After a few years of recession, mining investments have recently shown considerable growth in Finland. A dozen or so new exploration companies have started operations during the last year, and exploration has been activated, leading to some notable discoveries. A number of prospects are undergoing feasibility studies and proceeding towards mine development. Finland remains one of the most interesting destinations for mining investment right now, according to the Fraser Institute’s study on mining companies. So, the near-future outlook is positive.

The global political situation is currently unstable and forecasts of economic growth are uncertain. New technologies will be based on minerals. For example, there is expected to be a boom in mining of so-called battery metals as electric cars replace those with internal combustion engines in the decades to come. It is not only lithium which is required, a typical electric car of the future will also need about 160 kg of copper, 11 kg of cobalt and 11 kg of nickel. Therefore, copper, nickel, lithium and cobalt should all particularly benefit, as well as graphite. Interestingly, we have existing deposits and excellent exploration potential for further discoveries of all these commodities in Finland.

GTK is applying long-term roadmaps to guide expertise development to meet our stakeholders’ needs, from geology and exploration techniques, to minerals processing, sustainable management of mine environments, and material studies related to the circular economy. GTK’s strong partnerships in Europe and globally make it possible to offer cutting-edge knowhow to our clients. In Finland, GTK is actively building new ways to cooperate with universities to support the development of the minerals sector innovation ecosystem in Finland, where the role of the companies is becoming increasingly important. Together we can create world-class expertise and success.

Promotion of investment opportunities in Finland and support for export of Finnish minerals sector knowhow have become important tasks for us. We are always pleased to help newcomers establish their operations in Finland.

Pekka Nurmi
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Future is made of minerals

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IN BRIEF

The annual review 2016 of GTK is available in online format. Read more about our operations!

annualreview2016.gtk.fi

Bedrock maps of Finland to new age

During the last ten years GTK has renewed the bedrock map production so that in addition to lithological maps presenting rock types and associations, also maps based on stratigraphic units are produced. As the result, we have for the first time a geological unit register that is based on international standards (ICS Stratigraphic Guide and IUGS CGI GeoSciML) and covers the entire Finland.

A map dataset at the scale 1:1,000,000 was produced by generalisation of the digital, unit-based spatial dataset that covers the whole of Finland. From this dataset, the printed map “Geological Map of Finland – Bedrock 1:1,000,000” was produced at the end of year 2016 for scientific purposes, and another one (Generalised bedrock 1:1,000,000) which is suitable for example for use at schools. A metamorphic map dataset at the scale 1:1,000,000, covering the whole of Finland, was produced as well.

In June 2017 GTK published three articles that explain the outcomes of the new approach (Special Paper 60). The first one of them is an explanation of the principles of division of the bedrock into stratigraphic units, and major units are presented. The second one is an explanation to the legend of the map “Geological Map of Finland – Bedrock 1:1,000,000”. In this article the evolution of the bedrock during 3000 million years is explained using tectonic model figures. In the third article, an explanation to the digital map “Metamorphic Map of Finland 1:1,000,000” is given, with numerous examples of variously metamorphosed rocks.

Kokkola Material Week: Towards the circular economy

The GTK, together with other research, education and development organizations in the Kokkola region, organizes an annual Kokkola Material Week (www.material-week.fi) event. Finland’s leading experts and business executives present the most recent research and development outlook for the chemical industry, the bioeconomy and the mineral economy. During the week, GTK specialists present the latest results in peat and acid sulphate soil research, as well as the mineral economy and recycling. This year’s specialty is the international battery conference, the 3rd Nordic Battery Conference (www.chydenius.fi/nordbatt2017).

Central Ostrobothnia has excellent opportunities for renewing the various industries. Kokkola Industrial Park is the most significant concentration of the chemical industry in Northern Europe. Together with strong chemical expertise and primary production these allow e.g. for the development of biomass value chains or utilization of lithium resources to battery chemicals.

Significant chromium resources remain undiscovered in Finland’s bedrock

GTK has evaluated chromium resources in stratiform and podiform chromium deposit types in the Finnish bedrock to a depth of one kilometre. Altogether, 18 areas that could contain undiscovered chromium deposits were delineated in Finland. The areas are expected to contain approximately 32 undiscovered deposits.

At 50% level of probability, the undiscovered chromium deposits in Finland contain at least 350 million tons of chromium. Comparison to the known resources indicates that over 90% of the chromium endowment in Finland occurs in poorly explored or yet undiscovered deposits.
Finnish lithium interests car manufacturers

Text: Jaana Ahlblad

The growth prospects of the electric car industry have raised concerns about the sufficiency of raw materials for batteries. Europe is about to get its own lithium carbonate production in Finland.

It has been plain sailing, as the saying goes. This is at least according to Pertti Lamberg, CEO of the Finnish mining company Keliber Oy. The company owns vast lithium deposits in Central Ostrobothnia in western Finland.

