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Research and Innovation

CORDIS Results Pack on strategic mineral exploration

Advancements in geoscientific methods and exploration techniques

A thematic collection of innovative EU-funded research results

October 2025

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Editorial

Europe depends upon critical raw materials to drive its transition to a low-carbon digital economy. To achieve this goal, it is essential to build public trust and understanding to secure access to these vital resources with minimal environmental damage. This new CORDIS Results Pack features seven EU-funded projects that reduce the impacts of locating and extracting critical raw materials.

Ensuring reliable, unimpeded access to important raw materials is a growing concern within the EU. Recent events, from the COVID-19 pandemic to the Russian invasion of Ukraine, underline the vulnerability of certain EU supply chains to disruptions as well as their excessive dependence on third countries.

To monitor and address this challenge, the European Commission established a list of critical raw materials (CRMs), reflecting their importance to the EU economy and the high risk associated with their supply. The latest list, which was drawn up in 2023, also includes a subgroup of 16 so-called strategic raw materials of great importance, forecasted demand growth and difficulty of increasing production.

Securing access

These materials provide a sound industrial base for the EU economy, enabling it to create products and applications used both in daily life and in modern technologies. Spanning sectors as diverse as electronics, renewable energy, healthcare, transportation and defence, CRMs underpin EU prosperity and security.

The recent Critical Raw Materials Act (CRMA) will help secure EU autonomy and support the transition to a greener, climate-neutral future by strengthening the European raw materials value chain.

This value chain starts with geological exploration, with discoveries of new deposits and subsequent geological data gathering and development to better understand the deposit and assess its economic potential.

Sustainable solutions

This Results Pack features seven projects funded under the EU's Horizon Europe research programme that contribute to the sustainable discovery of mineral deposits while raising public awareness of the role played by modern mining technologies in a green and digital future. Technologies developed under these projects can provide a contribution to geological exploration in the EU, particularly to the national exploration programmes under the CRMA.

Project partners developed new, non-invasive methods for mineral exploration and site monitoring across a range of geological settings, using Earth observation and mapping, machine learning and advanced data processing algorithms to identify mineral deposits containing CRMs.

Low-impact technologies advance search for critical raw materials

Innovative, non-invasive geophysical survey methods and public awareness raising of critical raw materials' importance support Europe's transition to a greener future.

Europe is in the midst of a transition to a low-carbon digital economy reliant on critical raw materials (CRMs). These materials, which include lithium, cobalt, nickel, gallium, boron, tungsten and many others, have been designated CRMs because of their economic importance and supply chain risk.

As Europe moves forward, it is essential to build public trust and secure access to CRMs with minimal environmental damage. The EU-funded AGEMERA project has made substantial advances in both these areas.

Test sites for mineral system mapping

AGEMERA tested innovative exploration technologies in Finland, Bosnia and Herzegovina, Spain, Bulgaria, Poland and Zambia. The sites were chosen to accelerate the discovery of CRMs and to demonstrate innovative, non-invasive exploration methods across a variety of settings. In parallel, geological field work and updated mineral system models were developed to improve understanding of the subsurface at each site.

Studies in Finland increased understanding on the occurrence of cobalt in an area known for orogenic gold systems. In Bosnia and Herzegovina, the project targeted bauxite deposits that may contain REEs.

In Spain, the focus was on tungsten and in Bulgaria, the project targeted geologically complex porphyry systems with high CRM potential. Cobalt, molybdenum and vanadium were the focus in Poland, where technologies were tested in a mature copper and silver mining area.

In Zambia, a key EU partner in Africa, AGEMERA focused on lithium and manganese.

Cutting-edge non-invasive exploration technologies

The project tested three types of technologies: passive seismic methods, drone-based systems and cosmic-ray muography. Passive seismic methods use background vibrations to image underground features. Of the passive seismic techniques tested, Rayleigh Wave Ellipticity (RWE) proved most successful.

> *Similar to how X-rays reveal the inside of a body, muons can be used to detect density differences in rock, helping geologists locate voids, faults, or dense ore bodies.*

Drones mounted with magnetic and electromagnetic sensors allowed AGEMERA to collect data from the air. This approach is especially useful in areas with difficult accessibility due to terrain or vegetation.

