



SCRREEN
Coordination and Support Action (CSA)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730227.

Start date : 2016-12-01 Duration : 30 Months
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Identification and quantification of primary CRM resources in Europe

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Summary

Identification and quantification of primary CRM resources in Europe

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Deliverable 3.1:

Identification and quantification of primary CRM resources in Europe

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SUMMARY

The SCRREEN project concentrates on the value chains of the critical raw materials (CRM), with the aim of building an expert network that covers all aspects of CRM from the exploration and mining to recycling, re-use and substitution. The CRM list includes the commodities that are considered as critical for the EU industry either due to economic importance, supply risk, or both. For many of the CRM the import dependency is 100 %.

The SCRREEN Work Package 3 (WP3) focused on the identification and quantification of primary and secondary CRM resources available in the EU. This report summarizes the available information on the primary geological resources of CRM in the EU28. In addition, the data from Norway and Greenland is included. The main data sources for the primary resources are found in various databases that are at least to some extent downloadable from the websites of the geological surveys (FODD) or of previous projects (ProMine, Minerals4EU, EURare). The report goes through the commodities by country, listing both current production and known occurrences of the CRM.

A mineral deposit contains one or more commodities which may be exploited depending on the economic considerations. Base metals like copper and nickel, and platinum group metals (PGM) commonly occur together and are produced from the same mine, the base metals as the main products and PGM as by-products.

Industrial minerals are commonly mined from single commodity deposits. However, similarly to the metals, a set of industrial minerals may occur in sufficient amounts in a deposit to warrant multiple mineral production. The phosphorus mineral apatite may occurs as both single-commodity deposits and as a potential by-product in certain Fe-Ti-V deposits.

Many of the CRM are mainly or only extracted as by-product of major metals or minerals. These include bismuth, cobalt, gallium, germanium, hafnium, indium, REE, and scandium, which are produced together with gold, nickel, aluminium, lead, zinc, zirconium, phosphorus, and copper. For these commodities, the bottleneck of production is usually further up the value chain, that is, they typically are extracted from the mine in the ore, but are not recovered at the refineries or smelters due to the lack of economic incentive or simple technology.

Current mine production covers from 3 % to 40 % of the EU supply for those commodities that are produced from the mines. For some commodities the import dependency is 100 %, which is not likely to change in the near future. The need for new exploration activities and opening of new mines in the EU28 is necessary for decreasing the import dependency. The current report gives a strong support for CRM exploration and extraction within the EU, as it shows the large potential for such raw materials to exist in potentially economic concentrations within the European bedrock.

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INTRODUCTION AND BACKGROUND

The SCRREEN project concentrates on the value chains of the critical raw materials (CRM), with the aim of building an expert network that covers all aspects of CRM from the exploration and mining to recycling, re-use and substitution.

The SCRREEN Work Package 3 (WP3) focused on the identification and quantification of primary and secondary CRM resources available in the EU. This report summarizes the available information on the primary geological resources of CRM in the EU28. In addition, the data from Norway and Greenland is included.

The report was compiled by experts from the geological surveys of Finland (GTK), United Kingdom (BGS), Denmark and Greenland (GEUS) and Germany (BGR) using data from databases available in the EU countries and adding more recent data on ore deposits and mineral resources wherever possible.

DEFINITION OF THE CRM

The European Commission launched the Raw Materials Initiative in 2008 and following this, published the first list of CRM in 2010 (EC 2010). The list was updated for the first time in 2014 (EC 2014) and the second time in 2017 (EC 2017). The list of materials that have moved in and out of the CRM list is seen in Table 1. The list includes the commodities that are considered as critical for the EU industry either due to economic importance, supply risk, or both. For many of the CRM the import dependency is 100 %.

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Table 1. CRM for the EU in the lists of 2010, 2014 and 2017.

Commodity	2010	2014	2017
Antimony	x	x	x
Baryte			x
Beryllium	x	x	x
Bismuth			x
Borate		x	x
Chromium		x	
Cobalt	x	x	x
Coking coal		x	x
Fluorspar	x	x	x
Gallium	x	x	x
Germanium	x	x	x
Graphite (natural)	x	x	x
Hafnium			x
Helium			x
Indium	x	x	x
Magnesite		x	
Magnesium	x	x	x
Niobium	x	x	x
Phosphate rock		x	x
Phosphorus			x
Platinum Group Metals	x	x	x
Rubber (natural)			x
Heavy REE	x (grouped with LREE)	x	x
Light REE	x (grouped with HREE)	x	x
Scandium	grouped with REE		x
Silicon metal		x	x
Tantalum	x		x
Tungsten	x	x	x
Vanadium			x

MINING OF THE CRM: MAIN PRODUCT VS. BY-PRODUCT

A mineral deposit contains one or more commodities which may be extracted depending on the economic considerations. Base metals like copper and nickel, and platinum group metals (PGM) commonly occur together and are produced from the same mine, the base metals as the main products and PGM as by-products. The PGM may also occur as economic deposits on their own, as is the case, for example, in South Africa, which is the leading global producer of the PGM.

Industrial minerals are commonly mined from single commodity deposits. However, similarly to the metals, a set of industrial minerals may occur in sufficient amounts in a deposit to warrant multiple mineral production. For example, baryte and fluorite may occur in concentrations and qualities high enough that both are extracted from an individual deposit. The phosphorus mineral apatite may occurs as both single-commodity deposits and as a potential by-product in certain Fe-Ti-V deposits.

Many of the CRM are mainly or only extracted as by-product of major metals or minerals. These include bismuth, cobalt, gallium, germanium, hafnium, indium, REE, and scandium, which are produced together with gold, nickel, aluminium, lead, zinc, zirconium, phosphorus, and copper. For these commodities, the bottleneck

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of production is usually further up the value chain, that is, they typically are extracted from the mine in the ore, but are not recovered at the refineries or smelters due to the lack of economic incentive or simple technology.

Global Supply of EU Critical Minerals and Metals

The pie charts show the percent distribution of the production of critical metals and minerals. In total, it is 100% for each raw material. The area of the pies are proportional. SGU 2017.

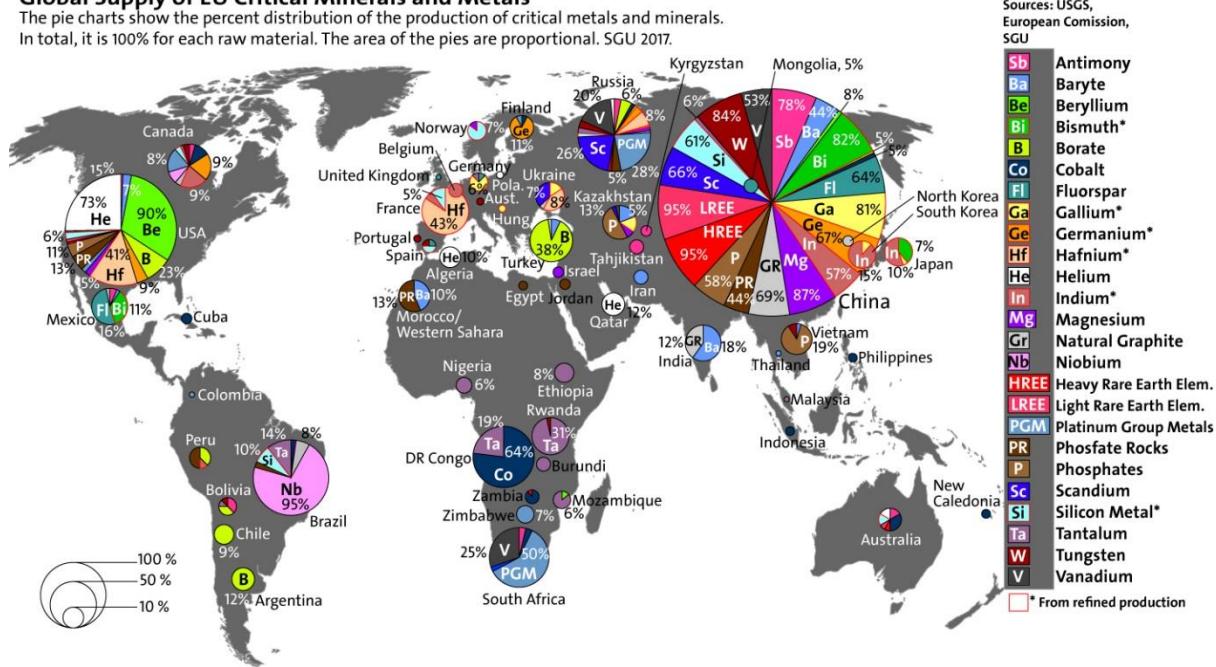


Figure 1 Global supply of EU Critical Minerals and Metals. Source: SGU

BIOTIC MATERIALS

Biotic raw materials are defined as “materials which are derived from renewable biological resources” and “are of organic origin but not of fossil origin” (Chapman et al. 2013). The criticality assessment of 2017 brought biotic materials into the CRM list for the first time, as natural rubber exceeded the criticality threshold (EC 2017). Natural rubber is mainly used in the production of tyres (75 % of total EU consumption), other uses being tubing, footwear, construction materials etc. EU is 100 % reliant on imported natural rubber, as the tree species (*Hevea brasiliensis*) from which rubber is extracted only grows in the tropics. For this reason natural rubber is left out of this report, as it is unlikely that there would be a primary source for it in the EU in the near future.

SCOPE OF THIS STUDY

The main data sources for the primary resources are found in various databases (Table 2) that are at least to some extent downloadable from the websites of the geological surveys (FODD) or of previous projects (ProMine, Minerals4EU). More often than not, these databases are not updated after the end of the project. A major example of the latter is the ProMine database which has never been updated.

This report covers most of the commodities in the CRM list of 2017. However, the following non-biotic commodities were left out: borate, coking coal and hafnium. Borate deposits are known in southern and south-western Europe, but there is no information available in the databases used in this study. The situation is

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similar with hafnium, which is found as a trace element in zirconium minerals. Typically, zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources are not available. Coking coal fell at the borderline between critical and non-critical commodities in the study of 2017 and will probably be dropped out of the list in the next study.

A hierarchical system was used in SCRREEN WP3, in accordance with availability of data:

1. FODD because this is updated continuously and is of high quality (data source: GTK, SGU and NGU mineral resource databases).
2. EURare database because this was subjected to an increased level of quality control compared to Minerals4EU or ProMine. However, EURare database only contains information on REE.
3. Minerals4EU database, as it is more recent than ProMine
4. ProMine database where no other data sources were available. The ProMine data had to be used instead of the Minerals4EU data for some countries, as there is more information in the former.

For all countries that are not included in the FODD:

- a) Data for rare earths was taken from EURare database
- b) For all other CRM, the data sources are shown in the table below

Table 2 Data sources for primary CRM deposit data in EU by country.

Country	Data Source to be used	Comment
Austria	Minerals4EU	no data, known deposits
Belgium	Minerals4EU	no data
Bulgaria	ProMine	
Croatia	ProMine	
Cyprus	ProMine	
Czech Republic	Minerals4EU	no data
Denmark	GEUS	
Estonia	ProMine	
Finland	Fennoscandian Database (FODD)	updated 2017
France	Minerals4EU	
Germany	ProMine	Collected from literature
Greece	Minerals4EU	Other documents and company data to be checked in addition
Greenland	GEUS	
Hungary	Minerals4EU	
Ireland	Minerals4EU	
Italy	ProMine	
Latvia	ProMine	
Lithuania	ProMine	
Luxembourg	ProMine	Limited number of deposits
Malta	ProMine	Limited number of deposits
Netherlands	Minerals4EU	Limited number of deposits
Norway	Fennoscandian Database (FODD)	updated 2017
Poland	ProMine	
Portugal	Minerals4EU	
Romania	Minerals4EU	no data
Slovakia	Minerals4EU	
Slovenia	Minerals4EU	no data
Spain	Minerals4EU	periodically updated from national DB (BDMIN)
Sweden	Fennoscandian Database (FODD)	updated 2017
Switzerland	Minerals4EU	
United Kingdom	Minerals4EU	no data, known deposits

In the geological databases like ProMine, Minerals4EU and FODD the deposits are classified according to their size and the amount of data available. More often than not the amount of data available is very small. Some terms essential to the understanding of this report are briefly described below. The definitions follow the usage by the minerals industry and the resource assessment community (U.S. Bureau of Mines and U.S. Geological Survey 1980, U.S. Geological Survey National Mineral Resource Assessment Team 2000, Committee for Mineral Reserves International Reporting Standards 2013, National Instrument 43-101 2011, Australasian Joint Ore Reserves Committee 2012):

Mineral occurrence

A concentration of any useful mineral found in bedrock in sufficient quantity to suggest further exploration. The usage of the term 'mineral occurrence' is variable, depending on the source of information. A mineral resource is typically not estimated for an occurrence, but a group of occurrences may include both ones with and without a resource estimate.

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Mineral deposit

A mineral occurrence of sufficient size and grade that it might, under the most favourable circumstances, be considered to have economic potential. A mineral deposit has, at least, an *Inferred Resource* estimated.

Mineral resource

A concentration of material of economic interest in or on the Earth's crust in such a form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a mineral resource are known, estimated or interpreted from specific geological evidence, sampling and knowledge. An *Inferred Mineral Resource* is that part of a mineral resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. An *Indicated Mineral Resource* is that part of a mineral resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. A *Measured Mineral Resource* is that part of a mineral resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence.

Mineral reserve

Mineral Reserve is the economically mineable part of a *Measured* or *Indicated Mineral Resource*. It includes diluting materials and allowance for losses which may occur when the material is mined. Appropriate assessments, which may include feasibility studies, have been carried out, and will include consideration of an modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Mineral Reserves are sub-divided in order of increasing confidence into Probable Mineral Reserves and Proved Mineral Reserves.

PRIMARY CRM RESOURCES IN EUROPE

ANTIMONY

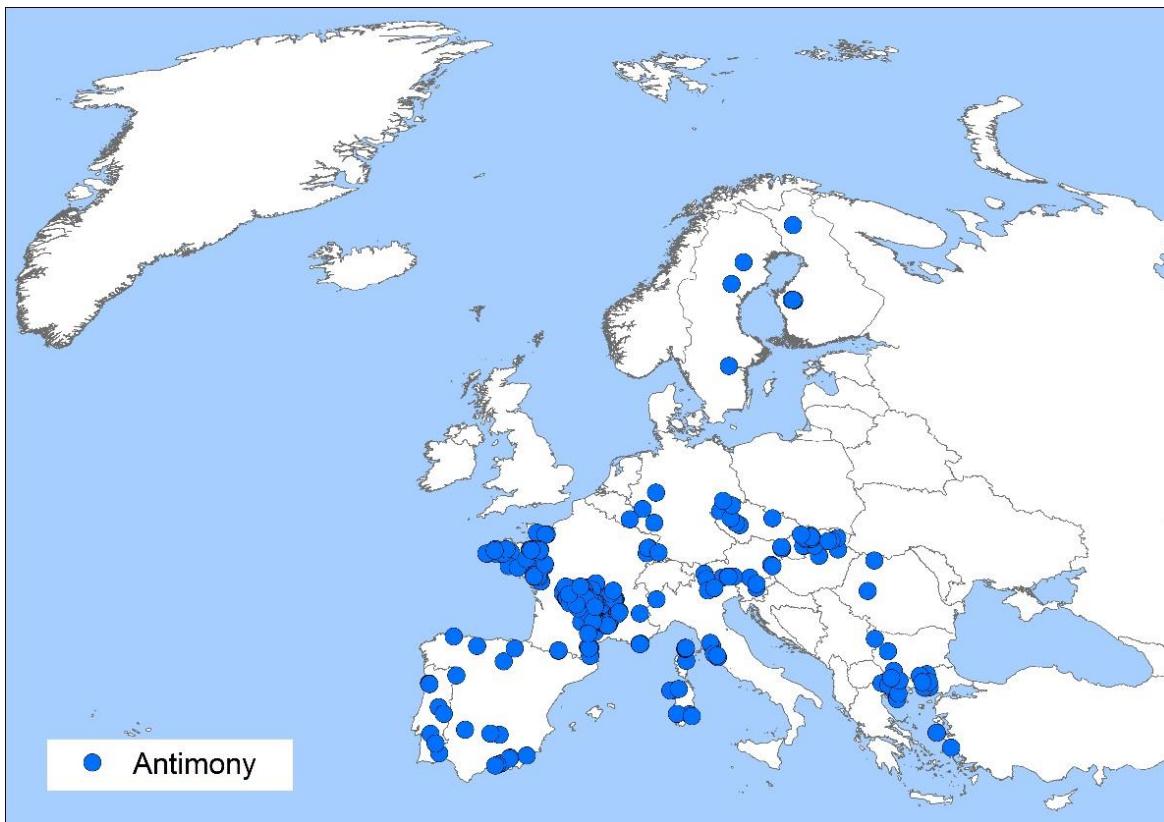


Figure 2 Antimony occurrences in the EU according to the databases (FODD, ProMine, M4EU).

