Foresight Study

Thematic Report I

European Raw Material Potential

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This thematic report has been developed in the context of the first Foresight Study report that comprises a central report, five topic reports, and 15 case studies. These contributions were designed according to a well-defined structure to fit the purposes of the central Foresight Study report. The scope and targets of the first draft Foresight Study significantly determine the nature of the documents and may not be suited for unspecified or differing purposes.

1 Primary raw material potential of Finland

Mari Kivinen, Mira Markovaara-Koivisto (GTK)

1.1 Executive Summary

Finland is currently one of the most interesting countries inside the EU for mineral exploration due to the geological potential and favorable legislation, taxation system and societal conditions. However, the lack of early stage investments for mine development, especially from domestic and EU sources currently hinders the growth of the industry in the country.

The economically most important commodities are nickel, zinc, copper, chromium and gold. In addition, the importance of platinum group metals has increased lately and there exists potential for critical mineral deposits. Finland also hosts phosphate, talc and carbonate rock mining with most important mineral resources for phosphate inside the EU.

Lately, many of the mineral exploration and mine development projects have came cross with Natura 2000 regions. This is due to the mineral potential of the Northern Finland which also hosts most of the Natura 2000 areas in the country. The existing and up-coming decisions about the mineral exploration and mining activities on the Natura 2000 regions may have an effect on the future activities on these areas in Finland but also on the other regions in the European Union.

Key domestic factors to hinder the development of the Finnish mineral potential are currently the conflicts with other land use types (especially Natura 2000), lack of investments to early stage mine development and permitting times. Suggestions to improve the situation are 1) supporting the mechanisms to enhance investments to mineral exploration and mine development especially from domestic and EU sources, 2) developing a clear procedure for mineral exploration and mining activities in protected areas, especially in Natura 2000, and 3) reducing permitting times without compromising the environmental impact assessment quality.

1.2 Introduction

This case study paper is part of the WP6 (Foresight study) work in the Minerals4EU project. The case study report contributes to the topic European Mineral Raw Material deposits, providing an insight to mining and exploration activities in Finland with specific focus on the future potential. Finland was selected as a case study country due to its long mining history and its current mining activities especially in base metals and gold. The paper considers different aspects of the mineral based industrial sectors in Finland: 1) mineral deposits and exploration, 2) future mineral potential, 3) existing and planned mining activities in metallic and industrial minerals, 4) minerals policy, and 5) characteristics of companies operating in these sectors (exploration and mining) with insight in to the role of the state.

Increased price levels of metals resulted in intensified mineral exploration and mine development activities in Northern Europe, in particular in the countries Finland and Sweden during the first decade of the 21st century. These countries have a long history of mining starting from the 16th and 10th century, respectively. In Finland, the exploration and mining industries suffered a downturn in the 1990s, which reversed to a fast growth at the beginning of the 21st century (PwC 2012). During this time, several domestic and foreign exploration and mining companies started operations in the country, and several new metal mines were opened. In addition, the mining law in the country was renewed (Mining Act 621/2011), with increased attention being paid to environmental and societal aspects of mining and increased compensation to property owners.

The companies´ interest in mineral resources in Finland is reflected by the highest rank in the Fraser Institute’s 2012/2013 survey for mining companies (Wilson et al. 2013). The increased activity in exploration and mining generated expectations towards these industries to provide a new economic stimulus, especially in the economically regressive areas of Eastern and Northern Finland (Hernesniemi et al. 2011; Törmä et al. 2013; Törmä and Reini 2009), and possibly to provide a boost to the national economy (Finland’s Minerals Strategy 2010; Hernesniemi et al. 2011; Reini et al. 2011). However,at the same time concerns over a sufficient balance to be achieved between regional socio-economic benefits and environmental impacts have been expressed by the general public and scientists (e.g., Eerola 2008; Haltia et al. 2012; Rytteri 2012).

After the year 2012, the boom in mineral-related sectors started to fade out driven by decreasing metal prices and a broad insecurity in the markets. During 2013–2014, several new mining projects, especially those working with gold deposits have faced financial challenges due to decreased metal prices. At this time (August 2015), the activities in mineral exploration have also decreased notably.

1.2.1 Scope

In this case study, we provide an overview of the recent developments of mineral exploration and mine development in Finland, and give an idea of the existing future mineral potential in the country. The case has special focus on time series and future potential with descriptions of the new, highly promising grassroots discoveries in Northern Finland. The overview of the known mineral deposits and the estimation of the deposits still to be found are included in the review of the most important metals. The analysis includes copper, zinc, gold, PGM and nickel, but also industrial minerals like limestone, talc and phosphorus. In addition, we describe the investment trends on exploration and mining in Finland.

1.2.2 Relevance of the case

Finland was selected as a case country due to its long mining history and existing potential for mine development and new mineral deposits. Finland, together with Sweden, forms one of the best mineral raw material reserves and technology and knowledge hub in minerals inside the European Union.

1.3 Mineral resources and mines in Finland

1.3.1 Metallic minerals

Finnish bedrock contains mineral deposits of multiple metals needed for industrial uses. During history, several of these have been exploited in Finland, including deposits that contain iron, chromium, copper, nickel, zinc, gold, platinum, palladium, vanadium, titanium, lead, cobalt, silver, tungsten and molybdenum. Furthermore, ores containing rare earth elements have been mined and test mining has been carried out for uranium. A potential to find new mineral deposits exists for all these metals and also for the high-tech metals for which demand has recently grown due to the industrial developments for high-technologic products. The economically most important mineral resources in Finland are based on nickel, zinc, copper, chromium and gold.

The currently most active mining and mineral exploration areas are situated in Northern and Eastern Finland (Figures 1 and 2) where the probabilities for finding large deposits seem to be higher than in other parts of the country. From Figure 1 two important regions can be identified: one situated in the far north and another one in the middle of the country.

On EU scale, Finland is an important country in terms of mine production. It hosts the single chromium mine within the EU (Kemi chromium mine, Figure 1). There are currently (August 2015) nine operating metallic ore mines in the country (Figure 1): **Pyhäsalmi** (First Quantum Minerals Ltd: copper, zinc, silver, gold), **Kemi** (Outokumpu Oyj: chrome), **Kylylahti** (Boliden: copper, cobalt, nickel, zinc), **Kevitsa** (First Quantum Minerals Ltd: nickel, copper, platinum, palladium, gold), **Talvivaara** (Terrafame Oy): nickel, copper, zinc, cobalt), **Kittila** aka **Suurikuusikko** (Agnico Eagle Mines Ltd: gold), **Orivesi** (Dragon Mining Ltd: gold), **Pampalo** (Endomines AB: gold) and **Jokisivu** (Dragon Mining Ltd:, gold). In addition, operations at four mine sites are currently suspended: **Hitura** (Belvedere Resources Ltd: nickel, copper),

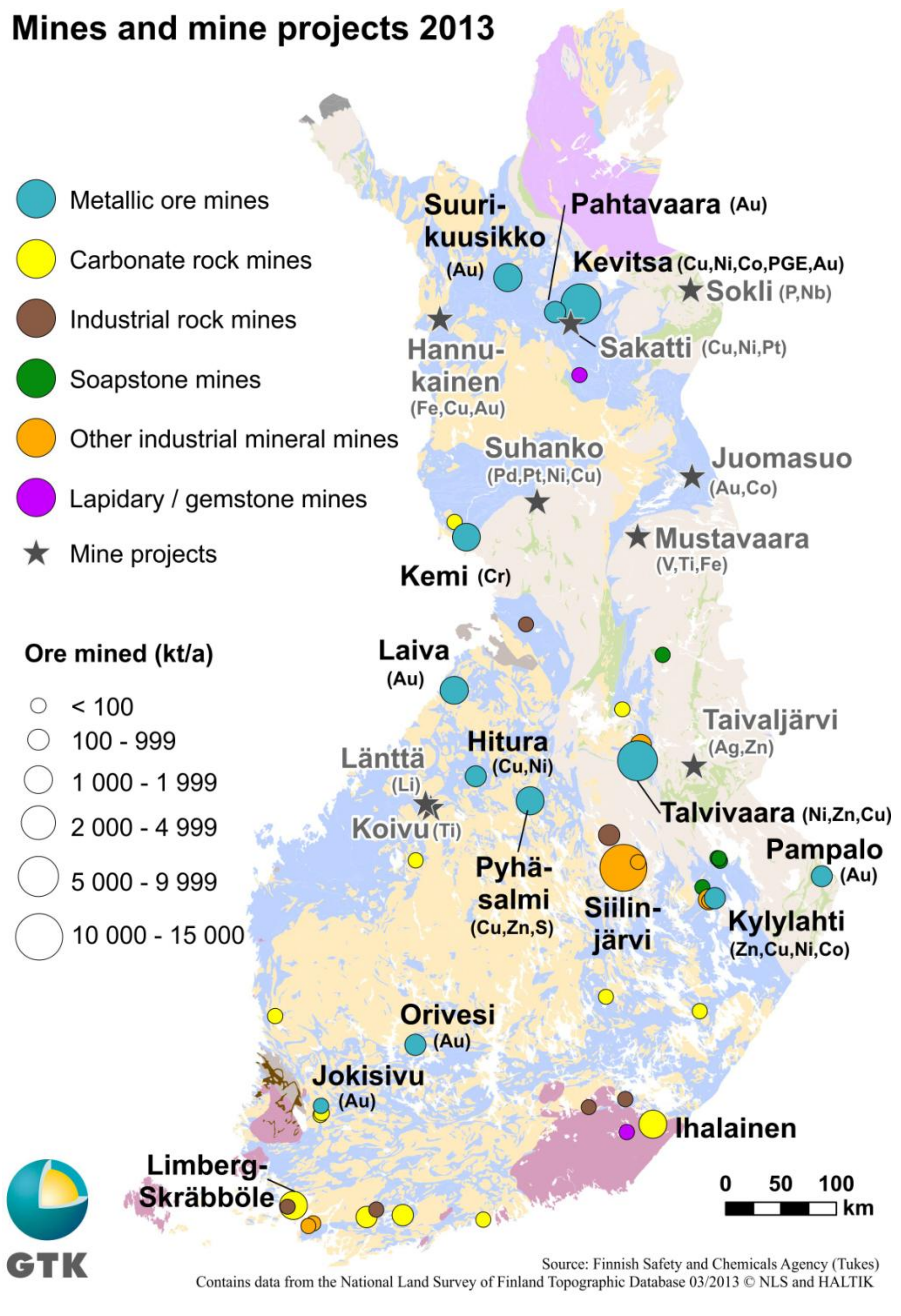

Figure 1: Active mines and mine projects in Finland in 2013. Source: Geological Survey of Finland (GTK)

Pahtavaara (gold, holder Lappland Goldminers AB went to bankruptcy in May 2014), and **Laiva** aka **Laivakangas** (Nordic Mines Marknad AB: gold).

The amount of ore and of waste rocks extracted per individual mines in Finland during 2000–2013 is presented in Figure 3. The figure also presents a long-term view on the overall amounts of ore and waste rock extracted. The mining has intensified to an all times high during the 2010s. The change is driven by the opening of several large open-pit mines producing mainly base metals, gold and platinum group metals.

In addition to these operating mines, there are several advanced exploration and mine development projects especially in northern Finland. Of these, development of the **Hannukainen** iron ore project is the most mature. Promising exploration projects include **Sakatti** (Ni, Cu, PGM), **Mustavaara** (V, Ti, Fe), **Suhanko** (Pd, Pt, Ni, Cu), **Juomasuo** (Au, Co) and **Taivaljärvi** (Ag, Zn) (Figure 1).

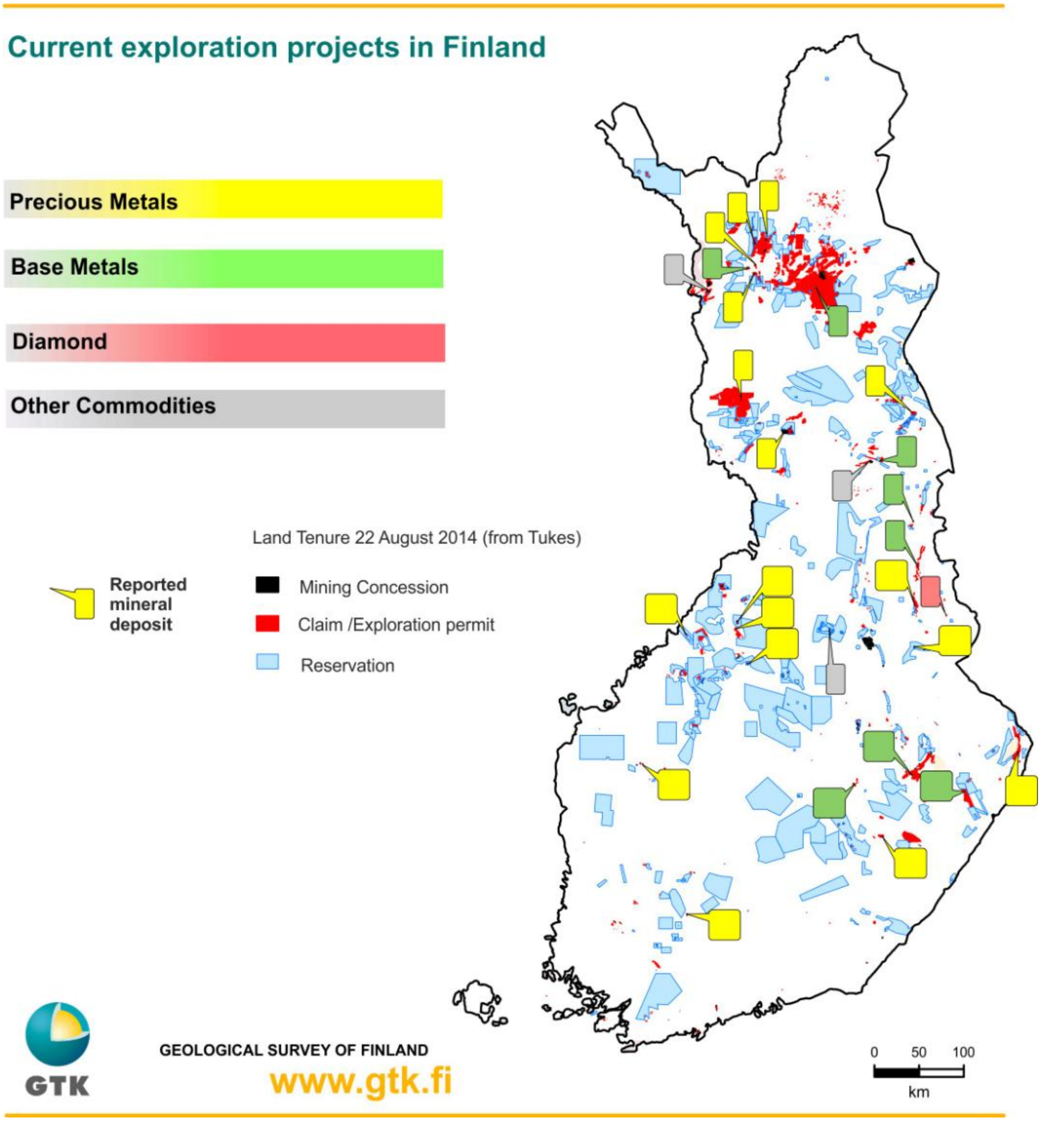

Figure 2: Exploration projects in Finland in August 2014 with land tenure information. Source: Geological Survey of Finland (GTK)