Muons are subatomic particles that constantly bombard the Earth from space. Thanks to their high energy, they can penetrate deep underground. Muography exploits this. "Similar to how X-rays reveal the inside of a body, muons can be used to detect density differences in rock, helping the industry to locate voids, faults, or dense ore bodies", notes project coordinator Jari Joutsenvaara.

"Alongside sensor innovations, AGEMERA has developed an AI-powered digital platform that brings together all the project's data sources into a single, accessible, web-based environment," Joutsenvaara adds.

Building public trust

The public's understanding of modern mining is often limited and outdated. Some of the sites tested by AGEMERA have long histories of mineral extraction that caused environmental damage.

Given the magnitude of Europe's economic transition, it is important to educate and raise public awareness of modern mining priorities and technologies — especially their role in enabling the green and digital transformation. To that end, AGEMERA is conducting extensive outreach and awareness activities, aiming to reach 5 000 000 citizens by 2030.

Through university courses, workshops, seminars and stakeholder meetings, AGEMERA has made progress in raising public awareness. A noteworthy project achievement is an online CRM serious game that has potential for mass outreach.

Through these activities, AGEMERA is helping citizens learn about the importance of CRMs in the modern economy, contributing to broader public engagement. In doing so, and building on its technical and societal innovations, AGEMERA is advancing Europe's CRM-centred economic transformation.

PROJECT
AGEMERA - Agile Exploration and Geo-modelling for European Critical Raw materials

COORDINATED BY
University of Oulu in Finland

FUNDED UNDER
Horizon Europe - Digital, Industry and Space

CORDIS FACTSHEET
cordis.europa.eu/project/id/101058178

PROJECT WEBSITE
agemera.eu/

Extraction of critical raw materials valorises geothermal brines

An assessment of critical raw materials in geothermal fluids and the development of extraction technologies advance Europe's capacity to meet demands for essential minerals.

© Neil Williams_Cornish Lithium

Certain raw materials – due to their economic importance and supply risk – have been designated as critical raw materials (CRMs). Some of these materials are present in geothermal fluids, and preliminary studies have shown that even a single well has the potential to produce considerable quantities of certain CRM for key industry sectors.

Developing this untapped resource presents challenges. Promising locations must be identified and characterised with respect to CRM potential, and effective extraction technologies must be developed. The EU-funded CRM-geothermal project is working to address these challenges.

To find out which geothermal fluids could be of economic interest for CRM co-production, we mapped a wide range of these materials in geothermal wells in Europe and the East African rift. We have noted a significant amount of lithium, strontium, boron, and helium in geothermal fluids.

Locating promising geothermal brines

The project aims to establish an overview of CRMs in geothermal brines. "To find out which geothermal fluids could be of economic interest for CRM co-production, we mapped a wide range of these materials in geothermal wells in Europe and the East African rift. We have noted a significant amount of lithium, strontium, boron, and helium in geothermal fluids," shares project coordinator Simona Regenspurg.

Test sites include Cornwall (UK), Northern Germany, Iceland, Kenya and Turkey. In Cornwall, geothermal brines are enriched with lithium and helium. The North German Basin fluids have rich concentrations of lithium and strontium. In the Icelandic sites, with temperatures up to 250 °C, the project investigates CRM enrichment in precipitates that form when the fluid is cooled during the power production process.

Test sites in Turkey produce high volumes of geothermal fluids, making them useful for testing extraction methods. In addition, the alkaline geothermal fluids of East Africa are investigated for their rare earth elements content.

Developing extraction technologies

"Because every geothermal site is unique in terms of heat, pressure, fluid chemistry and the CRMs present, suitable extraction methods vary considerably. CRM-geothermal explored many approaches, including selective ion exchange, ion sieves, adsorption by crown-ethers, bioaccumulation and gas membrane extraction.

For lithium extraction, CRM-geothermal has adapted existing techniques to meet their needs. Regenspurg explains: "For example, we use ion sieves which are components with special crystal structures where only the small Li+ ion can fit in. This ensures selectivity so that we avoid extraction of other dissolved elements, which is one of the main challenges when using geothermal brines."