RESOURCES BY COUNTRY

Austria: Austria has several deposits or occurrences where antimony is the main commodity and others where it is mentioned as a possible by-product. It has been produced from, at least, two deposits (Stadtschlaining area and Rabant area), which had several small mines. Production in the Stadtschlaining area finished in the 1990s, whereas in the Rabant area mining took place during the WW1. The Austrian antimony deposits are mostly of polymetallic type with a commodity association Sb+Ag±Cu±Fe±Pb±Hg±As±Zn. The Minerals4EU database mentions a reserve of 8000 t of ore for the Stadtschlaining area.

Bulgaria: Antimony occurrences and deposits of several genetic types are known in Bulgaria. The Chernichevo deposit has records of historical small scale mining in the early 1900s, but no resource information is available. There is current exploration activity for Au-Sb deposits in Bulgaria, with Frontier Exploration (2017) reporting an exploration license with a total endowment of 124,000 t Sb, according to the resource calculations.

Czech Republic: There are several occurrences and deposits in the Czech Republic where antimony is mentioned either as the main commodity or in association with other metals such as Au, Pb and Zn. Small-scale historic production is mentioned, but no resource information is available.

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Finland: There are three mineral occurrences in Finland in which antimony is mentioned as the main commodity and in three others as a companion metal (FODD 2017). Two deposits, Kalliosalo and Törnävä, have a non-compliant resource estimate available, the former containing 2550 t and the latter 4.25 t of antimony. The total amount of 2555 t represents a minimum for Sb resources in Finland.

France: There are tens of small antimony occurrences and deposits recorded in France (Minerals4EU). Most of these are mentioned as having been in production in the 19th and early 20th century. The Minerals4EU database (2017) contains reserve and resource information on several deposits, with at least 5200 t of proved and probable ore reserves and 21500 t of inferred mineral resources (as Sb) remaining in the antimony deposits in France. This may be considered a minimum figure, as many of the deposits do not have any data available. Recent exploration activities for antimony have also taken place in France (Le Boutillier 2014).

Germany: Several polymetallic deposits that contain antimony as the main commodity or as a part of the metal assemblage are known in Germany. Historic small-scale mining operations have also taken place in some deposits, however, no resource information is available in the databases.

Greece: Historical antimony mining has taken place in Greece and there are several small antimony deposits and polymetallic deposits where antimony forms a part of the metal assemblage in the Minerals4EU database. The ProMine database suggest 400 t of Sb resources in Greece.'

Greenland: Two antimony deposits are known from East Greenland (Stensgaard et al. 2016). The deposit at North Margerie Dal has a resource of 108,000 t @ 3.5 % Sb. The Broget Dal copper-antimony occurrence has no resource reported.

Hungary: Two antimony-bearing deposits are known in Hungary, but no resource information is available from either of these.

Italy: Antimony deposits and occurrences are known in Italy and some of these have been in production in the past. The Su Suergiu antimony deposit in Sardinia, a closed mine, has a probable reserve of 400 t of Sb (Minerals4EU 2017). The ProMine database gives about 20,000 t Sb reserves and resources for Italy, of which 400 t Sb at Su Suergiu.

Luxembourg: The Goesdorf antimony mine in Luxembourg was worked intermittently from 14th century until 1938, when the mine was closed. It is currently open as a geotouristic attraction.

Portugal: Antimony was mined in Portugal until 1967, when the Barroca da Mina/Barroca da Santa mine was closed. The Minerals4EU database reports remaining resources of 17,700 t of antimony in the Portuguese deposits, which may be considered as a minimum figure for the country.

Romania: Two antimony-bearing polymetallic deposits are known in Romania, however, there is no resource information available for antimony.

Slovakia: Historical antimony mining has taken place in Slovakia up to 1990s. Deposits are located throughout the country and in the recent years there have been some exploration activities for antimony. For the Pezinok deposit a mineral resource of 39,000 t of Sb is given in the Minerals4EU database.

Slovenia: Two antimony deposits, one of which has been in production in the past, are known in Slovenia, but no resource information is available for either of them.

Spain: According to Gibbons & Moreno (2002) over 60 antimony deposits and occurrences are known in Spain. Mining of antimony took place until the end of 1980s, and there have been recent exploration activities in the Badajos area, where the San Antonio mine is located. No resource information is available for the Spanish deposits in the Minerals4EU database.

Sweden: In Sweden, three deposits contain antimony as a companion metal and two of these have a resource estimate. The Rakkejaur base metal mine, which was in operation in 1934–1988 has a remaining non-compliant resource of 17 Mt of ore at 0.06 % Sb. The Rockliden Cu-Zn deposit has a JORC-compliant resource of 10 Mt of ore at 0.18 % Sb.

BARYTE

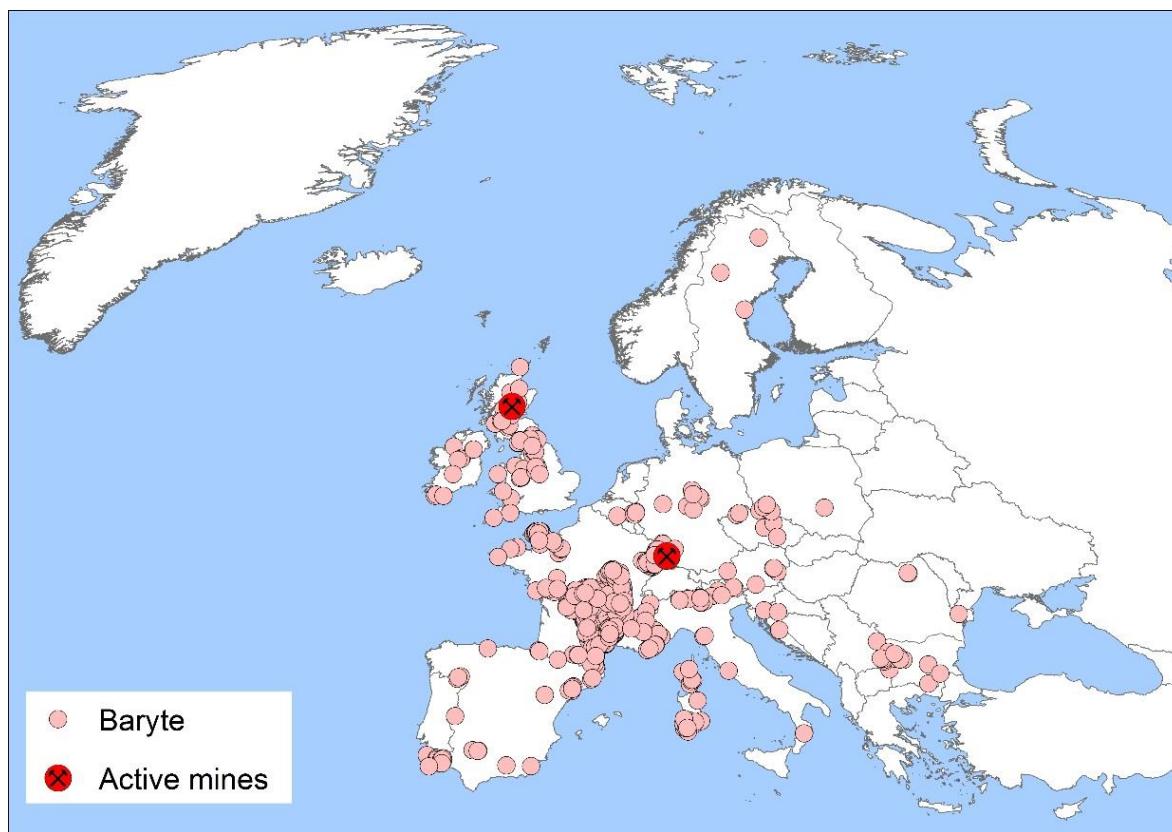


Figure 3 Baryte occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Germany: Two deposits are currently mined for baryte in Germany: Grube Klara in the SW of Germany and Niederschlag in the SE. In 2016, 95,345 t of baryte ore was mined at Grube Klara. From Niederschlag only a small amount of baryte was mined.

United Kingdom: In the UK, currently the only operating mine where baryte is the primary product, is the Foss Mine, near Aberfeldy in Scotland, operated by M-I Swaco, a subsidiary of Schlumberger. This stratabound, sedimentary exhalative deposit was discovered in 1973 and is of late Proterozoic age. The high-grade mineralisation occurs in the Ben Eagach Schist formation, with the mineralised zone extending intermittently

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over a 7 km strike length and up to 110 metres in thickness (BGS 2000). The Foss Mine has been operating since 1985 and personal communication in August 2014 indicated there was approximately 0.9 million tonnes of resource remaining (unknown classification system). Production is expected to cease once the new extraction begins at the nearby Duntanlich deposit.

In addition, there is some production of baryte in the UK as a by-product of fluorspar production in the Southern Pennine ore field near Castleton. These are vein and replacement deposits contained within limestones and sandstones of Carboniferous age. No figures are available to indicate the scale of the baryte resources that remain here and it is geographically variable.

RESOURCES BY COUNTRY

Austria: Several baryte occurrences are listed for Austria, but no production or resource information is available.

Belgium: Baryte occurrences are known in Belgium. The Fleurus deposit has been in production intermittently in the 20th century and has a remaining resource of 0.3 Mt of ore according to the Minerals4EU database.

Bulgaria: Bulgaria has several baryte deposits some of which have been in production mostly in the mid-20th century. Resource information is available for the Divlya baryte deposit, which has an inferred mineral resource of 124,000 t of ore and the Kremikovtsi iron deposit, where baryte is present as a possible by-product in the probable mineral reserve of 68.2 Mt of ore. On the other hand, the ProMine database (Cassard et al. 2013) suggests more the 12 Mt of baryte for Kremikovtsi.

Croatia: Three baryte deposits are listed for Croatia in the ProMine database. The Lokve deposit has been in production in the 20th century (Palinkaš et al. 1993), but there is no production or resource data available for any of the deposits.

Czech Republic: Baryte is commonly found in many mineral deposits in the Czech Republic, the most typical ore mineral association being baryte-fluorspar-pyrite-galena-sphalerite. However, no information on production or resources is available and currently baryte is only of mineralogical interest.

Finland: There are no baryte occurrences mentioned for Finland in the deposit databases. However, baryte has been produced earlier from the Pyhäsalmi Cu-Zn mine. It is also likely that the tailings of that mine contain baryte that may be considered as a secondary resource. The surrounding area may also have potential for baryte exploration.

France: France has been an important baryte producer with numerous small deposits and some larger ones having been in production. The most common mineral associations are baryte±fluorspar±lead±zinc, with baryte being either the main commodity or a possible by-product. Currently the most important deposits are in Chaillac (Les Redoutières, Raillier), which have a proved mineral reserve of 900,000 t of baryte ore and a measured mineral reserve of 200,000 t. There is no information available whether these deposits are currently in production. Many other deposits and occurrences in France also have resource information available in the Minerals4EU database, with a total of 3.5 Mt of inferred resources being available for baryte.

Germany: Baryte in Germany is in many cases associated with fluorspar deposits. Areas with known baryte deposits include Black Forest, Ore Mountains/Vogtland, Harz Mountains, Thüringer Forest, Oberpfalz, Sauerland, eastern part of Hessen and the Rhön area. Baryte occurrences are also known as lens-shaped, sediment hosted ore bodies, which are associated with Pb/Zn and Cu-ores. Meggen (Sauerland), Rammelsberg

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(Harz Mountains), Eisen (Hunsrück), Lohrheim (Taunus) and Günterod (Westerwald) are examples for this deposit type. The ProMine database lists about 20 Mt of baryte resources for Germany.

Ireland: During the collection of data for the Minerals4EU project, an historic resource estimate of 1.65 million tonnes was reported for Ireland with a weighted average grade of 36.14 % (Minerals4EU 2015). Baryte was worked from a number of localities in the past, with the principal deposits being in Counties Cork (e.g. Clonakilty and Ballynoe deposits) and Sligo (e.g. Benbulben deposit) although other occurrences also exist (Hallissy 1923).

Italy: Baryte has been produced in Italy up until the recent years, although most of the mines were closed in the late 19th century. About 5 Mt of baryte in mineral resources is reported for Italian deposits in the ProMine database (Cassard et al. 2013).

Norway: Baryte is mentioned among the ore minerals in four occurrences in Norway (FODD 2017). However, no analytical details of Ba contents are available and it is unlikely that baryte would be exploited from these deposits.

Poland: Five baryte deposits are listed from Poland both at the ProMine database and by the Polish Geological Institute (2016). Some of the deposits have been in production and there have been plans for re-opening some of them according to the Polish Geological Institute. Baryte resources in Poland are estimated to be 5.67 Mt (Polish Geological Institute 2016a).

Portugal: There are several tens of small baryte deposits in Portugal which have been in production in the mid-20th century according to the Minerals4EU database. The only one from which resource information is available is the Serras da Mina Fe-Mn-baryte mine, which has a proved mineral reserve of 112,500 t for baryte.

Romania: At least four baryte deposits are known from Romania and all of these have been in production, but no resource estimates are available for any of the deposits. Baryte is a common mineral in several ore types present in Romanian deposits.

Spain: Baryte has been produced in Spain in the late 1980s from several deposits. The main area for baryte deposits is in the south, in the region of Córdoba, Sevilla, Jaén, Huelva and Badajoz (IGME 1987). The ProMine database lists only 25,000 t of baryte resources for Spain, for the Minas de Barita mine.

Sweden: Three baryte deposits are listed from Sweden in the FODD industrial mineral database (FODD 2017). The largest of these is the giant Aitik copper-gold deposit in northern Sweden that contains an unexploited baryte resource. Two small deposits (Hartung-Pottäng and Strömnäs Västra) are also mentioned but there is no resource information available for any of the deposits.

United Kingdom: Aside from the resources remaining in the Foss mine, the UK's resources include the Duntanlich deposit, also near Aberfeldy in Scotland. This deposit is very similar to that at the Foss mine, being of the same type, age and within the same strike length. It received planning permission in September 2016 and the company, M-I Swaco, expect to begin extraction towards the end of 2018 (M-I Swaco 2017). Duntanlich contains a measured resource of 7 million tonnes, with an additional inferred resource of 13 million tonnes (unknown classification system).

Although a number of small mines were worked in the past for baryte in both the Northern and Southern Pennine ore fields, none of these have resources remaining with the exception of the fluorspar mines near Castleton. Similarly, occurrences of baryte are known to exist in other parts of the UK, including other parts of

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Scotland, northern or western England and in Wales, but none of these are currently considered to contain economic resources (BGS 2000).