The company’s prospects are great due to the fact that the lithium spodumene deposits of the area are the most significant in Europe, the global demand for lithium batteries is growing, the technical–economic analysis of the planned mine will be completed soon, evaluation of the mine’s environmental impact is progressing well and investors are interested. If the permit process goes through as planned, Keliber’s lithium mine and lithium carbonate production plant starts in 2019.

– If we could start production today, our share would be 5–10 percent of the global market, Pertti Lamberg, CEO of the Keliber Oy says.

Currently, battery-grade lithium carbonate is mainly processed in China. According to Lamberg, European car manufacturers have been interested in Finnish lithium production.

– There has not been a need to think about the raw material chain before, but now we are running short of lithium carbonate. Most of the production is owned by a few non-European actors. This would be the first lithium mine in Europe, and as such geopolitically important.

Riding the green wave

Keliber has also been helped by the positive attitude of public discussion. According to Lamberg, the public understands the need for lithium as an important component of electric cars and green energy.

– There are no sulphides or soluble metals in the ore body that would cause a risk of acidification of the water system, which makes managing and talking about the environmental impact easier. When we do things correctly, the risks are minimal.

Communication is also supported by the opportunity to tell the public about the circular economy. Keliber will actively try to utilise the by-products of excavation. The quartz feldspar residue remaining in the tailings can be used by the construction industry and the zeolite-based matter in water treatment. These and other options for reducing the amount of disposed tailings are currently being researched by the EU-funded FAME project.

If we could start production today, our share would be 5–10 percent of the global market, Pertti Lamberg, CEO of the Keliber Oy says.
– There is demand for new types of feldspar products, for example. Naturally, it would also bring added financial value to Keliber, if a larger fraction of ore could be utilised as commercial products.

Now is the right time

Hints of Central Ostrobothnia’s exceptional lithium deposits were found as long as 60 years ago. An ore enthusiast found a rock with a strange mineral that turned out to be spodumene, a rare lithium mineral. Extensive surveys were conducted for a long time, but as late as in the early 1980s, the market for lithium was too small for a mine to be viable.

The company now known as Keliber has owned two of its six deposits since 1999. Three of the company’s deposits were bought from the Ministry of Economic Affairs and Employment’s international auctions. GTK has surveyed and developed those deposits earlier. Pertti Lamberg appreciates the partnership with GTK. Keliber and GTK have worked together closely at each stage.

– Thanks to GTK, the ore potential is known and we have been able to develop an efficient production process in cooperation with Outotec. It must also be said that GTK’s map materials are exceptionally good.

Currently, Keliber and GTK are preparing a biochemical research on finding indications of lithium deposits from plants.

Via waterways and railways

The estimated size of Central Ostrobothnia’s lithium spodumene deposits is over 500 square kilometres, but according to GTK’s ore potential survey, the lithium veins may be spread over an even larger area. Data was gathered by analysing moraine samples collected in the 1970s.

– Because the soil in the area is thick, geological boulder mapping and geochemistry play an important role. The work requires a lot of resources, Lamberg says.

Updating the mineral potential estimate continues while Keliber is making preparations for the excavation operations and planning a production plant.

It would be easy to ship lithium carbonate containers to the world, because the production plant in Kaustinen will be located only 50 kilometres from the deep-water port of Kokkola and a railway station.

Pertti Lamberg believes in lithium – so strongly that he left the professorship of geometallurgy he held at Luleå University of Technology and took a position as Keliber’s CEO in 2016.

– The price development of Lithium has been positive, and supply will not meet demand in the near future. There is room in the market for new operators, Lamberg explains. ■

Finland also produces other metals for batteries

Finland is one of the largest producers of mined nickel in Europe. The largest known nickel and cobalt deposit is the Sokkamo mine, operated by Terrafame.

In addition to Terrafame’s mine, cobalt is being produced as a by-product at the Kevitsa nickel-copper mine. The Kylylahi copper-zinc mine also produces cobalt as a by-product, but it is not being refined at the moment. Sakatti is the fourth of Finland’s significant nickel and cobalt deposits. Its size is currently being surveyed actively.

In addition to Finland, Russia is the only other country on the European continent where cobalt is mined. Finland refines more nickel and cobalt than we excavate as raw materials.

– Geologically, Finland has a lot of potential for exploring new cobalt deposits as well. Where there is nickel, there is probably also cobalt, says Pekka Tuomela, head of GTK’s Ore Geology and Mineral Economics unit.

Finland’s bedrock contains graphite as well. It is being actively explored for, but it is not currently being produced. ■
A treasure trove in western Finland

- According to GTK’s estimate, the known deposits of the lithium province would last tens of years.
- Keliber’s mining operations will probably start at the Syväjärvi deposit, where the ore’s Li2O concentration is good and the ratio of ore and by-products is profitable.
- The Rapasaari deposit is the largest in the area. It consists of multiple veins, whose thickness varies from a few metres to tens of metres.