Because there are so many factors to be considered, there is no one-size-fits-all solution to CRM extraction from geothermal brines. CRM-geothermal is working to develop an array of technologies suitable for different circumstances.

Economic assessments for CRM extraction

The project is exploring the benefits of a dual extraction process. Extracting heat provides a clean energy source while CRMs provide essential industrial materials. Material flow analysis (MFA) quantifies inputs and outputs of the extraction process, as well as informing the cost-benefit analysis of extraction.

The combined extraction of heat and minerals has the potential to maximise returns on investment while also minimising environmental impact. The project is developing guidelines to apply the United Nations Framework Classification (UNFC) for evaluating the geological, technological, socio-economic and environmental viability of combined extraction projects.

CRM-geothermal will present the results of the CRM mapping in geothermal systems across Europe in an online CRM-Fluid Atlas to provide a clear picture of available CRM resources. By providing practical guidance for future project developers on suitable extraction technologies and the application of UNFC, CRM-geothermal is paving the way for the effective adoption of CRM extraction from geothermal brines.

PROJECT
CRM-geothermal - CRM-geothermal: Raw materials from geothermal fluids: occurrence, enrichment, extraction

COORDINATED BY
GFZ Helmholtz Centre for Geosciences in Germany

FUNDED UNDER
Horizon Europe - Digital, Industry and Space

CORDIS FACTSHEET
cordis.europa.eu/project/id/101058163

PROJECT WEBSITE
crm-geothermal.eu/

Advanced tools support low-impact mineral prospectivity mapping

A pioneering open-source platform integrates AI, machine learning and deep learning to precisely target high-potential CRM sources, supporting a sustainable independent CRM supply.

To succeed in the green transition and become climate neutral by 2050, the EU needs an increasing amount of critical raw materials (CRMs). Responsibly sourcing and recycling CRMs will reduce the impact of exploration and mining on nature and the environment.

One of the best ways to do this is to conduct 'prospectivity mining' in silico for both primary and secondary raw materials, using models to precisely identify high-potential targets with zero environmental impact. The EU-funded EIS project developed tools integrating AI, machine learning and deep learning to analyse extensive datasets from previous exploration campaigns. This data-driven approach should accelerate discovery, minimise ecological disruption and support more sustainable and efficient exploration for CRMs.

Advanced modelling tools leverage existing big data

The integration of AI, machine learning and deep learning into mineral exploration offers transformative potential. By analysing vast datasets from previous exploration campaigns – including geophysical, geochemical and geological data – these technologies can uncover patterns and correlations that are beyond human capability to detect," explains project coordinator Hafsa Ahmed Munia of Geological Survey of Finland.

The use of AI will significantly reduce the need for expensive and invasive field operations, thus lowering both financial and environmental costs. Machine learning and deep learning models that can continuously improve with new data will lead to more precise and reliable predictive capability over time.

Digital library of primary mineral systems and advanced analysis tools

"Existing non-commercial tools for mineral prospectivity analysis are scattered and require significant expertise to use effectively. "To address this critical gap, EIS developed two software applications that include new geomodels as well as novel, fast and cost-effective spatial data analysis tools for mineral exploration analysis, mapping and mineral systems modelling," says Munia.

The EIS toolkit is a stand-alone Python library of mineral systems. It integrates machine learning and spatial data analysis to facilitate mineral prospectivity mapping at a level unmatched by currently available free software. The tools in the toolkit can be used individually in Python scripts or via the EIS QGIS wizard.

The EIS QGIS wizard is a user-friendly interface that enhances accessibility to the toolkit, streamlining workflows for geologists and exploration professionals. The plug-in allows users to navigate each step of mineral prospectivity mapping. The repository includes documentation for the installation of the software.

© EIS

Sustainable European CRM supply with minimal environmental impact

Supporting exploration teams in all stages of their projects, EIS' tools will streamline workflows, enable better decision-making, and facilitate the sustainable discovery of CRMs through more precise targeting of deposits.

EIS evaluated the capability of the EIS tools to produce mineral prospectivity maps for secondary raw materials (from mines and/or from processing/metallurgical wastes). The evaluation noted gaps in information needed and resulted in recommendations on how to facilitate mineral prospectivity mapping for secondary raw materials.

