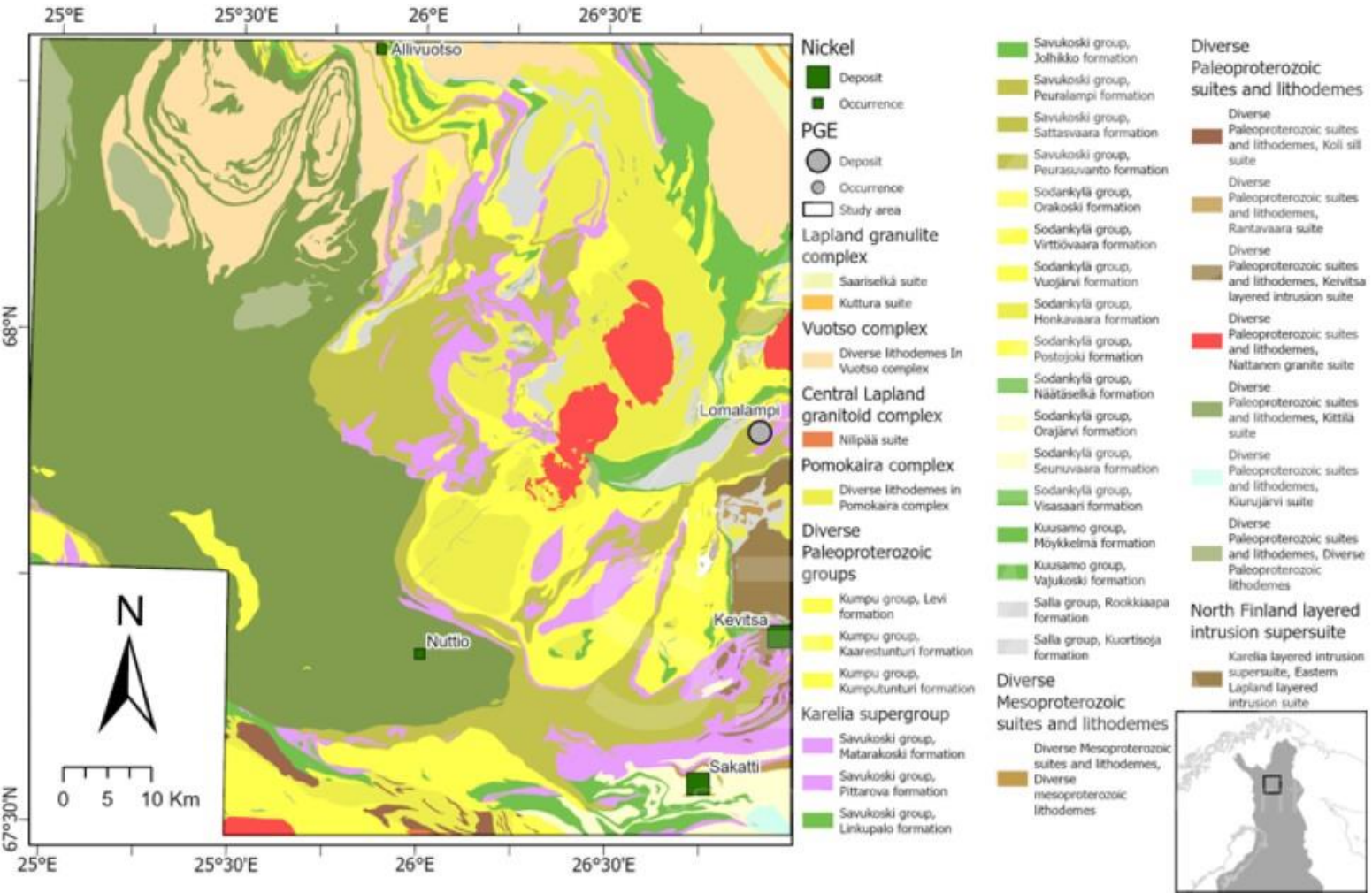


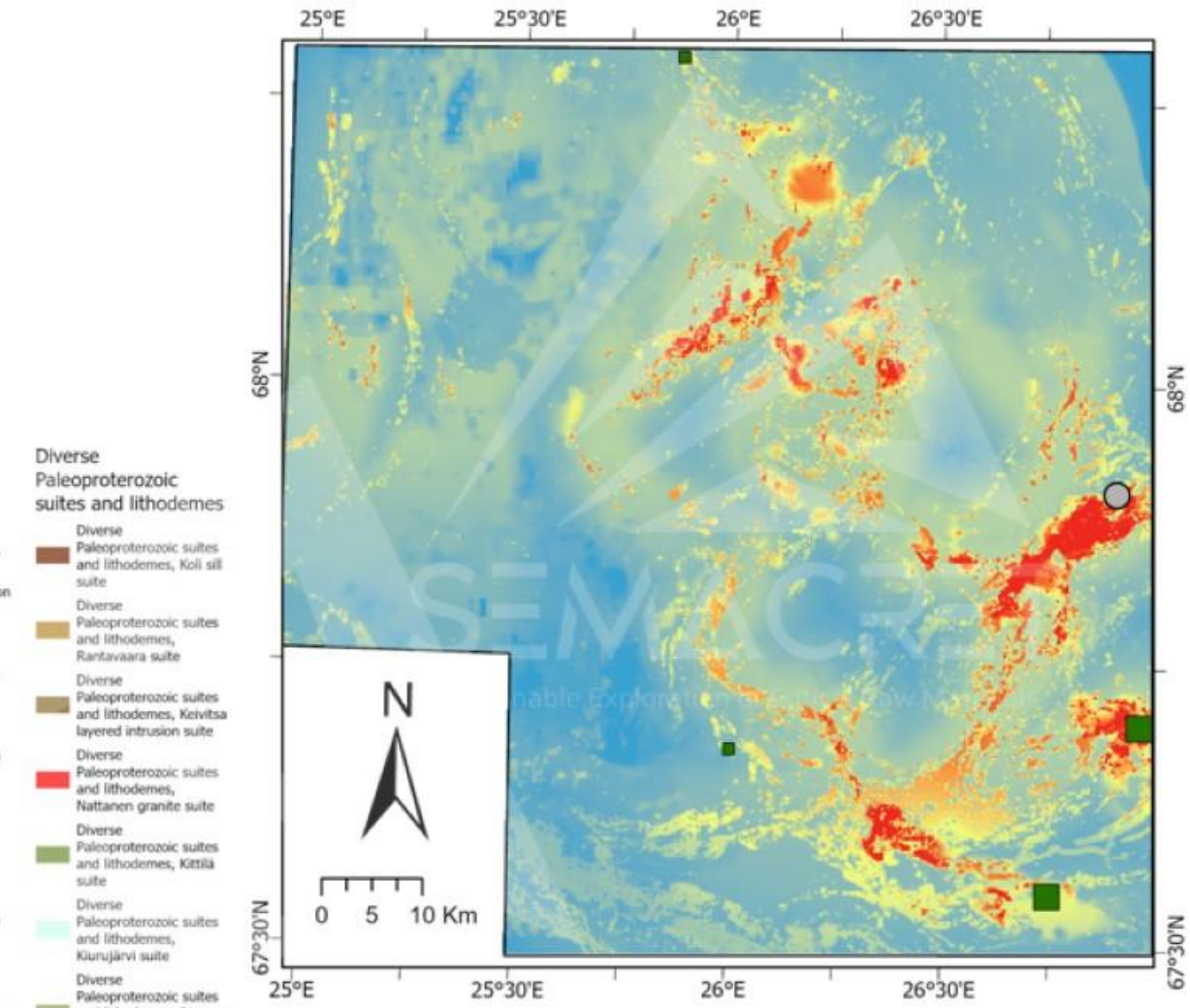
Integration of predictor maps using **Fuzzy Inference Systems**, structured on the mineral systems model


25°E
30°E
0 20 40 80 Kilometers
N
Legend
Study Area
European coastline
Finland political boundary
Nickel
Very large deposit
Large deposit
Medium sized deposit
Small deposit
Occurrence
Unknown size
Conduit-type Ni-Cu prospectivity
Value
1
0
68°N
66°N
25°E
30°E


25°E
30°E
0 20 40 80 Kilometers
N
Legend
PGE
Very large deposit
Large deposit
Medium sized deposit
Small deposit
Occurrence
Unknown size
Chromium
Very large deposit
Large deposit
Medium sized deposit
Small deposit
Occurrence
Unknown size
Study area
European coastline
Finland political boundary
Layered intrusions prospectivity
Value
1
0
68°N
66°N
25°E
30°E

