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CORDIS Results Pack on

mineral exploration

A thematic collection of innovative EU-funded research results

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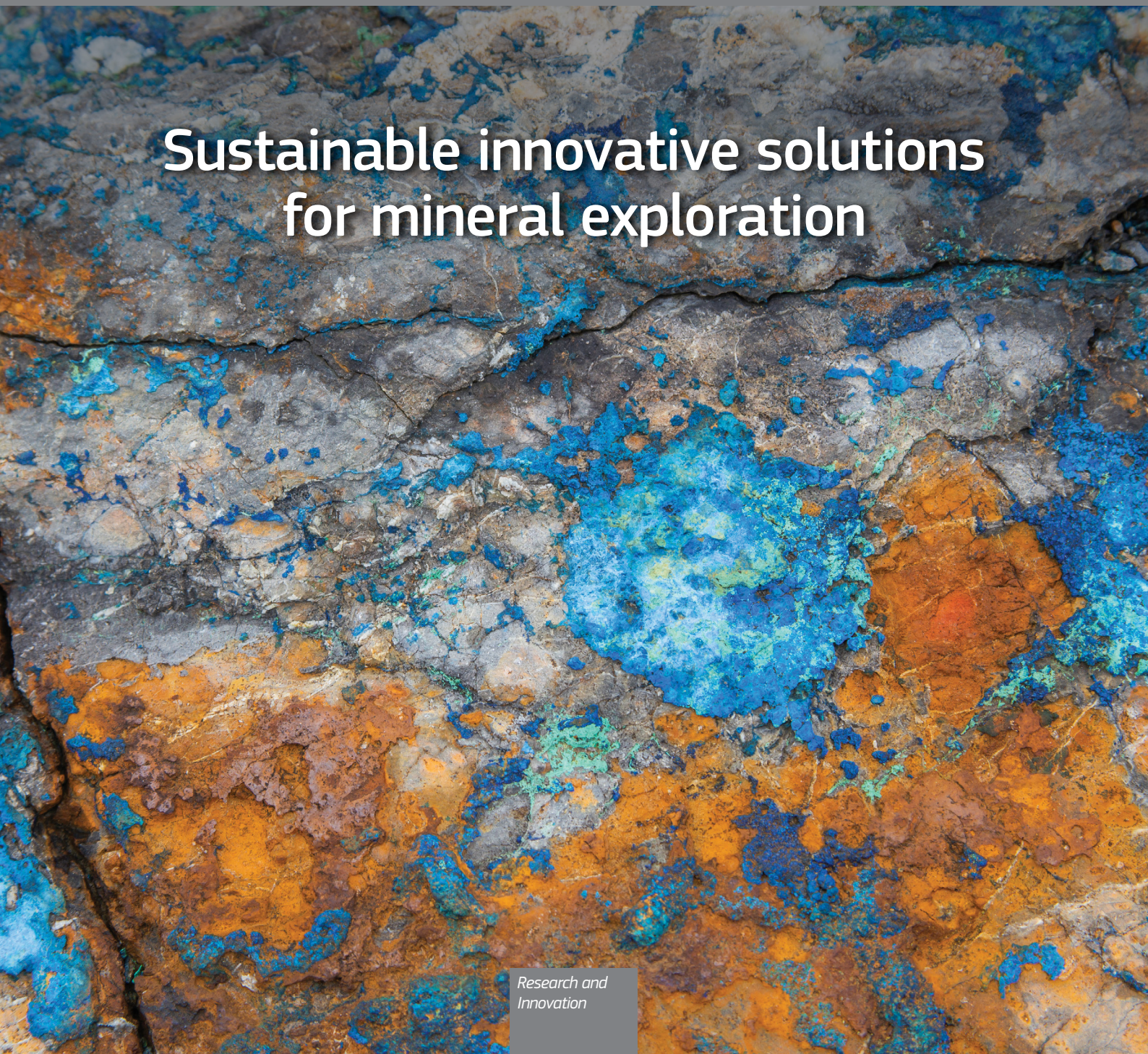

Sustainable innovative solutions for mineral exploration

Research and Innovation

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Editorial

Innovative exploration technologies developed by Horizon 2020–funded projects for finding metal ores and minerals are helping to transform Europe into a sustainable resource-efficient and competitive economy, while tackling environmental and climate-related challenges. This Results Pack highlights six cutting-edge EU projects that are helping to bring about this transition.