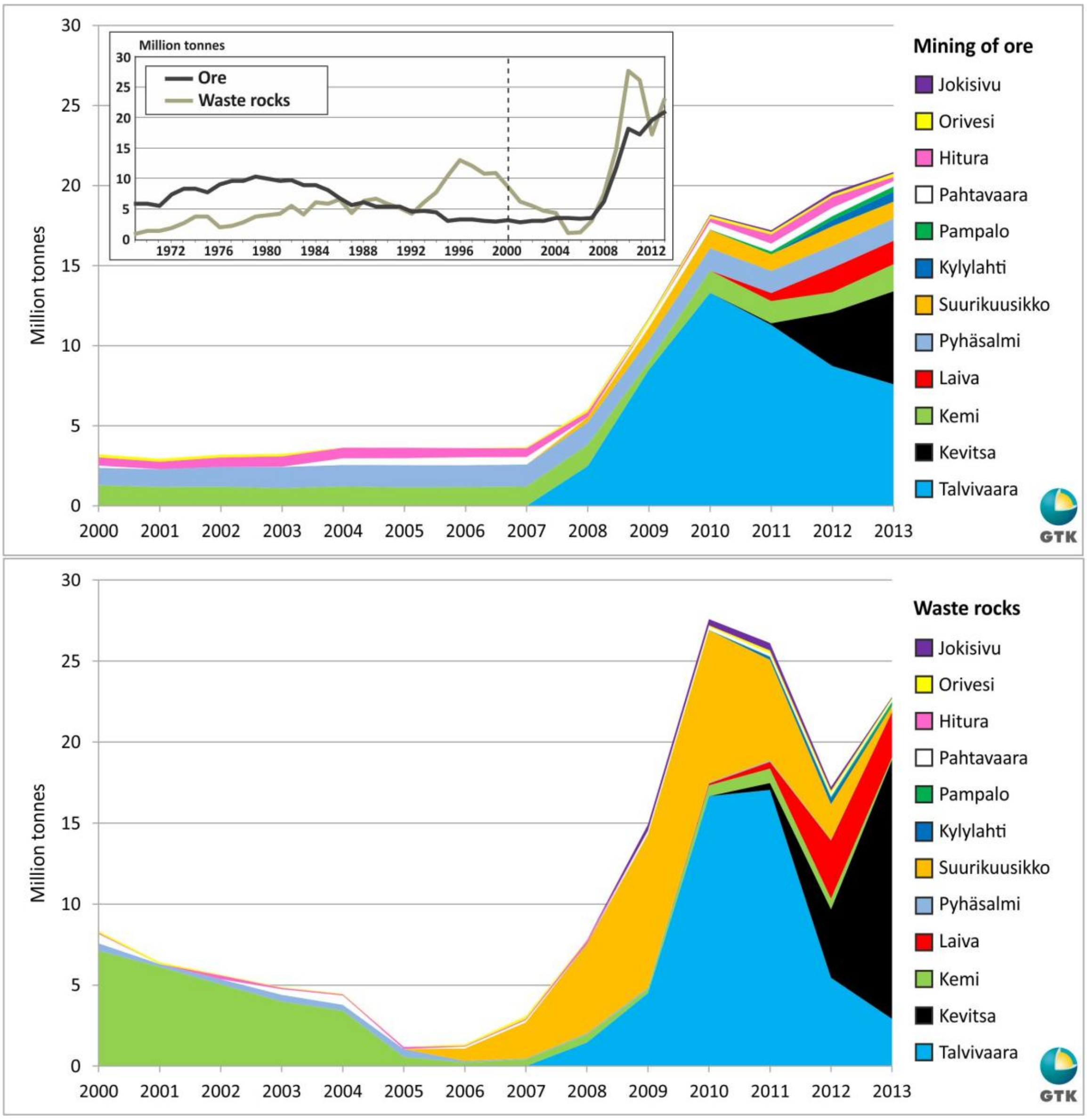

Figure 3: Mined ore (above) and waste rocks (below) from ore mines in Finland from 2000 to 2013. The inserted figure (above left) presents aggregated metallic ore and waste rock excavation in Finland from 1969. Sources: Years 1969–1996 Puustinen (2003), years 1997–2010 TEM, years 2011–2013 Tukes. Modified after Pokki et al. (2014).

1.3.2 Industrial minerals

Finland has currently 29 mines and quarries utilising industrial minerals (Figure 1). Eighteen of these produce carbonate rocks (calcite and dolomite) and eleven other industrial minerals including apatite (for phosphorus), talc, feldspars, quartz, micas and wollastonite. In addition, nine quarries produced soapstone (for ovens and stoves) and gemstones. Figure 4 shows that in terms of mined rock, apatite and carbonates form the most important classes of industrial minerals in Finland. In addition, Finland is the biggest producer of talc and wollastonite inside the European Union. The amount of mined ore has remained relatively stable from 2000 to 2012 except for a temporary decrease in 2009.The amount of excavated left-over rocks (i.e., waste rocks) has, however, been increasing mainly due to the significant extension of the open pit at the Siilinjärvi apatite mine.

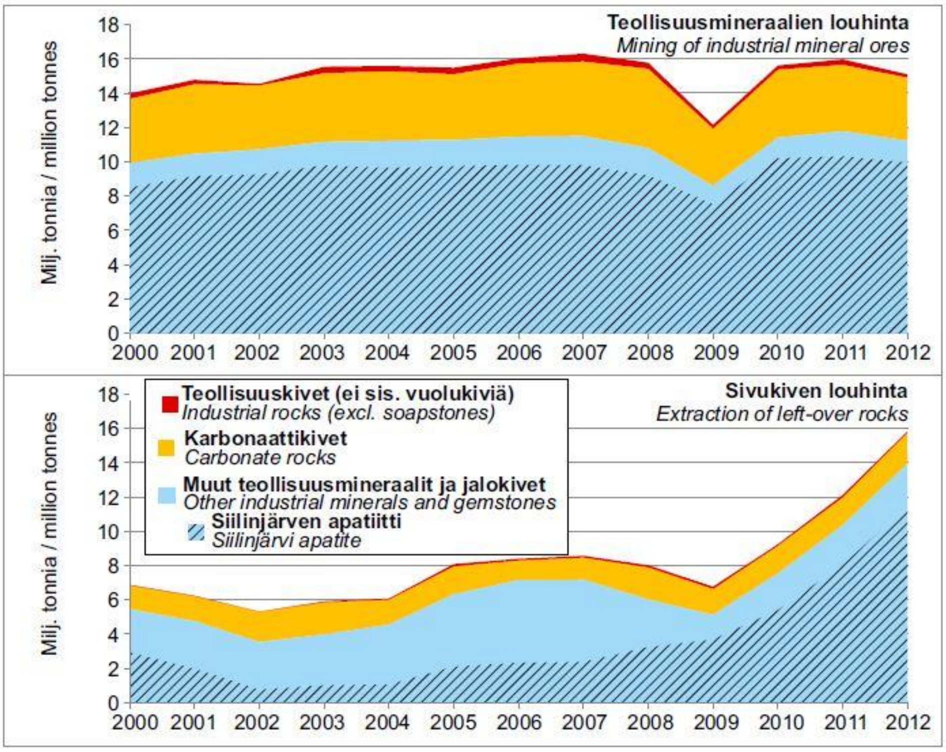

Figure 4: Mining of industrial mineral ores and waste rocks (left-over rocks) in Finland. Source: 2000–2010 TEM, 2011–2012 Tukes. Published before by Pokki et al. (2014).

Several new mining projects for industrial minerals are currently under development in Finland. Yara International ASA, for example, has development targets at **Sokli** and **Siilinjärvi** (extension for the currently utilised deposit) and Keliber Oy developes lithium deposits at **Länttä** in western Finland (Figure 1). New operations have also been prepared for talc and carbonates.

1.4 Future potential

Despite the long mining history in the country, resources for multiple metals are still known to exist in the Finnish bedrocks (Figure 5). The resources occur both in operating mines and at undeveloped deposits that are not yet mined.

Finland has a potential for deposits containing metals defined as critical by the European Commission (2014) (Figure 6) as follows. Platinum group metals and cobalt are currently being produced, and niobium is expected to come into production in the near future. There is also a potential for tungsten, antimony, tantalum, beryllium, rare earth metals, indium and graphite. In addition to critical metals, Figure 6 also shows Finnish production and potential for other mineral raw materials with varying importance for the European Union economies.

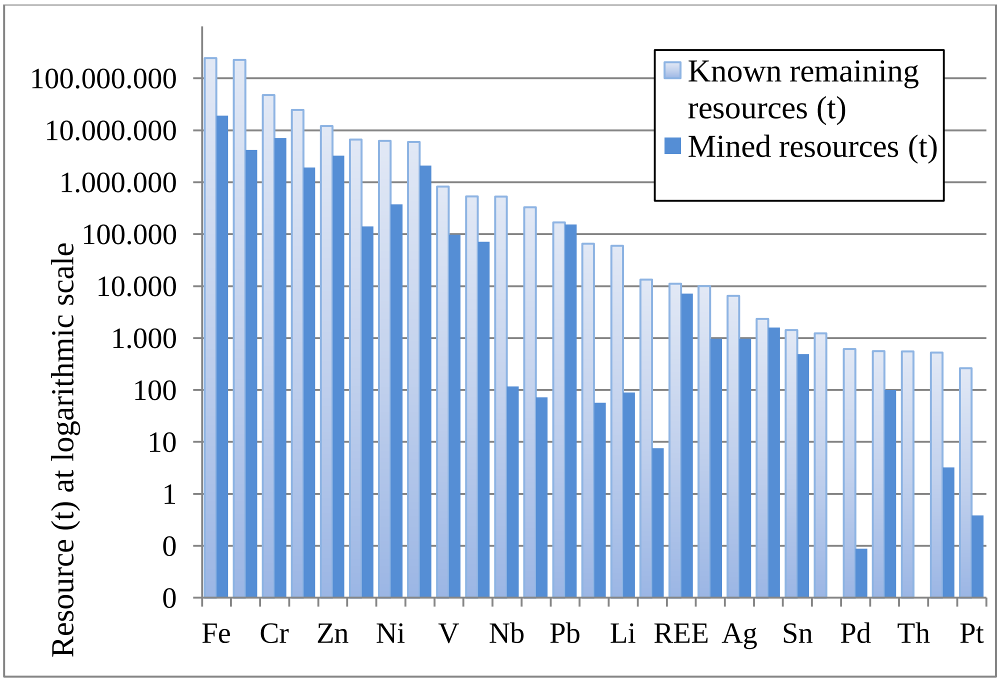

Figure 5: Remaining known and assumed resources of metals in Finnish mineral deposits compared with the cumulative amount of metals already mined. Modified after Nurmi and Rasilainen (2015).

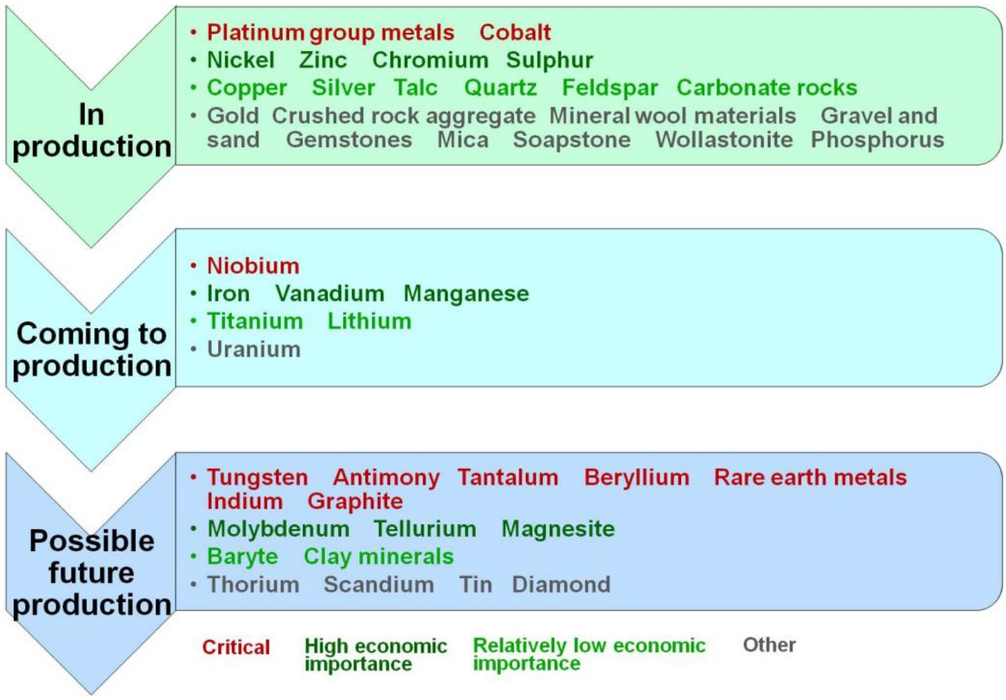

Figure 6: Production and potential in Finland with regard to of Critical minerals as defined by the European Commission (EC 2014). Modified after Nurmi and Rasilainen (2015).