In total, the UK's resources are estimated to be in the region of 22 million tonnes but this is not in accordance with any international standard of resource classification systems.

BERYLLIUM

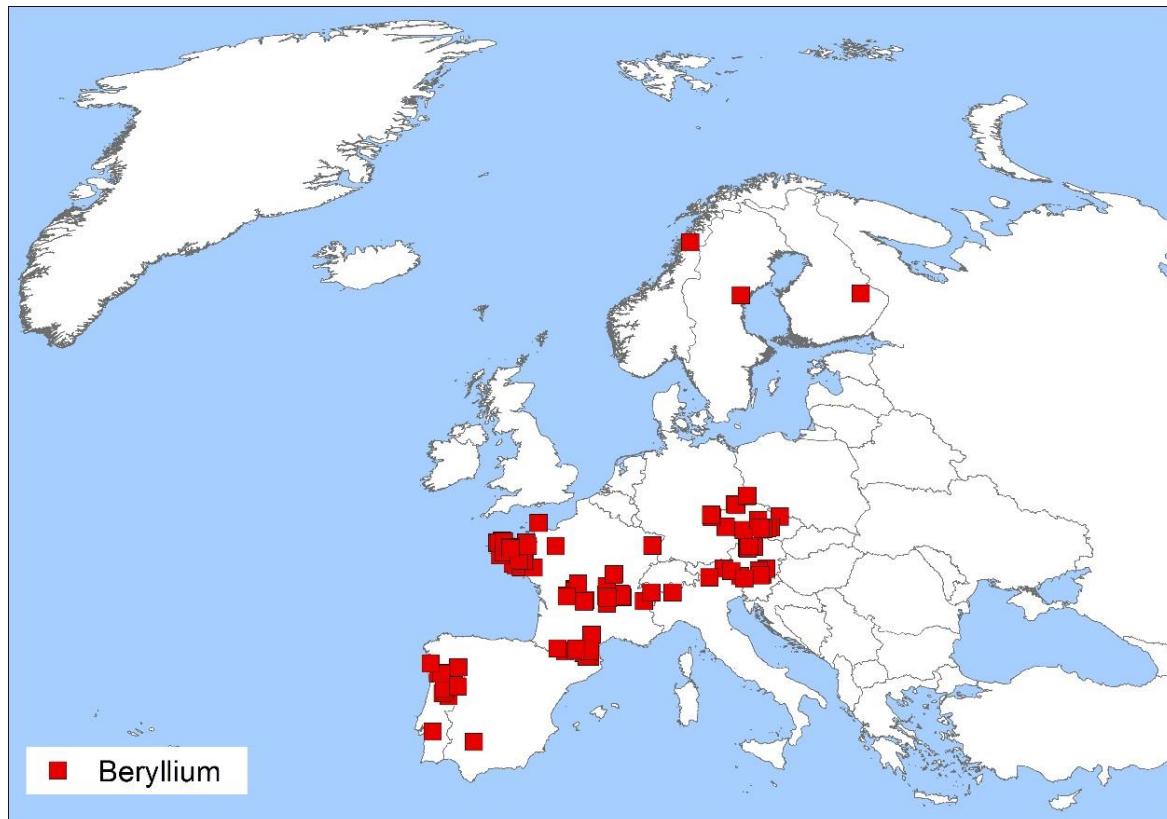


Figure 4 Beryllium occurrences in the EU according to the databases (FODD, ProMine, M4EU).

RESOURCES BY COUNTRY

Austria: Beryl-bearing complex pegmatites are known to be present in various locations in Austria. In addition, one emerald deposit in mafic-ultramafic rocks is also known. Only two deposits (Spittal/Wolfsberg feldspar deposit and Markogel granite quarry) are reported as having been in production in the past, but no data for beryllium is given. It is considered as improbable that these occurrences will now or in the future be of economic significance.

Czech Republic: Rare-metal pegmatites and granites are known from the Czech Republic. These commonly contain beryl as an ore mineral, but only two occurrences (Rasovna Maršíkov and Vetrny Vrch) report beryllium as the main commodity. It is unlikely that these occurrences will now or in the future be of economic significance.

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Finland: Beryllium minerals are known to be present in numerous complex pegmatites in Finland one of which (Kännätsalo) has small-scale production of gem quality beryl (FODD 2017). Be contents are reported from four deposits in Finland. The Li-pegmatites of Ostrobothnia (Rapasaaret, Leviäkangas and Syväjärvi) list beryllium as one of the main commodities with the Be content ranging between 0.005 % and 0.018 %, however, Be is not included in the JORC compliant resource calculations for these deposits (Keliber Oy 2017). The only, non-compliant, resource estimate available is for the Rosendal deposit in SW Finland, which has 206.85 t of beryllium.

France: Tens of granite intrusions and granitic pegmatites with beryllium minerals are known in France (Cassard et al. 2013). Most of these are in Bretagne in NW France, in the Massif Central area, and the Pyrenees, which all contain abundant mineralized granites. Although many of these occurrences have had some historical mining activities, e.g., at La Vedrenne in the 1950s, there are no production records available. The ProMine database mention 6,664 t of BeO (2,400 t Be) for the Treguennec deposit.

Germany: Beryllium minerals are present in many granites and granitic pegmatites especially in the Erzgebirge area at the Germany-Czech Republic border, where the granite ore province extends to both countries. These deposits have been exploited for tin, silver, uranium, fluorite and tungsten, but there are no records for beryllium mining.

Greenland: Four beryllium deposits are known from Greenland (Stensgaard et al. 2016). These are hosted by pegmatites and one by a felsic intrusive. No resource estimates have been published on these.

Italy: One occurrence in which beryllium is mentioned as the main commodity (Rio Masul) and several others where beryl and bertrandite are among the minerals listed are known in Italy. These occurrences are mainly associated with granitic pegmatites and only have mineralogical interest.

Norway: The only beryllium deposit known in Norway is found in Høgtuva, where several small deposits occur in an area of 8 km² (FODD 2017). The largest is the Bordvedåga deposit, which can be followed in outcrop in an area of 400 m x 20 m. With a cut-off grade of 0.1 % Be and the thickness of 1.5 m of the mineralized zone, a resource of 350,000 t with 0.18 % Be is identified (equals to 630 t Be). The main beryllium mineral is phenakite, whereas høgtuvaite, genthelvite and gadolinite are subordinate beryllium phases.

Portugal: Portugal has had small-scale beryllium production in the mid-1900s from several deposits. These deposits are in complex granitic pegmatites that contain beryl in addition to Sn, Nb, Ta, and W minerals. The main pegmatite district in Portugal is Viseu, where also uranium mining took place from the pegmatites. It is unlikely that beryllium production would start again from the Portuguese deposits. The ProMine database list 159 t of BeO (57 t Be) for the Portuguese deposits.

Spain: Four beryllium-bearing occurrences are listed in Spain. Three of these are granitic pegmatites that contain beryl as an ore mineral. One occurrence (Galiñeiro) is associated with peralkaline gneisses and is currently of interest in terms of REE exploration. It is unlikely that any of Spanish occurrences would be economic for beryllium production.

Sweden: The FODD database reports one beryllium deposit and closed mine, Selvitberget, from Sweden, but there is no resource estimate available (FODD 2017).

BISMUTH



Figure 5 Bismuth occurrences in the EU according to the databases (FODD, ProMine, M4EU).

RESOURCES BY COUNTRY

Austria: Bismuth is present in a number of ore deposits in Austria, but there is no resource information available for it.

Bulgaria: Several ore deposits with gold, lead-zinc, copper, tungsten and iron as the main commodities have bismuth as a minor metal in the assemblage. There is no data on the bismuth content of the deposits.

Finland: Bismuth is reported as a minor commodity in the Petrovaara Cu-Au occurrence, which has a non-compliant resource estimate of 0.15 Mt of ore @ 1.31 % Cu (FODD 2017). In addition to Cu, there is 0.1-4 ppm Au, up to 2.8 % Pb and up to 88 ppm Bi (Västi 2003). As bismuth is not routinely analyzed, there are other Cu, Cu-Au and Au occurrences that contain potentially recoverable bismuth, at grades in several tens of ppm Bi (Eilu & Pankka 2010), but Bi is not included into the mineral resources estimated.

France: Four deposits have bismuth as the main commodity in France and one of these (La Grande, Meymac) was mined in the late 1880s. Bismuth is a minor commodity in many other deposits but there is no resource information available for bismuth.

Germany: Bismuth has been found in the Erzgebirge Mountains in Germany already in the 14th century. It is a minor metal in many deposits, but no information about production or resources is available.

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Greece: Bismuth is present as a minor metal in almost all gold deposits in Greece (Voudouris et al. 2013). No information on resources nor production is available for bismuth.

Norway: The FODD database (2017) lists nine small to medium-sized deposits where bismuth is mentioned among the ore minerals. However, no information about bismuth content is available.

Romania: Bismuth is mentioned in the metal parageneses of several Cu, Pb-Zn and Au deposits in Romania, but no resource information is available.

Spain: Bismuth has been produced in Spain in the first half of 20th century from deposits in the Córdoba province (Marina 1987). Several bismuth deposits are included in the Minerals4EU database but no resource information is available.

Sweden: In Sweden, bismuth is reported as a by-product in the small historic Ädelfors gruvor Au deposit, which was in production in 1890–1916 (FODD 2017). The bismuth content of the ore is unknown. Similarly to Finland, bismuth is not routinely analyzed and there may be other Cu, Cu-Au and Au occurrences that contain it.

United Kingdom: Although there are records indicating minor past bismuth production from localities in south-west or north-west England and further known occurrences in Scotland, none of these are considered to be economic resources.

COBALT

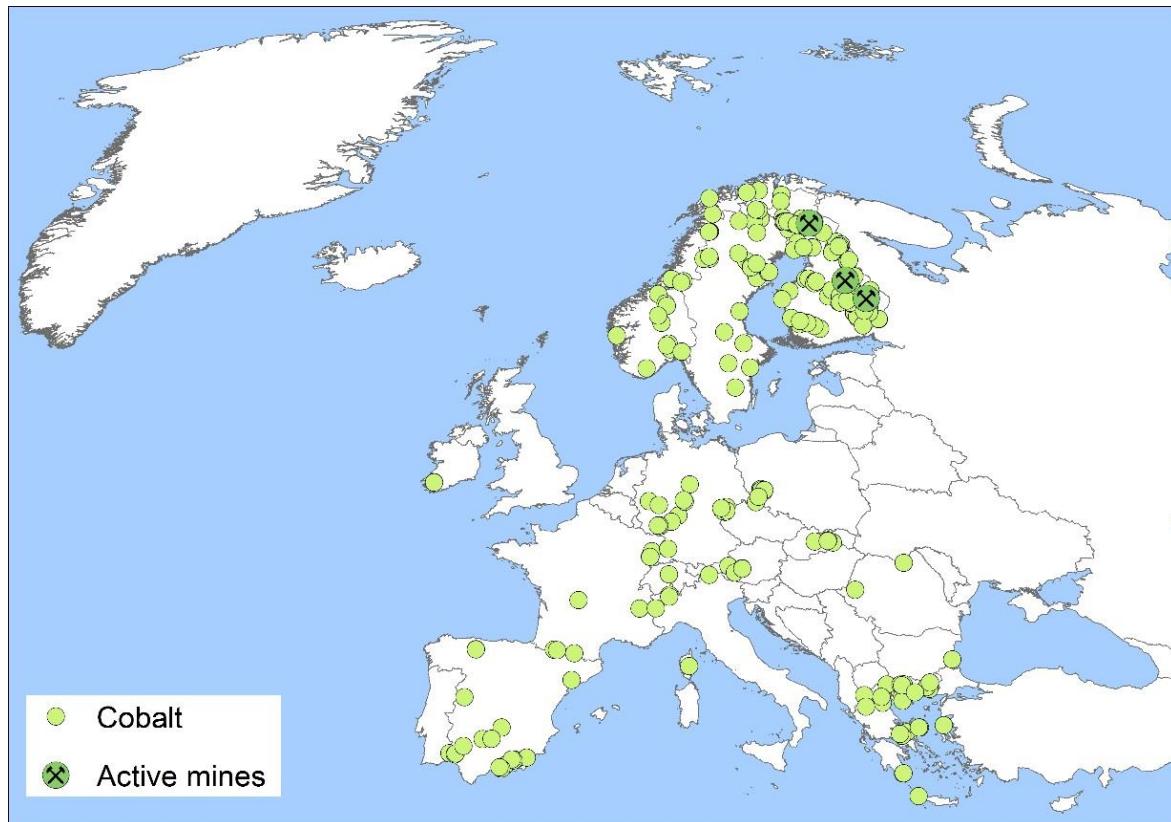


Figure 6 Cobalt occurrences in the EU according to the databases (FODD, ProMine, M4EU).

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PRODUCTION IN EUROPE

Finland: Cobalt is produced as a by-product currently in the Kylylahti Cu-Zn, Kevitsa Ni-Cu, and Talvivaara Ni-Zn mines. The current annual mine production of Co is about 2,500 t (Tukes 2017 and other undisclosed information). In addition, Finland is a globally significant refined cobalt producer (10 % of world refinery production in 2015; USGS), but most of the raw material is imported.

Greece: The lateritic nickel ores of exploited by Larco (Apostolikas & Kountourellis 2014) contain cobalt, which is extracted from the nickel ore and used in the ferronickel production. No Co production has been reported from these ores.

Poland: Cobalt occurs as a minor constituent of the Kupferschiefer stratiform copper ore mined in Poland but is not currently recovered during the processing stages (Pazik et al. 2016).

RESOURCES BY COUNTRY

Austria: Cobalt is listed as a minor metal in four Austrian metal deposits. No resource information is available, although some of the deposits are mentioned as having been in production.

Bulgaria: Cobalt is present as a minor commodity in two Bulgarian copper deposits (Rosen and Meden Rid) that have been in production in the second half of 20th century. No production or resource information is available for cobalt.

Cyprus: There are a few explored Cu-Ni occurrences in the Troodos Ophiolite Complex mafic-ultramafic rocks which also contain cobalt as a potential byproduct. This is indicated for the Black Pine prospect, for example (www.bmgl.com.au). However, none of these have a resource reported for any metal (SNL data 28 Feb 2018).

Czech Republic: Cobalt is listed as a by-product in the Jáchymov area, where silver, uranium and bismuth have been produced between the 16th and 20th century. No production or resource information is available for cobalt.

Finland: Cobalt is listed as a main commodity in 25 occurrences and as a minor metal in almost a hundred others in Finland (FODD 2017). The resource estimates available for these deposits give a total cobalt metal content of 517 kt, of which 401 kt are calculated according to JORC or NI 43-101 codes and 116 kt as non-compliant resource estimates. These figures are a minimum estimate for cobalt resources in Finland, as many of the deposits either do not have a resource estimate available or do not list any analytical data for cobalt. The Talvivaara polymetallic deposit has a resource of 336,800 t of Co metal. This is, by far, the largest single cobalt resource in Europe. Other important deposits in Finland, in tons of contained cobalt, include the Kevitsa Ni-Cu-PGE, Kylylahti Cu-Zn, Sakatti Ni-Cu-PGE, Hautalampi Ni-Cu-Co and Juomasuo Au-Co deposits.

France: Cobalt is a minor commodity in ten mineral occurrences and ore deposits in France. Cobalt has been produced in the early 20th century from the Kruth mine, but no production data is available. For the other deposits there is no production or resource data available.