Camp Scale analysis





Legend

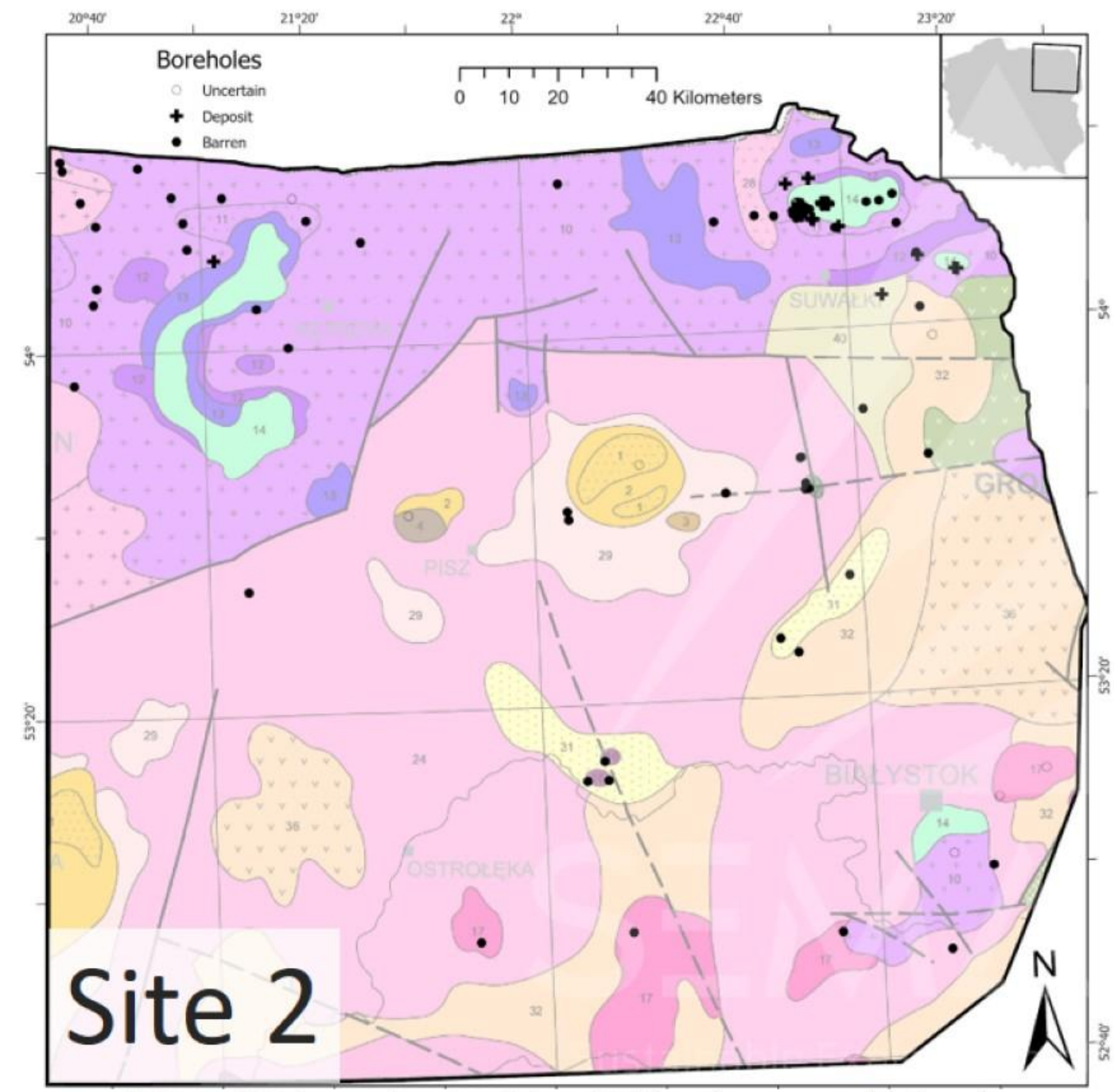
Nickel
- Deposit
- Occurrence

PGE
- Deposit
- Occurrence

Study area

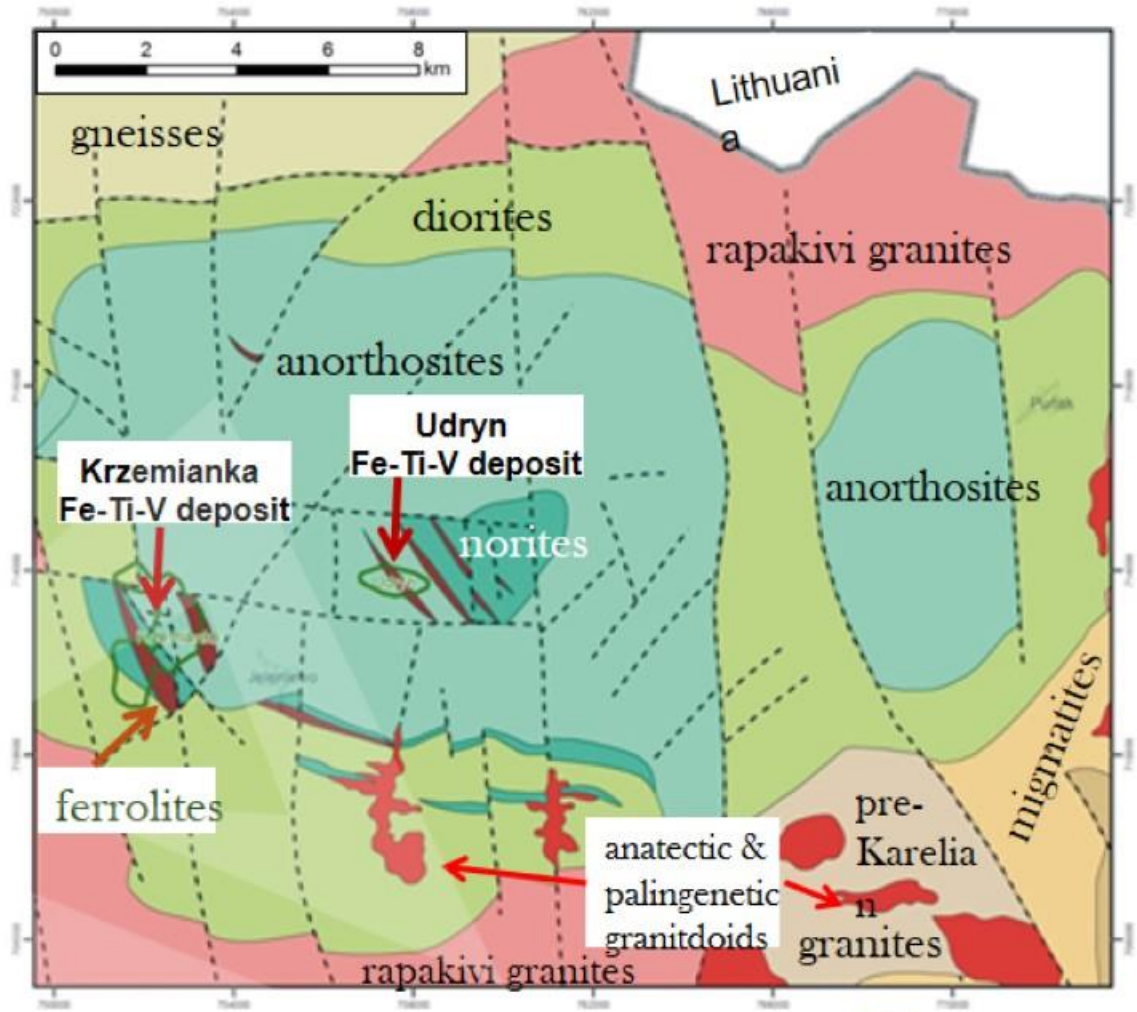
Prospectivity
Value
1
0

SEMACRET
Sustainable Exploration of Critical Raw Materials

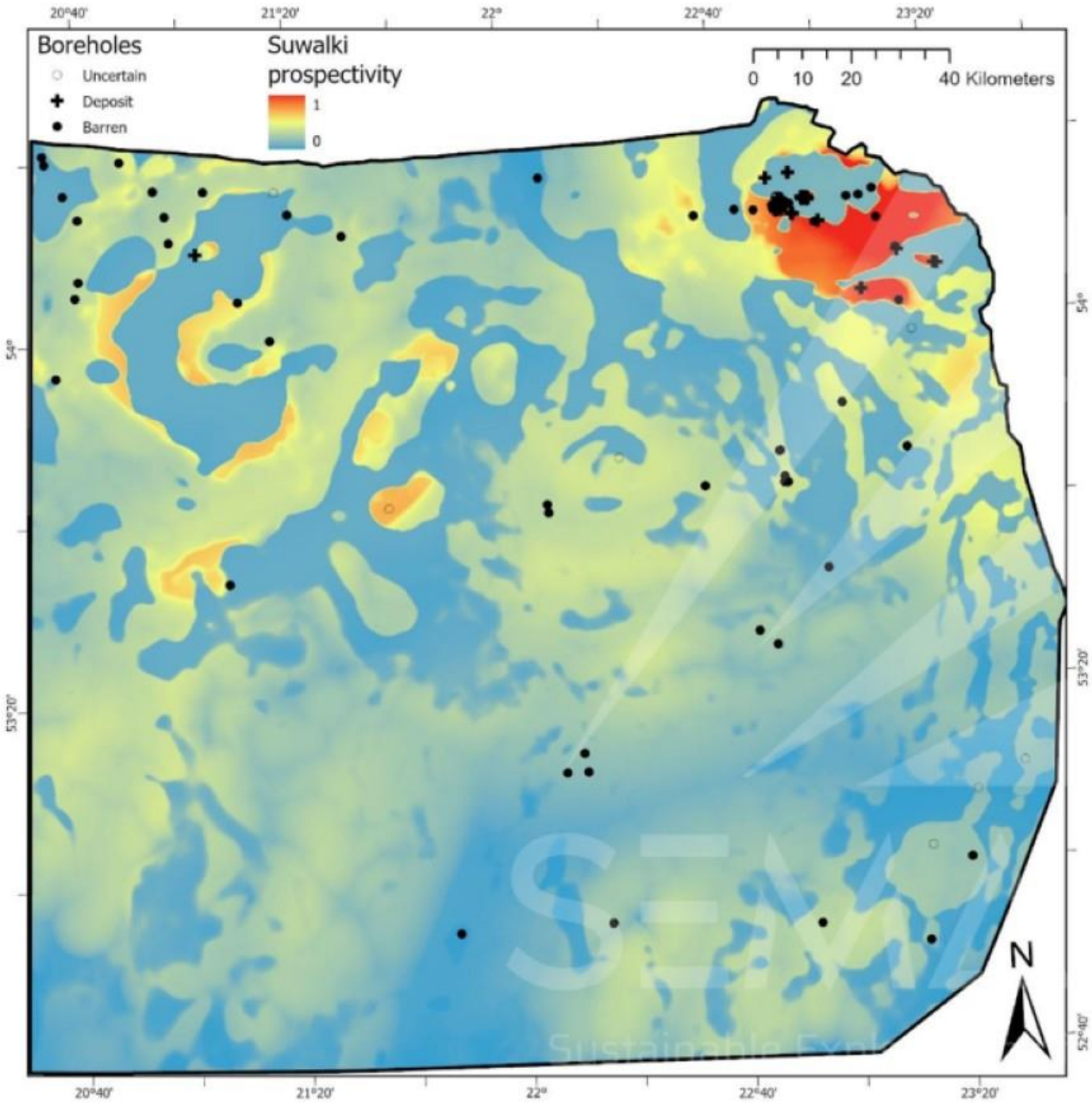


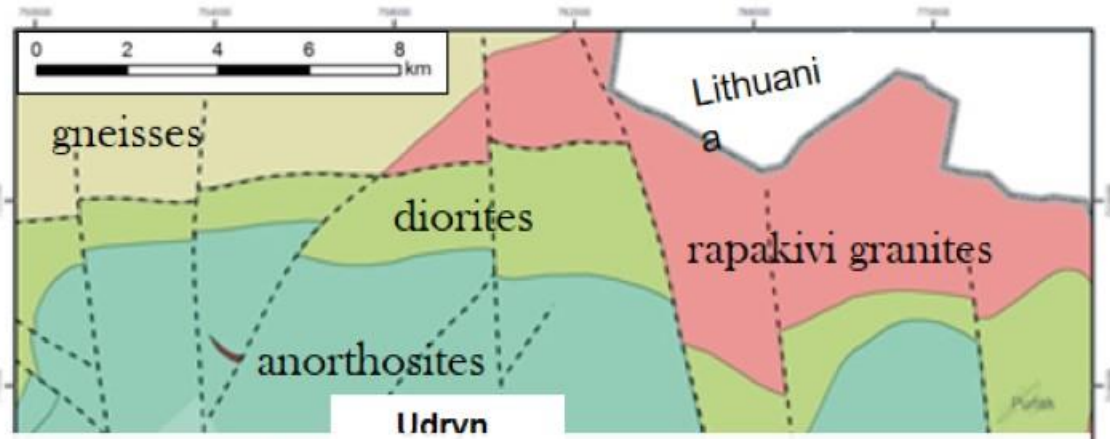
Site 2

around Suwałki Anorthosite Massif, Northeastern Poland



Anorthosite-
Mangerite-
Charnockite-
Granite (rapakivi)
Suite





Most known deposits are marked with high prospectivity

Would require camp-scale analysis to further refine targets

Low prospectivity at the interpreted occurrence in the south

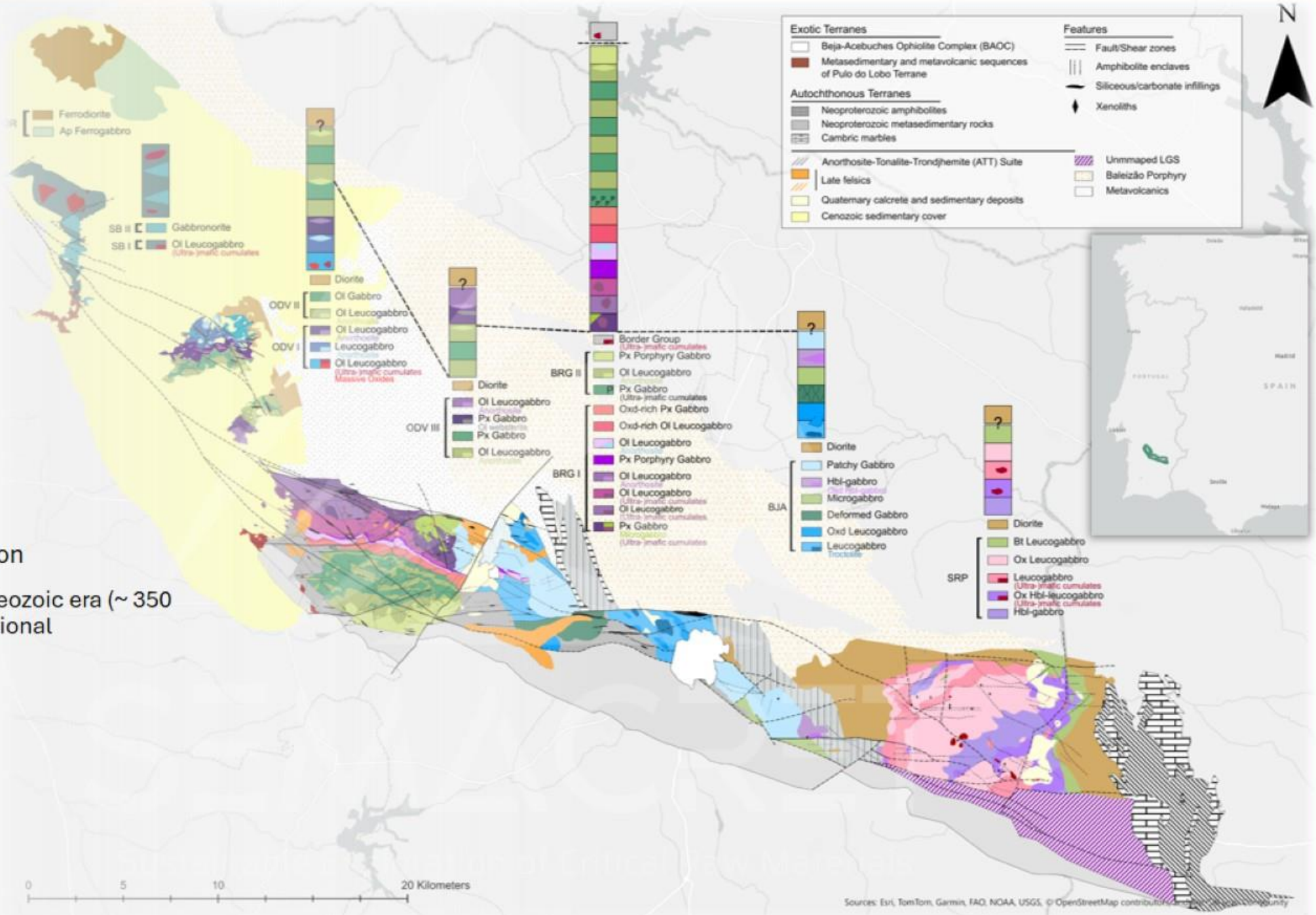
Deeper Kętrzyn occurrence has medium prospectivity, owing to its depth making it less viable.

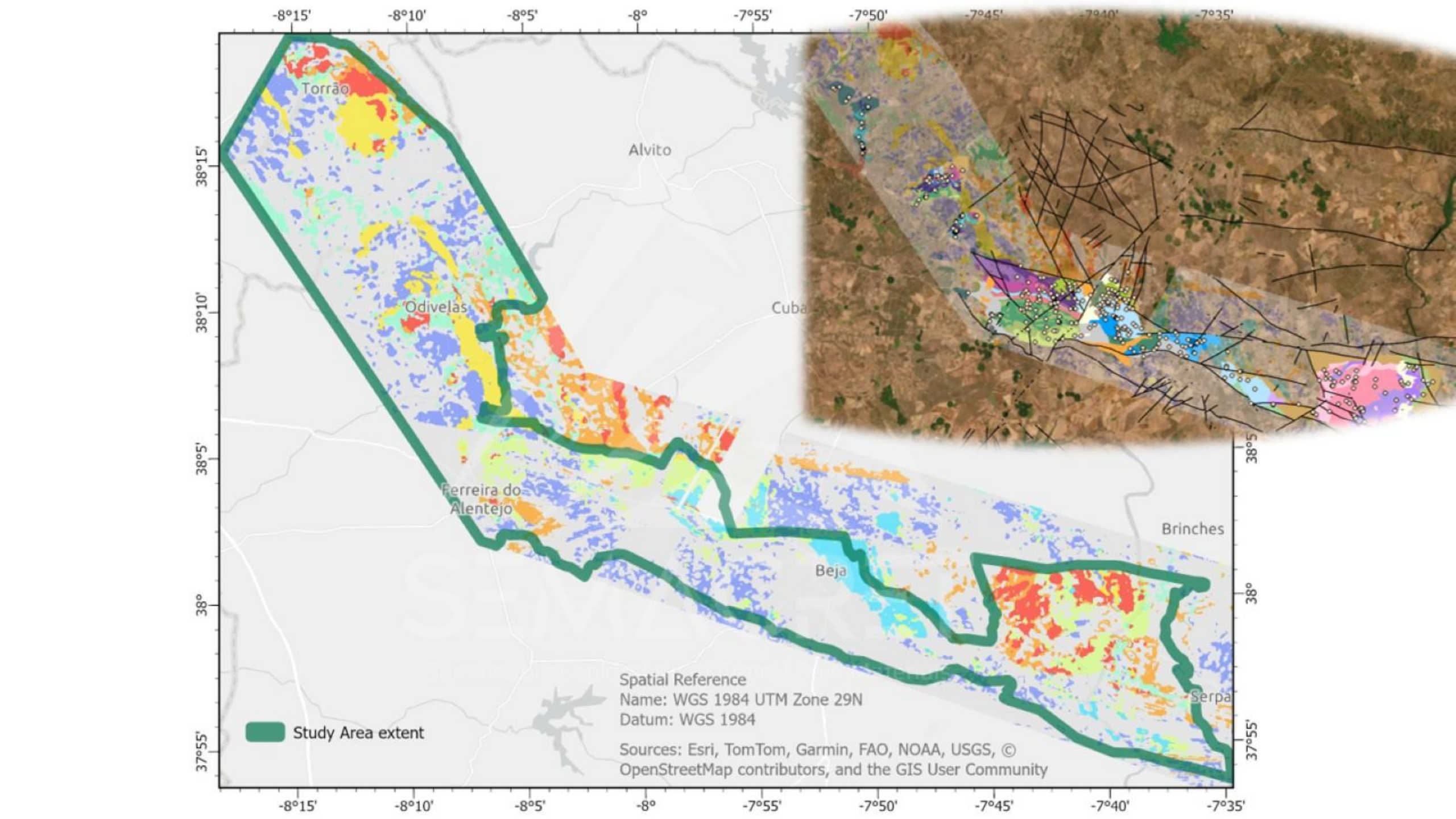
Modern data survey can be planned to address short-comings

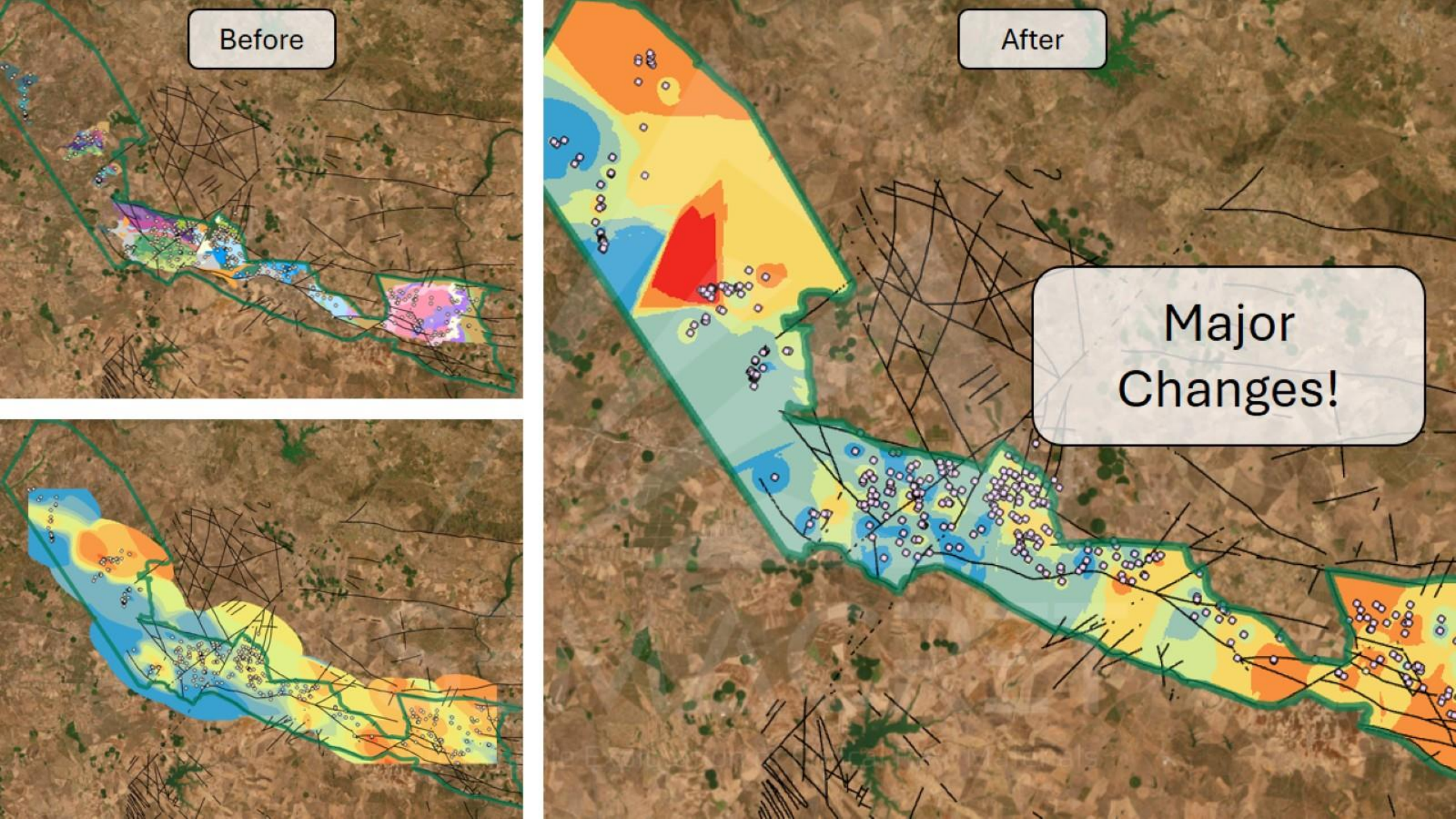
Projects such as DeepBEAT and DEXPLORE working on potential solutions for depth penetration

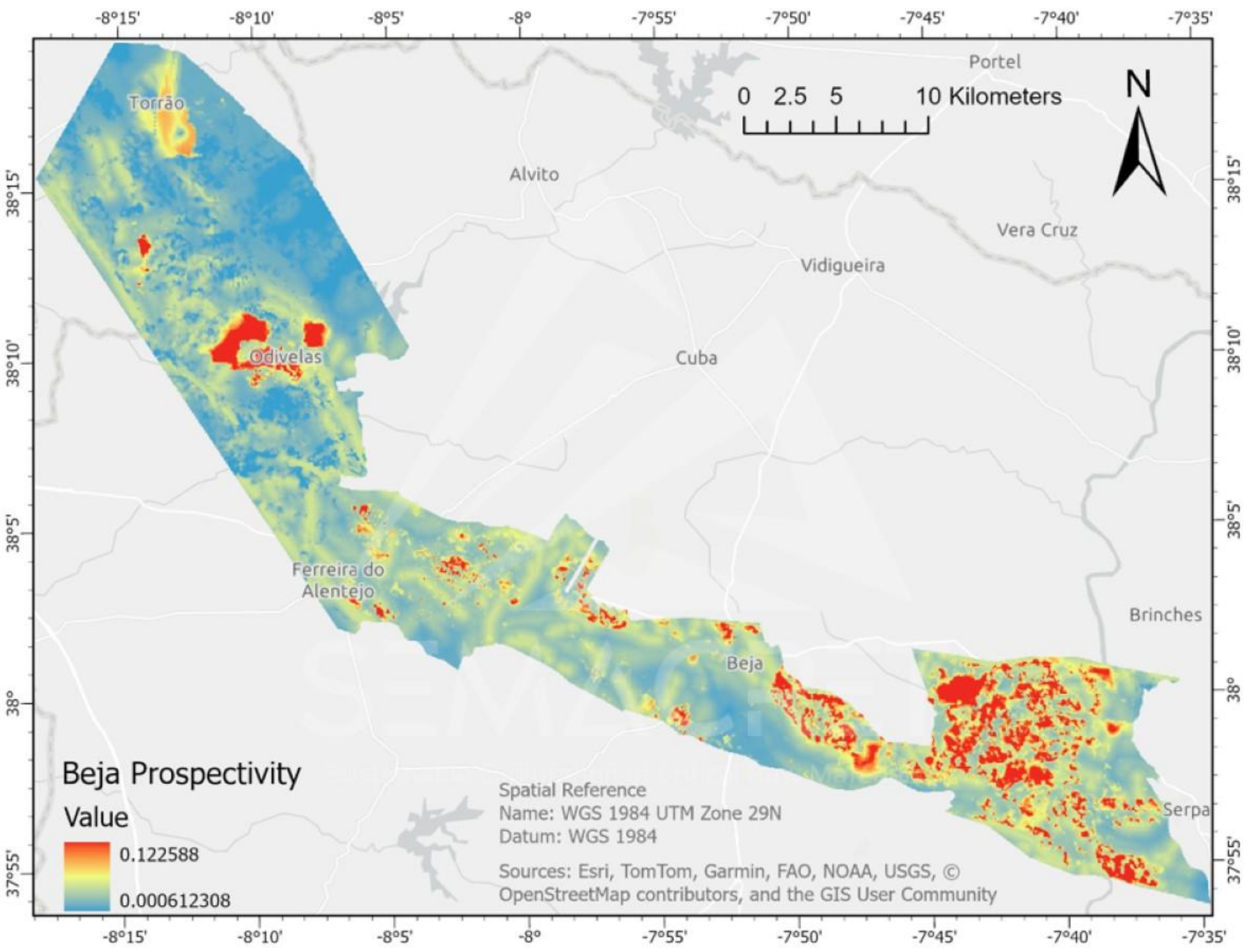
Site 3: BEJA

- Layered gabbroic intrusion
- formed during the late Paleozoic era (~ 350 Ma) in a syn- to post-collisional extensional setting




-8°15'
-8°10'
-8°5'
-8°
-7°55'
-7°50'
-7°45'
-7°40'
-7°35'
38°15'
38°10'
38°5'
38°
37°55'
Torrão
Alvito
Odivelas
Cuba
Ferreira do Alentejo
Brinches
Beja
Serpa
Study Area extent
Spatial Reference
Name: WGS 1984 UTM Zone 29N
Datum: WGS 1984
Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community


Before
After
Major Changes!