Access to resources is one of the most strategic security questions surrounding the delivery of the European Green Deal. The Green Deal aims to make Europe the first carbon-neutral continent by 2050. Furthermore, by summer 2020 the European Commission plans to raise the EU's greenhouse gas emission reductions target for 2030 to at least 50 % and towards 55 % of 1990 levels.

The sustainable utilisation of raw materials, including metals and industrial minerals, and particularly Critical Raw Materials (CRM) such as rare earths, is one of the main prerequisites to making this switch happen. This is due to their vital role in industrial value chains, especially in the energy, mobility and defence sectors, and the production of renewable energy technologies, electric vehicles, and mobile phones among others.

New approaches applied

As the demand for raw materials is growing, EU research and innovation funded under Horizon 2020 helps to improve access to metals and minerals, while optimising their consumption and improving extraction conditions across Europe.

Mineral exploration is conducted to search for commercially viable concentrations of ores and minerals for mining purposes. A highly accurate estimation of the volume of the deposits is crucial due to the capital-intensive nature of the mining operation.

Innovative and sustainable approaches to the discovery of metals and minerals include the autonomous exploration and mapping of flooded mines and seabed terrains to provide the high-resolution information needed for reliable identification of ore bodies. Another method is to improve the accuracy of geo-models and economic evaluation of ore reserves.

In addition, reducing high exploration costs and enhancing the participation of civil society from the start of exploration will help raise awareness and trust among local communities and other stakeholders. Scaling up the most promising technologies and launching them on the market will strengthen the competitiveness of European industries in this sector.

Focus on EU research

In this CORDIS Results Pack we focus on the innovative results developed by Horizon 2020-funded projects working on exploration technologies for a sustainable supply of raw materials. The HiTech AlkCarb project brings together partners from across Europe and Africa to significantly improve geological models for the exploration of high-tech raw materials like the rare earth elements associated with alkaline rocks and carbonatites.

ROBUST develops an autonomous robotic survey system for identifying and analysing polymetallic nodules at great depth in the ocean. Meanwhile, UNEXMIN creates a highly sophisticated robot to explore and map flooded mines, retrieve geological data and conduct analysis of water chemistry and mine wall properties. Then SOLSA combines sonic drilling, analytical equipment and informatics to optimise mining operations performance.

We also have INFACT, a designer of innovative, non-invasive and socially acceptable mineral exploration technologies to help unlock unrealised potential in new and established sites. Finally, Smart Exploration develops cost-effective and environmentally friendly solutions for deep mineral exploration in areas designated as brownfield (abandoned industrial property) and greenfield (area of land that has never been developed or built up).

Discovering Europe's high-tech raw material deposits, removing a bottleneck on production

New geophysical models will help boost extraction of high-tech raw materials such as niobium, tantalum, and the rare earth elements neodymium and scandium, to support advanced and green technologies.

High-tech raw materials such as niobium, tantalum, and the rare earth elements neodymium and scandium are of growing importance to areas including consumer electronics, renewable energy and low-carbon transport. Currently, almost all the EU's demand for specialist metals needed in these technologies must be satisfied by imports, often from just a few mines in one or two countries. This puts the metals supply at risk of disruption.

Alkaline igneous rocks and carbonatites are important repositories of many high-tech resources, and the hunt is on for deposits.

The EU-funded HiTech AlkCarb project brought together 13 partners from Africa and Europe representing SMEs, geological surveys, universities and a museum to deliver the geological models needed to find them.

Geophysical methods (based on the study of physical fields in the Earth's interior such as magnetic and electromagnetic) are essential to geological exploration. We had to first learn how to interpret these signals much better with respect to the minerals and metals of interest. We also needed to integrate environmental and social aspects into our geomodels since these are now essential at all stages of exploration and mining.

The best of both worlds

Compared to better-known metals such as copper and gold, exploration for rare earths, niobium and tantalum in alkaline rocks and carbonatites is in its infancy. As project coordinator Frances Wall explains, "Geophysical methods (based on the study of physical fields in the Earth's interior such as magnetic and electromagnetic) are essential to geological exploration. We had to first learn how to interpret these signals much better with respect to the minerals and metals of interest. We also needed to integrate environmental and social aspects into our geomodels since these are now essential at all stages of exploration and mining."