Europe is looking for flexible technology

How could we get more benefit from small mineral deposits? What are the best, most environmentally friendly and mobile processing technologies for compact operations? This is currently being investigated by the EU-funded FAME (Flexible and Mobile Economic Processing Technologies) project. All in all, 8 countries and 18 research institutions, universities and mining companies (mostly SMEs) are participating in the project.

The goal of this four-year project is to improve the self-sufficiency of Europe in regard to critical minerals. Multiple small deposits that are close to each other could be, for example, utilised by using a mobile processing unit and by pre-processing the minerals more effectively on site.

- The project has produced important observations, says FAME coordinator Chris Broadbent.
- Characterisation is fundamental to the successful development of the best processing option – mineralogy is often ignored by companies once the initial discovery has been made – but access to high quality mineralogical studies will assist interpretation of mineral processing results and help guide future test work.
- Lithium analysis is difficult. We have developed improved methodologies to determine Li contents, Dr. Broadbent continues.
- Practical results will be demonstrated after tests.
- Lots of results are scalable already but once the pilot testing is complete most results will be directly exploitable and demonstrated to be exploitable commercially.

The growth of the GDP is a sign of success

- Rather than produce solely research papers the project will only be regarded as successful in the eyes of the EU if it has impacted positively on GDP and jobs growth within the EU28. If Keliber in Finland and Saxore in Germany can commence mining operations earlier because of FAME than otherwise would have been the case FAME will quite legitimately be able to claim that the project was successful.

Chris Broadbent, who works as a research director at the Wardell Armstrong consultancy company, emphasises the importance of conserving energy and taking environment into account in all development work in the sector.

- About 4% of all the energy consumed in the world is used in the crushing and grinding of minerals. Even a small percentage improvement can lead to massive energy savings worldwide. Environmental impacts and optimisation of the environmental performance with respect to tailings is crucial to the public acceptance of mining projects. If you can avoid tailings altogether it is even better, he summarises.

FAME is part of the EU’s Horizon 2020 research programme. The budget for the project is approximately EUR 8 million. From Finland, GTK and Keliber Oy are participating in the programme.
The seismic soundings, conducted as a part of the XSoDEx project (Experiment of Sodankylä Deep Exploration), a joint project between GTK, Freiberg University of Mining and Technology, and the University of Oulu, began in early July. Over a period of two months during summer 2017, the researchers collected seismic data along tens of kilometers of gravel roads.

– The survey mapped bedrock in a region where Finland’s most promising ore deposits are located, says GTK’s research professor, Raimo Lahtinen.

On the northern side of Sodankylä, at the eastern end of the measurement line Boliden Kevitsa mine extracts nickel, copper and platinum-group elements (Ni-Cu-PGE) from an ore body. South of the ore body is the Sakatti Ni-Cu-PGE deposit. The mining company Anglo American describes it as one of the most significant European ore discoveries for more than a generation.

The measurement line continues towards the west, through the Petäjäselkä gold deposit to the Suurikuusikko area in Kittilä, where a company called Agnico Eagle Mines excavates gold ore. It is the largest gold mine in Europe.

– Local seismic soundings had already been conducted in the Kevitsa, Petäjäselkä, and Suurikuusikko areas before this. The measurement line of the FIRE4 sounding project, carried out in the early 2000s, also crosses Kittilä. These old surveys serve as comparison material for the new measurements, says GTK’s senior scientist, Suvi Heinonen.

Making the material available for everyone

The new vibroseis truck of the Freiberg University of Mining and Technology (TUBAF) was used for seismic sounding. The seismic waves generated by the vibrator reflect off structures when rock types change and the density or seismic velocity in the rock changes. The reflections are measured with small geophones that are inserted into the ground.

The University of Oulu contributed to the XSoDEx project by investigating the velocity changes of seismic waves in the bedrock. TUBAF’s vibroseis truck was used as the seismic source, but the wireless geophones were placed at a distance of approximately 114 m from each other resulting in over 10 km long refraction seismic profile. These surveys complement the data on the structure of the bedrock.

– Seismic soundings do not necessarily produce data about the location of ore deposits. Instead, we are primarily interested in the structure of the bedrock that contains ore, in the locations of the ore deposits, and in the shapes of the ore veins in the bedrock, Heinonen explains.

In the Kevitsa mine area, the ore deposit is located in a mafic intrusion, whereas the gold deposits of Kittilä and Suurikuusikko are hosted by bedrock shear zones. The purpose of the surveys is to reveal the special characteristics of these geological bedrock types and to reveal anomalous zones such as faults or fracture zones.
In addition to seismic sounding, the project studied changes in the electric conductivity with audio-magnetotelluric AMT measurements and changes in density using gravity surveys. Densities, seismic wave velocity and electric conductivity is measured in a petrophysical laboratory from samples that are collected from the Earth’s surface, and from drill core samples.