Germany: Two cobalt deposits (Bieber and Niederschlag) and fifteen other metal deposits where cobalt is listed as a minor commodity are known in Germany. The Bieber deposit was mined for cobalt ores in the 18th and 19th century (Wagner and Lorenz 2002). Other similar deposits are located in the vicinity of the Bieber deposit. The Niederschlag deposit has cobalt as the main commodity and silver, bismuth, baryte, fluorite and nickel as by-

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products, but no resource or production data is available. Cobalt is a common metal in the Kupferschiefer-type copper deposits and may be considered as a by-product if these are exploited. Currently there is no copper mining in Germany.

Greece: Almost thirty cobalt-bearing ore deposits and mineral occurrences are known in Greece. Cobalt reserves reported for the deposits in Greece comprise almost 50,000 t of Co from, mostly, lateritic Ni deposits. Mineral resources include additional 79,000 t of Co.

Greenland: Two cobalt-bearing deposits are known from Greenland (Stensgaard et al. 2016). At Itilli, there are syn- and epigenetic, low-grade Cu-Au-Co-occurrences. At Moriussaq, there is a heavy-mineral sand deposit containing magnetite, ilmenite, and zircon. The magnetite at Moriussaq contains, on average 0.1 % Co. No resource estimates have been published on these deposits where Co is a potential by-product. In addition, there are mafic-ultramafic intrusion hosted nickel deposits and occurrences which most probably have a by-product cobalt potential.

Ireland: There are no known cobalt resources for Ireland. Although waste from a former mine in Killarney, County Kerry, Ireland is known to contain cobalt (Moreton et al. 1998), it is not considered to be an economic resource.

Italy: Cobalt is present as a minor metal in several nickel and zinc deposits in Italy but no production or resource data is reported for any of these.

Norway: The FODD database (FODD 2017) has 23 occurrences in Norway, where cobalt is listed either as one of the main commodities or a minor metal. Most of these small to medium-sized occurrences have been historical mining sites in the 19th and early 20th century. The most important deposit is the Løkken VMS deposit that was in production continuously for 333 years from 17th to 20th century. The Norwegian occurrences contain a total of 72.3 Mt of ore, with Co grade varying between 0.01 % and 0.2 %. Of these, only the Stormyra Ni-Cu-PGE deposit has a NI 43-101 compliant resource estimate of 1.013 Mt of ore with Co grade of 0.04 %.

Poland: Cobalt is present in the Kupferschiefer-type copper deposits in Poland, but it is currently not recovered as a by-product, although this is being investigated (Pazik et al. 2016). Cobalt has also been mined in Poland in the 18th and 19th century from the deposits in Lower Silesia near the German border. There is also some recent exploration activity in the area. Ore reserves listed for Poland include 75,000 t of Co mostly in measured class, and additional 7300 t of mineral resources that are poorly documented.

Romania: Two copper deposits from Romania list cobalt as a minor commodity but no resource information is available.

Slovakia: Slovakia has several polymetallic mineral occurrences and ore deposits that contain cobalt. Some of these have been in production since 14th century. There is current exploration activity for cobalt associated with the Dobsina and Kolba deposits, but no resource estimate has been published (European Cobalt 2017).

Spain: Eight mineral occurrences and ore deposits where cobalt is the main commodity are listed from Spain and cobalt is present in several other gold and silver deposits as a minor commodity. Mina La Providencia has a measured resource of 350 t of cobalt at the grade of 0.7 % Co. The Aguablanca Ni-Cu-PGE mine includes cobalt as a by-product (Lundin Mining 2013). Cobalt content in the Aguablanca deposit varies from 0.01 to 0.09 % (Ortega et al. 2004). The reserves at Aguablanca, where operations currently are on hold, are 3.45 Mt of ore, but the Co grade is not reported (Valoriza Mineria 2017). For other deposits in Spain there is no resource data available.

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Sweden: Sweden has 24 occurrences where Co is listed as a main commodity or a minor metal (FODD 2017). Two of these, the medium-sized Kevus Fe-Co deposit and the potentially large Rönnbäcken Ni-Co deposit have either a JORC or NI 43-101 compliant resource estimate, with a total amount of 367.1 Mt of Co-bearing ore. In addition, the other known deposits include at least 57 Mt of ore with Co grade varying between 0.01 % and 0.56 %. In total, the Swedish deposits contain about 20,000 t of Co resources (FODD 2017).

FLUORSPAR

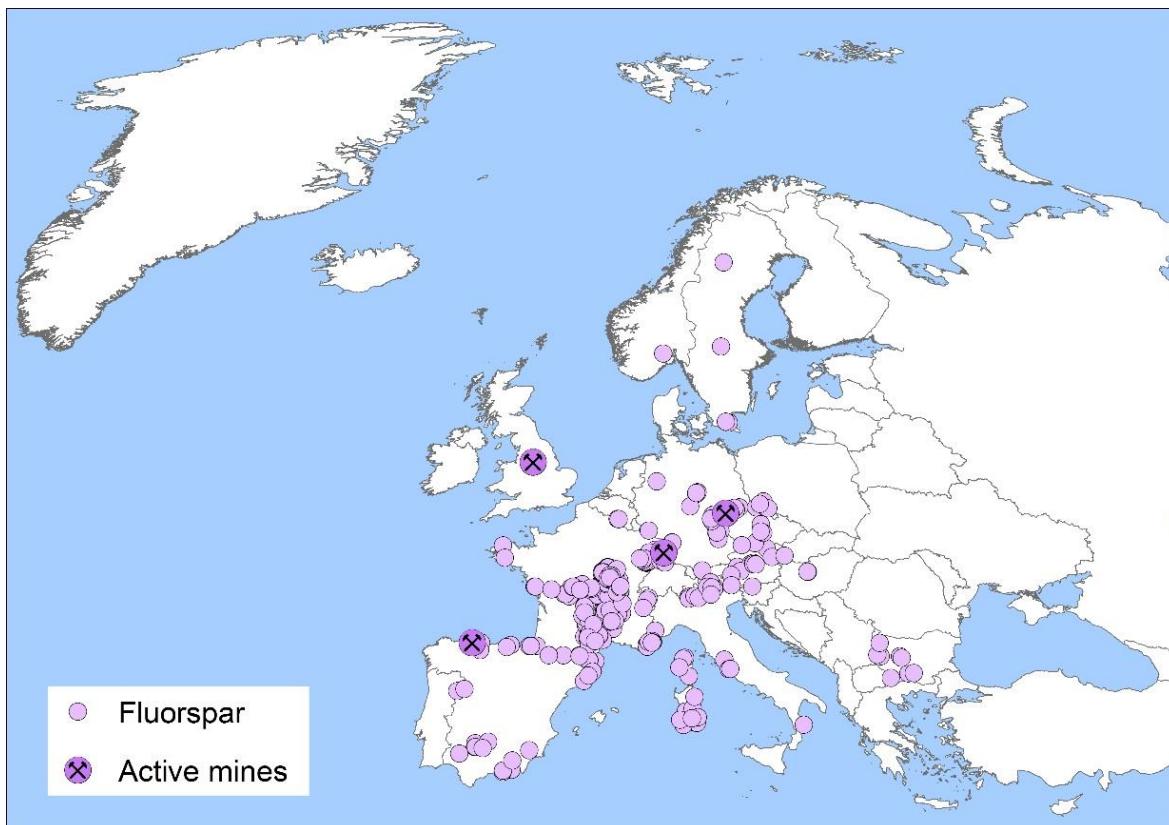


Figure 7 Fluorspar occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Germany: Two deposits are currently mined for fluorspar in Germany: Mine Klara in the SW of Germany and Niederschlag in the SE. A total of 148,974 t of fluorspar were mined from these deposits in 2016. In addition, Saxony Minerals and Exploration AG is working at the Pöhla deposit in Saxony, Germany with the aim of starting tungsten, tin, indium and fluorite production (SMEAG 2017). According to the company, pilot-scale production started in late 2017.

Spain: Spain has ongoing fluorspar production since 1942 from the mines in Asturias owned by MPD Fluorspar, which is part of the MINERSA Group. Spanish production currently covers 13 % of the EU supply of fluorspar (EC 2017). According to USGS (2018), fluorspar production in Spain was 130,000 t in both 2016 and 2017.

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United Kingdom: Fluorspar has been mined in the UK since 1874, with a cumulative production of just under 9 million tonnes. Peak output was achieved in 1975 when production reached 235,000 tonnes but since then annual production has declined steadily. Closure of the last remaining mines at the end of 2010 seemed to be the end of UK production but the operation was reopened under new owners, British Fluorspar, in 2013 and produced in the order of 17,000 tonnes in 2015. The current operation consists of one open-pit mine at Tearsall and the Milldam underground mine. Very minor production for mineral specimens and jewellery also occurs at the Blue John Mine near Castleton.

RESOURCES BY COUNTRY

Austria: Austria has several fluorspar deposits and past mining activities in the 1900s. Currently the deposits and occurrences only have mineralogical interest.

Bulgaria: Bulgaria has several fluorspar deposits, which have been in production in the 20th century and, in the case of the Chiprovtsi Pb-Ag-fluorspar deposit, up to 2016. The common ore mineral association in the Bulgarian deposits is fluorite+baryte and the deposits are mainly found in carbonate rocks. Some volcanic hydrothermal and granite-associated deposits are also known in Bulgaria. No resource information is available on the deposits, although some of them are mentioned as having been exhausted (Cassard et al. 2013).

Czech Republic: There are several fluorspar deposits in the Czech Republic and some of them have been in production until 1990s. Geological reserves are still known to exist but they are currently considered as uneconomic (Starý 2016).

France: There are numerous fluorspar occurrences in France, many of which have been in production in the 1900s. Important districts include Haute-Loire, Pyrenees-Orientales, Var, Tarn, Saone-et-Loire and Puy-de-Dôme (Kogel 2006). The most common association is stratabound fluorspar+baryte ore, but fluorspar has been found also in association with e.g., Pb-Zn, U, W and breccia deposits. According to the ProMine database (Cassard et al. 2013), the fluorite resources in France are about 7.3 Mt.

Germany: Several fluorspar deposits and occurrences are known in Germany. Fluorspar occurs mainly in mineralized veins. German fluorspar deposits also often contain baryte veins.

Areas with known occurrences of fluorspar and baryte are located in the Black Forest (areas of Neuenbürg/Pforzheim, Freudenstadt/Hallwangen, Kinzig valley between Haslach and Schiltach, Wieden/Todtnau). In Saxonia (SE Germany) fluorspar and baryte deposits are known from the former mines Schönbrunn and Bösenbrunn. Smaller deposits are e.g. Brunndöbra, the area of Zschopau/Augustusburg, Weißenborn and Berthelsdorf/Schlottwitz.

Fluorspar is also present in the Sn-W-deposits of Pöhla/Hämmerlein/Tellerhäuser in the polymetallic deposit of Zinnwald. Further deposits are located in the Harz Mountains (Brachmannsberg and around Schwenda). According to the ProMine database (Cassard et al. 2013), the fluorite resources in Germany are about 0.92 Mt.

Greenland: Fluorine is widespread and common constituent of the alkaline Gardar intrusions. Fluorine-bearing minerals are found within the intrusive bodies as well as in the metasomatized country rocks. The largest concentration of fluorine is found in the Illimaussaq intrusion. The fluorine-bearing mineral viliamite (NaF) is widespread as interstitial crystals and may form up to 20% of the rock by volume. The mineral is water-soluble and is only preserved at depths >50 m. The content of viliamite generally varies between 0 % and 4 % (Kalvig 1994). The license holder, GME, are aiming at an annual production of 16,000 t of fluorspar as a by-product to

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the REE production. The Ivittuut cryolite deposit in southern West Greenland also contains a fluorite resource. Resource estimates on the fluorite zone report an in situ tonnage of about 0.5 Mt @ 50 % fluorite (Stensgaard et al. 2016). In addition, to the above, there are extensive tracts of vein-hosted fluorite and MVT-type base metal mineralisation related fluorite potential in northern Greenland.

Hungary: Three fluorspar deposits are known from Hungary and two of these have been in production in the mid-1900s. Currently there are no economic fluorspar deposits in Hungary.

Ireland: There are no known economic resources of fluorspar in Ireland. It does, however, occur in a few locations as a minor component of multi-mineral assemblages.

Italy: Fluorspar has been produced in Italy in the 1900s and early 2000s, but currently there is no production. Both mainland Italy and the island of Sardinia have vein-type fluorspar deposits that have been in production, the latter in care and maintenance since 2006 (Mondillo et al. 2017). The volcanic ash-related deposits in the Castel Giuliano area have a calculated resource with CaF₂ contents ranging from 20 % to 55 %, but the fluorspar is too fine-grained to be recovered economically. Currently there is mainly mineralogical interest for fluorspar in Italy. According to the ProMine database (Cassard et al. 2013), the fluorite resources in Italy are, at least, 35 Mt.

Norway: Small fluorspar deposits and occurrences are known in Norway and some of these have been in production in historic times. The most important deposit is Lassesdal, which contains a JORC-compliant inferred resource of 4 Mt of ore with 24.60 % fluorspar (Tertiary Minerals plc 2012).

Poland: There are several deposits in Poland which have both fluorspar and baryte as potential commodities (Polish Geological Institute 2016a). The estimated fluorspar resources in Poland are 0.54 Mt (Cassard et al. 2013).

Spain: Spain has been a fluorspar producer since the 19th century and has several tens of known fluorite deposits. These include carbonate-hosted stratabound and vein baryte-fluorite deposits, brittle-fault related vein and breccia deposits and granite-related vein deposits. The most important area is in the Asturias in northern Spain, but fluorspar deposits are also known in other areas. According to the ProMine database (Cassard et al. 2013), the fluorite resources in Spain are about 3.8 Mt.

Sweden: Four fluorspar deposits are reported from Sweden in the FODD industrial minerals database (FODD 2017). The largest of these is the Storuman deposit, which contains a JORC-compliant mineral resource of 27.7 Mt of ore at fluorspar content of 10.21 % (Tertiary Minerals plc 2011). The total resource includes 25.0 Mt of Indicated resources and 2.7 Mt of Inferred resources. The other three deposits are small historic closed mines from which there are no resource estimates available.

United Kingdom: In the UK, fluorspar mineralisation, with associated baryte and lead, occurs mainly in two areas. In the Southern Pennine Orefield, the mineralisation primarily occurs in steeply dipping fissure veins within Carboniferous-aged limestones beneath a mudstone cover. Stratabound replacement deposits and some cave fill deposits also occur. In the Northern Pennine Orefield most of the fluorspar deposits occur in near-vertical veins within alternating Carboniferous-aged limestones, sandstones and shales or occasionally within basic intrusive rocks associated with the Whin Sill. Many of these veins have been exhausted, following the long history of extraction in the UK and the remaining production only occurs from the Southern Pennine Orefield. During the Minerals4EU project, an historical estimate for resources of 25 million tonnes was included. However, this estimate dates from 1970 and much of this resource has subsequently been worked.

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More recent (2009) estimates suggest that resources are approximately 4.5 million tonnes, but the classification system used for this figure is unknown (Bide et al. 2011).

GALLIUM

PRODUCTION IN EUROPE

Gallium metal production is reported in Germany (EC 2017), however, all of it is from imported bauxite ore. Primary Ga sources in EU are currently not in use for production.

RESOURCES BY COUNTRY

Austria: Samples from MVT deposits (e.g., Bleiberg) in the Alps display gallium contents ranging up to 200 ppm in sphalerite (Marsh et al. 2016).

Bulgaria: The Madan ore field in Bulgaria has Pb-Zn deposits in which Ga is marked as a minor metal, however, no data is available for resources.

France: Gallium is listed as a minor metal in sixteen ore deposits in France. The main commodity in most deposits is zinc, and gallium is most probably present in sphalerite in minor amounts. No resource data is available for gallium.