1.4.1 New highly promising grassroots discoveries

Since 2005, several new mines have been opened in Finland, including the Kittila gold mine and the Talvivaara and Kevitsa base-metal mines. All of these new mines are based on deposits that were identified for the first time already decades ago. There are, however, also new discoveries made due to the intensified exploration activities during the last two decades. These have not been mined so far, but form the potential for future mining in Finland. This chapter presents two new findings: Sakatti and Rompas. Both of the new discoveries presented here are partly situated under Natura 2000 areas, which create an extra challenge for the licensing of the exploration and mining activities in these regions.

Sakatti (Ni, Cu, PGM)

The Sakatti project is a copper-nickel-platinum group element discovery situated 150 km north of the Arctic Circle in the Sodankylä region, Finland. The deposit was discovered by Anglo American in 2009 and is still in the exploration phase. The current work is carried out to delineate the ore body. The deposit contains massive, semi-massive and veinlet parts of rich sulphide ore and is considered as a very promising (possibly world-class) grassroots finding. The Sakatti deposit is mostly situated under a Natura 2000 region that creates a land-use contradiction and a challenge for the exploration and mine development process. (Anglo American Plc. 2011 & 2014).

Rompas (Au, U)

The Rompas project is a new camp-scale discovery in the municipalities of Ylitornio and Rovaniemi, northern Finland, where high-grade gold (up to 2,8g/t Au) and uranium have been found within an area approaching 10 km by 10 km. Rompas was discovered in 2008 by Areva NC and the current holder Mawson Resources acquired the project in April 2010 and outlined the initial hydrothermal nuggety gold discovery over 6 kilometres along strike and 200–250 metres in width. In 2013, a new style of disseminated gold mineralisation was drilled at Rajapalot, 8 kilometres east of the Rompas vein system. Rompas–Rajapalot is a surface discovery containing visible gold in the best parts of the ore bodies. At this early stage of exploration, it is difficult to find a global analogue for the type of mineralisation at Rompas. Rompas is also partly within a Natura 2000 region that creates a challenge for the exploration and mine development process in the area. (Mawson Resources 2014)

1.4.2 Undiscovered resources

In addition to identified mineral deposits, the Geological Survey of Finland has carried out research on estimating existing but yet undiscovered resources that could occur in the country. This research is based on probability calculations and is divided into two types of approaches: 1) identifying spatial probabilities to find new mineral deposits in certain areas based on geology, exploration techniques and expert knowledge (), and 2) assessing the probable amount of resources existing in a certain region (results of these approaches are shown in Figure 7 and Figure 8, respectively). These studies provide information for targeting exploration for new mineral resources.

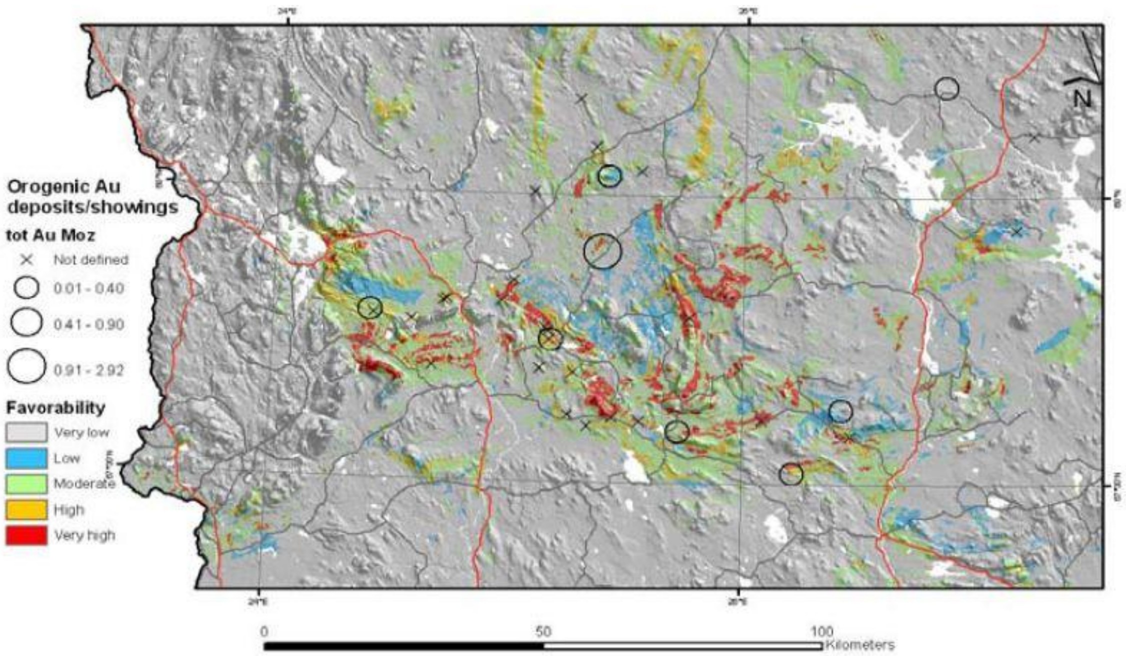

Figure 7: Mineral prospectivity mapping via spatial data analysis. Source: Nykänen 2012

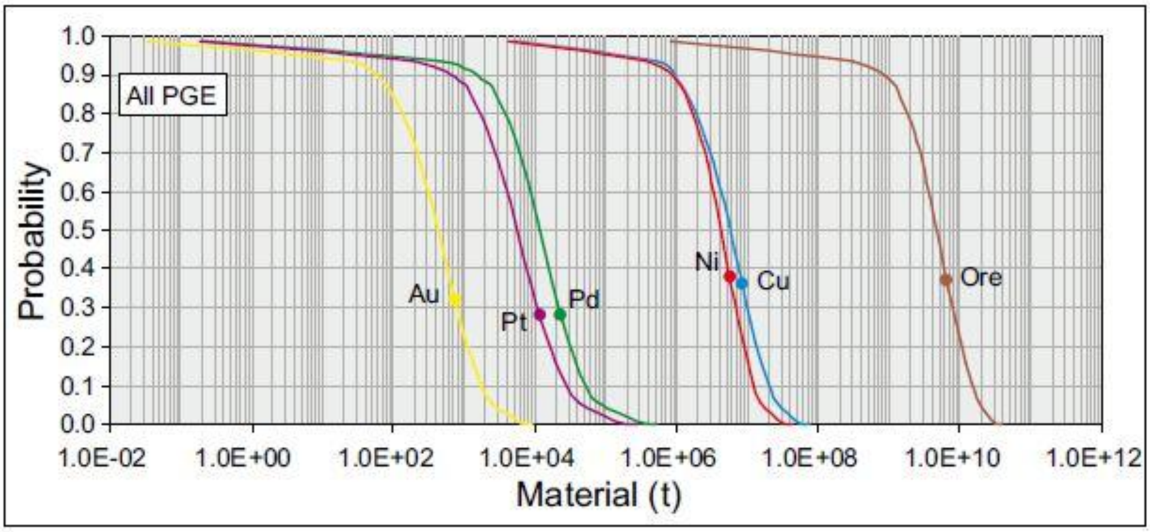

Figure 8: Cumulative frequency distributions of estimated metal and ore tonnages for undiscovered Finnish PGE deposits. Published before by Rasilainen et al. 2010.

1.5 National minerals policy

In Finland, the exploration and mining activities are primarily guided through the Mining Act (621/2011) that came into force on 1st of July 2011. The new act replaced the old Mining Act from 1965 with enhanced importance on public hearings and environmental aspects. At the same time, the compensation level to landowners was increased. In addition, Finland has published a Minerals strategy in 2010 (Finland´s Minerals Strategy 2010) and the action plan to guide the country as a leader in the sustainable extractive industry published in 2013 (MEE

2013). No mining royalties are paid in Finland, but the companies are subjected to real estate taxation and profit taxation common to all companies operating in the country (reduced from 24.5% to 20% from the beginning of 2014). Additionally, landowners receive compensation based on land use and mine production. In general, the politics in Finland are considered to be minerals industry supportive which is reflected, for example, by the high rankings during the recent years on the annual Fraser Mining Surveys assessing policy attractiveness and geological potential (e.g., Wilson et al. 2013).

1.6 Companies and investments

In this section, Finnish metals mining industry is considered from the perspective of companies operating in the mining and exploration sector. The studied factors include: number of companies, value of production, investments, and number of employees. The data was gathered within the scope of this case study from the public data sources maintained by Statistics Finland and the Finnish Safety and Chemicals Agency (TUKES), and from corporate quartile reports.

1.6.1 Number of companies and value of production

The mining of metallic ores has been steadily increasing in Finland since 2006 (Figure 3). According to Statistics Finland, the number of companies associated in producing metallic minerals increased from 15 to 24 between the years 2006 and 2012. The number of mineral exploration companies acting in Finland increased from 38 companies in 2007 to 52 companies in 2011. Then the number dropped to 38 companies in 2013.

The gross value of production almost quadrupled (375 %) during the same time. In 2006 the gross value was 209.5 M€ whereas in 2012 it reached 786.2 M€. Value added of production also more than doubled during this time (232 %) from 129 M€ to 299 M€. The increase was versatile: in 2010 both the gross value and the value added doubled and tripled, respectively, from the previous year, and after this peak in 2011 decreased again in 2012.

1.6.2 Amount of investments to exploration and mining

According to TUKES, the annual investments to mineral exploration and prospecting follow the same kind of trend as the number of exploration companies; investments increased from 53.3 M€ up to 86.8 M€ between 2007 and 2012 and then dropped back to 52.8 M€ in 2013. The investment targets can be studied by looking into the annual amount of exploration drilling, size of ore prospecting areas, the applications for additional ore prospecting permit areas and areas in reservation notifications. Exploration drilling metres increased rather steadily from 223,000 m in 2007 reaching paramount values of over 360,000 m during the years 2010–2012. In 2013 the exploration drilling meters dropped drastically ca. 60 %, and the drilling directed more into grassroots prospecting than in the previous year. The area claimed for ore prospecting has been increasing since 2010, now covering 140,000 ha. The area covered by the exploration applications has also increased since 2010 from 270,000 ha to 545,000 ha in 2013. The peak of areas applied for exploration covering 821,000 ha occurred in 2012. Currently, investments on mineral exploration have decreased.

According to TUKES, the number of operating mines and quarries in Finland increased from 45 in 2008 to 52 in 2011. After that, the number diminished to 46 in 2013. The investments in mines have gone up and down during this time. The top years with 578 M€ and 555 M € investments were 2008 and 2011, respectively.

1.6.3 Number of employees

According to Statistics Finland, the mining of metallic ores sector is increasing in importance as an employer in Finland. From 2006, the number of employees in the mining sector tripled from 558 to 1713 persons in 2012. The labour costs nearly quadrupled, but the mean annual payment to an employee increased approximately 21 % during the period in this sector. At the same time, the indirect employee costs increased only by 12.5 %.

1.7 Discussion

Identified mineral potential in the Finnish bedrock, studies on potential to find new deposits and the interest that exploration and mining companies have shown in Finland from the year 2000 onwards, indicates that Finland has a good potential for mineral-based development also in the future. During the last decade, the mining and exploration business has increased its importance as an employer – in contrast to the sector in (many) other European countries. Although, , the economic importance of mining remains relatively small at the national scale, its effects to local economies can be important. The development of the mineral deposits to mines depends on the markets, investments and the national minerals policy. The Finnish minerals policy is currently encouraging new activities and investments of the private companies in the minerals sector.

Since the mid-1990s, the state of Finland has adopted mostly a supporting role in mineral sector development although acting as a major shareholder in two companies practising mining (Outokumpu Oyj and Talvivaara Mining Company[1]). Important ways of support are the financial instruments directed to, for example, late-stage exploration and mine planning projects and infrastructure investments (MTC 2008). In addition, the governmental funding agency TEKES provides research and development funding also for mineral based sectors. The Geological Survey of Finland, funded by the government, performs metallogenic and mineral potential investigations and research to provide information about resources and geology to both the society and companies.

Talvivaara Mining Company has sold it´s mining rights to a new Terrafame Oy in August 2015. The new company will continue the mining operations at the Talvivaara mine site. Terrafame Oy is currently (August 2015) fully owned by the Finnish government.

The future mining and exploration activities in Finland are strongly driven by the investments and the development of metal prices. In addition, competition over land uses may have an increasing effect on the exploration and mining business in the future (see other two case studies in this Foresight Study considering Finland: 1) Legislative Challenges in Mining of Finland and 2) Societal challenges in Mining of Finland). Lately, many of the mineral exploration and mine development projects have come cross with Natura 2000 areas. This is due to the mineral potential of the Northern Finland which also hosts most of the Natura 2000 areas in the country. New mineral deposit discoveries in northern Finland, Sakatti and Rompas, will probably turn out to be test cases in mining in Natura 2000 regions, and the outcomes of these cases will possibly have an effect on the future exploration and mine development activities in northern Finland (and possibly elsewhere in EU) in those areas where the Natura 2000 regions are common.

Suggested actions to improve the mineral deposit accessibility in Finland are supporting the mechanisms to enhance investments to mineral exploration and mine development especially from domestic and EU sources. In addition, developing a clear procedure for mineral exploration and mining activities in protected areas, especially in Natura 2000 is an important issue. Also, reducing the permitting times without compromising the environmental impact assessment quality would benefit the industry.

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2 Primary raw material potential of Sweden

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2.1 Executive Summary

Sweden has become one of the most interesting exploration and one of leading mining countries in Europe in last 20 years. The change has been driven by the good potential to find and develop mineral deposits combined with the good infrastructure and politic. This report summarises the developments in the exploration and mining sector in Sweden with focus to the future potential.