Raimo Lahtinen notes that the reflection sounding was the most important part of the XSoDEx project, and the other geophysical measurements complemented it. One of the goals of the project is to develop the parameters used in seismic sounding to improve the accuracy of the method in specifying what the reflections measured from crystalline bedrock indicate.

The sounding must be conducted carefully, and the quality of the data produced must be as high as possible so that it can be interpreted and refined afterwards, Lahtinen says.

Seismic sounding produces a two-reflection cross-sectional image of the bedrock structure. Later, researchers make a 3D model out of it. All materials, data and observations collected using different methods are going to be used to create the model.

Interpreting seismic data takes time. When the work is finished, the material will be made available to everyone after an embargo period, Heinonen says.

Seismic sounding is sensitive to different kinds of interference

Measurement progresses at walking speed

The measurement group consisted of approximately 20 people. Eight of them were from TUBAF, three were from the University of Oulu, and the rest were from GTK. GTK was responsible for organising everything and for many practical issues. GTK’s researchers also participated in the measurement work.

When conducting measurements, the vibroseis truck lowers a metal base plate to the ground so that the truck’s mass of 32 tonnes is supported by the base plate. After that, the machinery installed on the car shakes the base plate at a specific frequency range. In the Sodankylä project, the length of the measurement line was almost four kilometres, and the distance between each geophone was ten metres. After measuring 12 shot points with 40 meter interval, 48 geophones and their cables had to be moved from the back of the measurement line to the front of the line.

The measurement team worked in two shifts, six days a week. We encountered unfortunate breaking of measurement devices in a sudden thunderstorm after which measurement slowed down significantly. However, our team worked fast and precisely and we were able to measure almost 80 km of reflection seismic profile despite the problems, Heinonen says.
Freiberg University of Mining and Technology (TUBAF) was responsible for the technical aspects of the seismic data acquisition. TUBAF provided the equipment and also contributes to processing the data afterwards to obtain a high-resolution subsurface image.

– XSoDEx is an important project for us in terms of establishing and strengthening cooperation with a leading geological survey in Scandinavia, and also a good opportunity to acquire interesting seismic data in the frame of mineral exploration, says Professor Stefan Buske from TUBAF.
– This was also a good opportunity to train our students in such field experiments. A total of ten TUBAF students were trained during the two months, Buske adds.

TUBAF’s expertise is the acquisition and processing of seismic data from different scales from very shallow investigations at around 100 m depth down to very deep investigations at around 100 km depth. Its main speciality is the development of seismic imaging methods and software to generate high-resolution images of the subsurface.

Expertise in seismic acquisition

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Measurement technology used in the Sodankylä area

• Vibroseis truck generating seismic waves
• Truck weight: 32 tonnes
• Seismic waves frequency: 10–170 Hz
• Exploration depth: up to 3 km
• 3,600 m long geophone spread
• 360 geophones
• Distance between geophones: 10 m
• Distance between shot points 20 or 40 m
Developing exploration of critical minerals

Text: Paula Böhling

The Geological Survey of Finland develops operating methods and models to speed up the exploration of critical minerals and metals. There is a growing demand for effective methods.

Increasing self-sufficiency in terms of critical minerals is one of the focus points of the mineral strategy of the EU and Finland. The aim is to decrease dependency on imports from outside the EU and, therefore, ensure the availability of raw materials for high-technology industries.

- As more and more critical minerals and metals are needed, self-sufficiency offers a significant competitive edge for the European industry, says Pertti Sarala, research professor at GTK.

Metals defined to be critical by the EU include rare earth elements (REE), antimony, cobalt, magnesium, niobium and platinum group metals (PGM) that are used in the electronics industry, smart products, catalytic converters and batteries.

- Currently, Finland’s production of critical minerals and metals, such as chromium and phosphates, is significant, even on an EU level. In addition, Finland, like other Nordic countries, has a significant potential for new profitable deposits, Sarala says.

A survey conducted by GTK indicates, for example, that there are rare earth elements in weathered bedrock areas in central Lapland, platinum group elements (PGE) in layered intrusions and a REE potential in weathered granite. Lithium deposits are also known to have elevated REE concentrations. Graphite potential has also been surveyed.

- Finland’s geodata material offers a good starting point for exploration. We have thorough knowledge of our bedrock and soil. Our surveys are extensive on a historical scale and information is widely available.

"Existing mining areas may provide companies with opportunities for new business"
An instant analysis conducted already in the field

GTK’s Indika project (Automated identification of indicator minerals in the exploration of critical minerals, 2016–2018) investigates the suitability of new automated field methodologies for the exploration of indicator minerals.

Indicator minerals are interesting in terms of research in that they accompany specific ore types and, therefore, indicate the existence of an ore deposit. Usually, there are more indicator minerals and in a larger area than actual ore minerals, which makes mineral exploration easier.