"Supporting exploration teams in all stages of their projects, EIS' tools will streamline workflows, enable better decision-making, and facilitate the sustainable discovery of CRMs through more precise targeting of deposits," Munia concludes. In this way, the project's outcomes will increase Europe's long-term self-sufficiency regarding CRMs and support the implementation of the European Green Deal, benefiting the EU economy, its inhabitants and the environment.

The public can learn more about the vital role of CRMs in daily life and in the economy, the green transition and sustainable development through the project's podcasts and videos.

PROJECT
EIS – Exploration Information System

COORDINATED BY
Geological Survey of Finland in Finland

FUNDED UNDER
Horizon Europe - Digital, Industry and Space

CORDIS FACTSHEET
cordis.europa.eu/project/id/101057357

PROJECT WEBSITE
eis-he.eu/

Advanced, real-time solutions set a new standard in mining operations

Mining operations have long struggled with the trade-off between satellite data lacking broad coverage and detailed field data arriving late. An EU-funded project bridges this gap through integrated systems and nearly real-time processing, enabling faster mineral analysis and smart decision-making.

A steady supply of various mineral raw materials is critical for driving growth in key sectors of the European economy. Yet, the mining industry faces persistent challenges: accurately separating ore from waste at the source, avoiding costly mistakes, such as misclassifying or re-handling materials, and consistently monitoring waste materials including tailings and waste rock.

Earth observation technologies can transform the mining industry by making operations more efficient, using less energy and reducing environmental impact. These technologies can bridge the gap between broad, coarse satellite data and fine yet slower analyses from laboratories or post-flight studies

At its core, m4mining aims to make mining decisions faster, greener and more reliable by bringing hyperspectral sensing and advanced analytics directly to decision-makers at the source.

Improving mining with hyperspectral technology

The EU-funded m4mining project is designed to transform how we map and monitor both active and inactive mining sites by using advanced Earth observation technologies based on hyperspectral imaging. "At its core, m4mining aims to make mining decisions faster, greener and more reliable by bringing hyperspectral sensing and advanced analytics directly to decision-makers at the source," notes project coordinator Edmond Hansen.

Hyperspectral imaging is an advanced imaging technique that captures data across the complete light spectrum for every pixel in an image, revealing valuable information about the properties of the objects being captured. This spectral information can be used to identify and analyse materials, detect their chemical compositions and assess the environmental conditions.

To achieve its goals, the consortium is developing innovative software and hardware to integrate high-resolution hyperspectral data from heavy-lift drones with the broader coverage of satellites. These tools are being tested and validated in real-world conditions at mining sites in Cyprus, Greece and Australia.

Turning complex data into actionable 3D mineral maps

The consortium has developed a highly integrated unmanned aerial vehicle platform (UAV) equipped with a hyperspectral camera, LiDAR, RGB imaging and inertial navigation. This set-up links every pixel of spectral data to a precise 3D model of the scene. The computing system is split between the drone and a nearby ground node, enabling edge processing. Part of classification and mapping occur mid-flight, delivering actionable mineral or alteration maps within minutes instead of days.

On top of this, the team has built end-to-end processing pipelines with decision-support and visualisation tools, presenting results as intuitive 3D mineral maps rather than raw data. These maps are generated from both drone flights and satellite data. To ensure reliability, the technology is supported by standards, deployment and safety guidelines, simulators for real-time testing and validation campaigns at the three mining sites.

Forging a smarter future for mining operations

"m4mining provides mines with a powerful decision engine that shrinks the loop between 'scan' and 'act'," highlights Hansen. This enables better grade control to extract high-quality ore, smarter material blending to meet standards and proactive tailing monitoring to tackle environmental concerns. It also supports data-driven re-mining of valuable materials from discarded waste.

On a broader scale, the project promotes standardised workflows, data sharing and safety practices for UAV hyperspectral mapping, guided by an industry advisory board. This should help lower adoption barriers across the sector, extending benefits beyond the pilot sites.

"The ultimate goal is a more efficient and transparent mining ecosystem, where valuable materials are recovered more completely, environmental risks are addressed early and operations align better with circular-economy principles," concludes Hansen.