Iron, zinc, copper, lead and gold form the economically most important mineral resources in Sweden. The country has currently 15 operating metallic ore mines with several development projects. In addition, operations at two new started iron mine are currently stopped due to the decreased metal prices.

Sweden has a proven potential for deposits containing European Commission defined critical metals, including rare earth metals fluorspar and graphite (known deposits).

The minerals policy in Sweden is considered favourable to the minerals based sectors.

Number of companies active in exploration and mining has, after several years of growth stabilized at over 100 companies. Investments in exploration has followed the trend on the world market and decreased over the past two years. Sweden is still high on the list of the countries where prospectors are investing at just over $ 100 million annually.

2.2 Introduction

Sweden's mining history can be dated back to the early 1000's. A lot of Sweden's prosperity is based on the income as Falun mine and iron ore in Bergslagen given since the Middle Ages and the ore deposites in Västerbotten and Norrbotten in the last hundred years. Ore extraction in the Falun mine started probably even before the 1000's. It gradually gained the growing economic and political importance. During a period in the 1600s, Sweden's Great Power, the Falun copper mine accounted for two-thirds of the world's copper production. Falun mine was closed down in 1992, after having been in operation for over a thousand years.

In the 1100s began iron production from iron ore. In Norberg are Sweden's oldest known mines, mentioned for the first time 1303. The oldest known blast furnace, Lapphyttan, is also in Norberg and it is dated to between 1150 and 1225. From the mid 1200s to the 1800s, Sweden was for long periods one of the world's leading producers of iron. Around 1750 iron ore accounted for about 70 % of all Swedish exports.

In 1696 mentioned the iron ore mountains Luossavaara and Kiirunavaara for the first time and LKAB was formed in 1890.

At the end of 1924 a large ore explored tre mil northwest of Skellefteå. This ore deposit developed into the Boliden Mine. The company decided to build its own smelter to ensure the production of gold, silver and copper. Operations at the smelter began in January 1930 and Boliden AB was founded in 1931. Boliden mine was the largest and richest gold mine.

In the late 1910s, there were almost 500 mines in Sweden that produced nearly 8 million tons of ore. Just 50 years ago there were about 100 mines in Sweden, which produced about 20 million tonnes of ore. Sweden produce about 80 million tonnes of ore per year in 2014, in fifteen operating mines[2]. The total amount of ore mined in Swedish mines is estimated at about 3 billion Swedish Crowns.

[2] Mining Inspectorate sgu.se

2.3 Metals and minerals in Sweden

Table 1: The table below illustrates active mines in Sweden in year 2014

Mine	County	Municipality	Owner	Mineral	Established
Aitik	Norrbotten	Gällivare	Boliden Mineral AB	gold, copper, silver	1968
Björkdalsgruvan	Västerbotten	Skellefteå	Björkdalsgruvan AB	gold, copper, silver	1989
Dannemora[3]	Uppsala	Östhammar	Dannemora Mineral AB	led, gold, iron, copper, manganese, silver, zink	1200s, Restarted 2012, March 2015 into liquidation
Garpenberg	Dalarna	Hedemora	Boliden Mineral AB	led, gold, copper, silver, zink	1200s
Gruvberget	Norrbotten	Kiruna	Luossavaara-Kiirunavaara Aktiebolag	iron	2010
Kankberg	Västerbotten	Skellefteå	Boliden Mineral AB	led, gold, coppar, silver, zink	2012
Kiirunavaara	Norrbotten	Kiruna	Luossavaara-Kiirunavaara Aktiebolag	iron	1860s
Kringelgruvan	Gävleborg	Bollnäs	Woxna Graphite AB	graphite	2015 spring
Kristineberg	Västerbotten	Lycksele	Boliden Mineral AB	led, gold, copper, silver, zink	1940
Leveäniemi	Norrbotten	Kiruna	Luossavaara-Kiirunavaara Aktiebolag	iron	1964-1983, Restarted 2015
Lovisa	Örebro	Lindesberg	Lovisagruvan AB	led, silver, zink	1993, 2004
Malmberget	Norrbotten	Gällivare	Luossavaara-Kiirunavaara Aktiebolag	iron	1820s
Maurliden	Västerbotten	Norsjö	Boliden Mineral AB	led, gold, copper, silver, zink	2000
Maurliden Östra	Västerbotten	Norsjö	Boliden Mineral AB	led, gold, copper, silver, zink	2010
Mertainen	Norrbotten	Kiruna	Luossavaara-Kiirunavaara Aktiebolag	iron	2015
Renström	Västerbotten	Skellefteå	Boliden Mineral	led, gold,	1948

[3] Bankruptcy march 2015

			AB	coppar, silver, zink	
Svartliden	Västerbotten	Lycksele, Storuman	Dragon Mining (Sweden) AB	gold, silver	2004-2013 mining, 2013 - ore dressing
Zinkgruvan	Örebro	Askersund	Zinkgruvan Mining AB	led, copper, silver, zink	1700s

In Kiirunavaara and Malmberget iron ore is mined, while in others they mine sulphide ore and gold. Kiruna mine is the world's largest underground iron ore mine. Aitik, located just two miles east of Gällivare, is Europe's largest copper mine, where mining takes place in the pits. From 2010, also began alloying metal molybdenum to be extracted at Aitik. Even gru mines in Maurliden, Svartliden, and Björkdal, open-cast mines. The other Swedish mines are underground mines. Sweden's deepest mine is Renström with the operation of the 1240 meter level.

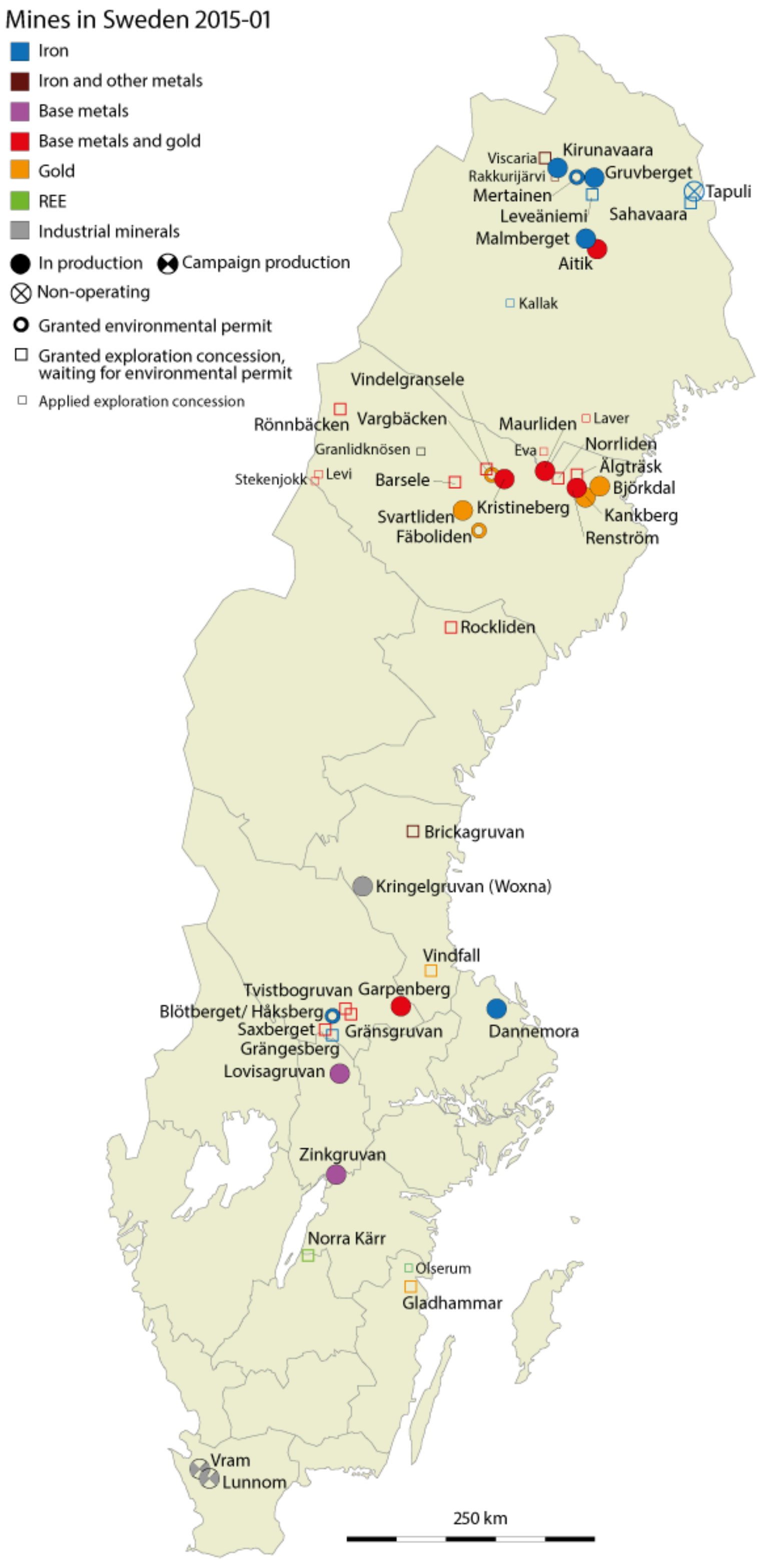

Figure 9: Mine s in Sweden (2015, Source: SGU)

2.3.1 Geological conditions

It is important to understand the geology of Sweden in relation to the rest of Europe. The vast majority of Sweden except the mountain range (Scander), southwest Skåne, Öland and Gotland and small areas, mainly in Östergötland and Västergötland, belongs to the Fennoscandian Shield. This also includes Finland and the northwestern part of Russia, including the Kola Peninsula and parts of Norway. The Fennoscandian Shield consists of old crystalline rocks, known gneisses and granites. It is in this environment that our ore deposits are located. The bedrock typically also has a high quality out of a construction-and materials standpoint. The Baltic countries, Northern Germany, Poland and Denmark are made up of younger sedimentary rocks, mostly limestones, which have different properties than the crystalline rock (Figure 3). In these sedimentary rocks are places ore deposits, such as in Poland and Ireland. Younger crystalline rocks are located in Europe and contain ore in some countries such as Spain and Portugal, but the Nordic countries and the Fennoscandian bedrock shield occupies a special position in terms of ore potential.

2.3.1.1 Reserves and resources of ore and minerals

Mineral deposits can be classified as either resources or reserves. The reserve is a concept that is limited by the knowledge level of the deposit in question and of the economic potential. For a resource to be classified as a reserve it should be possible to extract it economically and must be sufficiently known through surveys to its extent and characteristics should be well known. Sometimes it is also placed in a condition that a reserve should be legally possible to extract. The concept of resources is thus also with deposits at a particular time is not workable and based on information from the sparse studies and estimates of tonnage and grades. A resource can therefore turn to the reserve through more thorough investigations or by a more favorable price.

In Sweden, the reporting of ore reserves and resources are done as recommended by SveMin. Mining companies are investing large sums in the investigation of their deposits. The surveys are generally most accurate in areas where the nearest plans for mining. Areas that are more deeply needs more carefully to explore that are needed for mining planning. Likewise areas close of the mines to possibly discovering new deposits. For this reason, the reserves at a mine may vary over time, and the mines at a particular time might have reserves equivalent to one annual production of the mine could suddenly get increased reserves. Prices are contributing to the reserves development, as mentioned. If the price is increased significantly, as in many cases, the reserves also increase. On the other hand, the reserves decrease at lower prices to the point that a mine can be unprofitable to break. Another factor affecting the size of the reserve is the costs of mining and milling. If these costs can be lowered, for example, through a more rational mining, may increase the reserves. An example of this is the Aitik mine, where the doubling of production conducted a few years ago resulted in an increase in the reserves of the mine life has been increased significantly. The stated reserves and resources as well as concentrations in the following are taken from the companies' annual reports and other sources. The estimated iron ore reserves in Malmberget and Kiruna amounts to 1.01 billion tons. The ore reserves in the Dannemora iron ore mine in the municipality of Östhammar in Uppland amounts to 28.5 million

The total iron ore resources in Sweden is estimated to be about 730 million tonnes, of which more than half consists of resources in Kiruna, Malmberget and Svappavaara. A significant part (almost 177 million tonnes) is made up of the resources of iron ore deposit Stora Sahavaara and Tapuli in Pajala municipality near the Finnish border. The Canadian company Northland Resources started mining in Tapuli) in 2012 but went bankrupt in 2014.

The reserves of nonferrous ores in Sweden amount to 670 million tonnes. Ore resources for these metals are estimated at 1.055 billion tonnes, of which ore resources at Aitik constitute more than 90 percent.

2.3.1.2 Natural stone

Natural stone industry in Sweden extracts a number of unique types of stone that is internationally acclaimed, high overall quality and has a high market value. Annually around 1 million tons of natural stone is mined, mainly in southern and central Sweden and Öland and Gotland.

Sale value of these natural products is around 1 billion, of which 25 percent are exported.

2.3.1.3 Energy Minerals

The International Atomic Energy Agency, IAEA, compiles together with the OECD's Nuclear Energy Agency, NEA, the world's assets, production and future uranium requirements. This is published every two years in what is known as "The Red Book" (most recent version 2013). The global reserves are divided into four categories. It involves reasonable and assumed reserves, as well as forecasted and speculative reserves. In Sweden there are 10,000 tons of uranium of reasonable and assumed reserves as "The Red Book".

2.4 Critical metals and their potential for mining in Sweden

One of Europes largest deposit of fluorspar i.e. mineral with great importance for the steel industry as flux is found in the municipality of Storuman a significant share of Europes demand for fluorspar can be covered.

Sweden has one of the largest deposits of REE in Europe with low content of uranium and thorium in Norra Kärr. In addition to iron ore production like by product of apatite iron ore production become production of phosphates and REE. LKAB has in cooperation with LTU completed a major project on the possibilities of extracting phosphorus and REE from apatite concentrate in 2012 and 2013.