Using modern field analysers, such as portable XRD and XRF devices, samples can already be analysed mineralogically and geochemically in the field. Combined with the support of advanced electron optical methods, minerals can be identified automatically in full or in part, Sarala says.

The Indika project has produced a new pre-processing and research procedure for indicator mineral samples which has been tested in practice and documented. It speeds up the work process and improves the cost-efficiency of exploration. Another aim is to improve digital data collection and management.

According to Sarala, the developed operating methods and models are ideal for the exploration of new deposits, but they can also be used to identify older and existing mining areas.

The results of the project support the implementation of the circular economy in the mining industry. New technologies enable, for example, the cost-efficient evaluation of the ore potential of existing tailings basins or adjoining rock piles on site. Existing mining areas may provide companies with opportunities for new business.

As a result of the Indika project, mining operators will work and interact more closely together, which is expected to benefit, for example mineral exploration companies. Research partners in the Indika project are GTK, Oulu University and Lapland University of Applied Sciences. In addition, the project parties work together with a number of companies operating in the industry.

Using the research results to produce benefits

Ab Scandinavian GeoPool Ltd, a seller of mineral exploration services and equipment in Finland, Sweden and Norway, is one of the companies and partners that utilise the results of GTK’s research. Its customers range from major mining corporations to smaller exploration companies.

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– We also need to be able to develop continuously. The mineral exploration market offers huge potential, as long as we lead the way for development. ■

This means that varied expertise and methods are required in exploration, says Jens Rönqvist, a geologist at Scandinavian GeoPool.

It is advantageous to consulting companies if their methods have been tested and proven in practice.

GeoPool specialises in hyperspectral mapping which gives indications of the location of ore deposits. The company, together with the Indika project, is planning to test its recently acquired field spectrometer which directly indicates the name and consistency of indicator minerals.

Rönqvist believes that exploration methods will become more diverse in the near future, as the need for critical minerals is continuously increasing and mineral resources are deeper and deeper. It is no longer possible to start drilling without sufficient initial information.

– We also need to be able to develop continuously. The mineral exploration market offers huge potential, as long as we lead the way for development. ■
A mining company can thrive on recycling

Text: Jaana Ahlblad

Mustavaaran Kaivos Oy plans to obtain vanadium from the slag produced by steel industry and re-sell it to steel industry. Vanadium is a metal that is added to steel to strengthen it.

The company uses slag that is rich in vanadium, produced by the three steel mills of Swedish SSAB.

- It is a unique raw material, says Mustavaaran Kaivos Oy's Managing Director Jukka Pitkäjärvi.

Finding a source of vanadium and the development of a new kind of refining process changed the company’s plans entirely. Originally the idea was to restart operations in the vanadium mine located in Taivalkoski that was closed over 30 years ago. However, there is so much recycled raw material available that at least so far there is no need to excavate more.

- We have received a lot of encouraging feedback for our plans to recycle, Pitkäjärvi says.

Steel enforced with vanadium is used in, for example, construction, aircraft and vehicles. The goal of the Mustavaaran Kaivos is to produce 6–7 percent of global production.

- Production is now focused in four countries, which are all located outside the EU. We have received positive messages about starting vanadium production also inside the EU, Pitkäjärvi says.

Electricity in vanadium batteries?

If the ideas presented recently become reality, the demand for vanadium may increase a lot in the coming years.

- Some ideas about storing electricity with vanadium have been presented. Special storage in vanadium batteries would solve a problem of storing wind, water, and solar energy. Some commercial applications have already been developed, Pitkäjärvi says.

If the demand for vanadium would increase, it would be possible to start to exploit the significant vanadium deposit in Taivalkoski within a couple of years.

For now, Mustavaaran Kaivos plans to concentrate on recycling. A new kind of refining process allows the company to recover vanadium. The process has been developed by the company in cooperation with, for instance, GTK’s Ouloutokumpu unit.

Pitkäjärvi believes that the cooperation will continue.

- It is great that we have been able to restore vanadium expertise to Finland and to GTK through this project.

The next step for Mustavaaran Kaivos Oy is to establish a plant in Raase. According to plans, it will start operating in 2020. It is estimated that it will employ over 100 people.

We have received positive messages about starting vanadium production also inside the EU, says Mustavaaran Kaivos Oy’s Managing Director Jukka Pitkäjärvi.

Extraction of vanadium from the slag will be done in a smelter to be built at the port of Raase. According to plans, it will start operating in 2020.
Excitement over Finland’s ore resources has increased rapidly. The growth programme lead by GTK offers a thorough look at mining operators and opportunities in Finland.

While the mining industry faced quiet times a little more than a year ago, now every single drilling machine in Finland is up and running. Within one year, more than 20 new companies have started operating in Finland, especially in the field of early stage mineral exploration.