PROJECT
m4mining - m4mining: Multi-scale, Multi-sensor Mapping and dynamic Monitoring for sustainable extraction and safe closure in Mining environments

COORDINATED BY
NORCE Research AS in Norway

FUNDED UNDER
Horizon Europe - Digital, Industry and Space

CORDIS FACTSHEET
cordis.europa.eu/project/id/101091462

PROJECT WEBSITE
m4mining.eu/

New machine learning tools uncover hidden mineral resources in complex terrains

Finding new mineral resources is challenging due to limited *in situ* data and complex landscapes. New machine learning methods trained from data patterns with minimal guidance help researchers detect subtle changes in the landscape, identify mineral deposits and monitor environmental impacts.

The European Green Deal and related regulations aim to make the raw materials sector more sustainable and circular. To ensure a steady supply of raw materials, the EU must explore new mineral resources while protecting the environment.

Remote sensing offers low-impact tools to support all mining stages – exploration, operation, closure and post-closure. However, its full potential has remained undeveloped due to limited knowledge of its applicability for the mineral sector, lack of user-friendly data processing tools and insufficient verification of the interpretation results with *in situ* data.

Researchers working in the EU-funded MultiMiner project are developing advanced data processing algorithms to harness Earth observation (EO) technologies for mineral exploration and mine site monitoring. “We seek to unlock the potential of EO data, including Copernicus, commercial satellite, airborne drone and *in situ* data, to support the entire mining life cycle,” notes scientific coordinator Maarit Middleton.

The focus is on creating innovative EO data analysis tools using weakly and self-supervised machine learning methods. “These approaches require little to no *in situ* data for training, making them ideal for tackling the operational constraints of the mining sector. Applications include, for example, detecting subtle ground surface changes caused by mining and enhancing mineral exploration activities,” adds Middleton.

High-resolution approaches to complex geologies

MultiMiner’s multi-scale data approach developed for mineral exploration and mapping represent a notable improvement over conventional techniques, offering higher spatial and spectral resolutions and adaptability to complex geological environments.

The terrestrial hyperspectral scanning system enables high-resolution, *in situ* hyperspectral imaging directly on mining walls, supporting both exploration and exploitation while advancing geological research. The UAV-based hyperspectral imaging system introduces oblique scanning angles (45° and 90° off-nadir), significantly improving visibility and coverage of vertical and stepped surfaces. With a ground resolution of 6-8 cm per pixel, it delivers highly detailed surface characterisation.

Next-generation algorithms for continuous mine site monitoring

Regarding mine site monitoring, MultiMiner's work helps advance the field in two ways. First, dense image time-series analysis and less frequent drone imagery are combined for advanced detection of surface properties. Models are based on weakly supervised models designed to handle sparse *in situ* data.

Secondly, MultiMiner introduces generic mine site monitoring algorithm that integrates data from multiple sources (e.g. Copernicus Sentinels, hyperspectral and drones) across various spatial, temporal and spectral resolutions. This algorithm supports continuous monitoring, balances frequent and sparse data sources and adapts to diverse monitoring tasks.

Scalable solutions for sustainable and transparent mining

MultiMiner aims to significantly contribute to mineral exploration and mine site monitoring by delivering scalable technologies that seamlessly integrate scarce *in situ* data with multi-temporal and multi-modal EO data from all relevant sources. These novel solutions will enhance access to critical raw materials (CRMs), promote sustainable mining and support stakeholders across the mining cycle, including the mining, exploration and EO value-adding industries.

Our user-friendly, weakly supervised tools for remote sensing-based exploration and monitoring enable more effective use of EO data. This is expected to lead to discoveries of new CRM deposits, improved mining safety and better environmental monitoring.

"Our user-friendly, weakly supervised tools for remote sensing-based exploration and monitoring enable more effective use of EO data. This is expected to lead to discoveries of new CRM deposits, improved mining safety and better environmental monitoring," states Middleton. "Our solutions also increase transparency in mining operations, allowing early detection of environmental impacts, while their low environmental footprint makes them potentially more socially acceptable."