2.4.1 Granlidsknösen (Storuman) fluorspar deposit

Fluorspar is one of the very important additions in steelmaking slag production and is used as a flux in processes with high temperature which lowers the melting point of metals and saves energy.

The deposit Granlidsknösen is located in the municipality of Storuman in Västerbotten County about 25 km northwest of Storuman and it is one of the largest fluorspar deposit in Europe.The basis for the Storuman deposit is a large area of flat lying, sandstone hosted fluorspar mineralization that extends over an area of at least 3.6 km by 1.2 km where the mineralized horizon is typically 3-10 m thick. The deposit was discovered in the early 1960s. In the early 1970s, the company Granges International made 39 core drill holes and performed metallurgical testing in the laboratory. During 2008-2010 drilled Tertiary Minerals plc another 10 pieces drill hole and performed the Scoping Study. The company drilled another 46 drill hole in 2011. Metallurgic tests were performed in larger scale and showed positive results. A feasibility study was carried out in 2011 and an application for a mining concession was sent to the Mining Inspectorate in January 2015.

According to the feasibility study, the company made there is 17.96 to 22.96 millions tons ore with a content of 12.3 percent CaF_2. Ore calculations are based on the Australian JORC reporting and it is of 25 million tonnes of indicated and 2.7 million tonnes of Inferred Resources at an average grade of 10.21 percent CaF_2.

A conventional open pit strip mining operation of 1.0 million tonnes per year (Mtpy) is envisaged for the deposit, with a life of mine exceeding 20 years. Waste rock material generated from the stripping operations will be used to construct the tailings storage facility and excess waste material will be directly backfilled into the open pit during operations, effectively progressing pit closure during mining operations. A 1.0 Mtpy flotation process plant is envisaged for the Project with three stages of crushing, primary ball mill and two regrind stages. Ore will be delivered to a run of mine (ROM) pad and fed to the plant via a front end loader. The final concentrate product will be transported to a boat port for export.

In February 2013 was the deposit Granlidsknösen nominated to deposit of national interest

2.4.2 Norra Kärr REE deposit

Norra Kärr is a zirconium and rare earth element enriched peralkaline (agpaitic) nepheline syenite intrusion which covers 350m x 1200m in area. Tasman Metals Ltd is the 100% owner of the Norra Kärr

The rock units comprising the Norra Kärr intrusion are uncommon on a global scale, and include mineral phases that are comprised of or associated with REE's, zirconium (Zr), niobium (Nb), yttrium (Y) and hafnium (Hf). The Norra Kärr deposit is low in radioactive metals.The deposit is located in southern Sweden, 15km NNE of the township of Gränna and 300km SW of Stockholm.

Tasman Metals Ltd has acquired historic exploration data from the Swedish Geological Survey, completed site visits with geological reconnaissance, assayed rock chip samples from trenches and outcrops to confirm the presence of rare earth element and zirconium mineralization, completed a 43-101 technical report, drilled in excess of 40 holes on 100m spaced sections, calculated an Inferred Mineral Resource, and metallurgical testing with SGS Lakefield (Canada).

Norra Kärr received a mining concession by the Mining Inspectorate in May 2013.

2.4.2.1 Project History

Unusual intrusive rocks and the associated fennite aureole at Norra Kärr were first described in 1906 by the SGU geologist Alfred Törnebohm.Principal exploration in the area was conducted by Swedish mining company Boliden AB. In 1948 Boliden AB signed a contract with the landholders which gave them rights to mine. Test pitting at two sites and subsequent trial enrichment began in 1949. Boliden AB determined that with technology of the day separation of nepheline from feldspar and aegerin was difficult and the Fe grades were elevated. Profitable Zr extraction was not shown to be successful, due to the synchronous discovery and development of rich deposits of monazite and zircon in Brazil.In 1974 Boliden AB re-started exploration for nepheline, zirconium and hafnium. Norra Kärr lay on free ground from Boliden's exit in 2001 until Tasman's acquisition in 2009.

2.4.2.2 Geology and mineralization

The rock units comprising the Norra Kärr peralkaline (agpaitic) intrusion are uncommon on a global scale, and include mineral phases that are comprised of or associated with REE's, Zr, Nb, Y and Hf. The Norra Kärr intrusion area is surrounded by a 25-100m wide fennite aureole.

The nepheline syenite intrusion is hosted by a coarse grained microcline rich regionally significant granite (the Växsjö granite), the contacts between which are deformed with a clear schistosity. The Norra Kärr intrusion is interpreted to be part of the Neoproterozoic North Atlantic Alkaline Province

2.4.2.3 Resources

Tasman Metals has made an NI 43-101 compliant independent resource estimate for Norra Kärr 2011 and in july 2015 was “Amended & Restated Prefeasibility Study - NI 43-101 - Technical report for the Norra Kärr Rare Earth Element Deposit” relised[4].

The resource estimate was prepared and modelled by independent qualified person. With a base-case resource estimated using a TREO (Total rare elements oxide) cut-off of 0.4% hosts Norra Kärr an Inferred Mineral Resource of 60.5 million tonnes grading 0.54% TREO and 1.72% ZrO_2 (zirconium oxide), with 53.7% of the TREO being the higher value HREO (heavy rare earth oxide).

[4] http://www.tasmanmetals.com/i/pdf/Norra-Karr-Technical-Report-Jan13-2015.pdf

Table 2: The table below illustrates the grade averages for all of the rare earth oxides at the various cut-offs.

TREO % Cut-off	Million Tonnes	TREO %	% of HREO In TREO	ZrO_2 %	HfO_2 %	Tonnes
0,6	16,2	0,66	52 %	1,8	0,033	106 000
0,5	38,4	0,60	52 %	1,75	0,034	230 40
0,4	60,5	0,54	53 %	1,72	0,034	326 000
0,3	77,9	0,50	54 %	1,70	0,035	389 500
0,2	99,3	0,45	53 %	1,60	0,034	446 000

Notes[5]: The resource estimate has been classified as an Inferred Resource due to the wide-spaced sample data within the current deposit outline. The resource estimate is based on: A database of 26 drill holes total with 3,276m of diamond drilling completed by the Tasman Metals Ltd since December 2009.

Table 3: The table below illustrates tonnage for different types of REE at the various cut-off

Cut-off TREO %	Million Tonnes	La_2O_3	Ce_2O_3	Pr_2O_3	Nd_2O_3	Sm_2O_3	Eu_2O_3	Gd_2O_3	Tb_2O_3
0,2	99,3	0,042	0,091	0.012	0.047	0.010	0.002	0.015	0.003
0,3	77,9	0,048	0,105	0.014	0.053	0.011	0.002	0.016	0.003
0,4	60,5	0,054	0,117	0.015	0.059	0.012	0.002	0.018	0.004
0,5	38,4	0,060	0,134	0.017	0.067	0.012	0.002	0.020	0.004
0,6	16,2	0,065	0,149	0.019	0.075	0.012	0.003	0.022	0.004

[5] Total Rare Earth Oxides (TREO) includes: La_2O_3, Ce_2O_3, Pr_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3, Y_2O_3

Heavy Rare Earth Oxides (HREO) includes: Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3, Y_2O_3

Cut-off TREO %	**Million Tonnes**	**Dy_2O_3**	**Ho_2O_3**	**Er_2O_3**	**Tm_2O_3**	**Yb_2O_3**	**Lu_2O_3**	**Y_2O_3**
0.2	99.3	0.022	0.005	0.016	0.003	0.016	0.002	0.161
0.3	77.9	0.024	0.005	0.017	0.003	0.017	0.002	0.178
0.4	60.5	0.026	0.006	0.018	0.003	0.017	0.002	0.190
0.5	38.4	0.027	0.006	0.019	0.003	0.017	0.002	0.206
0.6	16.2	0.030	0.006	0.020	0.003	0.019	0.003	0.232

2.4.2.4 *Metallurgy*

A 100 kg sample was sent to SGS Lakefield (Canada) in November 2011. In May 2011, Tasman reported on the first leach tests carried out on the Norra Karr project. Three roast and leach tests have been performed to date by SGS on this representative sample without any pre-concentration process. The roast and leach process has been applied to a pulverized sample of ore. The third such test (NK3 in Table 1 below) was extremely successful, where a pre-leach at room temperature was followed by acid roast and leach, which successfully brought into solution in excess of 90% of all REE's and Zr.

Table 4: Table below provides a compilation of recovery for various leach tests performed on equivalent samples. ***Percentage recovery of key elements, and conditions of roast and leach testing***

	La	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Sc**	**Y**	**Zr**	**Fe**	**Si**
NK-1	58.3	56.6	56.4	56.2	51.4	49.0	48.3	46.5	46.0	43.4	44.3	43.3	43.1	42.7	37.3	47.0	61.4	8.5	1.0
NK-2	65.0	61.9	52.1	64.3	51.2	48.8	65.0	64.2	64.2	63.3	62.1	62.2	62.2	61.2	53.3	61.3	65.9	7.7	0.3
NK-3	**96.7**	**95.4**	**97.1**	**97.1**	**96.4**	**95.9**	**95.4**	**94.4**	**93.5**	**92.7**	**92.8**	**92.3**	**92.1**	**91.4**	**74.4**	**92.9**	**91.1**	**3.7**	**3.5**

NK-1: crushed ore where 80% of the sample passed a 24.6 micron screen; combined with 600 kg/tonne of ore of sulphuric acid, roasted for 4 hours at 150 degrees C

NK-2: crushed ore where 80% of the sample passed a 52.2 micron screen; combined with 2000 kg/tonne of ore of sulphuric acid, roasted for 4 hours at 150 degrees C

NK-3: crushed ore where 80% of the sample passed a 52.2 micron screen; combined with leaching solution at room temperature. This solution removed, then ore combined with 600 kg/tonne of ore of sulphuric acid, then roasted for 4 hours at 150 degrees C

2.4.3 Phosphorus and REE from LKABs apatite iron ore

Rich apatite iron ores has a great potential for the extraction of phosphorus and REE at LKABs iron ore production.

LKAB plans to resume apatite production means that the raw material source for the production of apatite concentrate, it becomes apatite rich waste from the daily production from the enrichment plant and the reserves are deposited in the tailings. Production was planned to start in 2015-2016 but is stopped until further notice. The total amount of apatite concentrate in tailings in Kiruna is estimated at 6.6 Mt.

Table 5: The table below shows the total amount of apatite and REE at Kiruna tailings

	Tailings Mt	P %	Apatite[2] Mt	Apatite[1] Mt	Apatite[3] Mt
Estimated quantity 2012	52	2,8	7,9	6,6	39,5
Estimated quantity 2013	56	2,7	8,2	6,8	41,0
Estimated quantity 2014-2020	28	1,5	2,3	1,9	11,4
84	2,3	10,5	8,7	52,4	

[1] Yield 70% concentrate containing 15.5% P

[2] 100% pure apatite contains 18.4% P

[3] Concentrate contains 0.6% REO

Table 6: Table below shows Phosphorus and concentrations of REE from LKAB's new deposits / ores

Deposit	% P	% REO	% REE
Kiruna	13.1	0.99	0.83
Malmberget	16.3	0.95	0.79
Leveäniemi	10.8	0.51	0.43
Lappmalmen	12.1	0.93	0.77
Nukutusvaara	15.1	0.98	0.81
Haukivaara	11.2	0.75	0.92
Mertainen	13.2	0.4	0.33
Pattok	8,5	0,4	0,336

2.5 Exploration and explorations costs in Sweden

Exploration costs in Sweden in 2014 show a down 8 percent compared with 2013. Total ended exploration costs to SEK 508 million (About 70 million USD). The decrease is lower in Sweden than at the global level, which primarily is due to the large operators in Sweden (Boliden and LKAB) still investing large exploration. The problems for junior companies to find investors also continued in 2014, which proves a decline in the number new serched exploration permit.

The northern counties of Norrbotten and Västerbotten accoun for over 70 per cent of exploration costs followed by Dalarna and Örebro. Most of the exploration costs terms of near-mine exploration and projects that are in the final phase, while grassroots projects (Greenfield) constituted only a few percent of the total exploration.

Base metals and gold remained the most prospected metals with 75 percent of the total effort, while prospecting for iron ore accounted for more than 20 percent. The Swedish mining company Boliden and LKAB accounted for 75 per cent of exploration costs in Sweden. Boliden has reduced its investment in exploration by 3 per cent compared with 2013, while LKAB has made the largest investment in exploration since 2011.

The number of current exploration permits at the end 2014 was 776 permits, compared with 959 one years ago. In 2014, applied for 150 new exploration permits which is an increase compared to 2013 when it applied for 130 exploration permits. The number of granted exploration permits was 7 percent lower in 2014 compared with 2013, 111 and 119. The number requests for extension has been reduced from 205 in 2013 to192 in 2014.

The primary goal of the companies was copper closely followed by gold and to a lesser extend silver, zinc, energy minerals, lead and iron. The new permites are concentrated in the three ore regions in the country: the Malmfälten in northern Sweden, Skellefteåfält and the Gold Line in Västerbotten and Bergslagen

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Tertiarymetals: http://www.tertiaryminerals.com/storumanfluorspareprojekt

3 Primary raw material potential of Greenland

Lars Lund Sørensen (GEUS)

3.1 Executive Summary

In the last 5-10 years Greenland has continuously reported encouraging exploration results from projects ranging from grass root exploration to feasibility and mining stage.

Several new mine projects have thus been approved within this period by the Government of Greenland. Many of these are based on already known, but previously considered uneconomic deposits, which have been re-assessed and developed into mining projects.

However, due to the decreased metal prices and insecurity in the markets and thus lack of funding for mine development globally - only one of these mining projects, the Aappaluttoq ruby project, currently being developed. In addition there has been a slowdown in the exploration activities in Greenland since 2014.

Lack of infrastructure and 'lower-than-optimal' geological knowledge levels can be possible challenges to investment in the Greenland raw materials sector. Despite the obvious challenges, the Arctic region contains some of the world's largest existing and prospective mines. Therefore while infrastructure risk is considerable, it is common to large number projects and is not limited to Greenland.