HiTech AlkCarb carried out numerous case studies, with particular insight coming from the 18 million-year-old Kaiserstuhl volcano in Germany. This site is not of economic interest but an excellent research site because both the volcanic lavas and the 'roots' (igneous intrusions) of the volcano where ore deposits form are exposed.

Wall continues: "Our Namibian partners brought experience regarding environmental and social impact assessments (ESIA). This 'Namibian best practice' was used during our work at Kaiserstuhl." The end result of the studies was a 3D model of the Kaiserstuhl volcanic complex combining geological and geophysical information. Project partner Lancaster Exploration (Ltd) continued this research at its active exploration site at Songwe Hill in Malawi and their scientists found the most effective geophysical measurements to improve their geological model.

Flexible and far-reaching application

A geomodels approach called 'Mineral Systems', applied to carbonatites and alkaline rocks for the first time, is already yielding exciting results. It has been used to investigate known deposits, to predict new places to test, and to identify other types of small and complex deposits. Results will be available free of charge to support public, private and research organisations alike. Partner SMEs are expanding their businesses via: additional funding; expanded knowledge, skills and services; and improved geomodels.

The project has also produced a special online course, already available, to ensure global outreach. "We integrated worldwide expertise to make our new geomodels. Our workshops included 60 expert counsellors from 20 countries. Several hundred people participated in the final project meeting in London, in person or online," Wall summarises. "We now understand more about alkaline rock and carbonatite deposits and are ready to explore more effectively in Europe and worldwide. The expertise and information to do that has been created in HiTech AlkCarb."

PROJECT
HiTech AlkCarb - New geomodels to explore deeper for High-Technology critical raw materials in Alkaline rocks and Carbonatites

COORDINATED BY
The University of Exeter, United Kingdom

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/689909

PROJECT WEBSITE
bgs.ac.uk/hiTechAlkCarb/

A high-tech robotic diver analyses the Earth's mineral riches on the ocean floor

At ocean depths up to 6 km, the Earth brings forth precious mineral and metallic formations that scatter the landscape. The first-ever deep-sea autonomous robotic explorer for in situ identification and analysis will soon be delicately investigating these deposits for potential use in electric cars and more.

The deep-sea floor is a vastly unexplored treasure trove of cobalt crusts, manganese nodules and polymetallic seafloor massive sulphides. These formations could make a significant contribution to burgeoning demands for electronics and technologies relying on rare and expensive metals. The global market for deep-sea mining is expected to grow from about USD 650 million in 2020 to USD 15.3 billion by 2030. The ambitious EU-funded ROBUST project has delivered an autonomous robotic survey and analysis system that will support this development while protecting the environment. It will also be an invaluable tool for oceanic research expeditions.

© ROBUST consortium

(Laser) lights, camera, action

Current deep-sea exploration of polymetallic nodules involves retrieving raw samples from the seabed using remotely operated vehicles (ROVs) tethered to exploration ships. The samples are brought up to the surface for analysis in a time-consuming, expensive and inefficient process. ROBUST set out to make deep-sea mining cost effective and environmentally friendly.

Ferromanganese crusts and manganese nodules are rich in industrially important nickel, copper, cobalt, lithium, molybdenum, manganese, while rare earth elements and seafloor massive sulphides are rich in copper, zinc, iron, gold, and silver-rich sulphide mineral deposits. Project coordinator Graham Edwards explains: "We use an autonomous underwater vehicle (AUV) to deploy a custom-made laser system capable of identifying manganese nodules at 300 m sea depth. We also developed a laser-induced breakdown spectroscopy (LIBS) system with in situ automated copper, manganese and zinc nodule identification capabilities integrated with seafloor massive sulphides detection capability. This powerful LIBS system is thus able to identify critically important mining targets under the sea in situ."

The systems are not only high-tech but must also work in the extreme subsea environment. Moving over the ocean floor, the ROBUST system creates 3D maps from data obtained via a combination of hydro-acoustics, laser scanners and photogrammetry. "A convolutional neural network pattern recognition algorithm detects manganese nodules in real time. When the AUV is within a few metres of the target, onboard cameras trigger precise vehicle positioning," explains project leader James Essien.

The first pulse initiates a gas cavity and the second pulse enables a hotter, longer excited state, with the acquired spectrum identifying the nodule.