Greenland: Titanomagnetite in the Au-Pd mineralised zone of the layered Skaergaard Intrusion, eastern Greenland, is enriched in Ga with concentrations of 81 to 117 ppm. The entire mineralised zone has a size of 1520 Mt (non-compliant to international reporting standard), and the titanomagnetite grade is 18 %; this means that the deposit contains 21,300 t Ga. Gallium is also a potential by-product of zinc production from Mississippi Valley Type (MVT) zinc-lead deposits for which there is an indicated potential in north and NW Greenland. Unpublished GEUS data shows that Ga concentrations in mineralised samples from North Greenland are irregular, with a maximum value of 66 ppm (Stensgaard et al. 2016).

Hungary: Gallium is listed as a minor commodity in the Tapolca and Ajka aluminium deposits, from the latter of which it has been produced. No resource information is available, but the Ajka deposit is listed as medium to high-grade in the Minerals4EU database, indicating >50 ppm Ga contents.

Poland: Polish Geological Institute (2017) reports an estimated resource of 130 t of Ga in the Zawiercie 3 deposit, which is covered by detailed exploration according to the Polish classification.

GERMANIUM

PRODUCTION IN EUROPE

Similarly to gallium, all germanium production in the EU (EC 2017) is from imported ore. In Finland, germanium has been recovered from imported cobalt ore at significant amounts to least up to 2015 when 13 t of Ge was produced from imported raw materials. Since 2016, Ge production in Finland has been minimal (100 kg in 2016; <http://en GTK fi/informationservices/mineralproduction/>)

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RESOURCES BY COUNTRY

Austria: One ton of Ge is reported for one deposit in Austria, the carbonate rock-hosted Pirkachgraben (or Pirkach–Hochstadel) lead-zinc deposit (Cassard et al. 2013). Samples from MVT deposits (e.g., Bleiberg) in the Alps display germanium contents up to 4900 ppm in sphalerite (Marsh et al. 2016)

Bulgaria: Two deposits (Chelopech and Radka) in Bulgaria have Ge listed as a minor metal, however, no data is available for resources. Both deposits have been in production for the second half of 20th century and Chelopech is currently operated by Dundee Precious Metals Inc., although they do not report any germanium extraction.

Czech Republic: Germanium is present as a minor metal in granite-related uranium and vein-type base metal deposits and coal deposits in the Czech Republic. No resource nor production information is available.

France: In total, 329 t of Ge is reported in resources in French mineral deposits (Cassard et al. 2013. Most of this, 300 t, is at Saint-Salvy which is a mesothermal, Ag-rich, sphalerite deposit.

Germany: Germanium is listed as a minor metal in six deposit in Germany that vary from base metal and coal deposits to iron and precious metal deposits. No resource nor production information is available for germanium.

Greenland: Ge is a potential by-product of zinc production from Mississippi Valley Type (MVT)

Zn-Pb deposits in N and NW Greenland. Samples from MVT-type mineralised showings in Peary Land and Kronprins Christian Land have Ge contents of up several tens of ppm (Stengaard et al. 2016).

Ireland: There are no known germanium resources for Ireland. Germanium may occur as an accessory mineral in some of the known zinc deposits in Ireland, but it is not considered an economic resource.

Italy: Germanium is listed as a minor metal in ten ore deposits and occurrences that vary from baryte and coal to base metal and iron deposits, Mississippi Valley-type and coal deposits being the most common. No resource nor production information is available for Italian deposits.

Poland: Polish Geological Institute (2017) reports an estimated resource of 30 t of Ge in the Zawiercie 3 deposit, which is covered by detailed exploration according to the Polish classification.

Portugal: The Iberian Pyrite Belt, that has deposits such as Neves Corvo and Barrigão, is potential for germanium, which is present in the latter with average whole-rock contents of 61 ppm (Reiser et al. 2010). Currently germanium is not recovered from these deposits.

Romania: Germanium is listed as a minor metal in one coal deposit (Lupeni) and two gold deposits (Corabia, Rosia Montana) in Romania, but no resource information is available.

Slovenia: The MVT-type base metal deposits of Topla and Mezica in Slovenia list germanium as a minor metal and in the latter it has been investigated as a possible by-product (Obal et al. 1992). No production nor resource data is available.

HELIUM

PRODUCTION IN EUROPE AND RESOURCES BY COUNTRY

Poland: Helium is found in natural gas fields in Poland, with contents varying from 0.02 % to 0.45 %. Polish Geological Institute (2016b) lists 16 helium-bearing deposits that are situated in the Zielona Góra-Rawicz-Odolanów area. In 2016, production of helium was 3 million cubic meters.

INDIUM

PRODUCTION IN EUROPE

We refer below on Werner et al. (2017) for some countries. However, it is not clear whether or not the indium endowment reported by Werner et al. (2017), is included into a resource estimate according to any current industrial standard. One should, hence, be cautious with these In tonnages.

Germany: Saxony Minerals and Exploration AG is working at the Pöhla deposit in Saxony, Germany with the aim of starting tungsten, tin, indium and fluorite production (SMEAG 2017). According to the company, pilot-scale production has started in late 2017.

Portugal: The large Neves-Corvo VMS-type Cu-Zn-Sn deposit contains the largest known In resource in Europe, 3480 t In (Werner et al. 2017). The Neves-Corvo mine produces Zn and Sn concentrates that, probably, also contain significant amounts of indium. However, as In is not recovered in all zinc and tin refineries, it is not clear how much In is produced from the Portuguese ores.

RESOURCES BY COUNTRY

Austria: Six tons of indium is reported for one deposit in Austria, the carbonate rock-hosted Pirkachgraben (or Pirkach–Hochstadel) lead-zinc deposit (Cassard et al. 2013).

Bulgaria: Werner et al. (2017) report 10 t of indium for the Elastite porphyry copper deposit.

Czech Republic: The Cinovec (Zinnwald) greisen-type deposit, a closed mine, is estimated to contain 50 t of indium (Cassard et al. 2013). The main commodities at Cinovec are Li, Rb, Sn, and W. In addition, Werner et al. (2017) report 87 t of indium for the Tisova VMS-type copper deposit.

Germany: The remaining resources at the Rammelsberg Pb-Zn±Cu mine (SEDEX-type) are estimated to contain about 680 t In (Cassard et al. 2013, Werner et al. 2017). The Rammelsberg deposit contained up to 300 ppm indium in Cu-rich material from within a feeder zone beneath the stratiform deposit (Marsh et al. 2016). In addition, Werner et al. (2017) report 40 t of In in the Freiberg tailings and slag.

Greece: Werner et al. (2017) report 11 t of In in high-sulphidation epithermal-type deposit of the the Kirki mine (Agios Philippou Mine). At Kirki, the Zn-Pb ores contain up to 1,000 ppm In in sphalerite and wurtzite (Goldfarb et al. 2016).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730227

Hungary: The Nagyborzsony intermediate-sulphidation epithermal deposit in northern Hungary is associated with Miocene dacites and andesites of the Borzsony volcanic complex. High-temperature polymetallic stockworks include sphalerite at Nagyborzsony with 0.01 to 0.08 wt % In (Goldfarb et al. 2016).

Ireland: Werner et al. (2017) report 58 t of In from the Lisheen Zn-Pb deposit.

Portugal: Besides Neves-Corvo (3480 t In), there is 12 t In reported for the Lagoa Salgada VMS deposit (Werner et al. 2017).

MAGNESIUM

RESOURCES BY COUNTRY

No magnesium metal is produced in the EU. Magnesium metal is mainly produced from the mineral magnesite. Hence, the figures quoted in this section relate to magnesite (with the exception for the Netherlands). One must keep in mind, however, that most of the magnesite production goes into other purposes than Mg metal production: e.g., refractory sand, metallurgical flux, filler, fertiliser, building materials, and in production of various Mg chemicals.

Austria: In 2015, Austria produced 702,504 t magnesite (Brown et al. 2017). According to the ProMine database (Cassard et al. 2013), there are 1.8 Mt of MgO resources in Austria, in magnesite deposits, in the active Radenthein mine and in the closed Augrabben mine. The USGS (2018) lists 50 Mt of magnesite reserves for Austria.

Bulgaria: The closed Gornoslav mine contains 50,600 t of MgO (Cassard et al. 2013). Brown et al. (2017) suggest that some magnesite was produced in Bulgaria in 2015, but no figures are available.

Finland: In 2016, 54,227 t magnesite was recovered as a by-product from talc mines (<http://en GTK fi/informationservices/mineralproduction/finmipr1116.html>).

France: The closed Urepel and Montner mines contain 0.9 Mt of MgO (Cassard et al. 2013).

Greece: In 2015, Greece produced 383,312 t magnesite (Brown et al. 2017). More than 10 deposits (including one active nickel mine?) in Greece have reported magnesium resources (Cassard et al. 2013). In total, these contain, at least, 18 Mt of MgO. On the other hand, the USGS (2018) gives 270 Mt of magnesite reserves for Greece. The deposits mainly include laterites after ultramafic rocks and unweathered, partly carbonatised, ultramafic intrusions.

Ireland: During the Minerals4EU project, a historic resource estimate of 2 million tonnes of magnesite was reported for Ireland which is believed to relate to the Westport talc-magnesite deposit in County Mayo. It is not known whether this is suitable for the production of magnesium metal. Dolomite does also exist but is not considered a resource for magnesium production.

Italy: The closed Baldissero mine has a MgO resource of 0.3 Mt (Cassard et al. 2013).

Netherlands: In 2015, 257,510 t of magnesium chloride was produced by solution mining (Brown et al. 2017).

Poland: in 2016, 77,920 t of magnesite was produced, for the Braszowice mine (geoportal.pgi.gov.pl). Six deposits in Poland have a combined MgO resource of about 17.8 Mt.

Slovakia: In 2015, Slovakia produced 501,200 t magnesite (Brown et al. 2017). The large Jelsava deposit (an active mine) has a MgO resource of 200 Mt (Cassard et al. 2013). USGS (2018) lists 120 Mt of magnesite reserves in Slovakia.

Spain: Magnesite production in 2015 was about 800,000 t (Brown et al. 2017). Mineral reserves are estimated at about 35 Mt magnesite (USGS 2018).

United Kingdom: There are no known resources of magnesite or other minerals used for the production of magnesium in the United Kingdom. Dolomite does exist but is not used for magnesium production and is not considered a resource for that purpose.

NATURAL GRAPHITE

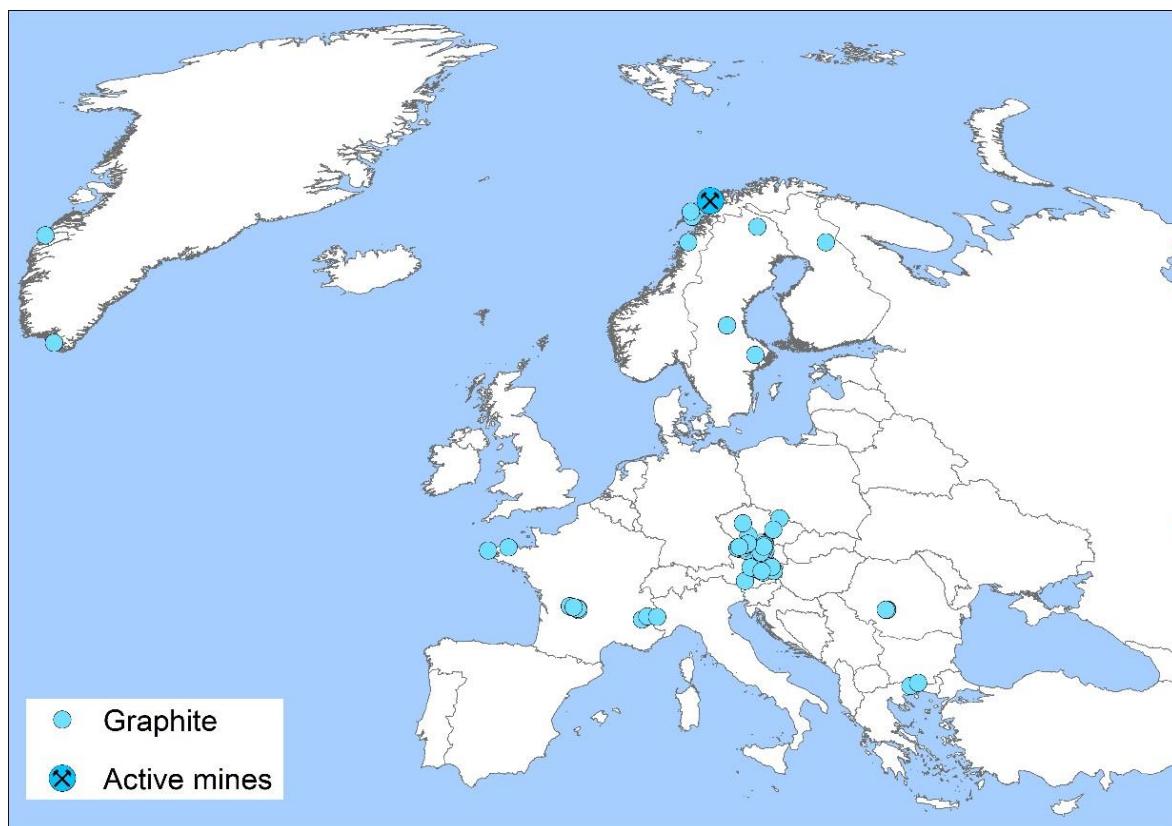


Figure 8 Natural graphite occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Norway: The only graphite mine currently in production in Europe is in the Trælen flake graphite deposit, which is located in northern Norway, in the island of Senja. The graphite grade in the Trælen deposit is 31 % Cg and proven reserves are 1.8 Mt (Gautneb 2015). Both in 2016 and 2017, 8,000 t of graphite was produced from the Trælen mine (USGS 2018).

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RESOURCES BY COUNTRY

Austria: Austria has over 40 known graphite occurrences and deposits some of which have previously been in production. The Kaisersberg deposit has been in production in the recent years but the current status of the operation is not known. Proved ore reserves of 160,000 t and mineral resources of 1,500,000 t are reported for the Kaisersberg deposit. No production or resource information is available for the other graphite occurrences in Austria.

Czech Republic: Graphite has been produced in the Czech Republic between the 18th and 20th century. The graphite mine in Český Krumlov was closed most recently and is currently used as a geotouristic attraction. Eight graphite occurrences are listed for the Czech Republic but no production or resource information is available.

Finland: Several small graphite occurrences are known in Finland, some of which were in production in the early 20th century (FODD 2017). Amorphous graphite occurrences in Juuka, Kiihtelysvaara and Kolari contain several Mt of fine-grained graphite. Flake graphite occurrences are known in Pertunmaa, SE Finland and Joutsijärvi, NE Finland, where beneficiation tests were performed in the 1990s (Pankka 1999). Currently, the Aittolampi flake graphite deposit is under exploration (Beowulf Mining 2018), but no resource estimate has been published for the deposit.

France: Several graphite occurrences are known in France but no information on production or resources is available.

Germany: Graphite has been mined in Germany since the Middle Ages. The most important deposit that has been in production in the recent years is the Kropfmühl deposit, but no production or resource information is available.

Greece: Greece has some graphite occurrences in the northern part of the country in the Polineri-Drama and Diasparto-Thermes areas. The resource estimate for the latter is 24,000 t of ore at 6 % graphite.

Greenland: The Greenland graphite potential is considered as high (Bondam 1992, Steensgaard et al. 2016), although only limited targeted exploration has taken place. Nine graphite occurrences are reported in Greenland, of which two are licensed for further investigation: Amitsøq in South Greenland and Eqalussuit, West Greenland (www.greenmin.gl). In both licensed occurrences, flaky and amorphous graphite, from graphite schist embedded in sillimanite-biotite gneiss, has been exploited in the early 20th century. Kryolitselskabet Øresund AS (1989) reported a non-compliant, resource for Eqalussuit, equivalent to 5.3 Mt grading 9.5 % Cg.