-8°15'
-8°10'
-8°5'
-8°
-7°55'
-7°50'
-7°45'
-7°40'
-7°35'
38°15'
38°10'
38°5'
38°
37°55'
Portel
0 2.5 5 10 Kilometers
N
Torrão
Alvito
Vera Cruz
Vidigueira
Odivelas
Cuba
Ferreira do Alentejo
Brinches
Beja
Serpa
Beja Prospectivity
Value
0.122588
0.000612308
Spatial Reference
Name: WGS 1984 UTM Zone 29N
Datum: WGS 1984
Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Key take aways..

- Proven effective methodology for efficient exploration
- Demonstrated innovative proxies and predictors
- New Fe-Ti-V occurrence discovery in Beja

Thank You

WWW.SEMACRET.EU

#SEMACRET
#CriticalRawMaterialsEU
#SustainableExplorationEU

m.aranha@hzdr.de

SEMACRET
Funded by the European Union
UK Research and Innovation

EIS
Exploration
Information
System

Tony Hand (TalTech)

DEXPLORE

Clustering session: Advancing mineral exploration through innovative technologies

11:00 – 12:15

DEXPLORE

Recognising European Potential for hosting deep-land primary CRM by combining new mineral models and advanced exploration and visualisation techniques.

EIS Final Event: Shaping the Future of Sustainable Mineral Exploration.

EIS Exploration Information System

Brussels, 7th October 2025

Tony Hand, PhD.
Sustainable Mining Project Manager,
Division of Mining and Mineral Technology,
Department of Geology,
Tallinn University of Technology – TalTech

Funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

Overview

Recognising EU potential for hosting deep-land primary CRM by combining new mineral models and advanced exploration and visualisation techniques

HORIZON-CL4-2024-RESILIENCE-01

Focus on deep-seated deposits

Increasing the acceptability of mining projects from the exploration stage

Targeting CRM and SRM at least up to 600 m depth; geophysic developement

CRM: F - Cu - Ni - C
SRM: Mn - Mo - Zn - Pb

DEXPLORE KEY DATA

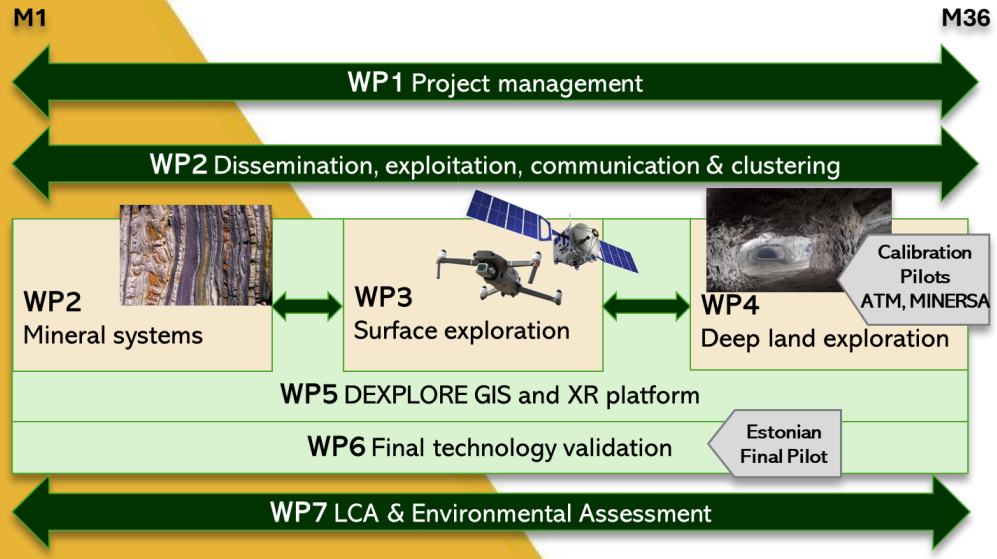
HE - PILLAR 2 CLUSTER 4: DIGITAL, INDUSTRY AND SPACE

CALL
HORIZON-CL4-2024-RESILIENCE-01

TOPIC
HORIZON-CL4-2024-RESILIENCE-01-0124-RESILIENCE-01-01

TYPE OF ACTION
RIA

TRL 3-5
by the end of the project



- **Project number:** 101178897
- **Granting authority:** European Health and Digital Executive Agency
- **Duration:** 36 months, 1st Oct 2024 – 30th Sept. 2027.
- **Total Budget:** 4,669,428.75; 100% EU contribution
- **8 WPs**, 642.3 PM, 34 tasks, 17 KPIs, 29 Deliverables, 14 Milestones

CONSORTIUM

11 Partners + 2 Affiliated Entities

Mineral Models and Final Pilot

EO + Visualization Platform + LCA

Geophysics
Calibration pilots

Optical techniques
(LIBS, RAMAN)

Pilot areas

Spain

Tests pilots for new geophysics

Iberian Pyrite Belt (VSHMS deposits)

Asturias (Fluorite mineralisation, 900m)

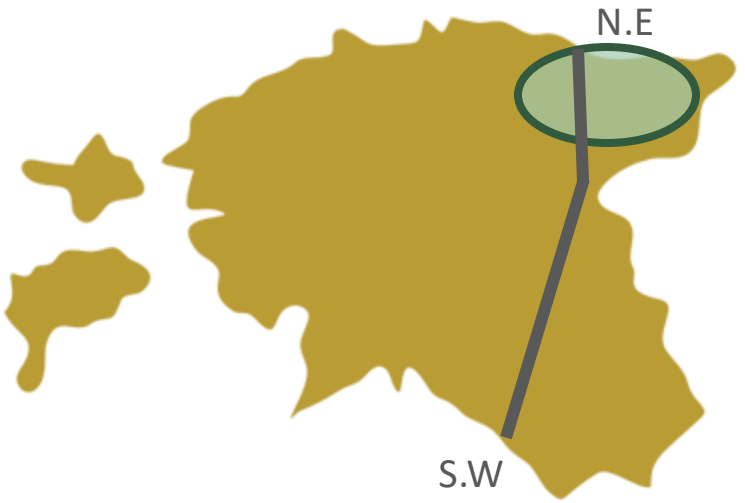
Development of remote sensing-based approaches

Compact Remote Raman+LIBS+Fluo

Aerial vehicle airborne gravimetry

Estonia

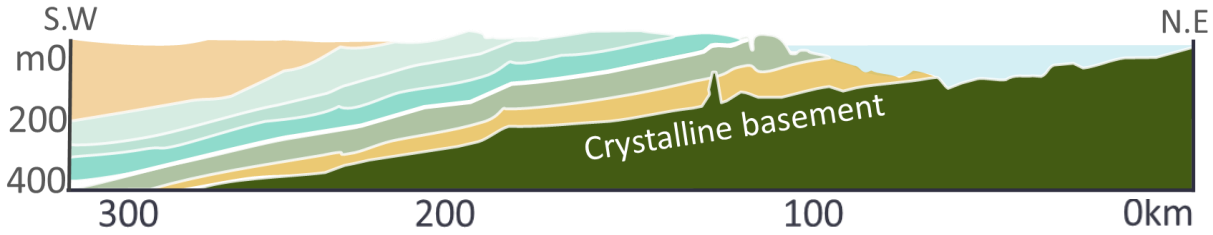
Final pilot



N.E Estonia

Deep land Exploration

Overburden 100-780m



TWO CALIBRATION PILOTS - SPAIN

ANDALUCIA

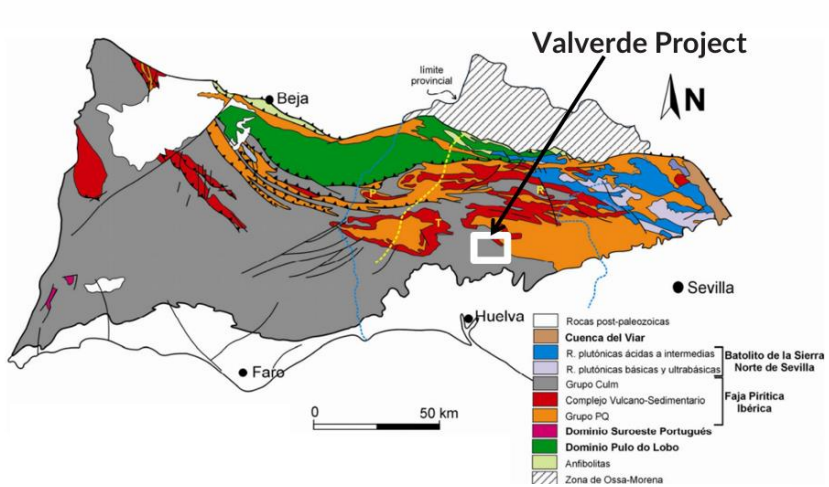
ATALAYA RIOTINTO

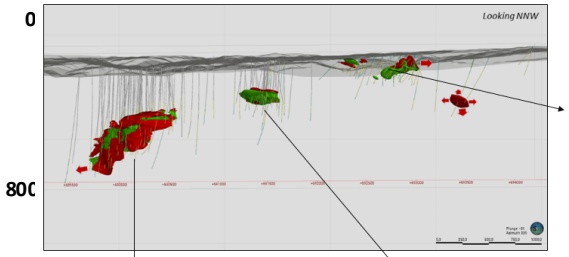
DIRECT METHODS

Cu (SRM), Zn, Pb

Massive/stockwork sulphides

Depths up to 900 m





Campanario-Descamisada Trend

- Cropping out
- 4km by 300m alteration trend
- 650m long, 200m wide and 20m thick
- >500 soil samples (33 elements analysed), 100x100m grid

Masa Valverde Deposit

- 400 - >800m deep, under Culm
- 1350m long, 300m wide, >100m thick

Majadales Deposit

- 300 - 450m deep, under Culm
- 650m long, 200m wide, 20m thick

Source: Modified from Donaire, T. et al., 2008; and Simancas, J. F. et al., 2003.

ASTURIAS

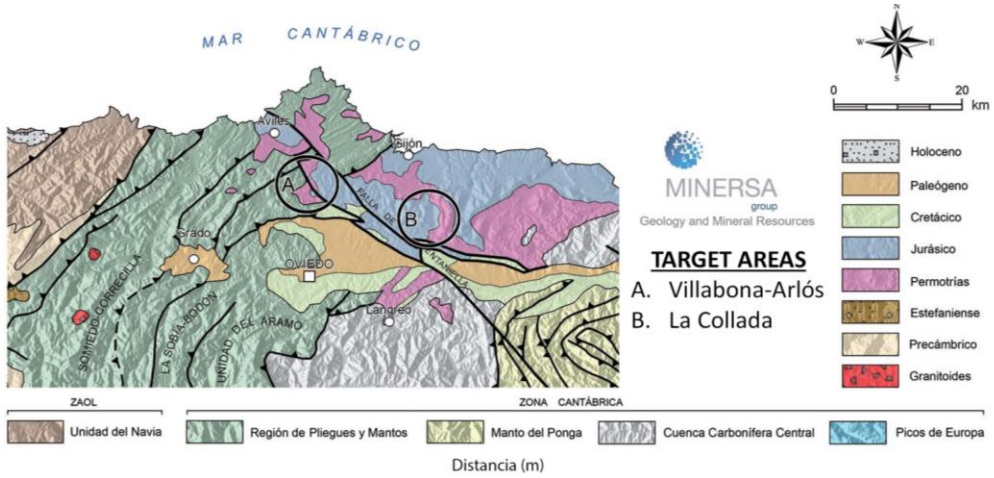
MINERSA group

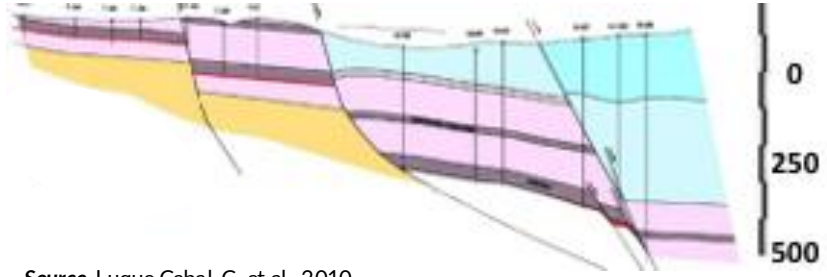
INDIRECT METHODS

Fluorite (Fluorspar – CRM)

Mineralization along planar structures

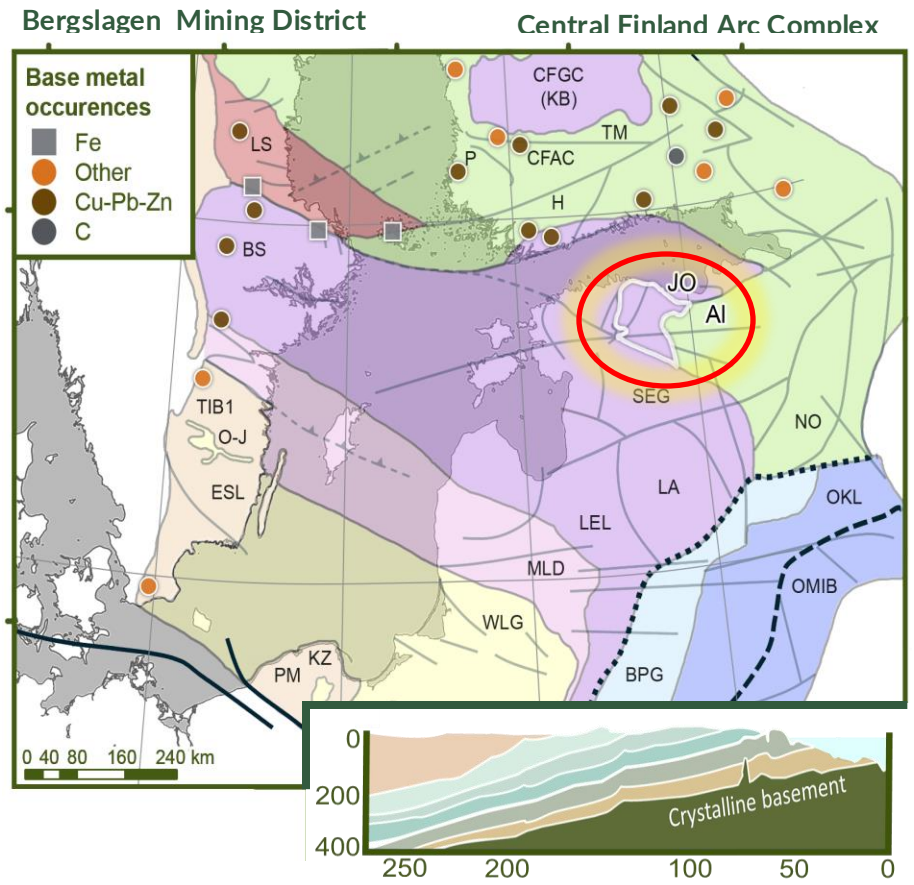
Depths >500 m

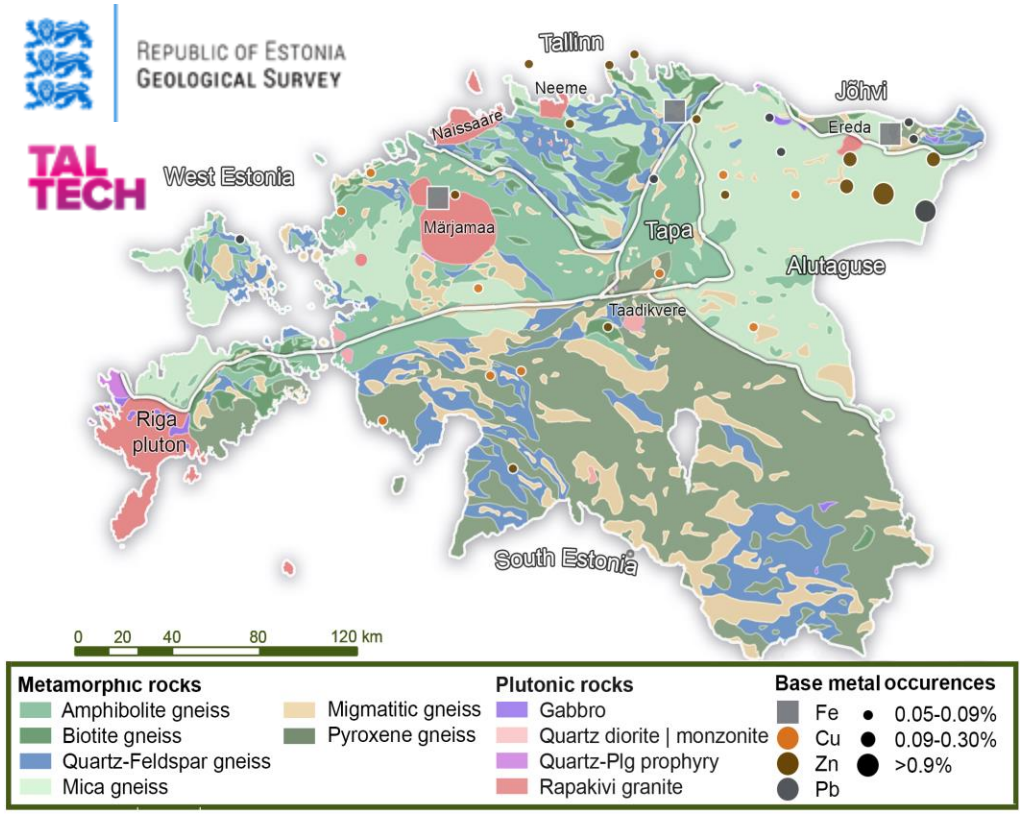




Source. Luque Cabal, C. et al., 2010.