Once the AUV is over the target, it positions its underwater vehicle manipulator system with the integrated LIBS system for optical, non-contact, in situ chemical analysis in real time. A double-pulse laser mechanism boosts the signal strength. "The first pulse initiates a gas cavity and the second pulse enables a hotter, longer excited state, with the acquired spectrum identifying the nodule," Essien explains. Fitted to an ROV, the LIBS system has operated at ocean depths greater than 4000 m.

PROJECT
ROBUST – Robotic subsea exploration technologies

COORDINATED BY
TWI Limited, United Kingdom

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/690416

PROJECT WEBSITE
eu-robust.eu/

A look back in time could reveal a way forward for Europe's uncharted treasures

In Europe alone, there are about 30 000 abandoned and flooded mines, some of which could once again become profitable. A pioneering robotic exploration platform is ready to dive in and find out which ones are worth reopening.

People have extracted the Earth's minerals and metals throughout history to support innovation. Over time, advances in mining, processing and smelting have lowered mining costs and demand has created new markets such as that for rare earth elements that support green technologies.

While many abandoned mines may be hiding valuable treasures for our economies, flooding makes human exploration difficult, if not impossible. The EU-funded UNEXMIN project has developed a safe, environmentally friendly and cost-effective alternative – the UX-1. Autonomous underwater robots will identify mines

with potential. Reopening them could boost the EU economy and relieve dependence on imports for critical raw materials.

Robotic explorers navigate and analyse flooded mines

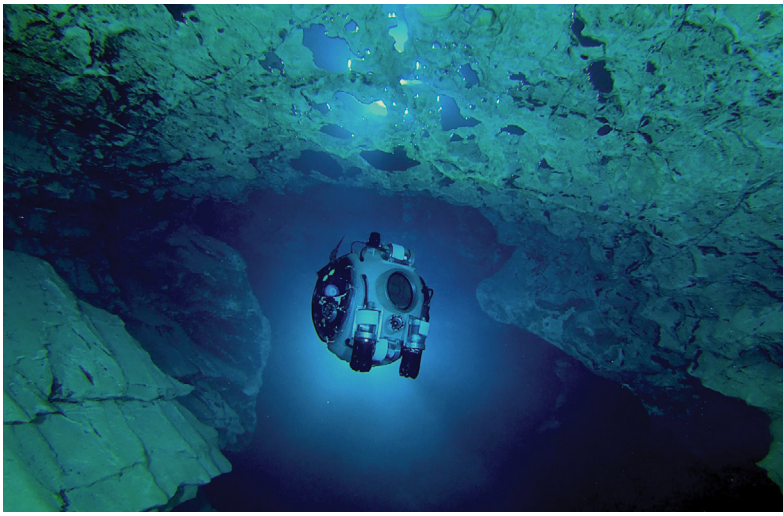
UNEXMIN's sophisticated multi-robot platform was developed to explore the flooded mines and retrieve geological data. Having multiple robots working as a team serves two key purposes. It allows distribution of payloads to reduce energy consumption and allow each to work longer with greater reliability. It also speeds data collection, with a dispersed team exploring numerous corridors and galleries simultaneously.

Real-time localisation, mapping and navigation capabilities combined with perception and survey software enable UX-1 to conduct autonomous exploration and analysis of complicated and hazardous underwater environments.

Project fellow Luís Lopes explains: "Real-time localisation, mapping and navigation capabilities combined with perception and survey software enable UX-1 to conduct autonomous exploration and analysis of complicated and hazardous underwater environments." Spherical in shape with a diameter of around 60 cm, a single UX-1 weighs about 112 kg and can work for up to 5 hours. "The data is processed after each mission with tailor-made software that yields 3D maps and models of the mine environments and a geological analysis of the water chemistry and mine wall properties. Our combination of onboard navigation and scientific instrumentation has never been seen in a robot of this size or even in a much bigger one," adds project coordinator Norbert Zajzon.

Rising to the challenge, descending to the depths

UNEXMIN tested the UX-1 multi-robot platform in highly varied and complex environments at five test sites including a UNESCO heritage site in Slovenia and an expansive thermal cave system in Hungary. According to Lopes, "the most exciting discoveries were in Ecton mine in the UK, closed for more than 150 years. They led to a new understanding of mineralisation and the tectonics and structural geology of the region and also elucidated how the mine worked during the 18th and 19th centuries." In total, UX-1 made 50 dives, covering 5 000 m of shafts and galleries in 98 hours and collecting about 9 TB of data.