Several graphite occurrences are known from W, SW, and SE Greenland, but no ore tonnage information is available from most of them (Stensgaard et al. 2016), with the following exceptions: The Kangikajik deposit (SE Greenland) has a non-compliant resource of 0.5 Mt flake graphite (based on 9 % Cg). The Grænseland deposit (SW Greenland) has a non-compliant resource of 10,000 t graphite.

Italy: Graphite has been produced in Italy from the Icla-Brutta Comba mine, which was in operation for 90 years between 1893 and 1983. No production or resource information is available for graphite in Italy.

Norway: Norway has four main graphite provinces (Senja, Lofoten-Vesterålen, Holandsfjord and Bamble) that host all known graphite deposits and prospects. In addition to the Trælen mine, there are four other prospects in the island of Senja. The Lofoten-Vesterålen area hosts ten known graphite occurrences some of which have

been in production earlier. The Norwegian Geological Survey NGU is currently exploring for graphite in northern Norway (Gautneb et al. 2017, Rønning et al 2017).

Romania: Graphite deposits are known in Romania and at least two of them (Catalinul and Ungurelașu) have been in production, however, no production or resource information is available.

Sweden: At least eight graphite deposits and occurrences are known in Sweden and in the recent years the ongoing exploration activities have revealed more targets. Leading Edge Materials Corporation started graphite production in their Woxna deposit in 2014, but this was put on hold in 2015 due to low prices. The Woxna deposit comprises three separate targets with a total NI 43-101 compliant resource of 7.7 Mt of ore at 9.3 % Cg (Leading Edge Materials 2016). The Vittangi (Nunasvaara), Raitajärvi and Jalkunen graphite deposits and the Piteå and Pajala prospects in northern Sweden are currently held by Talga Resources (Talga Resources 2017). The three deposits have JORC compliant mineral resource estimates, with Nunasvaara containing 12.3 Mt of ore at 25.5 % Cg, Raitajärvi containing 4.3 Mt of ore at 7.1 % Cg and Jalkunen containing 31.5 Mt of ore at 14.9 % Cg.

United Kingdom: There are no known resources for the United Kingdom. Graphite was produced in the United Kingdom from at least the late-16th century until the late-19th century but no economic resources remain.

NIOBIUM AND TANTALUM

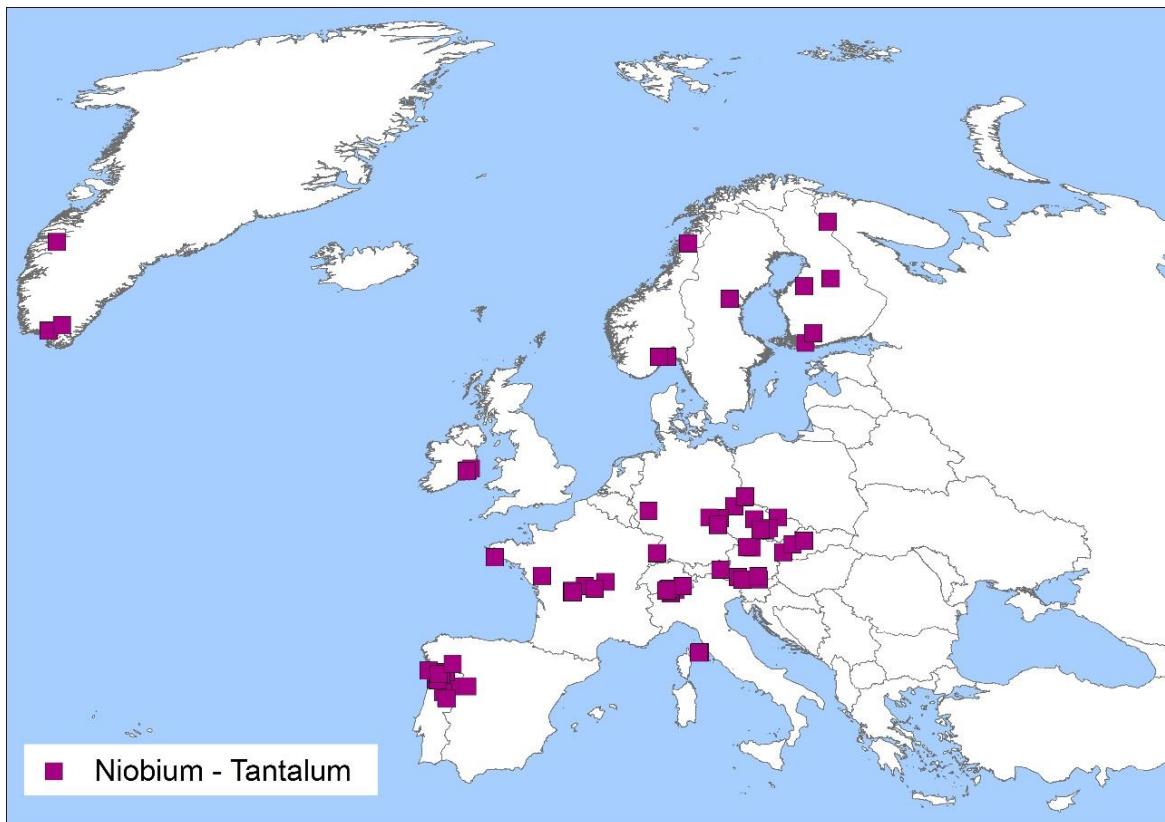


Figure 9 Niobium and tantalum occurrences in the EU according to the databases (FODD, ProMine, M4EU).

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RESOURCES BY COUNTRY

Austria: Austria has mineral occurrences associated with granitic pegmatites, which contain niobium and tantalum minerals such as columbite, tantalite and tapiolite. Although some of these pegmatites have been exploited for quartz and feldspar, there is no information available about Nb or Ta production.

Bulgaria: The Bourgas iron-titanium deposit is reported to also contain 17,000 t Ta_2O_5 (Cassard et al. 2013). The deposit is of heavy mineral sand type (placer), but the metal grades nor the ore tonnages are reported.

Czech Republic: The niobium and tantalum occurrences in the Czech Republic are mainly related to granitic pegmatites that contain Nb and Ta minerals. No production or resource information is available for any of the occurrences.

Finland: The most important deposit in terms of both niobium and tantalum is the Sokli P-Fe-Nb deposit, which contains Ta as a minor commodity. Non-compliant resource estimate for the Sokli deposit contains 250 Mt of ore at 0.21 % Nb and 0.005 % Ta (FODD 2017). Niobium is present as a main commodity in three other occurrences (Jokikangas, Katajakangas and Kontioaho) that are found in the Katajakangas area in central Finland. Non-compliant resource estimates for these three occurrences comprise 8.15 Mt of ore with Nb oxide contents ranging from 0.12 % to 0.76 % and a calculated total amount of 13,000 t Nb_2O_5 (FODD 2017). Tantalum is a main commodity in one complex pegmatite deposit (Rosendal) that has been mined for industrial minerals (quartz and feldspar). In addition to the Sokli deposit, tantalum is marked as a minor commodity in two other LCT pegmatite deposits (Länttä and Kietyömäki) one of which is under development for lithium production. In total, the known Ta resources in Finland comprise 12,786 t Ta metal. This is a minimum figure, as pegmatite granite-related deposits such as Länttä and Rosendal may contain additional Ta resources that have not been analyzed or reported. Such resources also are open at depth, as the drilling typically only extends to 50–100 m depth.

France: There are several Nb and Ta-bearing mineral occurrences in France, which are mostly in granitic pegmatites. The only resource information available is for the Tréguennec deposit, which is estimated to contain 1,950 t of Ta_2O_5 and 1,860 t of Nb_2O_5 , and the Les Montmins deposit, which has 24,000 t of Ta_2O_5 according to the ProMine database (Cassard et al. 2013). These deposits typically also have Li and Sn among the major commodities.

Germany: The known Nb and Ta deposits and occurrences in Germany are hosted by granitic and alkaline rocks. No resource data is available for any of the deposits.

Greenland: The main niobium (and tantalum) occurrences are related to the Mesoproterozoic Gardar Province in South Greenland (Motzfeldt; Kringlerne), and the Neoproterozoic Sarfartoq carbonatite complex in West Greenland. The Kringlerne Zr- REE-Nb-Ta deposit is hosted in the cumulates of the layered kakortokite unit, and an inferred resource of 4,300 Mt grading 0.65 % REO, 1.9 % ZrO_2 , 0.2 % Nb_2O_5 , and 0.025 % Ta_2O_5 was reported (Tanbreez 2013). A mining lease application is in progress. The pyrochlore enrichment of Motzfeldt Sø is a low grade–large tonnage deposit. A non-compliant Nb-Ta resource estimate indicates 500 Mt grading 0.14 % Nb_2O_5 , 0.012 % Ta_2O_5 (Tukiainen 1988).

The Sarfartoq carbonatite complex, central West Greenland, contains several mineralised bodies enriched in REE, Nd, Ta, Th and U. Of these, only one, Sarfartoq 1, has a resource estimated: 100,000 t @ 15 % Nb_2O_5 and 0.18 % Ta_2O_5 (Stensgaard et al. 2016). The Qaqarssuk carbonatite complex is reported to contain 1.2 Mt @ 0.8 % Nb_2O_5 (Stensgaard et al. 2016).

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Additionally, tracts with Nb and Ta resource potential are associated with the alkaline pegmatites in the Caledonian fold belt, East Greenland, and in the Paleoproterozoic Inglefield Mobile Belt, North Greenland.

Ireland: There are no known resources for Ireland. Niobium and tantalum minerals may occur, although only as accessory minerals, in pegmatites associated with the Leinster granite in southeast Ireland.

Italy: There are over ten Nb-Ta occurrences in Italy that are hosted by granitic pegmatites. No resource nor production data is available for any of these.

Norway: In Norway, there are four deposits which are reported as having niobium as a main or minor commodity, whereas no tantalum-bearing deposits are known (FODD 2017). The Fen carbonatite complex comprises both the Fen REE-Nb deposit and the Søve Nb deposit, which was mined out in the 1960s. The Fen deposit has a non-compliant resource estimate of 486 Mt of ore, but only the REE concentrations are mentioned in the mineral resource (EURARE 2017). The Sæteråsen Nb-Zr deposit contains a non-compliant resource of 8 Mt of ore at 0.245 % Nb. The Høgtuva Be deposit has Nb as a minor commodity, with a non-compliant resource estimate of 0.35 Mt of ore at 606 ppm Nb.

Portugal: The ProMine database (Cassard et al. 2013) mentions the Almendra deposit with 350 t Nb₂O₅ and 290 t Ta₂O₅ and the Monte da Alvorada deposit with 50 t Ta₂O₅. Almenrda also has a significant tin resource.

Slovakia: Four deposits are listed for Slovakia which have both niobium and tantalum as the main commodities. All of the deposits are hosted by granitic pegmatites, but there is no resource nor production data available.

Spain: The Penouta Olga deposit contains, in addition to significant Sn, 945 t Ta₂O₅ (Cassard et al. 2013).

Sweden: There are no Nb deposits and only one Ta-bearing deposit reported for Sweden. The Järkvissle Li-Ta-Sn deposit has a non-compliant resource estimate of 0.6 Mt of ore at 80 ppm Ta.

PHOSPHATE ROCK AND PHOSPHORUS

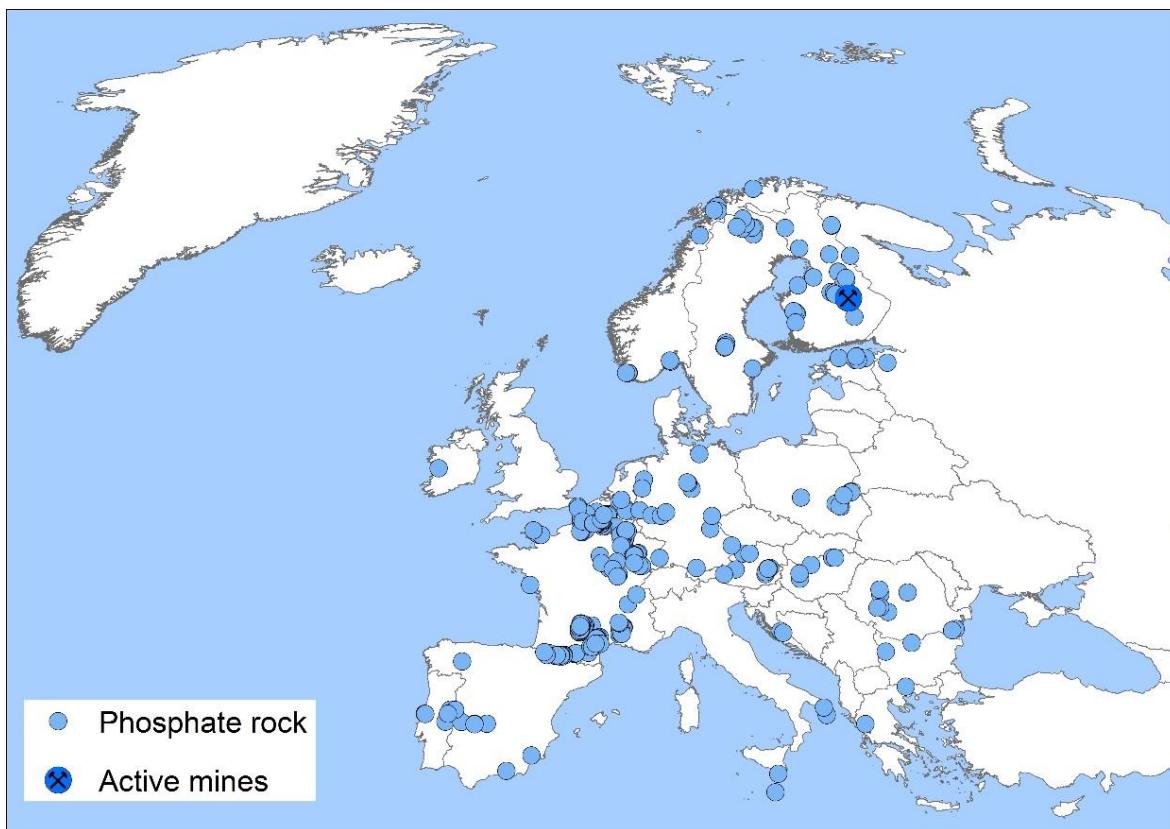


Figure 10 Phosphate rock occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Finland: The only currently operating phosphate rock mine and phosphorus production plant in Finland and in the EU is in Siilinjärvi, eastern Finland, where Yara International is mining the deposit hosted by the Siilinjärvi carbonatite intrusion. The apatite concentrate from the mine is used for phosphoric acid and fertilizer production in the adjacent plant. Full-scale mining of the Siilinjärvi deposit has taken place since 1979. Currently, about 10 Mt of ore is mined and 1 Mt of apatite concentrate produced annually to be further processed to 300,000 tons of phosphoric acid. The resource estimate (JORC) for the Siilinjärvi deposit is 1,617 Mt of ore with P₂O₅ content of 3.694 % (FODD 2017).

RESOURCES BY COUNTRY

Austria: There are ten phosphate rock deposits listed for Austria. Of these, the Plesching phosphorite deposit has a 0.45 Mt P₂O₅ resource (Cassard et al. 2013).

Belgium: The Belgian phosphorite deposits in the Mons basin have a combined resource of 600-800 Mt P₂O₅ (Decree et al. 2017). Some of these deposits have previously been in production.

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Bulgaria: Two sedimentary phosphorite deposits are listed for Bulgaria, but there is no resource information available for them.