PROJECT
MultiMiner - MULTI-SOURCE AND MULTI-SCALE EARTH OBSERVATION AND NOVEL MACHINE LEARNING METHODS FOR MINERAL EXPLORATION AND MINE SITE MONITORING

COORDINATED BY
Geological Survey of Finland in Finland

FUNDED UNDER
Horizon Europe - Digital, Industry and Space

CORDIS FACTSHEET
cordis.europa.eu/project/id/101091374

PROJECT WEBSITE
multiminer.eu/

From sky to soil: leveraging Earth observation data to empower mining

New technologies and services are transforming the application of Earth observation data at every stage of the mining process.

The European Union (EU) depends heavily on raw materials for key industries such as energy transition and decarbonisation. Yet, this reliance has created significant challenges, as highlighted by the recent Critical Raw Materials Act.

Bridging the gap between space and Earth

The EU-funded S34I project was established to ensure a secure, sustainable and independent supply of raw materials within the EU. "S34I set out to develop data-driven, non-invasive Earth observation methods to support every stage of the mining process," notes project coordinator Ana Cláudia Teodoro. From exploring new deposits to managing extraction and monitoring environmental impacts after a mine's closure, S34I aims to make mining more sustainable and provide better insights for policymaking.

We embody the motto 'From sky to soil', reflecting the innovative use of Earth observation technologies to address challenges across different phases of the mining life cycle.

"We embody the motto 'From sky to soil', reflecting the innovative use of Earth observation technologies to address challenges across different phases of the mining life cycle," adds Teodoro. "By combining data from Copernicus satellite sensors (optical and radar) with other platforms such as airborne systems, low-altitude drones, ground-based methods and fieldwork, we have developed advanced solutions that push the boundaries of Earth observation technologies."

New technologies and services

S34I introduced 20 novel artificial-intelligence-based methods for analysing Earth observation data, created over 50 FAIR-compliant datasets and developed three categories of Earth observation-based services for mining stakeholders: raw material mapping, early warning systems and environmental monitoring. A dedicated geospatial processing platform was also established to integrate and visualise data from multiple pilot sites.

Beyond technology, S34I offers a publicly available MOOC and e-learning platform, along with a white paper containing policy recommendations, protocols and guidelines for using non-invasive Earth observation technologies in mining.

Tailored advances for exploration, extraction and monitoring

S34I's work goes beyond the state-of-the-art to tackle specific challenges in different phases of the mining life cycle. "For land exploration, we developed a prototype for cobalt exploration using advanced satellite sensors such as Landsat-9 and PRISMA, combined with AI methods," outlines Teodoro. The team also integrated airborne hyperspectral and LiDAR data to improve mapping accuracy while reducing the need for ground validation.

In coastal and shallow water exploration, the team created a systematic methodology to connect onshore and coastal deposits. Innovative underwater hyperspectral imaging technology was used to collect offshore data.

Other project activities included the development of a satellite photogrammetry method to estimate stockpile and waste dump volumes. A new artificial intelligence super-resolution technique helps enhance satellite Earth observation time series for monitoring ground surface deformation. Low-cost GNSS receivers were also deployed to collect continuous *in situ* data, eliminating the need for mine surveyors to work in potentially dangerous areas.

In environmental monitoring, researchers explored the use of high-resolution Earth observation data to map acid mine drainage (AMD) constituents in water bodies. A new AI-based method was implemented to analyse the relationship between surface reflectance spectra and AMD constituents.

A competitive mining industry in Europe

By promoting the use of Earth observation data, S34I is poised to drive significant advancements in the mining sector, enhancing EU autonomy in raw materials and equipping European exploration companies with state-of-the-art systems.

“The initiative should help boost the competitiveness of EU mining industries through improved decision-making, support circularity by exploiting waste materials and advance the green and digital transition,” notes Teodoro. “Furthermore, project innovations seek to minimise the environmental impact of mining, foster transparency with stakeholders and ensure safer mining operations.”

PROJECT
S34I - SECURE AND SUSTAINABLE SUPPLY OF RAW MATERIALS FOR EU INDUSTRY

COORDINATED BY
University of Porto in Portugal

FUNDED UNDER
Horizon Europe - Digital, Industry and Space

CORDIS FACTSHEET
cordis.europa.eu/project/id/101091616

PROJECT WEBSITE
s34i.eu/

New knowledge and tools target European supplies of orthomagmatic (critical) raw materials

Geophysical inversion and machine-learning-based 3D prospectivity mapping leverage ore formation processes to provide a sustainable regional exploration solution.