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Broad-sweeping and evolving benefits

Aside from mining companies, UX-1 can support both public and private enterprises in numerous ways. Zajzon explains: "Geological surveys, governmental bodies and universities can use the data for educational purposes. Water supply companies can assess their pipelines, environmental companies can assess underwater risks to the public, and even tourist sites can use the data for marketing to potential visitors." The team has secured funding for further development from EIT RawMaterials, the largest raw materials consortium in the world. In the meantime, the spin-off company UNEXMIN GeoRobotics will enable commercial use of the current UNEXMIN technology.

PROJECT
UNEXMIN – Autonomous Underwater Explorer for Flooded Mines

COORDINATED BY
University of Miskolc, Hungary

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/690008

PROJECT WEBSITE
unexmin.eu/

‘Bit by bit’ to a more sustainable metal and mining sector

EU-funded researchers have unveiled a groundbreaking expert prototype system that combines sonic drilling, analytical equipment and informatics to optimise performance of mining operations.

Over the years, the mining industry has been repeatedly criticised for the harmful effects its operations have on the environment and people. Mining activity can heavily impact the air, water and land of communities, causing problems that persist for generations. Less documented, however, are the EU’s attempts to invest in research and innovation of greener technologies to change the industry’s reputation from an environmental polluter to a sustainable energy-efficient industry.

Digital technologies create a clear pathway for transformation

Digital and technological innovations could transform key aspects of mining. They create a more detailed view of the concentration of valuable minerals or geological materials, increase process efficiency through automation, monitor performance in real time and optimise material flow.

The EU-funded SOLSA project has developed a robust expert system that can speed up and optimise the three major components of mining (exploration, mining and processing). The newly developed technology consists of different elements that together form the expert SOLSA system. These are the sonic drill part that simultaneously takes samples and measures different parameters in real time, and the laboratory in the field that analyses the composition of the soil core on the spot. The final part is the software solution that gathers all available analysis data in a database that automatically updates itself.

The SOLSA tool brings innovative technologies that can sustainably meet the growing demand for minerals and metals. They should help optimise metal production, ensuring that mining operations are more energy efficient and have a less degrading impact on the environment.

How does sonic drilling work?

“Sonic drilling is a soil-penetration technique that strongly reduces friction on the drill string because it causes liquefaction, inertia effects and temporary reduction of the soil porosity,” explains project coordinator Monique Le Guen. The reduced friction on the drill string means sonic drilling operations use less power compared to conventional drilling technologies. This unique characteristic of sonic drilling prevents torsional forces on the drill string.

Another benefit of applying sonic high frequency is the ease of retrieving the drill string, even in quick expanding clays or boulders and difficult conditions. All the drilling rods, casings and tooling are pulled out faster and easier. The additional rotational and vibrational parts in the drill head help operators to better control the force needed to optimally penetrate the soil and bedrock formations.

The SOLSA system combines for the first time – along the drill core – non-destructive sensors based on X-ray fluorescence, X-ray diffraction, vibrational spectroscopy and 3D imaging. It also brings together a profilometer and RGB and infrared cameras for mineral mapping. Automatic combined analysis provides accurate information about the mineralogical and chemical composition of the core.

© Monique Le Guen

The system's promising potential

At the moment, the SOLSA system is in a testing stage. The drilling rig has been shipped to New Caledonia for performing field tests in nickel laterites that are well known for their heterogeneity and difficulty to be drilled and well recovered. The SOLSA tool can clearly increase exploration efficiency by broadening the data field, while reducing costs and return time.

"The SOLSA tool brings innovative technologies that can sustainably meet the growing demand for minerals and metals. They should help optimise metal production, ensuring that mining operations are more energy efficient and have a less degrading impact on the environment," concludes Le Guen.

PROJECT
SOLSA - Sonic Drilling coupled with Automated Mineralogy and chemistry On-Line-On-Mine-Real-Time

COORDINATED BY
Eramet, France

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/689868

PROJECT WEBSITE
solsa-mining.eu/

Stakeholder engagement and technological advancements to realise Exploration 4.0

EU-funded researchers are addressing social, cost, political, legislative, technical and physical issues delaying advancements in sustainable mineral exploration.