Croatia: Two small phosphate rock deposits are known in Croatia and both have been in production in the past, each producing 3500 t of phosphate ore. Currently the deposits are listed as exhausted.

Estonia: Estonia has the largest reported phosphate resources in Europe. At least eleven known phosphorite occurrences that are classified according to the national non-compliant resource classification into passive supplies, reserve stocks and projected reserves. The estimate of total amount of phosphate ore in the Estonian deposits is almost 11.8 billion tons of ore with P₂O₅ grade varying between 7.1 % and 12.1 % (Eesti Mäeselts MTÜ 2017). Most of the data was collected in the 1970s and 1980s and there hasn't been any phosphate production since the 1940s (A. Soesoo, pers. comm. 2017).

Finland: All phosphate resource in Finland is in igneous intrusions. There are two major phosphate deposits in Finland from which a resource estimate (JORC) is available and a number of less well known deposits where apatite (Ca₁₀(PO₄)₆(OH,F,Cl)₂) is the main commodity based on investigations. In addition, non-compliant resource estimates are available for ten deposits, where the main commodities are Fe-Ti-V, Zn-Cu or U, and where phosphorus represents either a major commodity or a possible by-product. The total amount of ore in these deposits is approximately 2250 Mt, containing nearly 90 Mt of phosphate with grades varying between 2.0 % and 13.7 % P₂O₅. In addition, there is the speculative 12 Gt resource (at the grade of 4 %, equals to 480 Mt P₂O₅) in the deeper parts of the Sokli carbonatite intrusion, NE Finland (FODD 2017).

France: Phosphorite deposits occur throughout the Paris basin and are estimated to contain 12-15 million tonnes at 7–14 % P₂O₅ (Decree et al. 2017).

Germany: All information presented for Germany, unless otherwise is stated is from Decree et al. 2017). Phosphorite deposits occur in Rhenish Schiefergebirge and Harz Mountains, but no mineral resource is available on them. The Lengede-Broitstedt iron deposit in Lower Saxony has a P₂O₅ grade of 4 %, but apparently no ore tonnage is reported. The Lahn phosphorite deposits have a reported resource of 0.75 Mt @ above 20 % P₂O₅.

Greece: The Drimonas phosphorite deposit has a resource of about 1 Mt P₂O₅ (Cassard et al. 2013).

Greenland: The known phosphate deposits in Greenland are hosted by carbonatite and alkaline intrusions (Stensgaard et al. 2016).

Hungary: Five sedimentary phosphate deposits are listed in Hungary, but there is no resource information available.

Ireland: Phosphate was extracted from mines in the Doolin area of County Clare during the second world war, but production ceased in 1947 (Cronin 2001) and it is no longer considered to be an economic resource. According to Cassard et al. (2013), the Lisdoonvarna (Doolin area) phosphorite deposit has a resource of 0.75 Mt P₂O₅ or, according to Decree et al. (2017) 1.25 Mt P₂O₅. This is a typical example of variation and contradiction between sources of information in mineral resource data.

Italy: The undeveloped phosphorite deposits of Miocene and Pliocene age in the Salentino (Salento) Peninsula, Puglia, have a joint resource of about 5.2 Mt P₂O₅ Cassard et al. (2013). In Sicily, at Donnalucata, there is a 7 Mt resource at about 15 % P₂O₅ (Decree et al. 2017).

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Malta: Malta has one sedimentary phosphorite occurrence, but no resource information is available.

Netherlands: Two sedimentary phosphorite occurrences are known in Netherlands, but there is no resource information available.

Norway: Thirteen igneous-hosted phosphate-bearing deposits are reported for Norway in the FODD database (FODD 2017). The deposits and occurrences are mostly medium-sized to large, and non-compliant resource estimations are available for ten of these. The total amount of ore in these deposits is approximately 650 Mt with P₂O₅ grades ranging from 1.8 % to 4.0 %. The figure is probably a minimum estimate, as one apatite deposit (Lillebukt carbonatite) is estimated as 'large' (the size class would mean >25 Mt P₂O₅, if phosphorus is the only commodity), but does not have any resource calculation available.

Poland: Phosphorite deposits of Middle to Upper Cretaceous age are also known for Poland, and some of them have been mined in the past. However, there is no information on the remaining resources.

Portugal: The phosphate rock deposits in Portugal fall into sedimentary phosphorite and iron oxide apatite categories. No resource information is available.

Romania: Two phosphorite deposits, containing 4.6 Mt and 600 t of P₂O₅, are reported by Cassard et al. (2013), at Ivrinezu-Dobrogea and Huda lui Papara-Alba, respectively.

Spain: Cassard et al. (2013) report of 2 Mt P₂O₅ and 1.4 Mt P₂O₅ for the Fontanarejo and La Costanaza deposits, respectively.

Sweden: The most important phosphate deposits in Sweden, by tonnage, are the iron oxide-apatite deposits in the Kiruna area in the north and the Bergslagen area in south-central part of the country. Currently, only iron is produced from these deposits, but apatite is present in the tailings and some beneficiation pilots have been made (e.g., Pålsson et al. 2014). Total estimate of apatite-bearing ore (including JORC, NI-43 101 and non-compliant estimates) is approximately 1,250 Mt, of which 682 Mt are calculated as reserves in the Kirunavaara deposit (FODD 2017). P₂O₅ content varies between 1.42 % and 5.51 % (Decree et al. 2017, FODD 2017).

United Kingdom: The largest known phosphate resource in the UK is hosted by the Silurian (c. 430 Ma) Loch Borralan Alkaline Igneous Complex in north-west Scotland. The complex comprises a suite of felsic (syenites) and ultramafic (pyroxenites-hornblendites) rock types. The pyroxenites contain between 1 % and 10 % apatite, which is the primary phosphate-bearing mineral in these rocks. The resource, based on geophysical surveys and shallow diamond drilling, is estimated to be in the order of 100 Mt at about 2 % P₂O₅ (Notholt et al. 1985).

Sedimentary phosphate resources have also been identified in the UK. These resources are typically lower tonnage, but are much higher grade. Early Cretaceous greensand units in Cambridgeshire are estimated to contain about 250,000 tonnes of phosphatic material grading 26–27 % P₂O₅ (Notholt et al. 1977). In Buckinghamshire, Late Cretaceous phosphatic chalk units are estimated to contain about 500,000 tonnes of material grading approximately 27 % P₂O₅ (Hawkins 1940).

All the above figures are considered to be 'historical' estimates and are not in accordance with any current industrial standard.

SCANDIUM

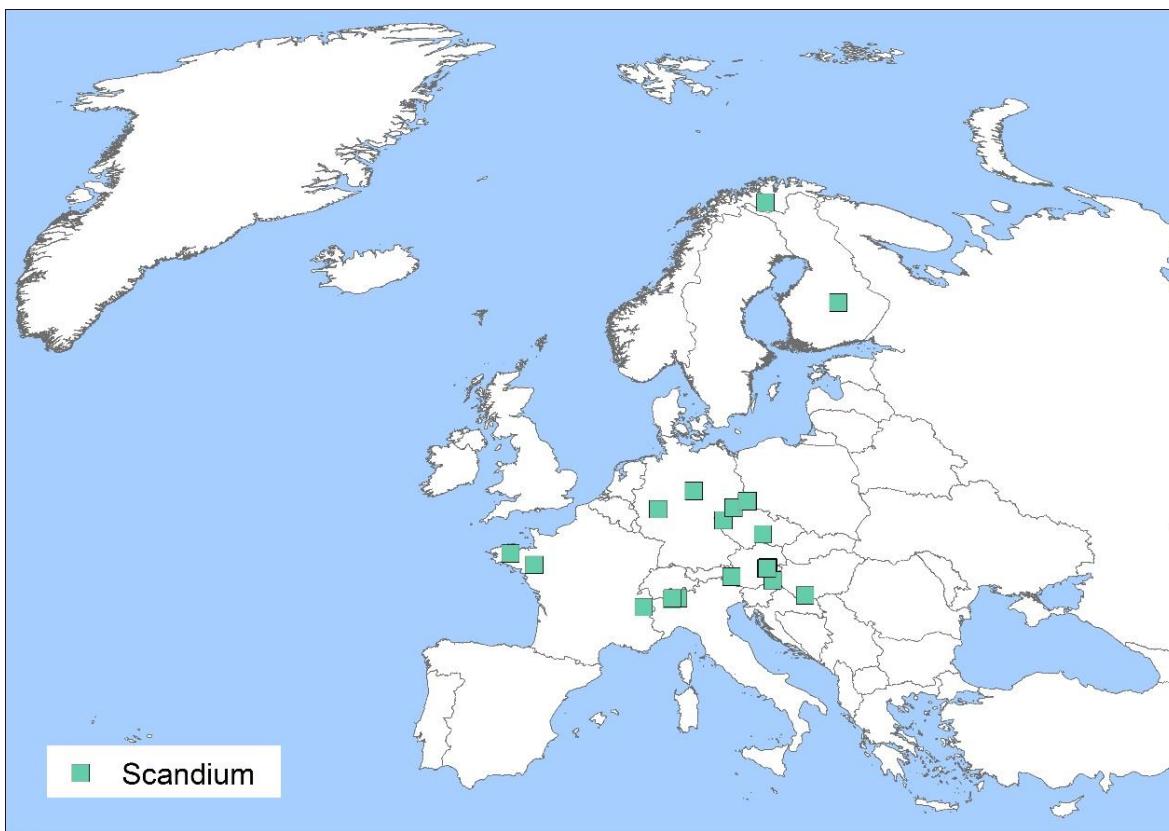


Figure 11 Scandium occurrences in the EU according to the databases (FODD, ProMine, M4EU).

RESOURCES BY COUNTRY

Austria: There are eleven mineral occurrences or deposits in Austria where scandium occurs as the main commodity (Höllkogel Mountains, Traibach) or as a minor metal. In most Austrian occurrences scandium is present as Sc-phosphate prelutite (ScPO_4), which is originally described from these occurrences (Bernhard et al. 1998; Bernhard 2001). Currently the occurrences have mainly mineralogical significance.

Czech Republic: Two mineral occurrences in the Czech Republic list scandium as a minor commodity. These occurrences have no economic significance in terms of scandium.

Finland: One scandium deposit is known in Finland (FODD 2017). The Kiviniemi diorite intrusion in southeastern Finland hosts a Sc-REE-Zr deposit discovered in 2008 by GTK. A non-compliant resource estimate for the deposit is 13.4 Mt of ore at 162.7 ppm Sc and a total measure of 2,180 t of Sc metal (Hokka & Halkoaho 2016).

France: Scandium is present in three mineral occurrences listed in France. No resource information is available and the occurrences most probably have no economic significance.

Germany: Seven mineral occurrences in Germany list scandium as a minor metal. No resource information is available for any of these and they most probably have no economic significance.

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Greece: Scandium is a minor commodity in the Perama Hills polymetallic deposits, which are reported to contain 107 t Sc (Cassard et al. 2013).

Hungary: Scandium is listed as a minor commodity in the Mecsek uranium deposit, which was in production in the second half of 20th century. No production or resource data is available for scandium.

Italy: Italy has five mineral occurrences where scandium is listed as the main commodity (Baveno) or a minor metal. Currently these occurrences mainly have mineralogical significance.

Norway: One scandium deposit is known in Norway (FODD 2017). The small Biggejav'ri REE-Sc-U deposit in N Norway has a non-compliant resource estimate of 0.05 Mt of ore at 0.013 % Sc. The Sc-REE-U mineralisation occurs as dissemination in completely albited basaltic and basaltic komatiitic amphibolite. It was discovered after airborne radiometric survey and was extensively drilled by Folldal Verk A/S in 1983–84.

Sweden: No scandium occurrences are reported from Sweden. Some indication of Sc enrichment in the Alnö and Åvike Bay alkaline complexes have been reported, with average Sc contents between 47 ppm and 95 ppm in the former and 9–22 ppm in the latter (Kresten 1976). No resource information is available for these occurrences.

SILICON METAL

PRODUCTION IN EUROPE

In 2015, silicon metal was produced in Norway (150,000 t), France (100,000 t), Germany (29.953 t), and Spain (22,000 t). Besides Norway, which has local mine production, there appears no information wherfrom the mined raw material for this production comes from.

RESOURCES BY COUNTRY

Below, we list quartz mines and resources. However, it is not clear if any of these has high-purity quartz necessary for silicon metal production.

Austria: The ProMine database (Cassard et al. 2013) lists 21 deposits where quartz is the main commodity. Only for one, Spittal/Drau (Lippnik), there is data on past production, and for none there is a resource tonnage.

Bulgaria: There are three quartz deposits in the ProMine database for Bulgaria, but no resource data for them.

Finland: Currently there are two active quartz mines in Finland, with a joint production of 92,813 t quartz in 2016 (<http://en.gtk.fi/informationservices/mineralproduction/finmipr1116.html>), some of this may be categorised to medium to high-purity quartz. There also are dozens of quartz vein occurrences with at least some having a potential for high-purity quartz, but none with a resource estimate (FODD 2017).

Greece: The ProMine database lists five quartz deposits, none with a resource reported, for Greece.

Germany: The Cornelia mine in Germany has a past production of 100,000 t and a resource of 1.8 Mt of quartz (Cassard et al. 2013).

Italy: The ProMine database lists two quartz deposits for Italy, with no resource reported.

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Norway: Information here is from an unpublished manuscript by Peter M. Ihlen and Jan Egil Wanvik (February 2018), unless otherwise is indicated. In 2015, Norway produced 1.1 Mt quartz from five mines; most of this went into ferrosilicon and silicomanganese production in Norway. The Austertana mine annually produces 700,000-800,000 t quartz. At the Mårnes mine, annual production is 120,000-160,000 t quartz. Another high-purity quartz producer is the Nedre Øyvollen (Drag), pegmatite-hosted mine. The Kvinnherad quartz vein deposit is under development; it has a JORC-compliant resource of 4.29 Mt @ 65 % medium to high-purity quartz (Nordic Mining 2017). Another major deposit of vein quartz, Nasafjell in central North Norway with resources at >10 Mt quartz (open pit reserves estimated to 7–10 Mt), is also under exploration. The Nesodden high-purity quartz deposit in south-western Norway has an inferred resource of 2.7 Mt quartz. In addition, there are tens of smaller vein quartz deposits containing 0.1-0.5 Mt of quartz across the country. Of the unexploited pegmatite-hosted deposits hosting potentially high-purity quartz, we mention here Eiterelvdalen, in the Caledonides of the Nordland county, with an inferred resource of 0.425 Mt quartz. Of a completely different type are the recent discoveries, which include several deposits of very high purity quartz in kyanite-rich quartzites. Large tonnages are available, especially near Solør in southern Norway. This type is considered as a target for future interest as progress in technology develops.

Poland: The PGI lists five vein quartz deposits containing, in total, 7.3 Mt of quartz (geoportal.pgi.gov.pl).

Portugal: The ProMine database lists one quartz deposits for Portugal: the Assuncao beryl-columbite-phosphate pegmatite-hosted mine, with past production of 23,000 t of quartz.

Sweden: The FODD database (2017) lists 52 quartz deposits for Sweden. These include three active mines in the Dal Group quartzites in central Sweden, with a joint annual production of 100,00 t of quartz concentrate used in the ferro-alloy industry (SGU 2016). Of the known unexploited occurrences, at least the Lumivaara, Naakajarvi, Pajeb Muitunitjaure, and Långsjökullen vein occurrences in northern Sweden contain medium to high-purity quartz. The Långsjökullen and Naakajarvi deposits are estimated to contain 150,000-200,000 t and 8,400 t quartz, respectively (FODD 2017).