With excellent mineral potential, a stable political environment, favourable mineral legislation and a highly competitive fiscal regime in place, Greenland has the potential to become an important producer of raw materials in the future, especially relating to minerals currently regarded as critical by the European Commission, such as Light and Heavy REEs, niobium, graphite, PGEs, and tungsten, in addition to the more conventional commodities such as iron, copper, zinc, and nickel.

3.2 Introduction

Greenland's history as a mining country reaches back to 1854 with the opening of the Ivittuut cryolite mine. The mine was active for more than 130 years and played an important role for the Greenland society and economy and was especially important during Second World War, as cryolite was a strategic mineral that was used as a flux in the production of metallic aluminium for the warfare industry.

During the 20th century additional mines were in operation for longer or shorter periods, with the most important being the Black Angel Mine (1973–1986) and the Qullissat coal mine (1924–1972). The closure of both the Ivittuut and Black Angel mines in 1986-87, marked the end of more than a century mining tradition in Greenland.

The mineral exploration activities remained fairly high in the 80-90's with a large drop in the activity level from 1999. Greenland thus reached a historically low activity level in 2002, with nearly only one project, the Nalunaq Gold project spending money on exploration. However, from 2003 there was a renewed exploration interest, mainly driven by the increased metal prices. In 2004, the opening of Nalunaq Gold Mine, marked an important milestone for the development of Greenland's mineral resources, as this was the first mine to open in nearly 20 years and also the first new mine in the history of the Greenland Home Rule that came into force in 1979.

As seen in Finland and Sweden the exploration activity rose sharply from 2004 and several new mine projects (e.g. Seqi, Malmbjerg, Black Angel, Isua and Aappaluttoq) have now been approved by the Government of Greenland. Many of these are based on already known, but previously considered uneconomic deposits, which have been re-assessed and developed into mining projects.

However, falling metal prices and lack of funding, due to the global financial crisis which began in 2008, have resulted in only one of these mining projects, the Aappaluttoq ruby project, currently being developed. Active mineral exploration has also identified important new green field findings such as the Isortoq Fe-V-Ti deposit and the Tikiusaaq REE deposit.

The case study will give an overview of the mineral potential in Greenland with special focus on the EU 2013-list of critical minerals, the known deposits and undiscovered potential of base metals (Zn, Ni & Cu) as well as detailed descriptions of some of the most interesting deposits currently being explored and/or developed. These include the Maniitsoq deposit (Ni, Cu, Co PGM), the Kvanefjeld (REE, U, Zn), and Kringlerne deposits (REE, Ta, Nb, Zr). Investment and corporate structure trends will also be described and an overview of the mineral statistics related to licensing and exploration activities will be conducted.

The main sources of data for this study will be various scientific papers, survey reports, mineral resource databases (e.g. DODEX & GMOM), company press releases and a recent study on Greenland by Lawlor *et al.* (2015)[6].

3.2.1 Scope

This case study is intended to give the reader a brief introduction to the geology of Greenland, as well as an overview of Greenland's mineral potential including deposits of critical raw materials and base metals. The case study includes an overview of the recent developments in mineral exploration and mine development in Greenland. The study also briefly describes some of the challenges associated with developing the mineral resources sector in Greenland.

3.2.2 Relevance of the case

Greenland was selected as a case country due its long mining history and excellent potential for mine development and new mineral deposits. Greenland have a strategic relevance for EU industry and represents the first pillar of the EU Raw Materials Strategy where the EU has committed to pursuing Raw Materials Diplomacy by reaching out to non-EU countries through strategic partnerships and policy dialogues. So far, the EU has developed relations with Argentina, Brazil, Canada, Chile, China, Colombia, Greenland, Japan, Mexico, Peru, Russia, the United States, Uruguay, the EuroMed countries and the African Union.

3.3 Analysis

The global evolution of economic growth in new regions and a rapidly increasing population gives increased consumption of mineral resources globally. This, together with the recent awareness of supply restrictions for so-called critical minerals such as the Rare Earth Elements used especially in green technologies, has led to greater interest in the Greenlandic mineral potential. The following text, figures and illustrations relating to the chapters: Geology of Greenland, Mineral Potential, Deposits of Critical Minerals in Greenland, Deposits of base metals and other raw materials in Greenland & Licensing and Current Exploration Activities are all derived from Lawlor *et al.* (2015).

3.3.1 Geology of Greenland

Greenland has a more than four billion year-old geological history and hosts many different geological environments (Figure 1). The oldest rocks, the North Atlantic Craton (a central Archaean craton), is bounded by two later Proterozoic orogenies (foldbelts), the Nagssugtoqidian to the north and the Ketilidian to the south. Subsequently, subsidence created large sedimentary basins in North and East Greenland, and rifting and volcanism created igneous provinces including the Gardar Province, and the North Atlantic large igneous province. Limited kimberlitic volcanism and carbonatites are found locally in several regions.

[6] Lawlor *et al.* 2015. Study on EU Needs with Regard to Co-operation with Greenland, 152 pp. This study has been prepared by Milieu Ltd, the Geological Survey of Denmark and Greenland (GEUS) and Oeko-Institut e.V. under EU Contract No 30-CE-0604902/00-84 – SI2.666954. Not yet published.

So, while Greenland is underexplored, mostly due to its remote location and limited infrastructure, its diverse geological record and an ice free area of about 440,000 km², warrants it a good potential for becoming a producer of a wide variety of commodities.

These include, for example:

- Iron, gold, chromium, and diamonds especially in the Achaean basement;
- Base metals in sediments and metamorphosed sediments;
- Platinum group elements (PGEs), and nickel in igneous Proterozoic rocks;
- Rare earth elements (REEs), niobium, tantalum and other speciality metals in alkaline and peralkaline intrusions and in carbonatites.

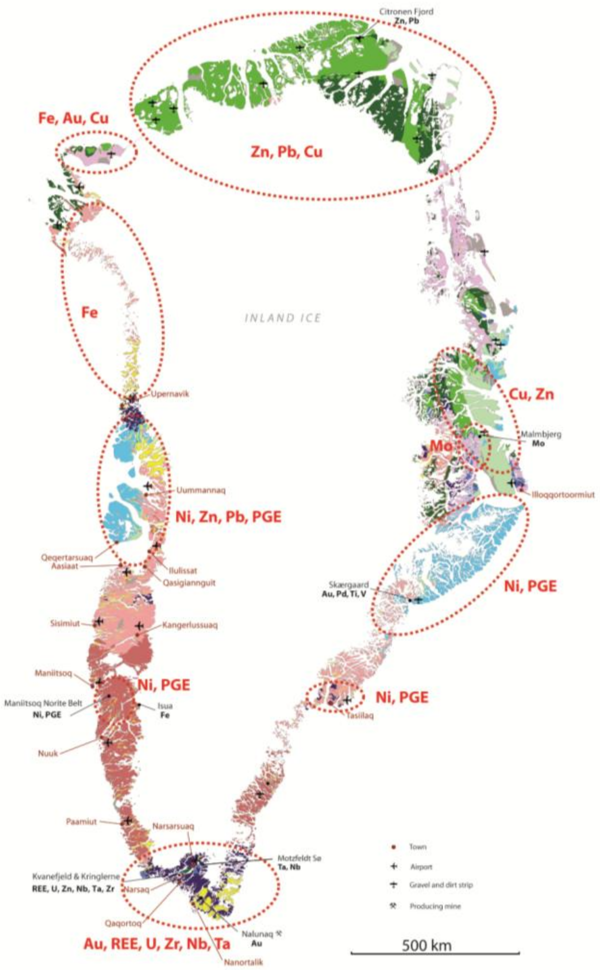

Figure 10: ***Greenland main geological environments including areas with important known economic potential. For a geological legend please refere to figure 14 in this study. Copyright GEUS.***

3.3.2 Mineral Potential

Compared to countries with similar geological conditions (e.g. Canada, Sweden, Finland) Greenland can be regarded as underexplored and, as most other countries in the Arctic region, it has significantly large exploration activity and has active mining, although to different degrees than the above mentioned countries. Nevertheless, the potential for the following is considered especially high in Greenland (Figure 1): zinc (North, West and East Greenland), copper (East & Northeast Greenland), rare earth elements (South and West Greenland), uranium (several regions), nickel (East and West Greenland), and iron (North and West Greenland). Furthermore there is good potential for a number of speciality metals; antimony, chromium, graphite, niobium, tantalum, tungsten and the platinum group elements (PGEs).

3.3.2.1 Deposits of Critical Minerals in Greenland

Minerals are considered critical when they are both important to society's needs and there is a significant risk to their supply. The evaluation of criticality varies as industrial and societal needs, and resource endowment and indigenous production capacities vary between countries or trade blocks. Therefore, there is a difference between what is critical for countries/regions like China, Japan, USA and Europe. As a result, quantitative methods and tools to evaluate critically and resulting assessments have been developed both globally, at the European Union scale (EU, Commission on Raw Materials 2010 and 2014), and nationally e.g. U.S (US Research Council, 2008), UK (British Geological Survey, 2013)). Additionally, the importance of industry specific commodities has been evaluated using similar tools (e.g. the automotive industry in Germany, the electricity supply in USA).

Table 7: ***EU critical raw materials (2010/14 list) - occurrences and potential in Greenland. Source: GEUS***

EU critical raw material	Known occurrence	Region	Potential	Exploration status	Comments
Antimony (Sb)	North Margeries Dal on Ymer Ø	Central East Greenland	Moderate	No active exploration	
Beryllium (Be)	Ilimaussaq and pegmatites e.g. Storø	South and West Greenland	High (Kvanefjeld)	No active exploration	Not part of the Kvanefjeld project
Cobalt (Co)	Disko Bay area. Thule district (placer) Maniitsoq Norite Belt	West and North Greenland	Low to moderate	Part of Ni exploration at Maniitsoq	Best potential with Ni deposits
Fluorspar (F)	Kap Simpson, Hudson Land, Ivittuut, Kvanefjeld	East and South Greenland	Moderate	No active exploration Part of REE exploration	By-product potential to REE from Kvanefjeld
Gallium (Ga)	Illimaussaq Skaergaard intrusion	South and East Greenland	Moderate	No active exploration	Only by-product potential.
Germanium (Ge)	None		Low	No active exploration	Only by-product potential. Ge is low in the Citronen Fjord Zn deposit
Graphite (C)	Amitsoq/ Eqalussuit/ Langø	South, West and East Greenland	Moderate - high	Two active exploration licenses	Several deposits are known and several have been exploited during the past

					century
Indium (In)	None		Low	No active exploration	Only by-product potential. In is low in the Citronen Fjord Zn deposit
Niobium (Nb)	Motzfeldt Sø Kringlerne Sarfartoq Tikiussaq	South and West Greenland.	High	Active exploration	By-product potential from several REE projects
Platinum Group Elements (PGE)	Skaergaard Fiskenæsset Maniitsoq Norite Belt	East and West Greenland	Moderate - high	Active exploration	Advanced stage exploration at Skaergaard and Maniitsoq
Rare Earth Elements (REE)	Ilimaussaq Motzfeldt Sø Sarfartoq Qeqertaasaq Tikiussaaq Karrat REE Milne Land	South, West and East Greenland	High	Active exploration	Several advanced stages exploration projects
Tantalum (Ta)	(See Nb)	(See Nb)	High	Active exploration	By-product potential from several REE projects
Tungsten (W)	Ymer Ø Ivisaartoq	East and West Greenland	Moderate	No active exploration	Only Ymer Ø is currently being explored

The first criticality analysis for raw materials within the European Union was published in 2010 by the European Commission. Fourteen critical raw materials were identified from a candidate list of forty-one non-energy, non-agricultural materials[7].

In 2013 a similar exercise with fifty-four non-energy, non-agricultural materials were conducted. The same quantitative methodology was used as in the previous 2010 exercise having economic importance and the supply risk of the selected raw materials as the two fixed criterias

The table above lists critical minerals along with their known occurrences and discovery potential in Greenland as evaluated by GEUS. The table includes 12 critical minerals on the European Commission's list from 2014 including tantalum from the 2010 list. The table shows that the discovery potential for the critical minerals niobium, graphite, PGE and REEs is especially high in Greenland.

3.3.2.2 Deposits of base metals and other raw materials in Greenland

Greenland represents a region with an excellent potential for base metal mineralisation. Since 2008, GEUS and Greenland's Ministry of Mineral Resources have jointly conducted annual mineral resource assessment workshops on selected mineral resources. From the workshop discussions and estimates it has been concluded that many areas in Greenland have a large potential for undiscovered deposits of copper, nickel, and zinc. The workshop estimates for each commodity and different geological regions are summarised in the table below. The underexplored sedimentary successions of East, North-East and North Greenland are of particular interest. This is also confirmed by the many known copper and zinc occurrences known from these regions.

[7] From http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/crm-report-on-critical-raw-materials_en.pdf

Table 8: Summary of estimates on copper, nickel and zinc. *Source: GEUS*

Commodity	Region	Known resources (Metric tons)	Mean estimate of undiscovered resources (Metric tons)
Zinc	North Greenland	5,400,000	18,490,000
	Rest of Greenland	1,661,000	6,347,000
Nickel	The Maniitsoq Norite Belt		490,000
	Disko Island		460,000
	Rest of Greenland		1,016,400
Copper	East Greenland		3,478,000
	Rest of Greenland		160,300

Greenland also has considerable deposits of gold, iron ore, molybdenum, uranium and other minerals.

3.3.3 Licensing and Current Exploration Activities

According to the Government of Greenland, the area covered by mineral licences has gone up from 6,000 (year 2002) to 48,000 km^2 in 2013, reflecting the gradual increase of the number of mineral licences (Figure 3). Therefore the area covered in 2013 equalled approximately 10 per cent of the total ice-free land in Greenland. However, as of March 2015 the total area covered by exclusive licences has fallen to 23,500 km^2 although the number of licences only has made a small drop.