– In addition to gold and nickel, cobalt and lithium are currently raising special interest, says Harry Sandström, programme director at GTK. Sandström is the director of the Mining Finland growth programme which is a partnership network of roughly 40 companies. The aim of the programme is to attract mining companies to explore minerals in Finland and to speed up exports for small and medium-sized Finnish mining companies.

Finland is already attractive

When comparing mining industries on an international scale, Finland is nearly always ranked at the top, both in terms of mineral and investment potential. In Finland, the mining industry has a long tradition and our soil contains many valuable elements, such as chromium and phosphate. What is more, Finland is the largest producer of gold in the EU and has good exploration potential for hi-tech metals like cobalt, lithium and rare earth metals. When it comes to attracting international mining companies, it is also important that Finland already has an extensive mining industry and existing technologies.

– Finland and Sweden have an incredible reputation around the world in terms of mining technology. We are the source of many significant technologies, such as flash smelting. Many Finnish brands, such as Outotec, Metso and Normet, are well-known and perceived reliable, Sandström says.

Large corporations often open up doors, but Finland has nearly 300 small and medium-sized mining technology companies that operate in different parts of the value chain, ranging from mineral exploration to the decommissioning of mines, some as subcontractors and some as independent and international operators.

Local knowledge and networks

Markku Iljina GeoConsulting Oy, a member of the Mining Finland network, helps international mineral explorers in Finland by providing them with exploration targeting services in Finland, Sweden and Norway.

According to Markku Iljina, exploration targeting has turned out to be an unexpectedly large field.

– I have not run into a single customer who would simply ask where to start. Some are interested in locations with previous mining activities, while some want to go to places where no mining has been carried out before. The selection of the location is preceded by a survey of geology, mineral indicators and potential. This requires geological expertise and is the most intriguing part of the targeting process. What is more, while some are attracted by iron alloys, others may seek precious metals or base metals. Targeting largely depends on the customer, and it includes a wide array of different options, Iljina says.

Markku Iljina GeoConsulting is often hired for projects as the local representative of international companies to establish relationships with partners and, for example, landowners. Local presence is often necessary, as is knowledge of the local legislation and practices.

Geodata helps to get started

What attracts international mining companies to come to Finland is that not all parts of the country have been fully explored, even though the Nordic countries have long mining traditions and areas with a high mining potential. According to Markku Iljina, the highly functional Mining Act and good governance are important factors for new companies. Political predictability in Finland is indicated in that mines have
Why should it take 10 to 15 years from the discovery of a deposit to the launch of mining operations? IMA Engineering Ltd Oy, a member of Mining Finland, has developed the Time to Mine vision, the aim of which is to shorten this timespan.

This is possible by improving the efficiency of deposit surveying. Using IMA Engineering’s method, samples are scanned and analysed as the drilling process proceeds.

– The purpose is that drilling can be controlled according to each sample drilled, already during the campaign. Potential areas are accessible even before any samples have been delivered to the laboratory, says Jukka Raatikainen, managing director of IMA Engineering.

The network uses two sustainability systems: one for mineral exploration and one for mining operations. In addition, it has developed a toolbox, with which companies can prevent any unnecessary conflicts with the local community. The network has developed separate evaluation tools for the protection of biodiversity, the treatment of tailings and water management. The network offers practical instructions. Before mineral exploration, it is useful to notify landowners of any future activities and listen to stakeholders. Plans should be modifiable so that different viewpoints can be taken into account, if possible.

According to Yrjö–Koskinen, the mining industry should aim at a closed cycle in which, by decreasing material flows and through circulation, it can be ensured that no pollutants can access the soil or watercourse surrounding the mine.

– The fewer repercussions there are, the easier it is to accept mining operations. It is important for the reputation of companies that, for example, wastewater containing heavy metals are not released into the environment, Yrjö–Koskinen says.

To make mining more sustainable

A few years ago, a model of sustainable mining was established in Finland. Its aim is to make mining more sustainable and prevent any conflicts between mining companies and their stakeholders.

– Mining and exploration companies should openly communicate their plans beforehand. By listening to stakeholders and revising plans, it is possible to reach a sustainable solution that satisfies all parties, says Eero Yrjö–Koskinen, secretary general of the Finnish Network for Sustainable Mining.

– In the network, stakeholders are in an equal position with mining companies. As a result, we have been able to prepare ambitious tools for mining and exploration companies, Yrjö–Koskinen says.

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– By using these methods, the time spent on mineral exploration and the launch of mining operations can be reduced by one third or more. When we talk about five years instead of 10 to 15 years, not only major corporations, but also private investors may be attracted, Raatikainen says.

Quickly to profitable mining operations

Why should it take 10 to 15 years from the discovery of a deposit to the launch of mining operations? IMA Engineering Ltd Oy, a member of Mining Finland, has developed the Time to Mine vision, the aim of which is to convert Finland’s drill core archive into digital format. It offers volumes of information to support claims, as many samples were taken decades ago when completely different tools and measuring technologies were in use. In addition, there are now lower demands, for example, for copper content in profitable mining operations.