ONE FINAL VALIDATION PILOT - ESTONIA





Sources. DEXPLORE: Unravelling CRM potential of Estonian Precambrian basement
Is the Estonian Alutaguse Section of Eastern Fennoscandia a continuation of the Southern Svecofennian Finnish Terranes, or is it akin to the Swedish Bergslagen region?

Precambrian basement

Metamorphic basement
Mostly meta-volcanic, sedimentary rocks in the amphibolite to granulite facies and plutons covered by up to 700 m thick sedimentary sequence.

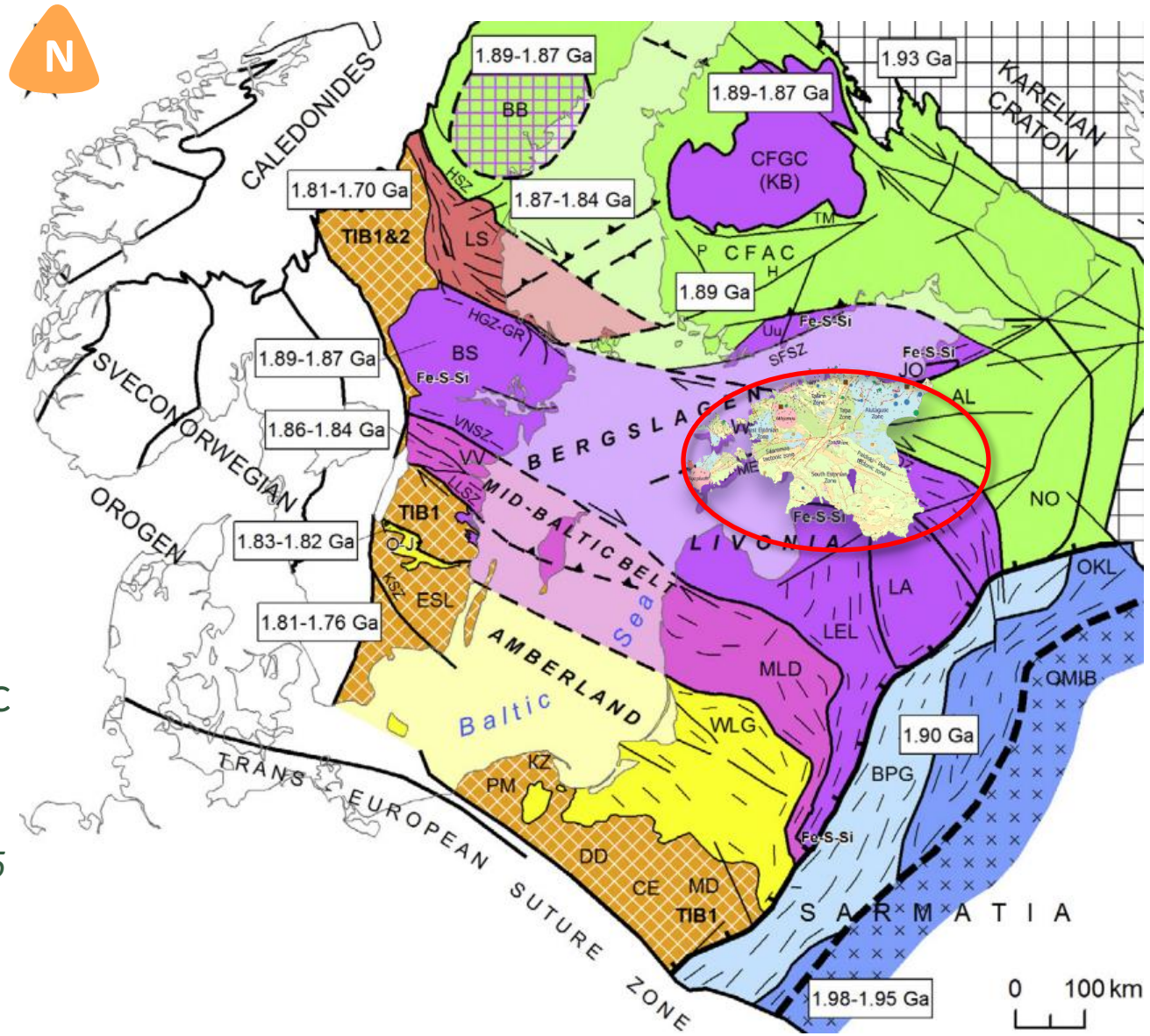
Alutaguse:
Cu – Pb – Zn

Jõhvi:
Fe, Ti - V

Geological settings

Crustal structure in the central and southern parts of the Svecofennian orogen as integrated across the Baltic Sea

Bogdanova et al. 2015

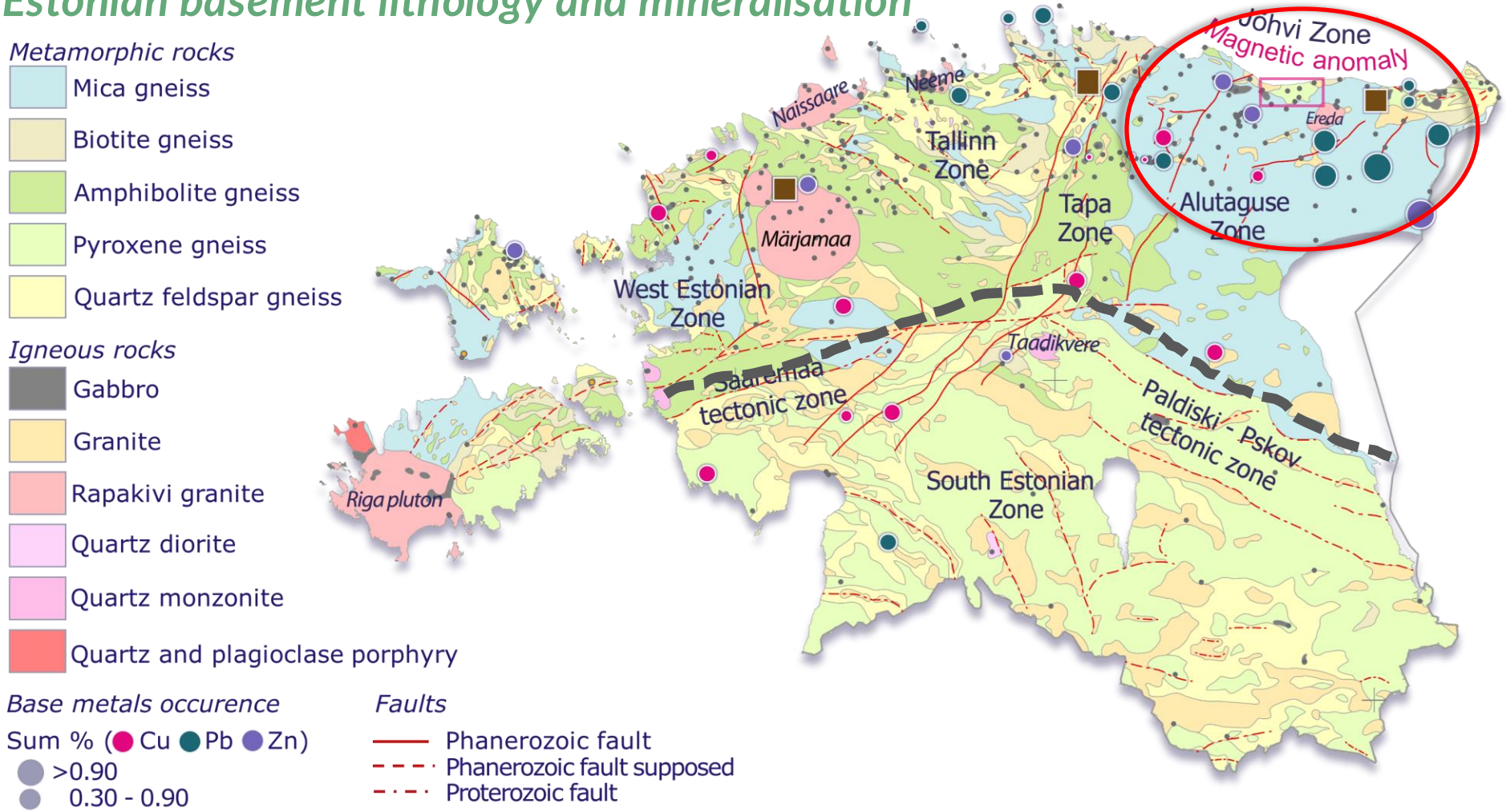


Estonian basement

- Palaeoproterozoic Svecofennian orogen in the Fennoscandian Shield
- Relations to the **Berslagen-Livonia** microcontinent and **Central Finland Granitoid Complex**.
- In Estonia, mostly meta-sedimentary rocks in the amphibolite to granulite facies and Rapakivi plutons

Geological settings

Estonian basement lithology and mineralisation



Two main facies

- Amphibolite facies rocks of northern Estonia (±S. Finland), mica and amp. gneisses
- Granulite facies rocks of southern Estonia

Nirgi and Soesoo, 2021

Projects aims in Estonia

Exploration

Increase the knowledge about the occurrence of primary CRM by identifying anomalies and target promising mineralisation by using advanced laboratory methods and data analytics to examine large, multi-element datasets.

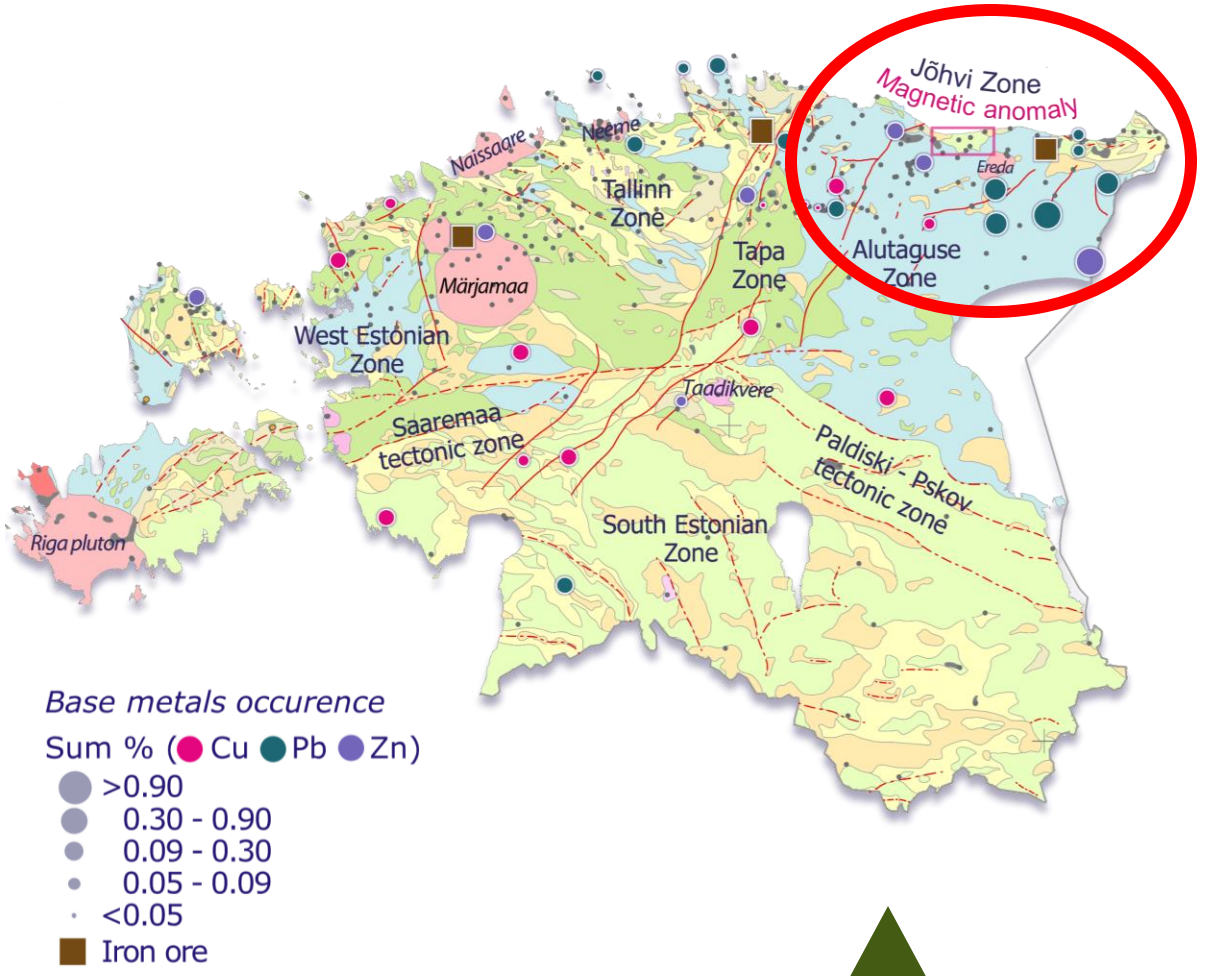
- *Assessing current data, historical drillcore XRF and hyperspectral scanning*
- *Geochemical and textural analyses campaigns*
- *Preparing for upcoming geophysical surveys*

Metallogeny

Define mineral systems for the targeted phases (Sulphides, magnetite, graphite and Mn-garnet) and geological/geophysical models

Broader picture

Compare the characteristics and CRM potential of the Estonian Precambrian basement with the Swedish (Berslagen) and Finland (Uusimaa) related provinces.



Nirgi and Soesoo, 2021

DEXPLORE EXPLORATION PACKAGE

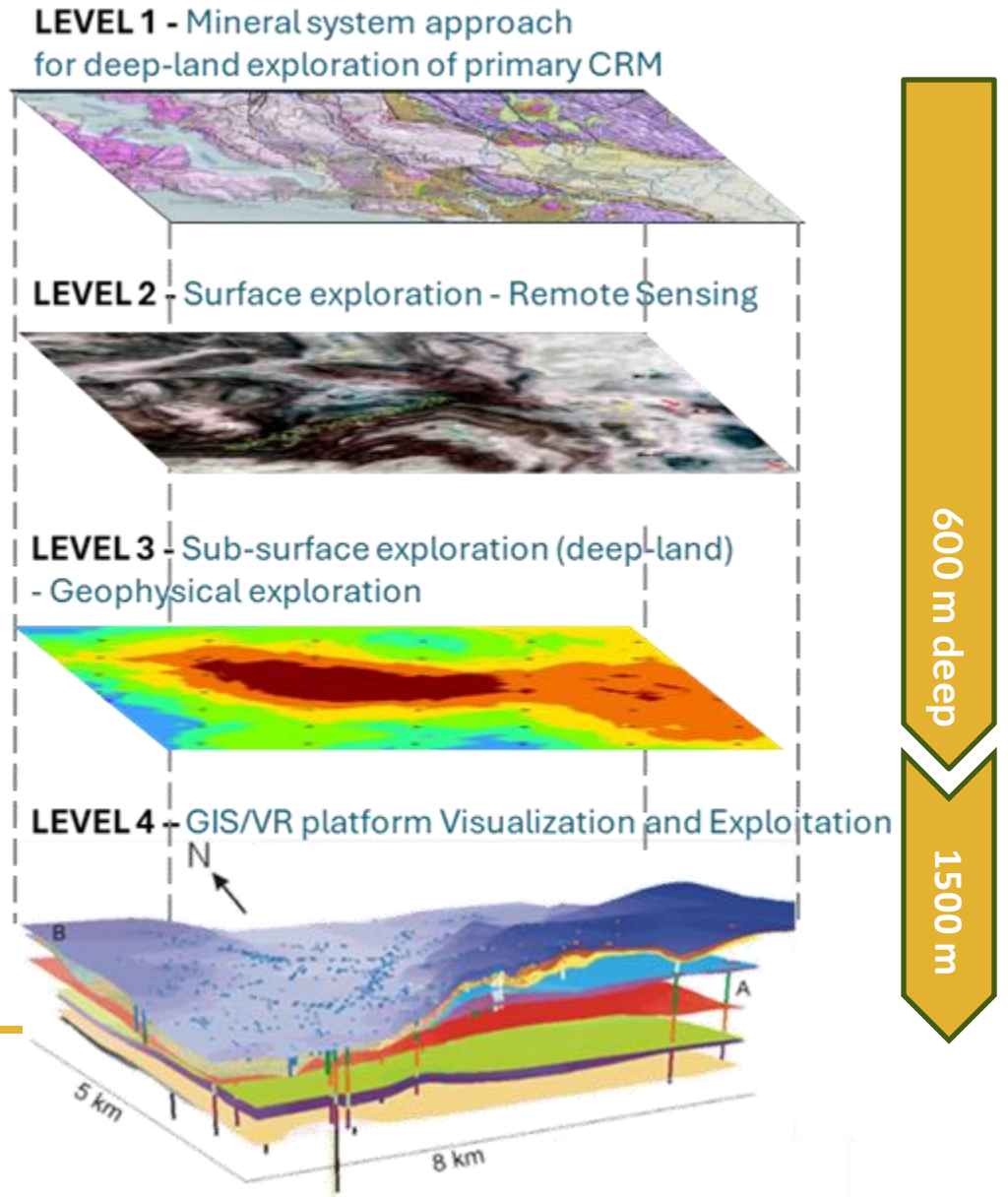
Updated Ore Models: **Preexisting data (**geochemistry, geophysics, petrophysics) **+** new geochemical data acquired with **modern techniques (XRF, XRD, ICPMS, SEMEDS/EPMA, LA-ICP-MS) + multiscanning of drill cores**.

Multispectral and Hyperspectral: Imaging analysis (Copernicus).