This upward exploration trend until 2013 is consistent with the general global increase in interest in mineral resources. The last couple of year's major drop in licence area reflects the slowdown in the world economy and thus new investments. Large licence areas in Greenland are very expensive to keep for the exploration companies, as the annual work commitment on the licences are defined by the size, so the companies reduce the areas to a minimum. While uninhabited land in Greenland is 'crown land', and mineral exploration activities are permitted, more stringent rules apply in certain areas (such as in the very large National Park covering an area from central East Greenland to North Greenland). As of mid-January 2015, 106 mineral licences (78 exclusive exploration licences, 23 non-exclusive prospecting licences and 5 exploitation (mining) licences[8]) were granted or were under application. The distribution of these licences, as well as their holders, is illustrated in Figure 2.

[8] A company with an exploration licence has exclusive rights in a given area while a prospecting licence is not exclusive. An exploitation licence provides both exclusive rights and a right to mine.

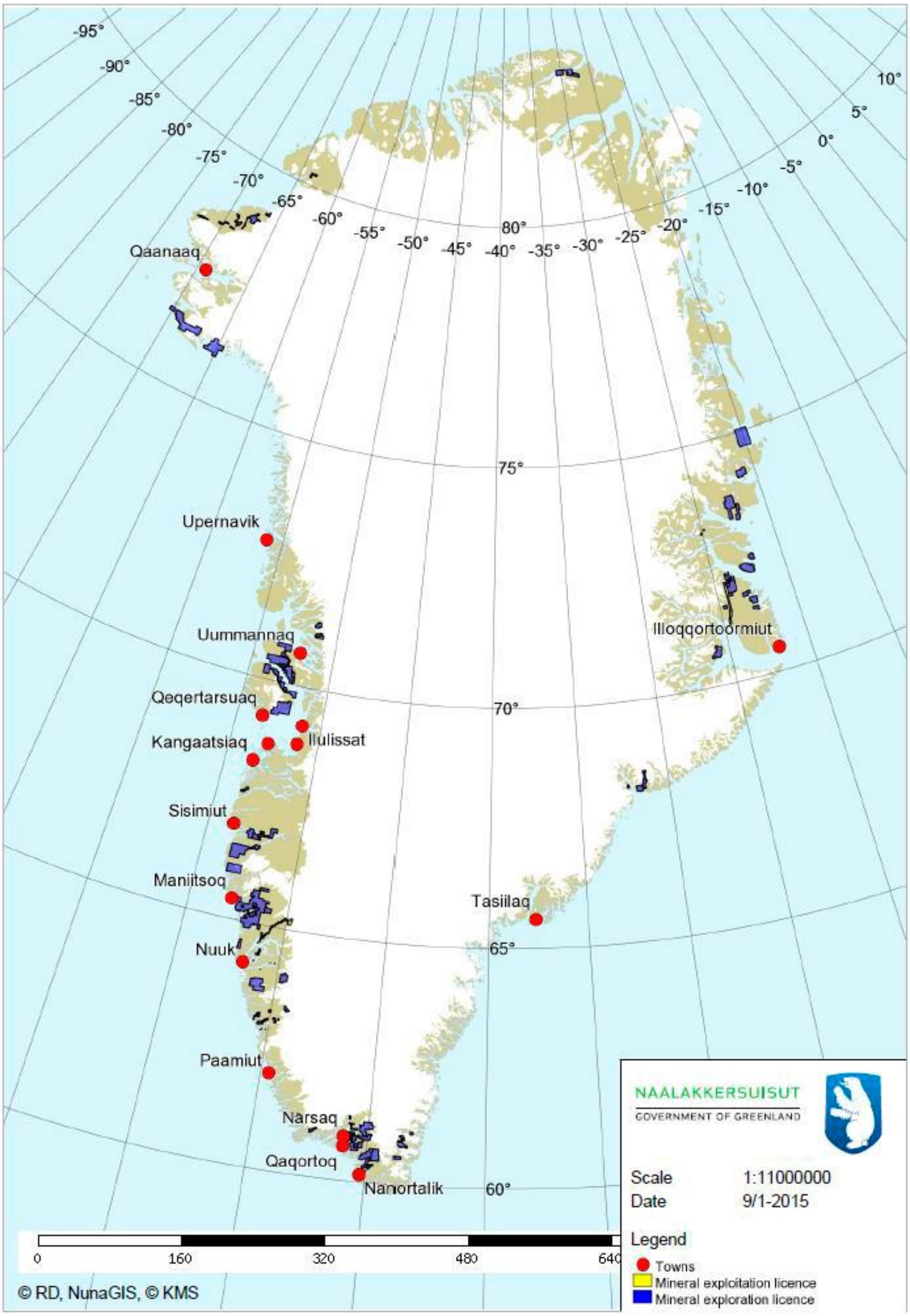

Figure 11: ***Map of active mineral exploration and exploitation licences as of 9 January 2015. Source: Government of Greenland (2015).***

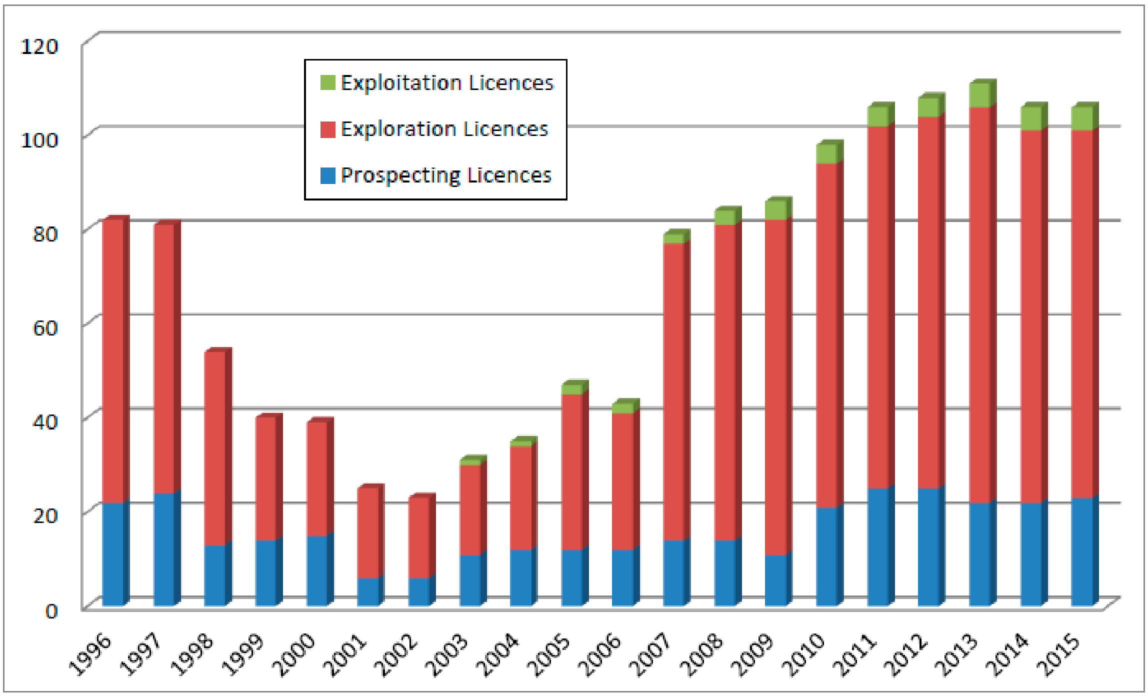

Figure 12: ***Evolution of the number of granted or under evaluation mineral licences in Greenland 1996-2015. Source:Government of Greenland (2015).***

As can be seen from the Figure 12 above, the number of exploitation licences applied for and granted is considerably smaller than the number of exploration and prospecting licences. This is an industry characteristic which is not unique to Greenland. Likewise, even when an exploitation license is granted there is still no guarantee that this will result in a mine being opened.

Care should be taken however when looking at the nationality/corporate structure of mining companies. For example, as mineral exploration in Greenland is typically structured similarly to what generally happens in the mining sector worldwide, junior companies carry out the initial exploration and start-up activities and, subsequently, the project are sold (or joint ventured) to major companies with greater financial strength and technical capacity who can carry the project forward to a feasibility study. Therefore the 'nationality' may change as projects come to fruition. The nationality, or 'home' country, of the companies currently conducting exploration activities in Greenland is outlined in Figure 4 below.

The feasibility study[9] together with environmental impact assessment and social impact assessment studies (EIA and SIA respectively) constitutes the basis on which an exploitation license is granted and is also essential for getting financing for the project. For speciality metals (i.e. Rare Earth Elements) there will be relatively few companies who are willing and able to

[9] The feasibility study is paid for by the company but is conducted by a third "impartial" party with skills and "license" to provide these things. This approach is the industry standard in other countries.

enter projects in their final stages because the exploitation of these deposits is technologically and commercially challenging.

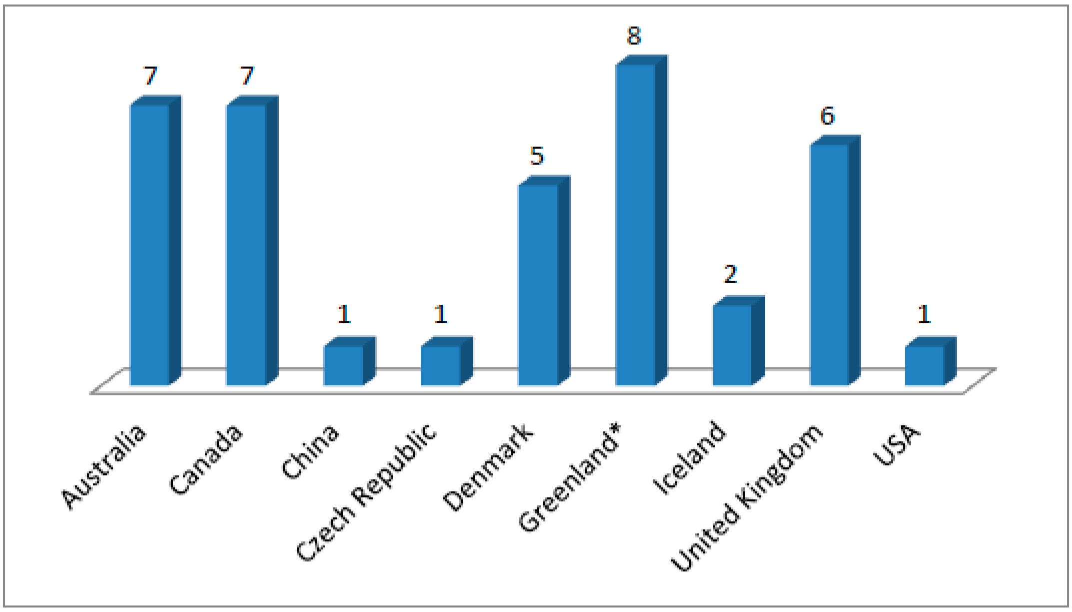

Figure 13: ***Number of companies and partners conducting exploration activities in Greenland, by country of origin. Only two of the 8 registered Greenlandic companies are exploration companies. The rest are companies associated with exploitation licenses. Source: Government of Greenland (2014).***

Most exploration companies active in Greenland are listed at various stock exchanges e.g., TSX, ASX, LSE, but there are also a few privately owned companies e.g., Avannaa Resources Ltd, Rimbal Pty Ltd. and Hunter Minerals Pty Ltd.

When applying for and awarded an exploration licence the companies are not required to state for which commodity they are exploring and, in several cases, companies explore for several minerals in the same licence area, concurrently or sequentially depending on the markets. Table 3 below gives an overview over some of the most frequently explored minerals (e.g. REEs, zinc and gold). The overview does not necessarily reflect the international industries general interests, and also it cannot be deduced to which extent the Greenlandic geological potential is sufficiently explored. It is relatively difficult to evaluate what determines the exploration strategies of junior companies, and specific measures to significantly increase exploration in Greenland, other than improved markets and increased investments, cannot be identified.

In terms of exploitation licences four out of six projects have held this type of licence for some time but are not in production. These are the (i) Nalunaq gold mine (exploited and closed), (ii) the Black Angel lead-zinc mine (under construction for re-opening but on stand-by due to lack of funding), (iii) the Seqi olivine mine (closed), and (iv) Malmbjerg molybdenum deposit (lack of funding/market down-turn).

In 2013 & 2014, two new projects i.e. Isua Iron deposit and Aappaluttoq Ruby/Sapphire deposit have been granted exploitation licences, however only the Aappaluttoq project have been able to secure the necessary funding to initiate the project.

Table 9: Number of exploration licences by target commodity (March 2015)

License – focus	Number of licences
Rare Earth Elements (including Nb, Ta)	18
Zinc (all/ main product)	18/11
Gold (all/ main product)	17/10[10]
Copper (all/ main product)	10/4
Nickel (all/ main product)	7/6
PGE (all/ main product)	10/2
Uranium (by-product)	4

Most of the currently advanced projects correspond to deposits found decades ago. For instance Kvanefjeld (REE/U) was found in the 1950s, Malmbjerg (Molybdenum) in the 1950s, Isua (Iron) in the 1960's, Skaergaard (Gold and PGE) in the 1980s and Citronen Fjord (Zinc) in the 1990's. The logistical constraints or bottlenecks of Greenland make it more complex to evaluate maturation periods. As such, it is therefore difficult to predict where and when future mining activities in Greenland will start, but some of the most advanced and mature exploration and mining projects are given in Table 4 and shown on the map in Figure 5.

Recent developments of some of the most advanced and active projects are highlighted below:

The Maniitsoq project (Ni, Cu, Co, PGM)[11]

In 2011 the North American Nickel (NAN) was granted an exploration license near Maniitsoq on the southwest coast of Greenland. Historical work on the property (1962-2000) resulted in the recognition of a belt of nickel-copper-cobalt bearing norite intrusions currently referred to as the Greenland Norite Belt (GNB). Since 2011, NAN has flown more than 6000 line kms of helicopter-borne geophysical surveys focused mainly on the GNB. More than 200 conductive zones are recognized. The conductors were modelled in three dimensions, providing well-defined sub-surface drill targets that when drill tested returned significant drill intercepts. The present deposit model for Maniitsoq hinges on mantle melting in response to a giant meteorite impact where hot ultramafic magma flows to surface through a "conduit system" comprised of restricted conduits and larger magma chambers.. High grade results from the drilling programme have yield 18.62m @ 4.31% Ni, 0.62% Cu, 0.14% Co. The company are in 2015

[10] The first number (17) is the total amount of licences with gold reported as main focus or where gold is reported as by-product in the deposit; the second number (10) is licences that exclusively explores for gold.
[11] From www.northamericannickel.com

continuing the previous years extensive exploration campaigns which comprises drilling, airborne, surface and borehole geophysics, mapping, sampling and prospecting.