The Earth has a layered structure rich in metals. Over the core, the mantle is the thickest shell. It is made of very hot molten or semi-molten rock (magma) that creates 'currents' as hot rock rises from the depths towards the thin, outermost crust and cooler rock descends. Magma (called lava when it reaches the Earth's surface) forms igneous rock rich in minerals when it cools and crystallises.

'Orthomagmatic' sulfide and oxide ore deposits were the focus of the EU-funded SEMACRET project. It considered Earth systems and processes beyond conventional mineral deposits for sustainable exploration of (critical) raw materials for a green energy transition. Scientists studied mantle-derived magmas, addressing gaps in the understanding of ore formation processes from magmatic sources of metals deep in the Earth to crystallisation and formation of mineral deposits at shallow depth.

© Shenghong Yang

Mineral systems approach

“SEMACRET used advanced simulations to enhance understanding of magma generation, deep magma transportation and magma-crust interactions during ore-forming processes. Modelling work was complemented by high-temperature experimental studies elucidating the role of favourable host rocks in ore formation,” explains project coordinator Shenghong Yang of the University of Oulu. Project research focused on both ‘rifting’ and ‘orogenic’ settings – where tectonic plates split and trigger seismic events and magma formation, or collide and deform (creating mountains), respectively.

The project identified the main source of metals in rifting settings, structures called mantle plumes (large columns of hot rock rising through the mantle). The scientists also showed how the structure of the lithosphere (the crust and upper mantle) can control the formation of specific deposits. SEMACRET concluded that, in orogenic settings, the sub-continental lithospheric mantle and higher volatility of magmas play an important role in magma generation and ascent.

“SEMACRET also improved various proxies used to predict high potential areas by using unconventional geodata reflecting the deep lithospheric structure and geological processes,” Yang notes. For example, seismic data was used to predict deep magma reservoirs.

Innovative geophysical inversion methods

SEMACRET developed machine learning-based 3D mineral prospectivity modelling and resource modelling for nickel-copper sulfide deposits based on drill core databases.

Importantly, SEMACRET developed innovative ‘geophysical inversion methods’ essential for low-impact mineral exploration. These mathematical techniques estimate subsurface properties from geophysical measurements taken at or near the surface.

For example, “low-environmental-impact passive seismic imaging is commonly used for imaging deep Earth structures. In SEMACRET, we developed an innovative inversion method targeting ore bodies in the shallow crust a few kilometres deep,” Yang explains. SEMACRET also developed methods for optimised 3D electromagnetic inversion and ‘full tensor magnetic gradiometry’, a relatively recent method in exploration.

Finally, induced polarisation is another geophysical inversion technique that is very useful for low-sulfide deposits when the electromagnetic signal is not prominent. “Induced polarisation surveys are generally ground-based. In SEMACRET, the induced polarisation signal was extracted from more efficient and less time-consuming airborne-acquired electromagnetic data,” notes Yang.

The team developed a QGIS plugin integrating data processing, inversion, and visualisation for electronic and electromagnetic data to support others working in sustainable exploration.

3D mineral prospectivity modelling using drill core databases

Moreover, “SEMACRET developed machine learning-based 3D mineral prospectivity modelling and resource modelling for nickel-copper sulfide deposits based on drill core databases,” adds Yang. These have the potential to significantly reduce exploration drilling.

SEMACRET has developed sustainable, low- to no-impact solutions for mineral exploration at the regional and local scale. They should support exploration companies and policy makers in their roadmaps to securing a sustainable supply of (critical) raw materials for Europe’s green energy transition.

PROJECT
SEMACRET – Sustainable exploration for orthomagmatic (critical) raw materials in the EU: Charting the road to the green energy transition

COORDINATED BY
University of Oulu in Finland

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RESULTS PACK ON SUSTAINABLE MINERAL EXTRACTION

Modern life and its accompanying devices like mobile phones, flat screen televisions, automobiles, solar panels, space guidance systems, jet engines and pacemakers depend on mineral resources. This Results Pack showcases seven Horizon 2020 funded research and innovation projects offering concrete technological solutions for sustainable mineral extraction.

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