Optical Techniques: **Novel remote (UAV) field mineral detector (RAMAN, LIBS).** ML/DL for detection of target minerals with remote sensing data.

Novel UAV-based airborne gravimetry: capable of measuring 1mGal accuracy at wavelengths of 500m.

Seismic Land-based survey: Based on an avant-garde Passive seismic methodology (wireless seismic nodes) applied to **complex geological settings (potential up to 1,500 m depth).**

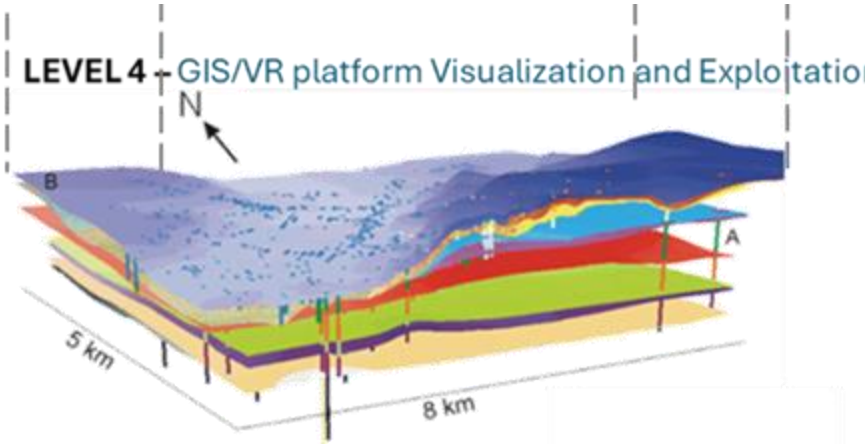


Non-invasive, cost-effective, and sustainable exploration technologies

SOCIAL AWARENESS

Engagement with the general public and stakeholders:

- The importance of RM for a successful green transition
- The need for a secure, sustainable, and responsibly-sourced supply of RM to strengthen autonomy and reduce over-dependence on third countries.



Databases integration and **3D geological modeling** combined with + **Extended reality** visualization advanced technologies

LEVEL 4 – GIS/VR platform Visualization and Exploitation

General public

- Education about the need of a secure and sustainable CRM supply
- Socialization of exploration advancements and promising geological terrains

Stakeholders

- Exploitation of results
- Next steps of development
- Clustering activities

Technicians

- Technical discussions about next steps for exploitation and exploitation
- Decision-making process

SOCIAL LICENSE TO OPERATE (SLO)

The use of extended reality (XR) for social engagement:

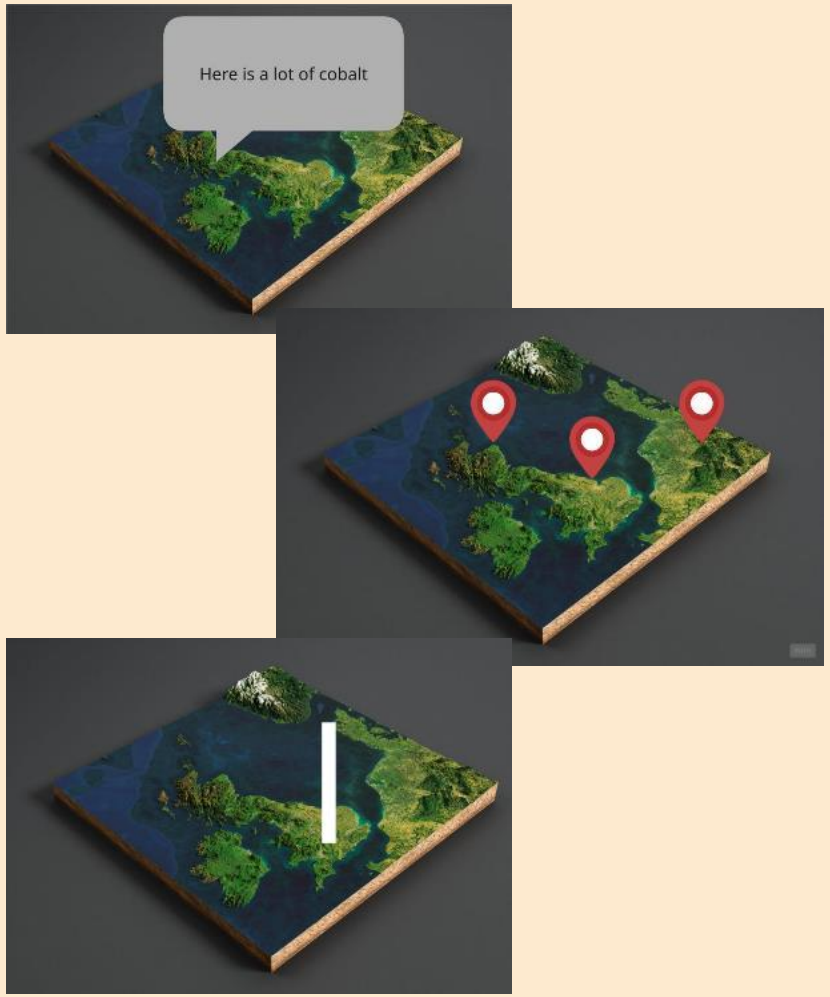
- **Enhanced Public Understanding**: Intuitive & immersive experiences help non-experts grasp complex concepts by making abstract or technical content visually and spatially accessible.
- **Stakeholder Engagement:** Virtual spaces where citizens, policymakers, and experts can interact with data and simulations in real time.
- **Trust Building Through Transparency**: By visualizing underground processes or environmental impacts, XR tools promote transparency and can help build trust in industries traditionally viewed with skepticism.
- **Education and Awareness**: Enable informed discussion and participation.

SOCIAL LICENSE TO OPERATE

The use of XR in DEXPLORE

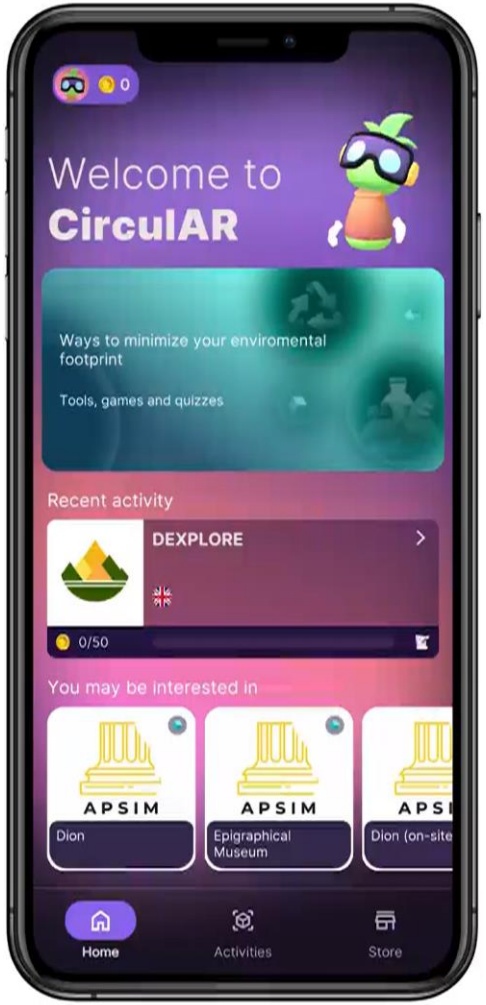
- **Immersive Public Consultations**: Local communities virtually "walk through" subsurface models of exploration sites, grasping the scope and impact of DEXPLORE and fostering informed dialogue.
- **Participatory Site Design:** Users propose or comment on exploration or restoration plans, enabling a co-creative process with stakeholders and supporting SLO efforts.
- **Narrative-Driven XR Experiences**: Storytelling elements within the XR platform can engage citizens emotionally, contextualizing technical data.
- **Mobile XR Outreach in Rural Areas**: Lightweight or mobile XR units can be deployed at schools, libraries, or festivals, making advanced geoscientific knowledge accessible and stimulating early-stage community involvement.

In the DEXPLORE XR experience, users navigate a digital map of Estonia that highlights six real-world mineral exploration sites. Tapping on each site reveals detailed information about the minerals found there. Through this interactive journey, users gain insight into why responsible mineral exploration is crucial for a sustainable future.



SOCIAL LICENSE TO OPERATE

- **Location-based AR content**
  that activates when users are near exploration sites
- **Interactive 3D geological models**
  overlaid on the physical environment
- **Virtual drill cores and subsurface layers**
  visualized in AR
- **Data pop-ups**
  showing geophysical measurements
- **Scan-to-unlock interactions**,
  prompting users to point their device at specific markers
- **Quiz and knowledge checks**
  integrated into the AR experience
- **Points and leaderboard system**
  rewarding exploration and correct answers
- **Photo capture and annotation tools**
  for documenting field observations in-app



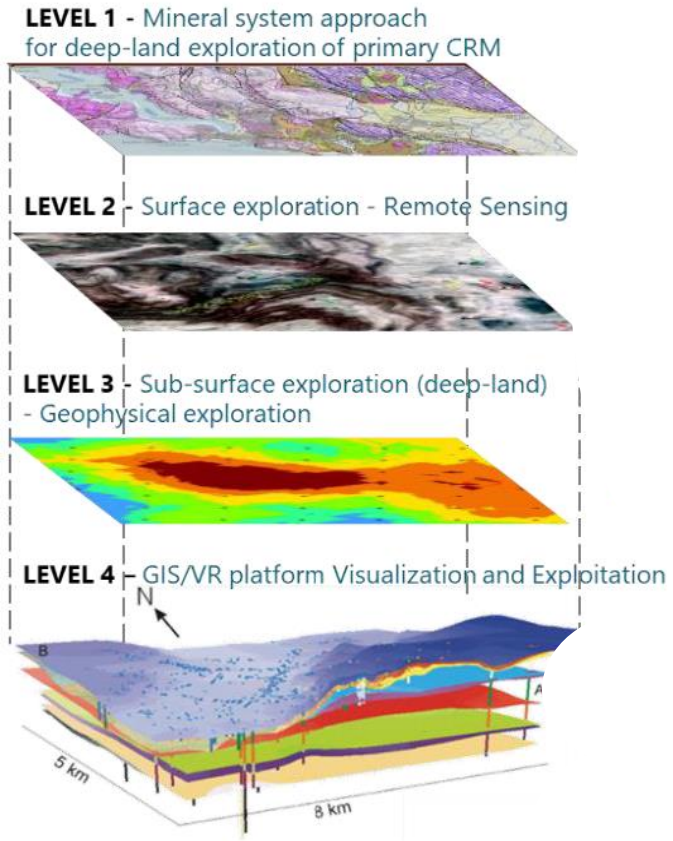
SOCIAL LICENSE TO OPERATE

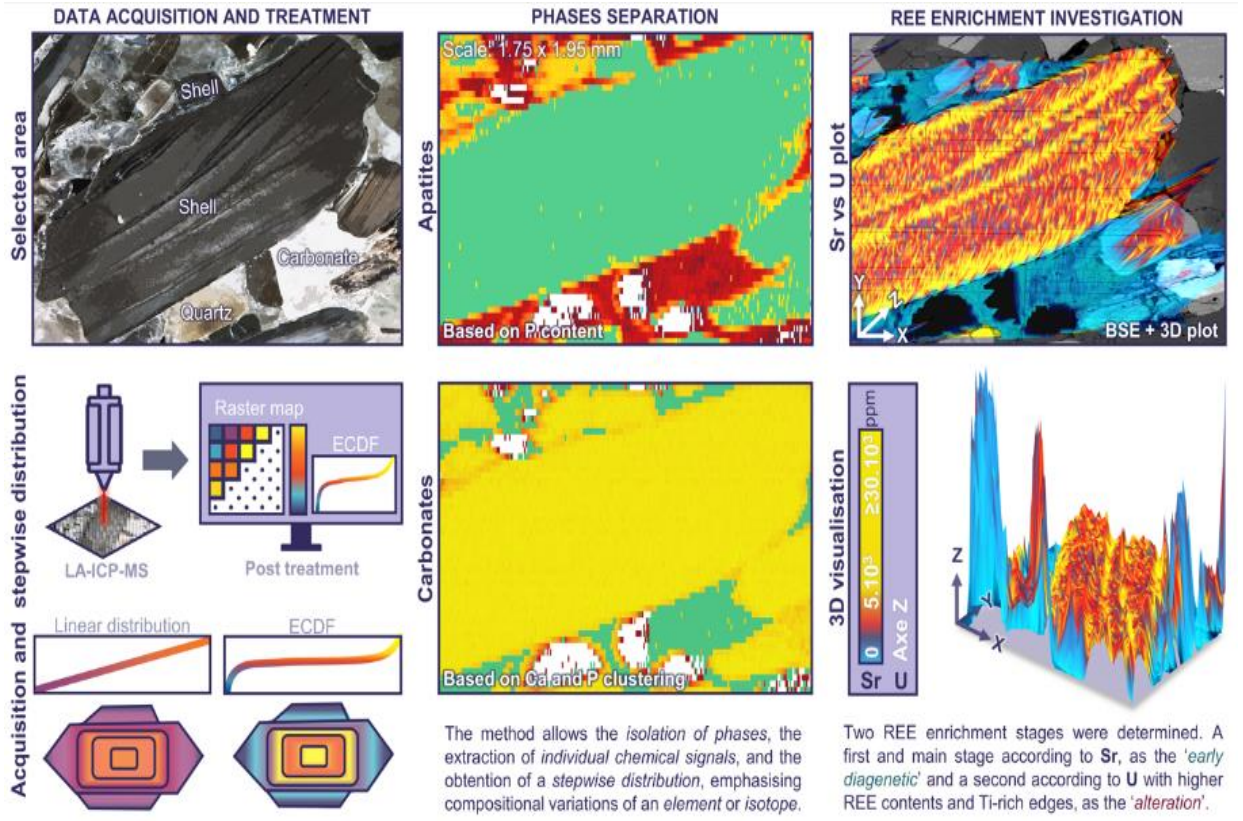
Empowering users to share their views in diverse formats

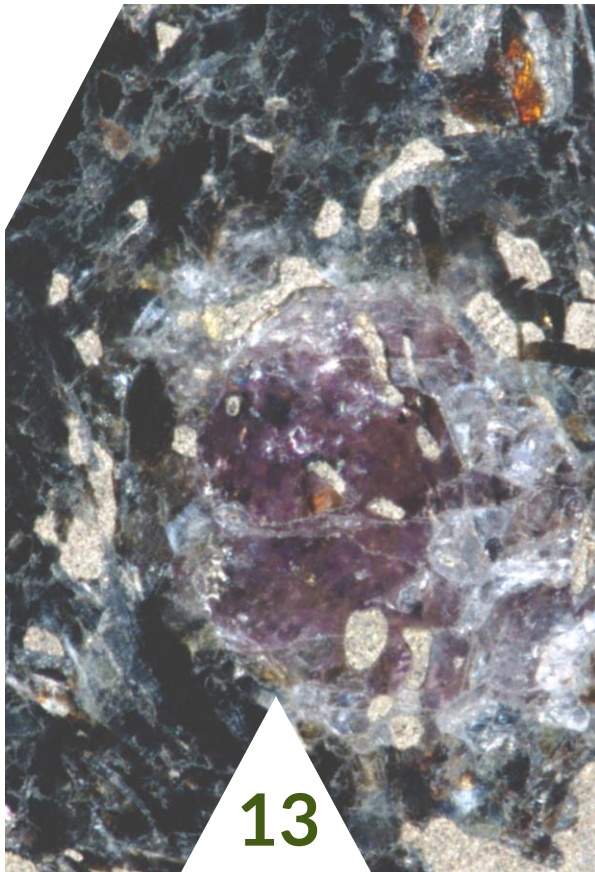
- Upload photos, videos, or text
- Text and voice narration options to accommodate different communication preferences
- Multi-language support for broader community participation
- Geo-referenced feedback tied to specific AR content or locations
- User-friendly prompts encouraging reflection, opinion-sharing, and storytelling

Expected outcomes

- Developement of advanced visualisation and interaction platform (3D & XR)
- New approaches and models; Resources estimates for Estonian basement
- Training and knowledge-transfer programs, e-learning activities including MOOCs







DEXPLORE

THANK YOU

PROJECT COORDINATION
Catalina Hernandez-Moreno
c.hernandez@ismc-iberiamine.com

Website: https://dexplore.eu/
LinkedIn: DEXPLORE EU PROJECT

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EIS
Exploration
Information
System

Lucija Dujmovic (HZDR-HIF)

DEEPBEAT

Clustering session: Advancing mineral exploration through innovative technologies

11:00 – 12:15

Funded by the European Union

HELMHOLTZ INSTITUTE FREIBERG FOR RESOURCE TECHNOLOGY

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

DEEP EXPLORATION BOOSTED BY ADVANCED EXPLORATION TECHNOLOGIES – DEEPBEAT

Lucija Dujmović
Doctoral Researcher in Biogeochemical Exploration
Department of Modeling and Valuation
Helmholtz Institute Freiberg
On behalf of the DEEPBEAT team

EIS Final Event: Shaping the Future of Sustainable Mineral Exploration

Brussels, 7th October 2025

EIS Exploration Information System

Deep exploration boosted by advanced exploration technologies

Duration: 10/2024 – 09/2027

Coordinator:

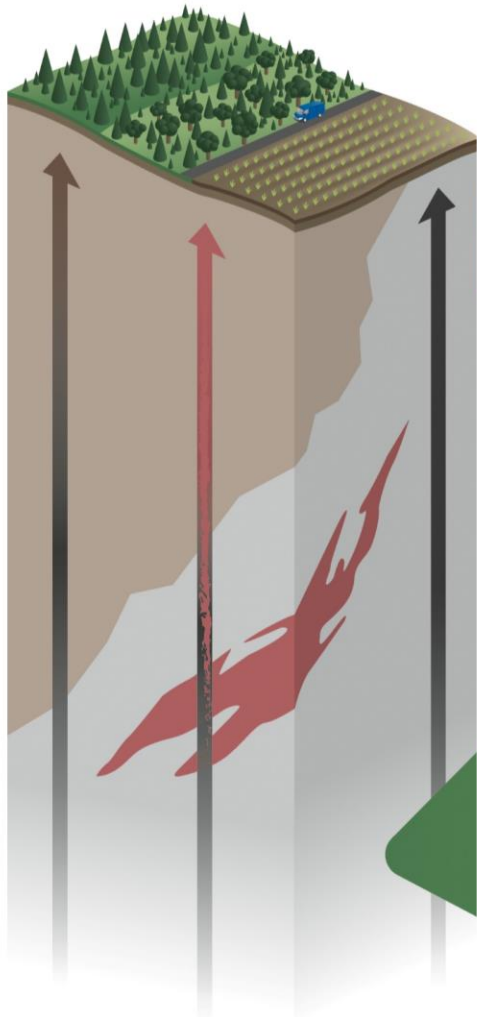
Partners & associated partners:

Funded by the European Union

Motivation

- Near-surface deposits are increasingly depleted
- Deep-seated deposits present significant challenges in detection and extraction

1. **Aim:** Develop geochemical methods for deep exploration
2. **Aim**: Accelerate geochemical data acquisition and reduce exploration costs



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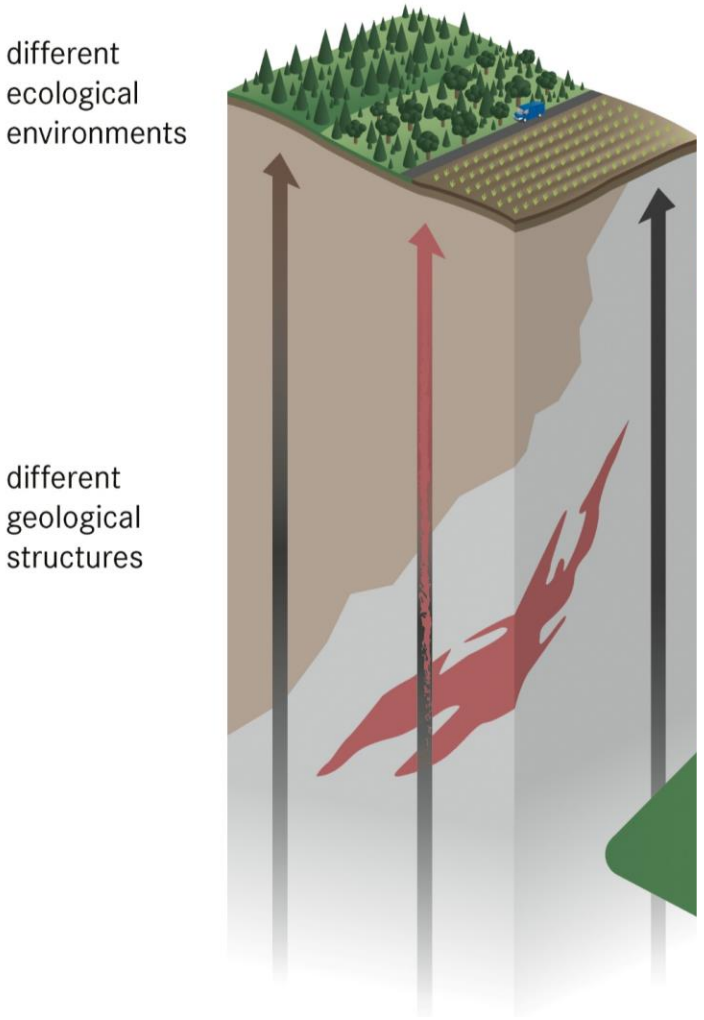

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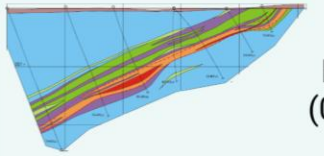
Funded by the European Union

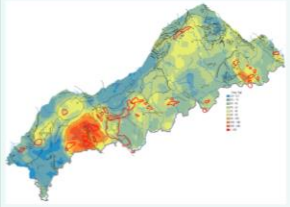
Innovative approach

test sites

Effective spatial sampling strategies



VMS - Finland (0-700m)



Granite hosted Li-Sn-W - Germany (0-800m)

Metasomat. REE - Czechia (0-400m)

sample media

Defining source & testing (new) biogeochemical media

legacy drill cores

stream sediments

soil/till

plant (UAV-assisted)

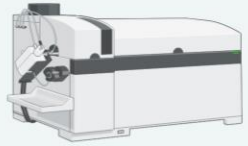
mushroom

analytical tools

Multi-sensor scanning technology and data fusion

onsite/ field methods

LIBS/ XRF

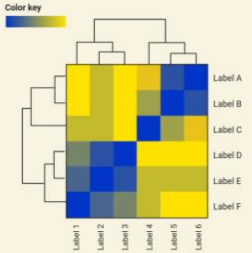


(LA-)TQ-ICP-MS

High-resolution/ isotopy

statistical tools and modelling

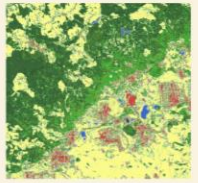
Sampling strategy, data handling & interpretation



Sample and station selection

$$\langle x, y \rangle = \frac{1}{2D} \sum_{i=1}^{D} \sum_{j=1}^{D} \log \frac{x_i}{x_j}$$

Compositional calibration



AI- assisted 3D prospectivity modelling

Funded by the European Union

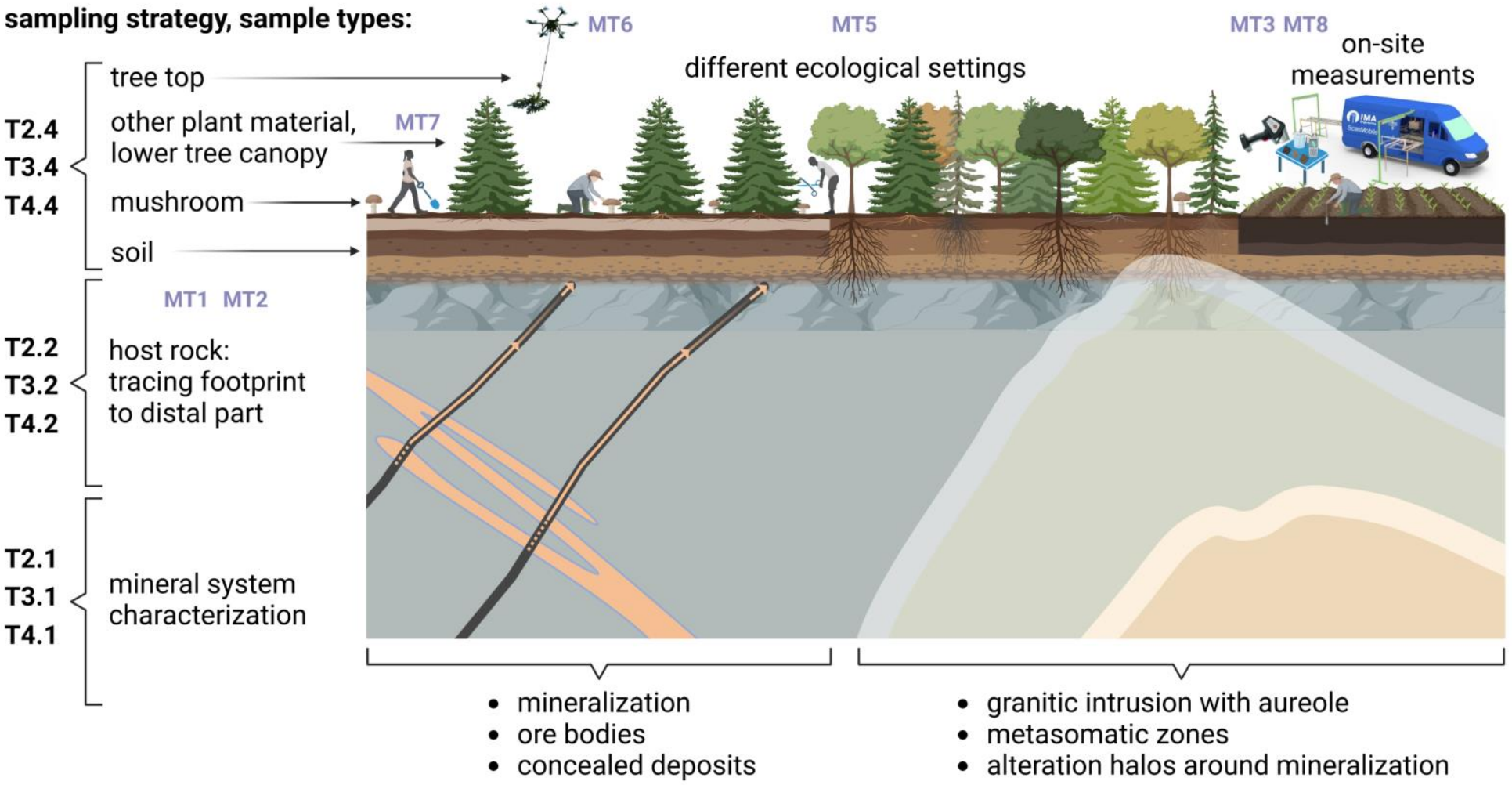
Test sites

	Saramäki (FIN)	Erzgebirge (DEU)	Hůrky (CZE)
Ore	• Volcanic massive sulphide	• Granite hosted Li, Sn, W	• Alkaline Metasomatite Rare Earth Elements (REE)
Host rock	• Serpentinite and its alteration products within predominantly mica shists	• Calcitic and silicitic metamorphic units	• Shear-zone related alkaline metasomatites in granite. Pluton is buried beneath younger sediments
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

* Target commodities

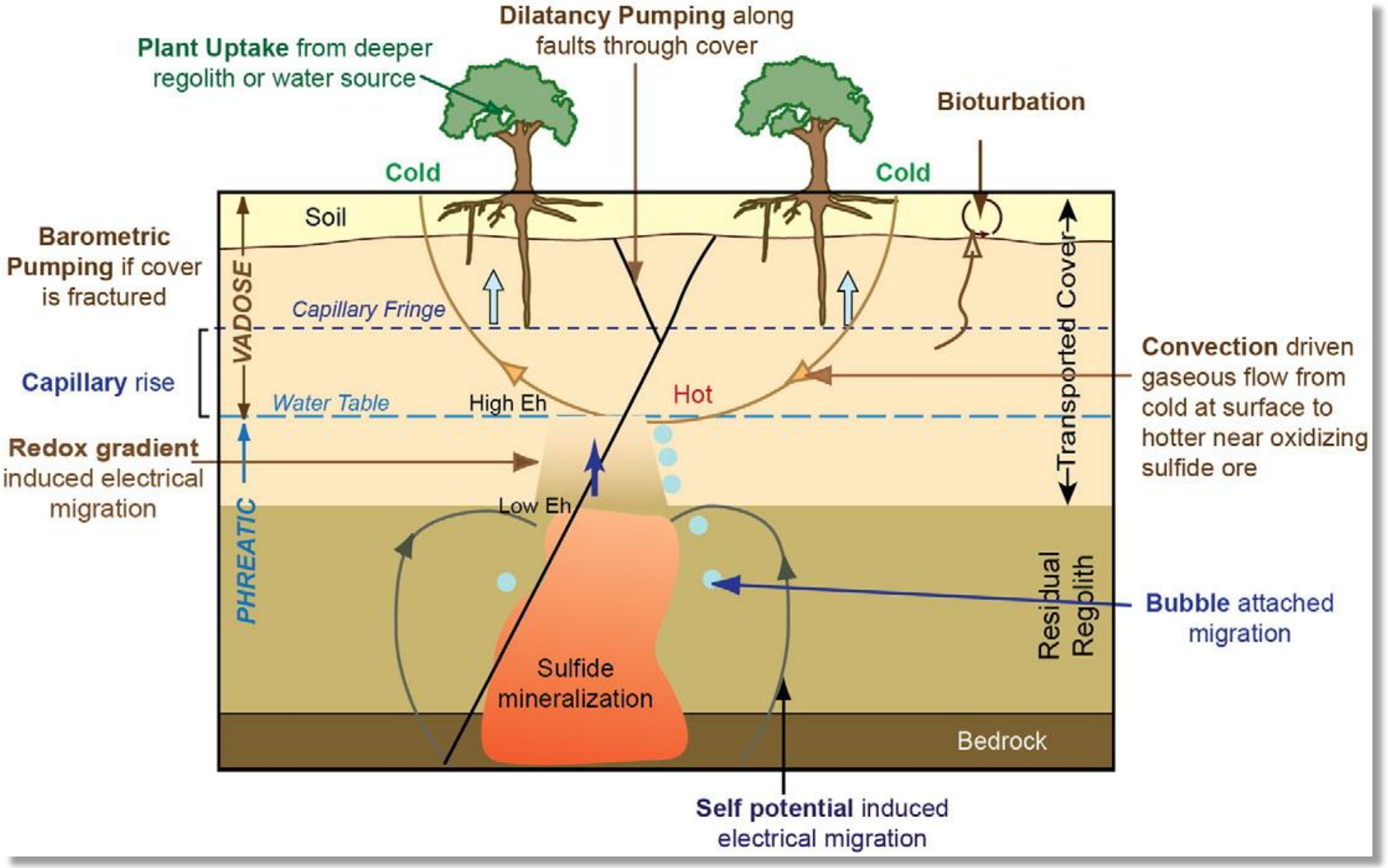
Funded by the European Union

Exploration model



Funded by the European Union

Exploration model



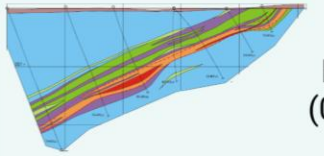
Anand et al (2016)

Funded by the European Union

Innovative approach

test sites

Effective spatial sampling strategies



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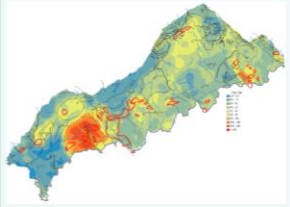

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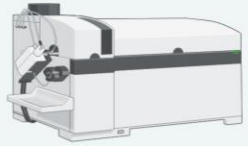

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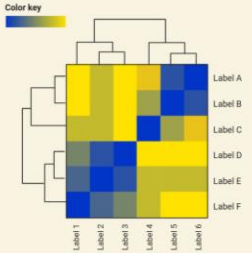
High-resolution/ isotopy

statistical tools and modelling

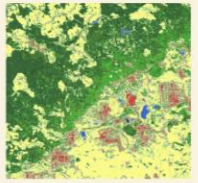
Sampling strategy, data handling & interpretation



Sample and station selection

$$\langle x, y \rangle = \frac{1}{2D} \sum_{i=1}^{D} \sum_{j=1}^{D} \log \frac{x_i}{x_j}$$

Compositional calibration



AI- assisted 3D prospectivity modelling

Funded by the European Union

Expected Outcomes & Impact

- **Content:**
  - Enhance deep exploration by a workflow (“cook-book”)
  - Provide decision points for where to integrate the novel methods
  - Environmentally friendly geochemical exploration with regard to the mineral system(s)

- **Test site specific adaptions:**
  - Mineral exploration for VMS-style deposits in (vegetation/till) covered terrains
  - Identification of concealed granites and porphyries, their mineral type and mineral potential
  - Metallogenetic model for “Hurky”- type of mineral system/deposit

- **Specialties**
  - Community events in all three test sites:
    - Raise awareness for the need of exploration activities in Europe
    - Understand stakeholder positions
  - Integrates geological and geophysical 2D Data to deploy geochemical results
  - Should lead to potential perspective of deposit occurrences mainly in Pre-Variscan and Variscan fold belts in Europe

Funded by the European Union

THANK YOU FOR YOUR ATTENTION!