© INFACT

Despite growing demand for mineral resources in Europe, and the importance of raw materials in the production of clean technologies, there remain a range of obstacles to raw material exploration. The EU-funded INFACT project targets the delivery of solutions across social, legislative and technical domains that will promote and facilitate sustainable mineral exploration via research on low-impact technologies, outreach to society at large and practical field work.

Researchers are studying good practices in countries that are more active in mineral exploration, such as Australia and Canada, to adopt guidelines applicable in Europe. They are working to

tailor stakeholder engagement in the exploration industry to the European context. Project coordinator Leila Ajjabou notes that INFACT also aims to "provide a narrative to stakeholders by offering a base for an informed decision for all the stakeholders of mining – from the general public and industry to national and EU authorities."

Technological advancements

A further aim, elaborated on in a short INFACT movie, is to assess the technical performance of non-invasive technologies as well as the factors influencing their acceptance by the public. In practical terms, scientific coordinator Richard Gloaguen reports, "The project has pushed drone-based geophysics and hyperspectral imaging developments as well as new airborne geophysics techniques called full tensor magnetic gradiometry."

Laying the groundwork for sustainable exploration

INFACT is currently establishing three reference sites in Saxony (Germany), Andalusia (Spain) and Lapland (Finland). Here, technologies will be assessed and evaluated based on legal, environmental, sociological and technical performances. "These European reference sites have been selected to provide a rich and diverse exploration portfolio including extensive drill hole and geophysical databases," Gloaguen explains. These cover a wide range of geological, social and climatic conditions to ensure a rich variety of exploration challenges are catered to.

The very heterogeneous legal framework in Europe regarding mining-related activities is a challenge to any harmonised view on European mineral exploration.

The team is also developing a business model for defining the range of services these three sites will offer. Amongst others, these include training in responsible exploration practices, evaluation, and the attribution of a responsible exploration label for future exploration technologies.

Project work and developments are not without challenges. Ajjabou comments on this: "The very heterogeneous legal framework in Europe regarding mining-related activities is a challenge to any harmonised view on European mineral exploration." Another difficulty lies in the industry's lack of culture of stakeholder engagement in exploration projects already running in Europe.

Towards Exploration 4.0

Notwithstanding, INFACT is set on achieving Exploration 4.0, defined by Gloaguen as "technologically efficient and acceptable mineral exploration." Strides have already been made in this direction. Hence, centres of excellence in mineral exploration at the three reference sites will boost visibility and business appeal. The impact of INFACT is also already evident by numerous offers to join the project by technology providers and relevant institutions in the EU and beyond.

Another example of a successful project initiative involves a stakeholder event held in Geyer (Germany) in 2018 that enabled discussions with scientists regarding the use of technologies. "To sum up, we are proud to bring societal and technical worlds together," Ajjabou enthuses. At the same time, Gloaguen concludes, "It is important for us to emphasise that we are not a lobbyist: We are not working for the mining industry or NGOs. We hope to maintain a very neutral view on the sector and to provide a holistic view on mineral exploration."

PROJECT
INFACT – Innovative, Non-invasive and Fully Acceptable Exploration Technologies

COORDINATED BY
Helmholtz-Zentrum Dresden-Rossendorf, Germany

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/776487

CORDIS FACTSHEET
infactproject.eu/

High-tech and legacy data open new avenues to deep mineral exploration

There are challenges to deep mineral exploration, with in areas previously developed (brownfield) or new ones with development potential (greenfield). The EU-funded Smart Exploration project is introducing solutions for both area types.

Introducing the project, coordinator Alireza Malehmir, professor at Uppsala University in the Department of Earth Sciences, notes: "The main goal of Smart Exploration is to develop cost-effective and environmentally friendly solutions for deep mineral exploration in brownfield and greenfield areas." The EU-funded work is centred on the development of five system prototypes and six improved methods for 3D imaging and modelling. "The newly acquired data, through the prototypes combined with the new methodologies, provide better target and geological characterisations at greater depths," Malehmir reports.

Mapping mineralisation

The GPS-time synchronisation system (for denied-access environments such as underground mines) and an electric seismic source with broadband frequency (E-Vib) are two of the prototypes. These enabled the project team to conduct an upscaling semi-3D surface and semi-3D underground seismic survey in the Neves-Corvo mine (Portugal) at 600 m depth. "Without the two systems, such a survey would be either impossible or only limited to 2D lines in a small survey area," explains Malehmir. "We consider this survey a big leap forward for better targeting and thus potentially reducing costs and environmental impact from mining activities."