Finland is also attractive in terms of its functional infrastructure.

– There are normally roads within 50 kilometres of every deposit. This also applies to energy, as the power grid is always nearby, Sandström says.
Extracting valuable metals from slag

Timo Hämäläinen

Boliden Harjavalta aims to even better valuable metals recovery from the slags generated in the production of metals. To achieve this the company ordered a pilot-scale project from GTK Mintec.

Boliden Harjavalta’s plants are located on the coast of Southwestern Finland. The company’s main products are copper anodes and nickel matte. The copper anodes will be further refined into copper cathodes at the Pori unit. As by-products, the plants produce metals such as gold, silver, selenium and platinum-palladium concentrate. In addition, the plants produce sulfuric acid and liquid sulfur dioxide.

The raw materials used in the smelters are concentrates from the Boliden group’s own mines and external suppliers. Also recycled metals are used as raw materials.

As part of continuous process development and sustainability, Boliden Harjavalta is researching different options to utilization of the slags and improve the recovery of the valuable metals.

– Our goal is to produce metals with maximum recovery and with minimal amount of waste. It means that we have to extract valuable metals from slag and find different ways to utilize the slags – for example in land construction, concrete industry or manufacturing bricks, says research and development engineer Ville Naakka.

Getting rid of impurities

The biggest challenge for making slags as a product instead of waste is the impurity content of the slags and the solubility of the impurities. The first step for utilising slags as a product is to fill up the environmental limits set by the authorities. They can be achieved by extracting impurities from slag or by processing the slag into a more harmless form.

– We have to discover suitable and economical methods. The profitability of utilisation of slags depends on the recovery of valuable metals, the deposition costs of slags and the price of possible new products, Naakka says.

Slag becomes a cost if it has to be deposited. First you have to find an appropriate deposit site. Then you have to do the groundwork required by environmental safety. In addition, you must transport and pile up the slag.

– The cost savings can be surprisingly big if metal recovery from the slags can be improved and slags can be utilized as a product. And of course it would be sustainable and environmentally friendly, Naakka says.

Valuable information

Boliden Harjavalta has earlier done some lab scale tests with slags to improve valuable metals recovery. At the end of 2016 the company decided to start pilot scale tests to confirm the findings and to see how the continuous processing works.

– We have a laboratory in Harjavalta, but our research equipment is limited. We turned to GTK Mintec, because they have a pilot-scale test plant and laboratory equipment suitable for mineralogical research.

Naakka and his colleagues monitored the test runs at GTK Mintec’s premises in Outokumpu. The tested process included crushing, grinding and separation of the different fractions.

– With GTK personnel we discussed both general issues related to the tests and details. When we saw how the material behaves, we received a lot of knowledgeable comments and suggestions on what we could try out and how we could refine the process.

Overall, Naakka considers the test run a success.

Boliden Harjavalta

Boliden Harjavalta is part of Swedish Boliden group, which has operations in Sweden, Finland, Norway, and Ireland.

Boliden is a metals company with a commitment to sustainable development. Core competence is in the fields of exploration, mining, smelting and metals recycling.

Boliden’s main metals are zinc and copper. Other important metals include nickel, lead, gold and silver.

Concentrate from Boliden’s own and external mines is sold to own and external smelters. Zinc metal is sold to steelworks for rust-proofing (galvanising) and copper metal to wire rod and copper rod manufacturers. Nickel matte is sold as an intermediate raw material to external customers for further refining into pure metals and/or compounds.

Lead is sold to car battery manufacturers. Gold and silver are sold for industrial production and as an investment object.
A more direct route for permit applications

Application processes for environmental permits for mining operations will be quicker and more straightforward in Finland, as the authorities take on the one stop shop principle.

Handling permit applications for mining operations will be streamlined in Finland through the establishment of a national permit authority. Different permit authorities are currently building electronic services so that companies applying for an environmental permit only need to contact a single authority, after which all authorities will receive information about the project at the same time.

– It may be possible to handle some permit issues side by side, which will make the process quicker. Having a shared platform for all authorities will also improve supervisory activities. This change will clarify the process, reduce the level of bureaucracy and, therefore, benefit companies, says Riikka Aalto- nen, senior advisor of the mineral policy at the Ministry of Employment and the Economy.

Finnish mining legislation was reformed in 2011. No changes in legal guidelines are expected, but minor technical specifications have been made.

– For example, mine maps no longer need to be sent to the authorities every year, only when necessary and when mining operations are discontinued. The aim of these changes is to reduce the number of standards and regulations as defined by the Finnish Government, Aaltonen says.

Legislation under lengthy consideration

The reform of mining legislation has received both votes for and against. The previous act dated back to 1965 when the world was completely different.

– Back then, mining companies operating in Finland were mainly Finnish and owned by the state. There was not much discussion of the environment in the 1960s. The Mining Act was very powerful and overruled everything else, Aaltonen says.