Contact Info:

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Nicole Körtge – Project Coordinator – deepbeat@hzdr.de

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LinkedIn:

X:

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EIS
Exploration
Information
System

Juha Kaija (GTK)

UNDERCOVER

Clustering session: Advancing mineral exploration through innovative technologies

11:00 – 12:15

UNDERCOVER
Redefining deep-earth exploration

GTK

UNDERCOVER – REDEFINING THE DEEP MINERAL EXPLORATION

EIS Final Event, Brussels, 7 January 2025

Juha Kaija[1], Jochen Kamm[1], Tuija Luhta[1], Tero Niiranen[1], Kathryn Cutts[1], Graham Hill[2], Mathieu Darnet[3], Sam Whittlesey[4], Michael Becken[5], Capucine Pineau[4]

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2 Institute of Geophysics of the Czech Academy of Sciences, Czech Republic
3 Bureau de Recherches Géologiques et Minières, France
4 LGI Sustainable Innovation, France
5 University of Münster, Germany

The UNDERCOVER project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N.101177528.c

UNDERCOVER
Redefining deep-earth exploration

Agenda

1. Relevant ongoing Horizon Europe projects
2. UNDERCOVER - basics
3. Other projects funded under the deep exploration call
4. UNDERCOVER – Consortium
5. Motivation behind UNDERCOVER
6. Main objectives
7. Work packages
8. Case study areas

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Relevant Horizon Europe projects 2025 – GTK´s participation

GTK coordinates:

- **UNDERCOVER - Unified Novel Deep ExploRation for Critical Ore discovery**
- **MultiMiner -** Multi-source and multi-scale earth observation and novel machine learning methods for mineral exploration and mine site monitoring
- **ISLANDR -** Information-based Strategies for LAND Remediation
- **EIS - Exploration Information System**

Coordination, Support Action, Networking

- **SCRREEN3 -** Solutions for CRitical Raw materials - a European Expert Network 3
- **CIRAN -** CrItical RAw materials extraction in enviroNmentally protected areas
- **BlueMissionBANOS -** Supporting the mission ocean lighthouse in the baltic and north sea basins
- **EGT-TWINN -** Enhancing research capacity at the Geological Survey of Estonia
- **CSA GSEU -** Geological service for Europe

Research and Innovation Action

- **DeepBEAT - Deep exploration BoostEd by Advanced exploration Technologies**
- **GOLDEN RAM -** Earth Observation Platform Supporting Critical Raw Materials Industry in Europe
- **EXCEED -** Cost-effective, sustainable and responsible extraction routes for recovering distinct critical metals and industrial minerals as by-products from key European hard-rock lithium projects
- **MaDiTraCe -** Material and digital traceability for the certification of critical raw materials
- **AVANTIS -** International Innovation Network for the Development of Sustainable, decarbonised vanadium, titanium and iron extraction from Europe’s low-grade vanadiumbearing titanomagnetite deposits
- **S34I -** Secure and sustainable supply of raw materials for EU industry
- **RAWCLIK -** Future RAW materials demand, supply and sustainability in the face of CLImate Change
- **REMHub -** Rare earth and magnets hub for a resilient Europe
- **MAGELLAN -** Magnets in resilient supply chains
- **FutuRaM -** Future Availability of Secondary Raw Materials

Other projects funded under the deep exploration call

Total EU funding of four deep exploration projects is 19 332 149€ (~30% to industrial partners)

- **DeepBEAT** - Deep exploration BoostEd by Advanced exploration Technologies
  - **Coordinator**: HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF, Germany
  - **EU funding**: 4 886 982 €
  - **LinkedIn**: DeepBEAT: About | LinkedIn
- **DEXPLORE** - Recognizing European potential for hosting deep land primary CRM by combining new mineral models and advanced exploration and visualization techniques
  - **Coordinator**: IBERIAN SUSTAINABLE MINING CLUSTER, Spain
  - **EU funding**: 4 669 429 €
  - **Website**: Dexplore
- **MINOTAUR** - Miniaturized Robotic Systems for Autonomous In-Situ Exploration of Critical Raw Materials In Deep Land Deposits
  - **Coordinator**: LULEÅ UNIVERSITY OF TECHNOLOGY - LTU
  - **EU funding**: 4 993 303 €
  - **Website**: Minotaur

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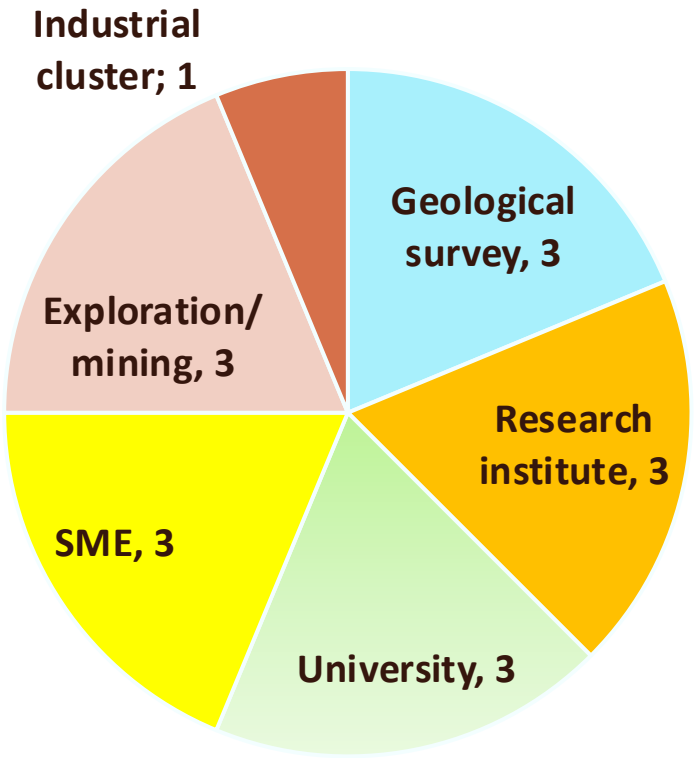
UNDERCOVER – Basics

- **Funding programme:** Horizon Europe
- **Call & topic:** HORIZON-CL4-2024-RESILIENCE-01: Resilient Value Chains 2024; HORIZON-CL4-2024-RESILIENCE-01-01: **Exploration of critical raw materials in deep land deposits**
- **Type of action:** HORIZON-RIA, Research & Innovation Action
- **Duration:** 1.1.2025 - 31.12.2027
- **Total budget:** 4 999 987.50 €
- **Total person-months:** 452
- **Consortium:** Fourteen partners from five EU countries + Namibia and Canada



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UNDERCOVER – Consortium

INDUSTRY & SME´s (7 partners, 26% of the budget)

- ASSOCIACAO CLUSTER PORTUGAL MINERAL RESOURCES (ACPMR), PT
- SUPRACON AG (SUPRA), DE
- LGI SUSTAINABLE INNOVATION (LGI), FR
- ONGWE MINERALS (PTY) LTD (ONGWE), NA
- LATITUDE 66 COBALT OY (LAT66), FI
- SMART SEISMIC SOLUTIONS (S3), FR
- REDCORP, LDA (REDCORP), PT

RESEARCH (6 partners, 58%)

- **GEOLOGIAN TUTKIMUSKESKUS (GTK), FI**
- BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES (BRGM), FR
- GEOFYZIKALNI USTAV AV CR, V.V.I. (IG CAS), CZ
- LEIBNIZ-INSTITUT FUER PHOTONISCHE TECHNOLOGIEN E.V. (IPHT), DE
- LABORATORIO NACIONAL DE ENERGIA E GEOLOGIA I.P., (LNEG), PT
- INSTITUT NATIONAL DE LA RECHERCHE SCIENTIFIQUE (INRS), CA

UNIVERSITIES (3 partners, 16%)

- UNIVERSITAT MUNSTER (UM), DE
- UNIVERSIDADE DE EVORA (UDE) (Affiliated Entity), PT
- TECHNISCHE UNIVERSITAT BERLIN (TUB), DE

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Motivation behind UNDERCOVER

Declining discoveries
- Fewer new mineral deposits discoveries despite rising exploration expenditures
- Most recent finds are deeper underground

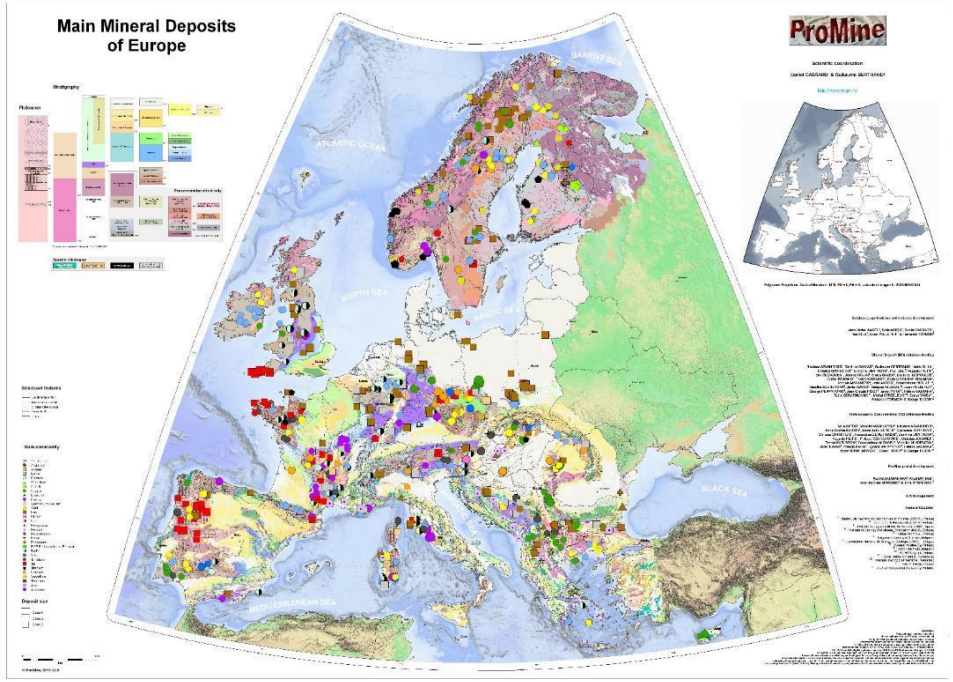
Rising demand
- Global mineral demand is expected to drastically increase

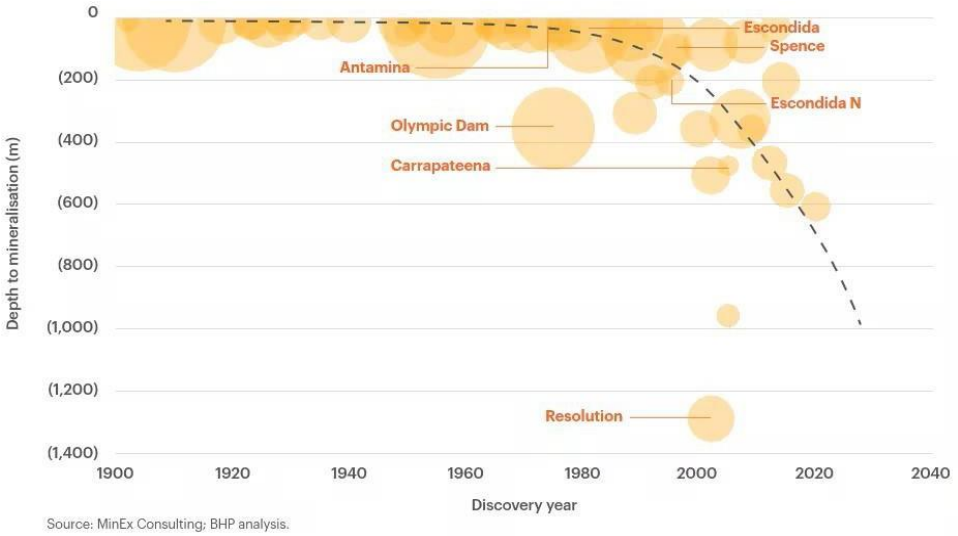
Exploration shift
- Exploration must evolve to meet future needs
- Focus moving to deeper levels, especially in brownfield areas

Europe's potential
- Systematic exploration is limited to top 0–100 m
- Significant mineral resources remain undiscovered
- Large deposits likely hidden beneath deep cover

Data & technology gaps
- Little organized base data collection across Europe
- Europe leads in many exploration-relevant technologies

Call to action
- New, cost-effective, and efficient exploration strategies are urgently needed





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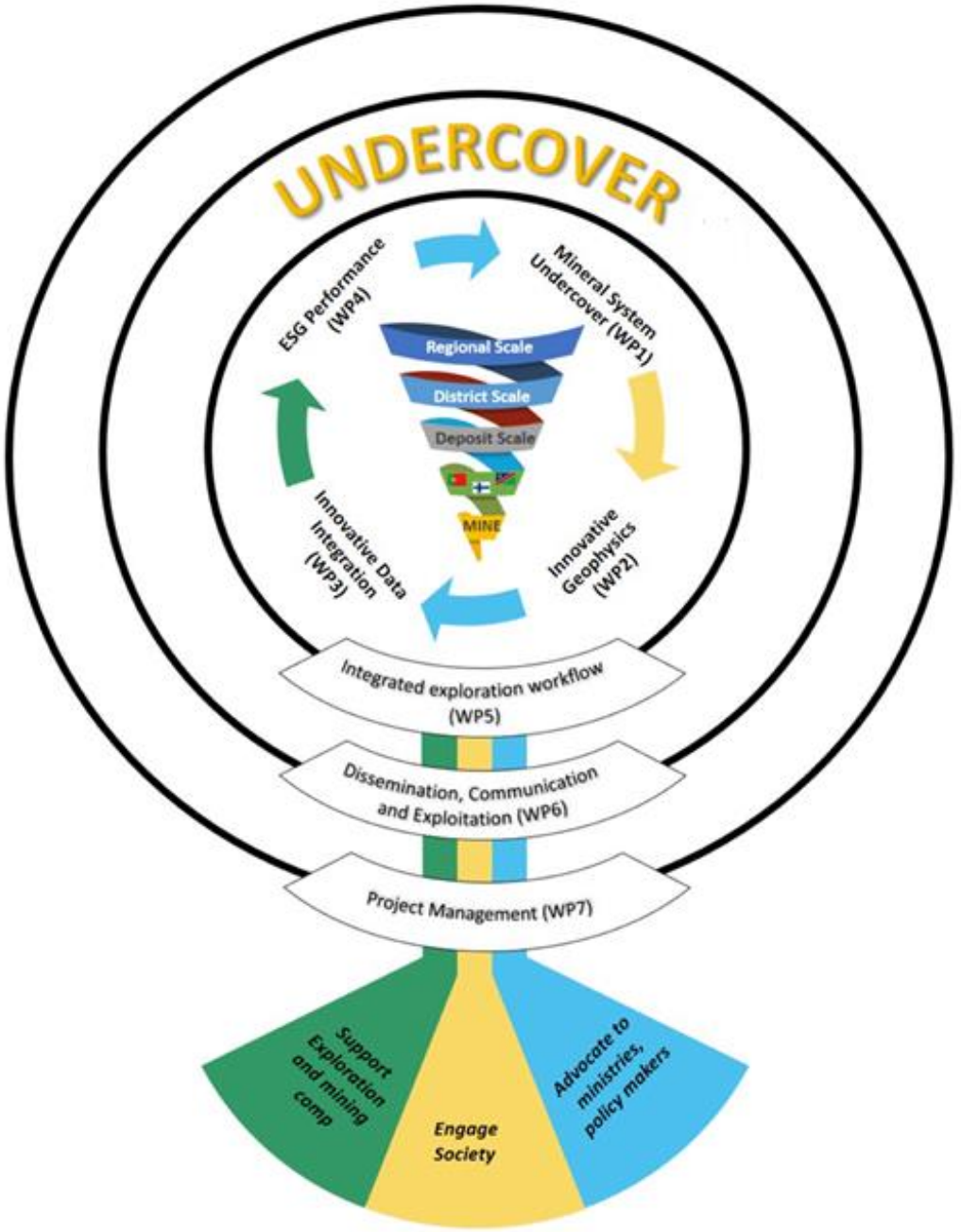
Work packages

- **WP1. Mineral Systems under Cover**: Kathryn Cutts, GTK
- **WP2. Innovative Geophysics**: Graham Hill, IG CAS
- **WP3. Innovative Data Integration**: Mathieu Darnet, BRGM
- **WP4. Environmental, Social and Governance**: Sam Whittlesey, LGI
- **WP5. Integrated Exploration Strategy**: Michael Becken, UM
- **WP6. Communication, Dissemination & Exploitation**: Capucine Pineau, LGI
- **WP7. Project Management**: Juha Kaija, GTK



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Main objectives

- Transform deep CRM exploration, introducing a paradigm shift by **extending the mineral systems concept**, currently underutilized in quantitative exploration, to deep exploration relevant spatial scales
- **Integrate** novel, cost-effective, and low-impact technologies and **methods for data collection and integration, including AI-based geological mapping and geophysical joint inversion.**
- Address and mitigate **environmental, social, and governance (ESG) aspects of mineral exploration at all stages**.
- **Map primary raw materials potential** in EU and non-EU countries across three major mineral belts
- Promote **the use of UNFC** for innovative and effective exploration strategies.
- **Advance deep mineral exploration technologies**, stimulate R&D, and ensure exploitation by EU stakeholders, inspiring confidence among policy makers and stakeholders.

The development of a comprehensive CRM exploration workflow suitable for exploration in both developed and remote areas.