Project partners have also used improved algorithms to successfully recover and reprocess a number of legacy data sets. While specifically relevant to the Neves-Corvo mine and Ludvika mines in Sweden, this feat underscores the value to be gained from the use of appropriate data and access to it. "Your next orebody might be in your legacy data," Malehmir points out.

Other achievements cover activities at Finland's Siilinjärvi phosphate mine. Here, Smart Exploration was able to distinguish the ore from the waste rock and to map vertical faults that could act on the stability of the mine wall.

Greenfield innovations

The project's validation sites either contain primary resources (EU-listed critical raw materials) or host them as secondary resources. Malehmir explains that in certain sites, steep topography makes it extremely difficult to impossible to use conventional geophysical methods for rock characterisation and structure imaging. "As a solution, the developed helicopter transient electromagnetic method

Smart Exploration supports more than 20 young professionals from academia, SMEs and mining companies. This younger generation is the key asset for the mineral exploration industry but also maybe future entrepreneurs who have learned how collaborative work can lead to commercial solutions and open up new businesses.

(HTEM) prototype, which has already been tested at the Ludvika brownfield site, will be flying over our greenfield sites in Greece and Kosovo to detect deep targets."

Smart Exploration also employed machine learning algorithms to reinterpret existing geochemical-geological-geophysical data, providing potential porphyry Au-Cu (gold and copper) targets in Greece. "The innovation here lies in the way the data has been harmonised and validated through geostatistical approaches," the coordinator reveals.

© Alireza Malehmir

Looking ahead

Project partners also had to overcome challenges off the slopes. The teams adopted agile engineering in instances where delivery of parts was delayed, and they built a custom-made drone to reduce noise level in the unmanned aerial vehicle system.

Next on the agenda is exploitation and commercialisation. Smart Exploration will introduce the solutions to relevant companies through exploitation tours, mining events, workshops and direct engagement. In the meantime, "Smart Exploration supports more than 20 young professionals from academia, SMEs and mining companies," Malehmir concludes. "This younger generation is the key asset for the mineral exploration industry but also maybe future entrepreneurs who have learned how collaborative work can lead to commercial solutions and open up new businesses."

PROJECT
Smart Exploration - Sustainable mineral resources by utilizing new Exploration technologies

COORDINATED BY
Uppsala University, Sweden

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/775971

PROJECT WEBSITE
smartexploration.eu/

These two newly funded projects may be mentioned in addition to the six projects highlighted above.

New exploration concepts and technologies reduce environmental impacts

NEXT is developing new geomodels, novel sensitive exploration technologies and data analysis methods that are fast, cost-effective, environmentally safe and socially acceptable. The aim is to reduce current high exploration costs and enhance the participation of civil society from the start of exploration, raising awareness and trust. Furthermore, the reduced environmental impact of the new technologies and better understanding of the factors influencing social licensing will help promote social acceptance of both exploration and mining, thereby supporting the further development of Europe´s extractive industry.

© NEXT

Radically new technologies spawned from traditional approach

The PACIFIC consortium will develop a new, low-cost and environmentally friendly tool for exploring for mineral deposits beneath the surface. The work builds on the 'traditional' passive seismic method, which provides useful broad-brush background information about the geological and structural setting of mineralised regions, but lacks the resolution needed for reliable identification of ore bodies. Two radically new developments are therefore planned: reflection passive seismics, which is appropriate for greenfields exploration, and the multi-array method, which will typically be deployed during drilling or in brownfields exploration. Both techniques have major advantages over current techniques, namely relatively low cost and limited impact on the environment.

© Nicola Ramm (IMS)

The project PACIFIC has collaborated with other H2020 projects: joint site experiments were organised in collaboration with INFACT and HiTech AlkCarb, while a winter school on sustainable mineral exploration was jointly organised with INFACT.

CORDIS Results Pack

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RESULTS PACK ON DIGITAL TRANSITION IN WATER

Dip into the Results Pack on digitalisation of the water sector, focusing on 12 EU-funded projects that have developed innovative ICT solutions as part the ICT4WATER cluster.

Check out the pack at
cordis.europa.eu/article/id/413408

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