The new act was ten years in the making. According to Aaltonen, the groundwork for the new act was done thoroughly; after all, acts are rarely reformed in their entirety.

– The aim was to include environmental issues, as well as the extensive abilities of municipalities and other parties involved to exercise influence. It is also worth mentioning that this new act pays much more attention to the rights of the Sami people than any other act.

Companies, show your face

The act defines minimum requirements, but this is not enough when planning mining operations. Companies need to show their face in order to obtain social and local acceptance.

– Companies need to open up their projects and allow people to study them. They should show themselves and what they do before anything else. Public events and presentations are important and draw a crowd. Nothing can replace face-to-face meetings, even though they cannot be required by law.

When mining legislation was reformed, the world changed a little unexpectedly from the authorities’ point of view.

– The Mining Act states that the authority must advertise permit applications and decisions in a regional newspaper. At the end of the 1990s, the newspaper still had a strong position, but what could be a similar channel now for reaching a large group of people?, Aaltonen ponders.

Comprehensive acts also benefit investors

According to Aaltonen, Finnish and Nordic permit processes are often considered to be complicated but, then again, they are also transparent and predictable. With regard to elimination, no single permit can have been shown to be unnecessary.

– EU directives form the large framework of regulation, including many environmental aspects.

Having comprehensive laws is also good for companies, as they are an indication of a stable society and operating environment.
Future success requires top expertise, focusing and partnerships

According to strategy, the GTK has defined areas in applied geosciences in which it particularly aims to improve scientific expertise. This will help us to develop successful innovations, strong partnerships and quality expertise services.

GTK’s focus areas in the development of top scientific expertise are geoinformatics, mine and industrial environments, hydrogeology, sustainable mineral economy, and geomaterials and applied mineralogy. In addition to geoenergy (led by Chief Expert Teppo Arola), disposal site research (led by Chief Expert Heini Reijonen) and geoscientific city modelling, GTK’s aim is to reach a high level of expertise and competitive service skills that will make it stand out.

The development of expertise requires determined long-term activities. Often, results are only visible after a few years. To ensure development, we have prepared roadmaps for the development of expertise in different areas. The timespan of these roadmaps extends to 2025. They serve to analyse the current situation, define the goals, and specify the areas of expertise and infrastructure that we especially want to turn into GTK’s strengths, says Pekka Nurmi, Director, Science and Innovations.

According to Nurmi, deselection is equally important, i.e. deciding on those areas where GTK should rely on the expertise of its partners. Building strong partnerships in Finland and globally is a key factor in the development of expertise and capacity.

We cannot succeed alone when facing fierce competition in an internationalising world. Our aim is to build strong competence centres and turn GTK into a key partner in innovation ecosystems. Examples include the EIT RawMaterials innovation community, in which GTK has already gained a firm foothold, and the reinforcement of GTK’s cooperation with universities nationally using bilateral measures.

To promote its cooperation with universities, GTK has already launched jointly funded projects with the Universities of Turku and Helsinki, with the aim of intensifying the Master’s level education of geologists in areas important to GTK. Next year, we will launch a development plan focused on geophysics in close cooperation with universities.

GTK is planning to strengthen cooperation with the Oulu Mining School throughout the mineral economy chain. With Aalto University and VTT Technical Research Centre of Finland, GTK is establishing an internationally significant competence centre with cutting-edge laboratories for inorganic material research at the Otaniemi campus in Espoo.

Research Professors Tommi Kauppila (mines and industrial environments), Vesa Nykänen (geoinformatics), Daniele Pedretti (hydrogeology), Raimo Lahtinen (sustainable mineral economy) and Alan Butcher (geomaterials and applied mineralogy) lead the development of scientific expertise in the spearhead areas at the Geological Survey of Finland.
New publications

**Bedrock of Finland at the scale 1:1,000,000 - Major stratigraphic units, metamorphism and tectonic evolution**

**Deep Groundwater Evolution at Outokumpu, Eastern Finland: From Meteoric Water to Saline Gas-Rich Fluid.**

**Developing Mining Camp Exploration Concepts and Technologies: Brownfield Exploration Project 2013–2016**

**Quantitative assessment of undiscovered resources in stratiform and podiform chromite deposits in Finland**

**Suomen korukivet = Gemstones of Finland**

**Getting mining policy right: The challenges of managing national mineral endowments and the mining industry in Bolivia, Ecuador, Finland, Mongolia, Namibia and Peru**

**Geochemical baselines in the assessment of soil contamination in Finland**
Sustainable solutions and independent information from the mining environment

- Mining products are part of everyday life
- Mining employs and enhances well-being
- Mining must not cause environmental damage

GTK’s services:
- research
- consulting
- new methods: development & testing
- modelling
- training

SOCIETY
- Local community
- Mining companies and subcontractors
- Mine workers

Water quality