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Case study areas

FINLAND: Kuusamo Schist Belt

- Orogenic Au-Co ± Cu, REE mineral system

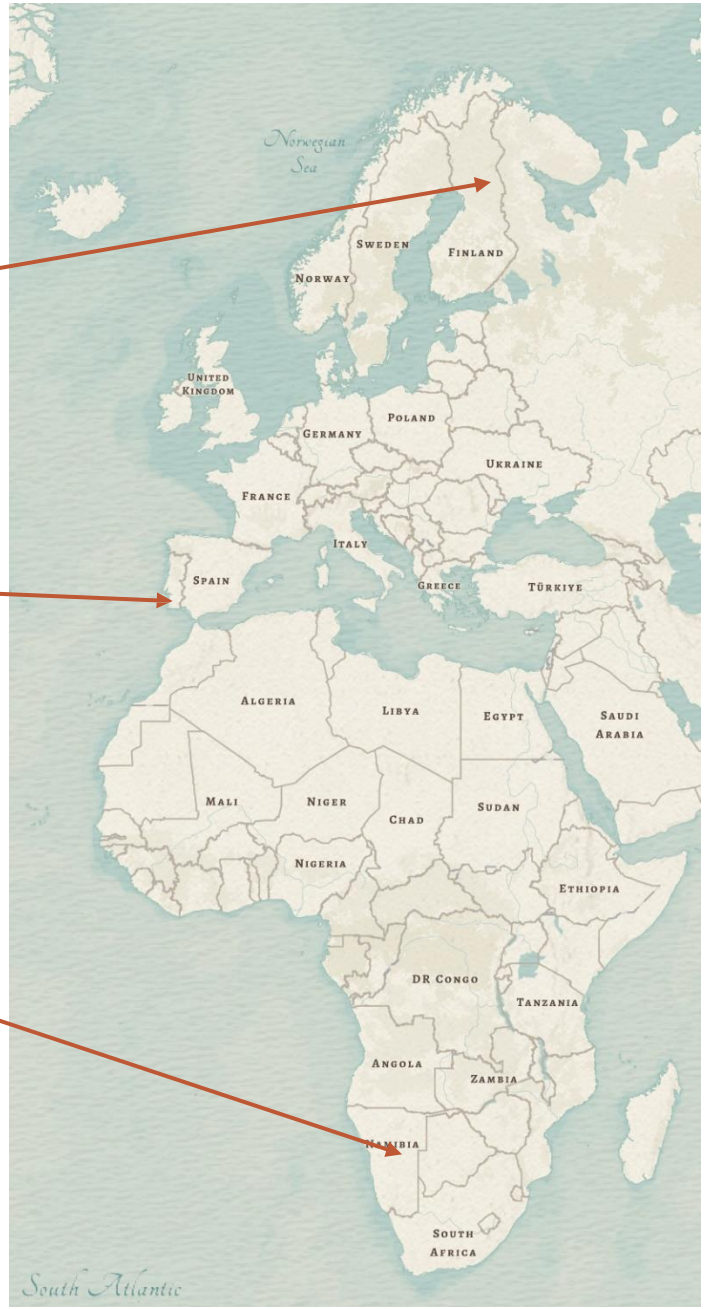
PORTUGAL: Iberian Pyrite Belt

- VMS Cu-Zn-Pb ± Sn, Ag, Au, In, Ga, Ge, V and Se mineral system

NAMIBIA: Kalahari Copper Belt

- Sediment hosted Cu mineral system

B



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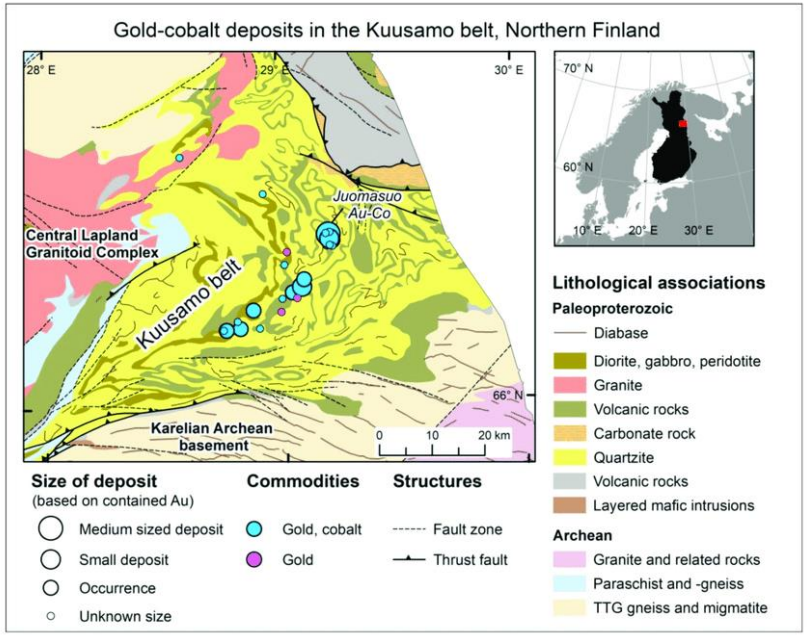
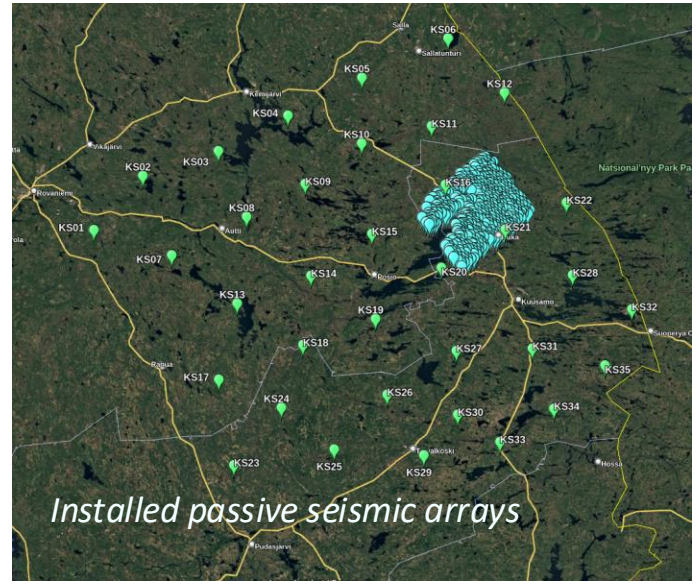
UNDERCOVER in Kuusamo Schist Belt

- Geophysical measurements
  - **AFMAG - audio-frequency magnetic /Semi-airborne EM**
  - **Belt-scale magnetotellurics**
  - **Passive seismic in core area**
  - **Active source ground EM**
- **Compilation of relevant existing data sets, geological field mapping and drill core sampling**
- Generation of **initial** & subsequently refined **mineral system model** (based on the results)
- Development of geochemical exploration methodology (MinExTarget BoT)
- **Petrophysical modelling of mineral systems**
- Geochronology (Lu-Hf + conventional U-Pb)
- Data integration
- 3D modeling (Geophysics-Geology)
- GIS based prospectivity modeling – application of AI based prediction algorithms in data preprocessing
- **ESG-SLO work**



The Kuusamo Schist Belt and its gold-cobalt deposits, including the Juomasuo deposit. Guzik et al. 2021 modified after © Geological Survey of Finland 2020.



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UNDERCOVER in Iberian Pyrite Belt

- Volcanogenic massive sulphide (VMS) deposit - an early-stage, potentially high-grade, polymetallic zinc-lead-copper exploration
- The exploration permit covering an area of approximately 10,700 hectares
- Zinc, Lead, Silver, Copper, Gold, Tin

UNDERCOVER:

- **Compilation of relevant existing data sets, geological field mapping**
- **Initial mineral system model**
- Multicopter semi-airborne EM
- **Passive-source seismics**
- **Active-source seismics**
- **Geochronology**
- Deposit and regional scale 3D modelling integrating lithology and alteration models, structural data, structural interpretation of 3D seismic and airborne EM data. - A refined mineral system model
- Aquifer studies close to Lagoa Salgada
- ESG studies

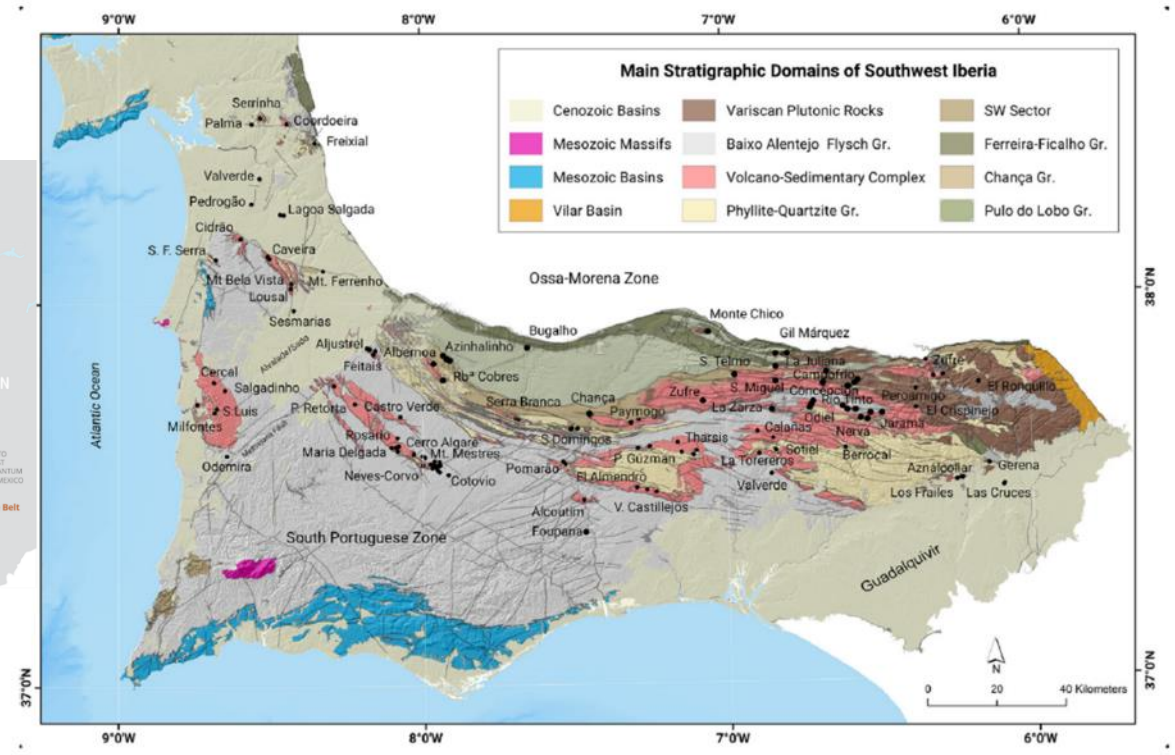

Fig. 1. Geological Map of South Portuguese Zone with emphasis on the Iberian Pyrite Belt (b). adapted from Díez-Montes et al., 2020a, 2020b

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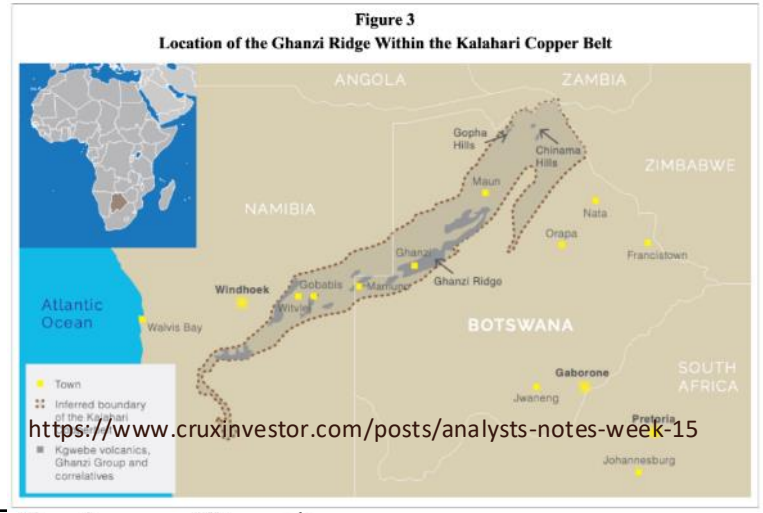
UNDERCOVER in Kalahari Copper Belt

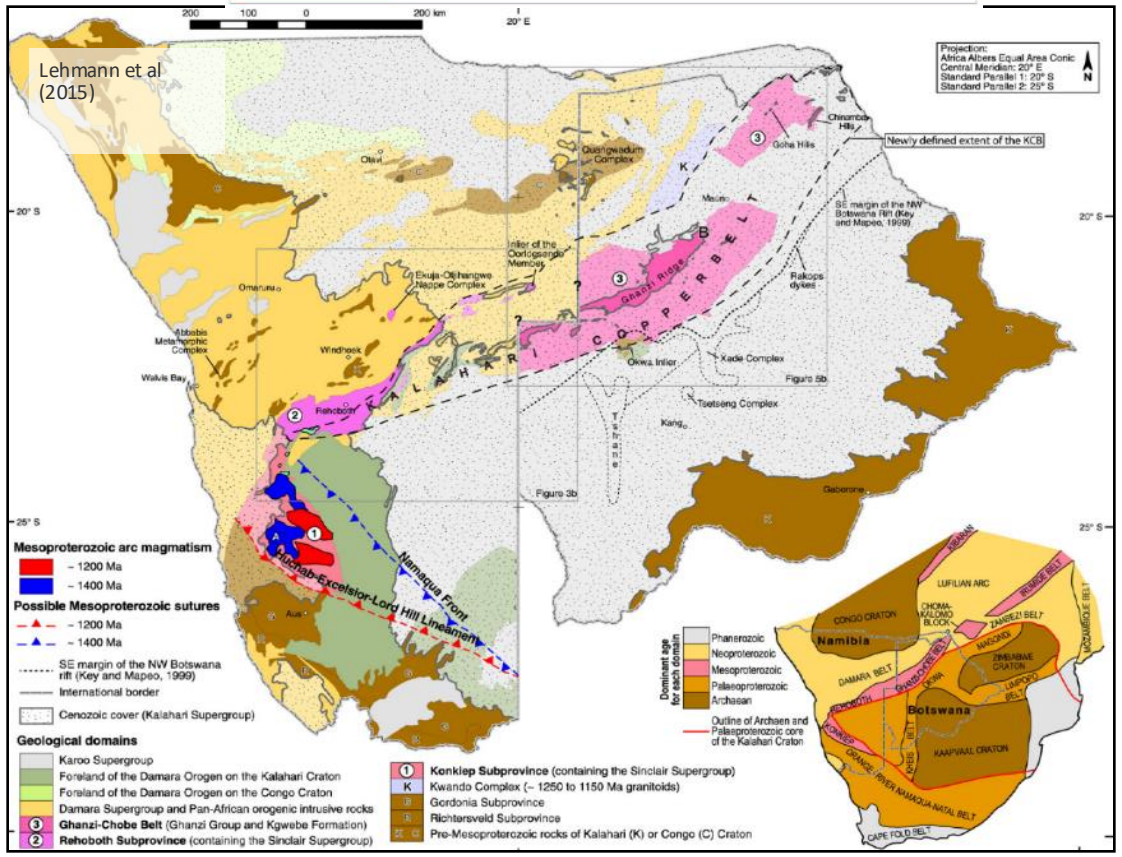
- Ongwe Minerals, holds ~963 000 ha of exploration licenses on the Kalahari Copper Belt
- Limited historical exploration proved the potential of the Copper Belt in Namibia
- Ongwe has identified multiple targets that require follow-up geophysics & drill testing

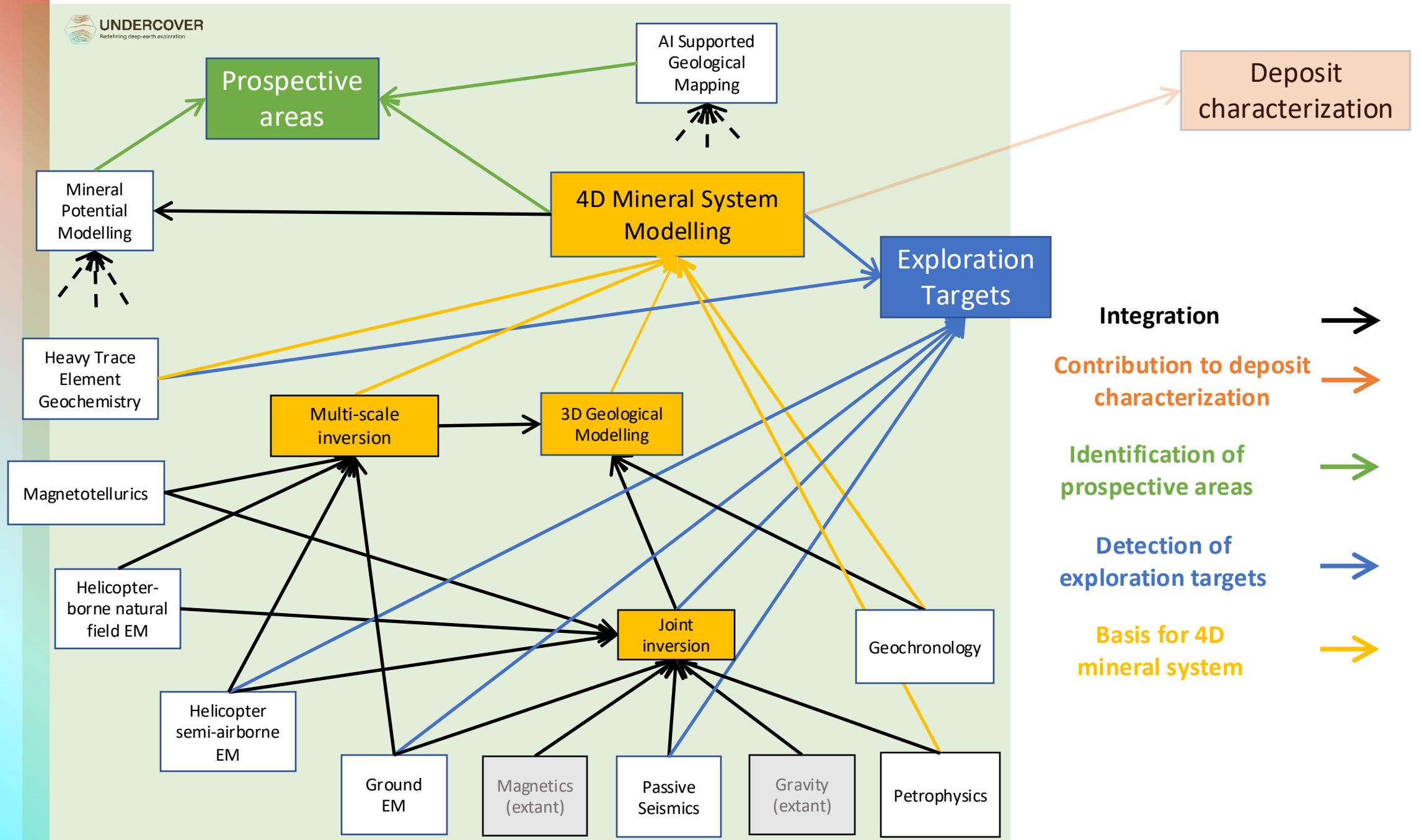
UNDERCOVER:

- **Initial mineral system model**
- **Multicopter semi-airborne EM**
- 3D inversion of semi-airborne EM data
- **ESG studies**



https://www.cruxinvestor.com/posts/analysts-notes-week-15

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Prospective areas
AI Supported Geological Mapping
Deposit characterization
Mineral Potential Modelling
4D Mineral System Modelling
Exploration Targets
Heavy Trace Element Geochemistry
Multi-scale inversion
3D Geological Modelling
Magnetotellurics
Helicopter-borne natural field EM
Joint inversion
Geochronology
Helicopter semi-airborne EM
Ground EM
Magnetics (extant)
Passive Seismics
Gravity (extant)
Petrophysics
Integration
Contribution to deposit characterization
Identification of prospective areas
Detection of exploration targets
Basis for 4D mineral system

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Redefining deep-earth exploration

Satellite event at the Raw Materials Week, 19 November 2025, Brussels

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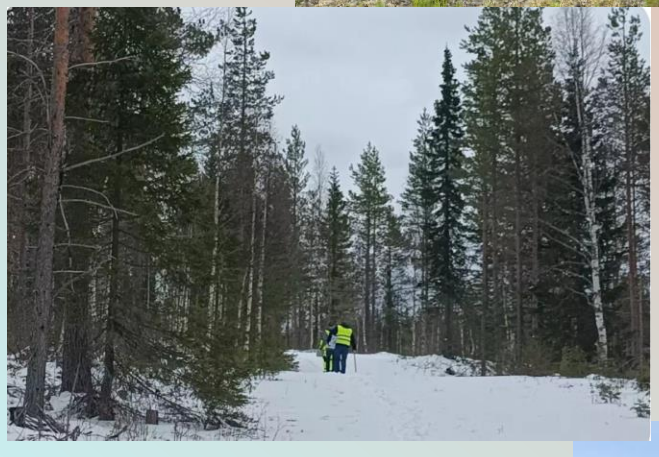

Thank you.

Connect with us to stay up to date!

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The UNDERCOVER project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N.101177528.c

Q&A

Advancing mineral exploration through innovative technologies

11:00 – 12:30

EIS
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System

Moderator
Imad Audi
(LGI)

Malcolm Aranha
(HZDR-HIF)

Tony Hand
(TalTech)

Lucija Dujmovic
(HZDR-HIF)

Juha Kaija
(GTK)

27/10/2025