Kvanefjeld (REE, U, Zn)[12]

The Kvanefjeld REE-U-Zn deposit, is located north of the town of Narsaq, South Greenland, and is a mega-breccia formed by various igneous rocks and supracrustals from the roof of the Ilímaussaq intrusion as well as rocks from the early phases of the alkaline intrusion, forming blocks and sheets within the later agpaitic magma. The bulk of the REE (as well as U and Th) is associated with the rock type lujavrite. Most of the REE is located in the minerals steenstrupine which makes up 5% of the lujavrite. The Kvanefjeld deposit has been explored for decades by various groups, but the early focus was mainly on the potential for uranium. The current license holder, Greenland Minerals and Energy Ltd (GME), have identified an indicated and inferred grand total resource of 956 Mt containing 10.33 Mt TREO, 575 Mlbs U_3O_8 and 2.25 Mt zinc at a cut-off of 150 g/t uranium. The resource is distributed in three deposits: the Kvanefjeld deposit the Sørensen deposit and Zone 3 deposit. GME are currently in the process of completing the Feasibility study as well as an Environmental and Social Impact Assessment (EIA and SIA) for the Kvanefjeld Project. Due to the uranium content, the impact assessments form critical components of the mining license application which is expected late2015.

Kringlerne (REE, Ta, Nb, Zr) [13]

The Kringlerne Zr-Ta-Nb-REE deposits is situated near the township of Qaqortoq and is hosted in the lower cumulates of the Ilímaussaq intrusion within the layered agpaitic nephenline syenites, referred to as kakortokite. The kakortokite cumulates form a total of 29 cyclic, and regular layers, with a total thickness of about 234 m, made by units composed of black (arfvedsonite dominated), red (eudialyte dominated) and white (feldspar dominated) kakortokite. The mineral eudialyte is enriched in Ta-Nb-REE-Zr-Y and the red kakortokite layers are thus the main exploration target for REE. The current license holder, TANBREEZ Greenland A/S estimate the resource to more than 4 billion tons. Linear correlations between ZrO_2 and individual REE indicate that eudialyte is by far the main REE bearing mineral in kakortokite. Estimated average grades are 1.75% ZrO_2, 0.18% Nb_2O_5 and 0.6% total REO, of which heavy REE make up 30% (including yttrium).

The company have submitted an application for an exploitation licence to the Greenland Government including a feasibility study and a SIA and EIA report for the project. As part of the hearing process and government approval of the project, the company have been asked to make further environmental studies and in addition investigate the potential for onsite processing of the ore in Greenland.

[12] From www.ggg.gl
[13] From www.tanbreez.com

Table 10: Status for some of the most advanced mineral projects in Greenland.

Company	Project	Commodity	Exploitation license	Infrastructure need	Jobs in production	Comments
London Mining Greenland A/S	Isua	iron	Granted	Large	700-800/ 20-55%	Large Scale. Project sold to Chinese
True North Gems Inc.	Aappaluttoq	ruby/ sapphire	Granted	Small - medium	50 - 80/ 75%	Jv agreement with
Greenland Minerals & Energy	Kvanefjeld	REE uranium zinc fluor	Expected application late 2015	Large, but close to existing infra-	400-600/ ~60%	Uranium is by-product from REE.
Ironbark Zinc	Citronen Fjord	zinc	Possible application	Large	200-300/ Low due to	MoU with China
Tanbreez	Kringlerne	REE tantalum niobium	Applied 2013 Under	Medium	200-300/ 75%	Seeking financing.
Angel Mining	Black Angel	zinc/ lead	Granted 2009	Medium		No activity.
Hudson Resources	White Mountain	anorthosite	Applied 2015. Under negotiation	Small-medium	50-100/100%	Seeking financing
KGHM Int	Malmbjerg	molybdenum	Granted 2008	Large	200-300	Not in productio
West Melville	Isortoq	iron vanadium	Unknown	Medium - large	100-200	Seeking financing.

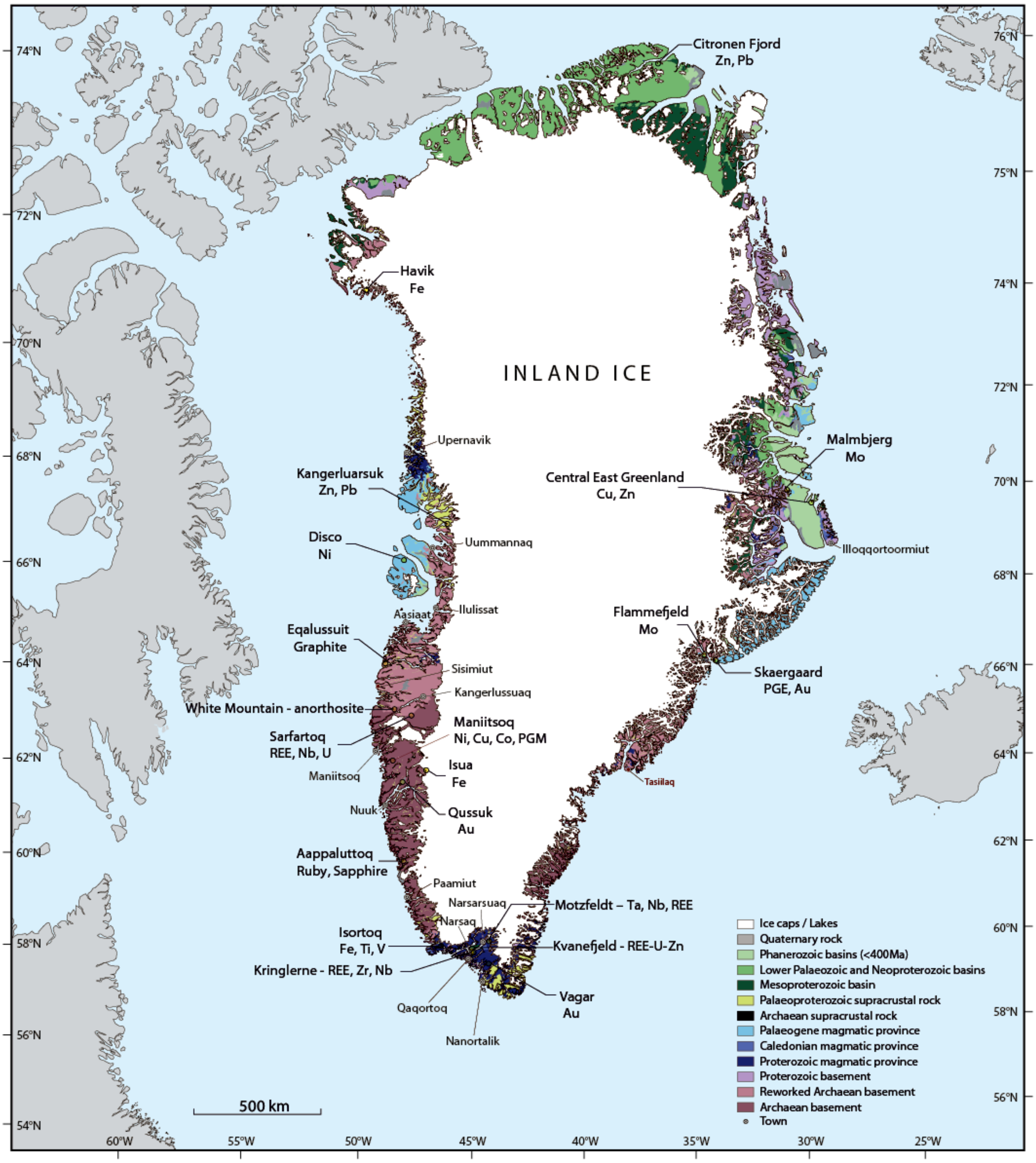

Figure 14: ***Geological map with location of some of the most advanced mineral projects in Greenland.***

3.4 Discussion

Large parts of Greenland have never been subjected to detailed exploration campaigns.

There is a fair chance of finding giant deposits in Greenland since a number of deposits at present are already categorised as 'giants' such as the deposits: Isua, Motzfeldt Sø, Kvanefjeld

(Kuannersuit), Kringlerne (Killavaat Alannguat), Skaergaard, Malmbjerg and Citronen Fjord. This case study has demonstrated that the geological environments and the related mineral deposits are in many ways similar to those found around the world. This means that the potential for new mineral discoveries that can sustain mining are excellent.

However, according to a recent study[14] looking at possible co-operation areas between EU and Greenland in the area of mineral resources, there are a number of challenges associated with the development of the raw materials sector in Greenland. Among these, lack of infrastructure and low geological coverage has been identified the most important barriers in that connection. The study concludes:

"A lack of infrastructure and 'lower-than-optimal' geological knowledge levels are barriers to further investment. As a result, there may be similar, alternative opportunities in other countries (e.g. Canada) which have similar geological characteristics but which may be better equipped to foster and manage investments. Against a background of falling mineral prices, it would appear that any such substantial barriers may result in limited investment for the foreseeable future. In addition, as the development of infrastructure, and in particular the enhancement of geological knowledge, is expensive and may take many years to bear fruit, another fundamental challenge is that any developments in Greenland – with the exception of 3 or 4 projects which are already well developed – may take several years to bring to the production stage. This time horizon, which may be too long for downstream companies who tend to buy minerals in the short to medium term, may therefore require leadership from EU and Member State public bodies to fill the gap. One possible solution here is to help level the playing field between Greenland and other mineral rich countries by providing investment lending for companies wishing to invest in mines in the EU and the Overseas Countries and Territories (OCT)s, including Greenland.

In practical terms, this may mean considering extending the possibility of EU support – for example European Investment Bank (EIB) lending – for investments in mining related infrastructure. As the level of funds available to OCTs like Greenland is low, such investments would have to promoted through own resource strategic funds, such as those currently used for promoting investment in the area of climate action. Likewise, given the current political focus on the need for EIB lending to promote growth and jobs in Europe, any EIB lending facility would need to be focused on how investment in mining-related infrastructure in Greenland would benefit Europe directly, namely in terms of how any materials mined in Greenland would be integrated in a supply chain involving EU member states and international partners.

In the area of geological knowledge, as with funding for infrastructure and related mining investment, such knowledge does not come cheap. For Greenland's potential to be fully understood, further long term investment in skills, facilities and knowledge would be needed.

[14] Lawlor et al. (2015)

To conclude, the ongoing development of an EU Arctic Policy and the promotion of closer relations with Greenland in raw materials are opportunities to address both the EU needs for raw materials as well as the development of a sustainable mining in Greenland".

At a joint raw materials diplomacy event, "EU-Greenland Workshop on Raw Materials" that was held in Brussels on 19 June 2015, the main conclusions of the study was presented together with other relevant topics relating to a possible cooperation between EU and Greenland. The workshop included presentation on:

- aeromagnetic acquisition of data;
- social, economic and environmental impact of mining;
- provision of support services for the mining sector;
- mining and management of radioactive ores;
- setting of a proper regulatory framework;
- experience gathered through the Kimberly process.

The economy of Greenland and a specific mining project were also presented at the event.

The workshop and study is part of the first pillar of the EU Raw Materials Strategy where the EU has committed to pursuing Raw Materials Diplomacy by reaching out to non-EU countries through strategic partnerships and policy dialogues. The next step will be for EU and Greenland to agree on and enter into possible cooperation agreements.

3.4.1 Greenland raw material potential and EU

As outlined in the EU Raw Materials Initiative (RMI) Communications[15] of 2008, 2011 and 2013, EU industry needs a more diversified and stable supply of certain materials. While Greenland is an important potential source for such materials, the EU can still look to other sources if the sector does not develop in Greenland.

Linked to this assertion is the view that while the EU takes a more short-term view of the need for certain critical materials in the next 10 years or so, Greenland is keen on developing a long-term, sustainable sector covering a broad range of materials such as gold, rubies, nickel, iron, base metals, and not just rare earths, one which will thrive for many decades until other sources of economic growth can be developed.

That said, the RMI covers base metals and other minerals aside from 'critical raw materials', with the main factor here being price rather than security of supply. If global economic growth and urbanisation in the emerging world continues, it is likely that the availability of base metals will continue to be, and may even increase in, importance for the EU.

[15] http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

For Greenland, there is much at stake, namely its political and economic status, and indeed survival, as a country. The flip side of this large imbalance is that while Greenland fully recognises that the business-as-usual situation cannot continue in the long-term, it is less apparent that the EU's industry is looking for sources of critical raw materials outside of China.

Given its potential future dependence on one or two sectors, namely mining and fisheries, it would appear reasonable that Greenland would want to diversify its export partners.

Currently most interest in the minerals sector is coming from Australian and Canadian mining companies and from downstream Chinese-based metal companies

It is therefore reasonable to assume that it may not be in the interests of the EU to directly or indirectly support mining activities in Greenland without at least providing that minerals resulting from such assistance end-up in Europe, or at the very least are not shipped to countries which do not abide by international trade norms. Related to this is the question of whether the EU could actually buy all of the materials Greenland would have to offer. For example, if the two REEs mines (e.g. Kringlerne and Kvanefjeld) in Greenland opened it is possible that they would supply up to 20% of the world's needs according to certain estimates. This exceeds the EU's 10% market demand share.

In 2013 Greenland's parliament voted in favour of lifting the country's long-standing ban on the extraction of radioactive materials, including uranium, opening up the possibility for companies to begin mining uranium and rare earth minerals. The move should among others enable the Kvanefjeld project to proceed.

Overall, the international interest in Greenland's mineral wealth is unlikely to fade, and while timetables may be pushed backwards due to the slowdown in the world economy and the lack of investment funding, Greenland's mining potential will for certain continue to attract the attention of the international mining and exploration community in the future.

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