TUNGSTEN

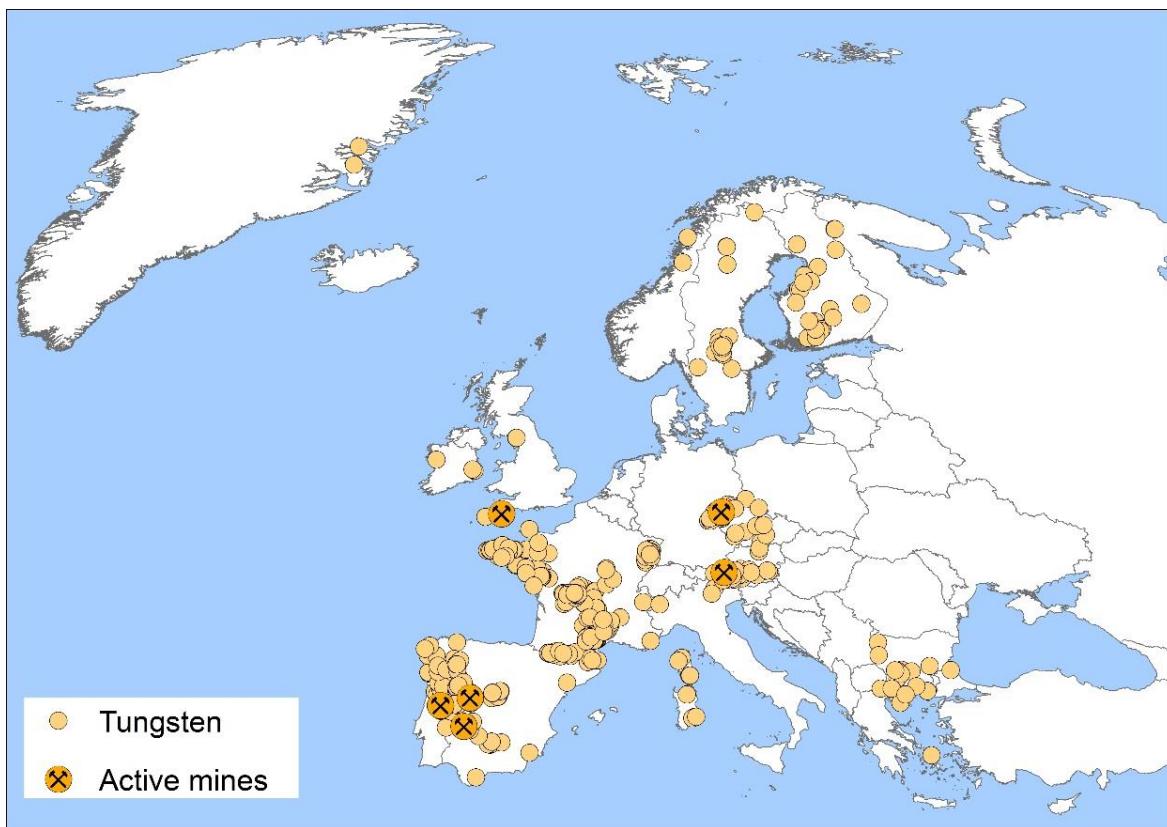


Figure 12 Tungsten occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Austria: Tungsten is produced from the Mittersill scheelite deposit in Austria by Wolfram Bergbau und Hütten AG. Mittersill is a metamorphosed granite-related stockwork-type tungsten deposit. The scheelite concentrate produced is used by the company for upstream products (tungsten carbide powder, tungsten metal powder and tungsten oxide). Annual capacity of the mine is in the range of 0.4 Mt @ 0.4 % WO₃ (Raith & Schmidt 2010). According to USGS (2018), the mine production of tungsten in 2017 in Austria was estimated at 950 Mt.

Germany: Saxony Minerals and Exploration AG is working at the Pöhla deposit in Saxony, Germany with the aim of starting tungsten, tin, indium and fluorite production (SMEAG 2017). According to the company, pilot-scale production started in late 2017.

Portugal: The Panasqueira tungsten mine in Portugal is operated by Almonty Industries (2018). The production has since 2000 varied at 630–1330 t/a W (Wheeler 2016); in 2017 the production is estimated to be 658 t W (USGS 2018).

Spain: In 2017, tungsten production in Spain is estimated to be about 570 t (USGS 2018). Almonty Industries holds the Los Santos mine, which produces tungsten concentrate. The La Parilla tungsten mine started operation in 2016; it has JORC-compliant resources of 49 Mt @ 0.10 % WO₃ and 0.11 % Sn by W Resources (2018). The W metal resource of the mine is, hence, 38,855 t.

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United Kingdom: The UK has a history of tungsten production spanning almost 120 years. During this time, the UK has produced approximately 5,000 tonnes of tungsten, primarily from mines in the south-west of England. The majority of this production occurred during the First (1914–1918) and Second (1939–1945) World Wars when demand for high-speed steel and munitions increased dramatically (Pitfield and Brown 2011).

In the UK, primary tungsten production only takes place at one mine, the Drakelands tungsten-tin mine in Devon, which is currently operated by Wolf Minerals Limited. The Drakelands Mine is working the Hemerdon deposit which was first discovered in 1867; however, it wasn't until 1917 that it was worked on a commercial scale. The deposit comprises a stockwork and sheeted greisen vein system hosted in the Hemerdon Ball Granite, a satellite intrusion of the Dartmoor Granite pluton. The Hemerdon Ball Granite is a dyke-like structure approximately 140 metres wide and 1,200 metres in length that dips steeply to the east. The primary ore minerals encountered in the mineralised veins are wolframite, cassiterite and some minor sulphides. Since its discovery, the Hemerdon deposit has been extensively explored and intermittently worked, particularly during the First and Second World Wars, but commenced its latest operations in September 2015 (Pitfield and Brown, 2011; Wolf Minerals Ltd, 2017). The Drakelands Mine produced about 200 tonnes of tungsten during the final 4 months of 2015 (Brown et al. 2017). In 2017, the UK tungsten production from mines was 1,086 t; this all came from the Drakelands mine (www.wolfminerals.com).

RESOURCES BY COUNTRY

Austria: The resources at the Mittersill (Felbertal) mine are about 24,000 t W (Cassard et al. 2013). The ProMine database lists also 24 other W occurrences for Austria but does not give any resource data on them

Bulgaria: Three occurrences with W as the main metal and a number with W as a companion metal are listed in the ProMine database, but none with resource data.

Czech Republic: The Cinovec (Zinnwald) tin granite system has a resource of about 24,000 t W (Cassard et al. 2013). In addition, the ProMine database lists six occurrences with W as the main metal, all without any resource figures.

Finland: Finland has 17 occurrences in the FODD database that have tungsten as the main commodity and additional six occurrences in which it is mentioned as a minor commodity (FODD 2017). Five occurrences have associated resource information and in the case of the Ylöjärvi Cu-W mine the data is for the ore mined. Altogether the four other deposits (Ahvenlammi, Apajalahti, Hieronmäki and Kuskoiva) have a non-compliant resource estimate of 2,333 t of tungsten metal, which may be considered as a minimum figure for tungsten resources in Finland.

France: The ProMine database lists 15 W deposits with resource figures and about 100 occurrences without resource data in France. In total, the 15 have a resource of 66,000 t W. There is ongoing exploration to re-open the Salau Au-Cu-W mine (Couflens Project; <http://apollominerals.com.au/projects/couflens-project-france/>), in the Pyrenees, where there may be a >5 km long zone of similar orebodies to occur. The ProMine database gives 2,700 t W for the remaining ore at Salau, whereas the largest single resource in France would in the closed Montredon-Labessonnie, with 16,700 t W (Cassard et al. 2013).

Germany: Tungsten is listed as a minor metal in several mineral occurrences in Germany, which are mostly granite-related. There is no resource information available for the deposits. The Pöhla deposit in Saxony is currently under investigations (SMEAG 2017).

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Greece: There is one medium-sized W deposit with a resource estimated in Greece: the Kimmeria polymetallic skarn. It has a non-compliant resource of 6,000 t W (Cassard et al. 2013).

Greenland: Greenland comprises geological environments that are highly prospective for tungsten mineralisation. However, only very limited exploration has been undertaken.

East Greenland is considered to have the highest potential for vein- and skarn-type tungsten deposits (Stendal & Frei 2008). Twelve outcropping scheelite occurrences are found in a 350 km long belt in central East Greenland, encompassing the skarn-type occurrences Kalkdal, Knivbjergdal, and Trekantgletscher, and the vein type occurrences Scheelitdal, Galenadal, and Ymer Ø (drilling from three sites revealed approx. 200,000 t @ 0.7-2.5% WO₃; Sørensen et al. 2014)

Several tungsten anomalies associated with gold and arsenic anomalies are present within the Paleoproterozoic Ketilidian Mobile Belt in South Greenland. This tract is considered to hold a moderate potential for tungsten vein deposits. Stratabound, skarn-type scheelite occurrences are known in the Nuuk area (at Ivisaartoq), but unlikely to be of economic interest due to their intermittency.

Ireland: Tungsten occurs in two separate localities in Ireland. In southeast Ireland, tungsten occurs as scheelite in veins and greisenized microtonalite sheet complexes close to Ballinglen and in nearby quartz veins or segregations in the country rocks of the Ballinacor area (Gallagher, 1989). In western Ireland, tungsten occurs primarily in skarns and veins associated with granite in Connemara (Kennan et al. 1987). Neither location is currently considered to be an economic resource.

Italy: One W occurrence, without a resource, is included into the ProMine database.

Norway: Norway has two tungsten occurrences according to the FODD database (2017). The Laksådal Mo-W deposit contains scheelite and molybdenite, which are present in diopside skarn as veins, lenses and dissemination. The Laksådal deposit was mined in the first half of 20th century. The Målvika tungsten occurrence comprises scheelite mineralisation with some Au+As+Bi anomalies. No resource information is available for the Norwegian deposits.

Portugal: At the end of 2016, the resources (including reserves) at Panasqueira were 10 Mt @ 0.23 % WO₃ plus inferred 5.16 Mt @ 0.22 % WO₃ (Wheeler 2016). With all the tonnages and tungsten grades calculated into one (no more NI-compliant), the resource is about 27,240 t W metal for Panasqueira. At S. Pedro da Águias (Tabuaço), there is an indicated resource of 0.76 Mt @ 0.58 % WO₃ and inferred 1.33 Mt @ 0.57 WO₃ (= total 9,500 t W) (Martins 2012). The ProMine database (Cassard et al. 2013) lists eight closed tungsten mines for Portugal; jointly these are reported to contain resources of nearly 40,000 t W. In addition, there are six W occurrences without resource data in the ProMine database.

Spain: At Los Santos, there is a Ni-compliant resource (inclusive reserves) 2.2 Mt @ 0.29 % WO₃ plus inferred resources of 1.88 Mt @ 0.25 % WO₃; this, together with W-rich tailings (2.062 Mt @ 0.15 % WO₃) and minor stockpile made a total resource of 15,334 t W metal (2015 data, http://www.almonty.com/projects/los_santos/). The Valtreixal project (xxx) in NW Spain has a Ni-compliant W resource of 2.828 Mt @ 0.25 % WO₃, 0.13 % Sn in the indicated and 15.419 Mt @ 0.08 % WO₃, 0.12 % Sn (Wheeler 2015). With all the tungsten values calculated into one (no more NI-compliant), the W resource is about 15,400 t for Valtreixal. Three additional W deposits with resource data are listed for Spain in the ProMine database. Jointly these contain 21,800 t W in resources (Cassard et al. 2013). In addition, there are 15 closed mines and other W occurrences without a resource in the ProMine database.

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Sweden: Sweden has abundant historical tungsten production with at least fourteen small deposits having been in production in 19th and 20th century (FODD 2017). The largest of these deposits is Yxsjöbergsfältet, from which slightly over 5 Mt of ore was produced during the 92 years' time when the mining took place. Non-compliant resource estimates are available for three W occurrences that have not been exploited and two of these give information on the tungsten content of the ore, with a total of 2.1 Mt of tungsten-bearing ore at 0.2 % of W. This may be considered as a minimum figure for tungsten resources in Sweden.

United Kingdom: The Drakelands Mine is the UK's largest tungsten resource. According to current JORC compliant resource estimates the deposit contains about 145 million tonnes of ore grading 0.15 % WO₃ (172,500 t W) and 0.02 % Sn. JORC-compliant reserve is about 36 Mt @ 0.18 % WO₃ (51,400 t W) and 0.03 % Sn (Wolf Minerals Ltd, 2017). Although historic tungsten production has taken place at a number of other mines in south-west and north-west England, any remaining resources associated with these mines have not been quantified.

VANADIUM

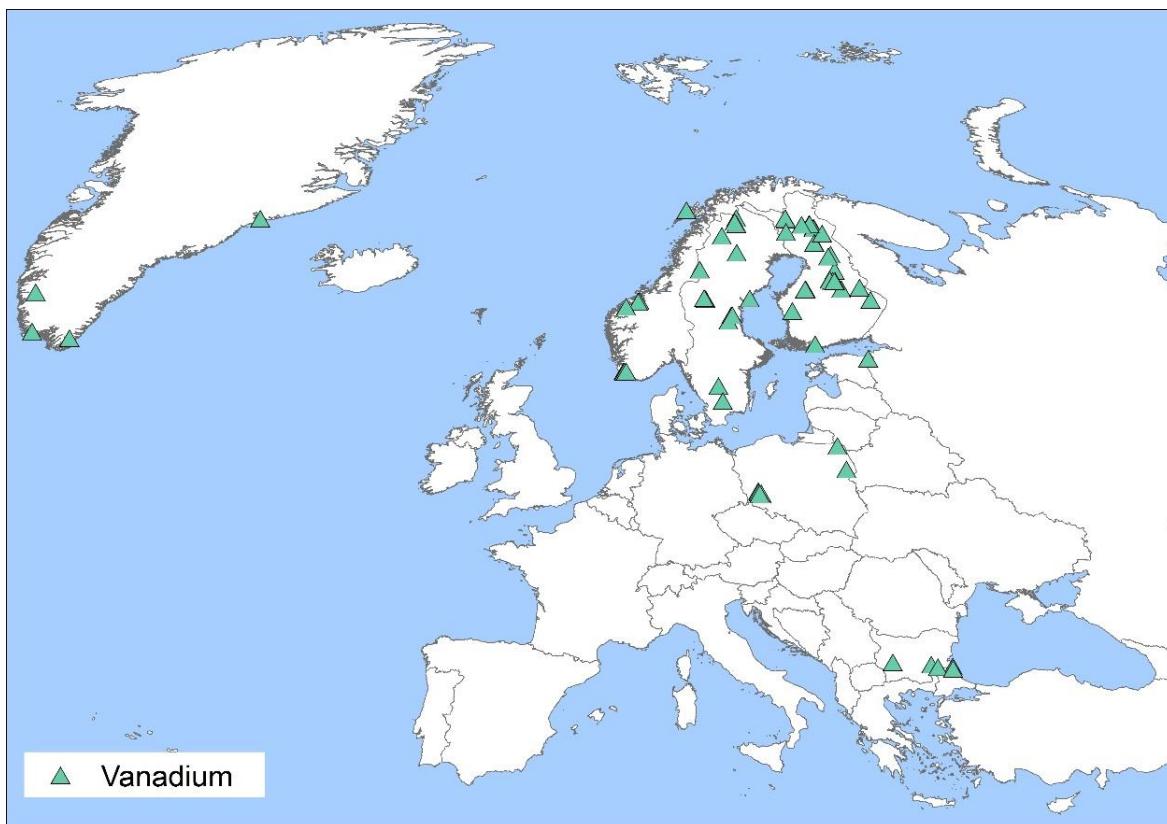


Figure 13 Vanadium occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Although the CRM list of 2017 (EC 2017) lists several European vanadium producers (Belgium, United Kingdom, Netherlands, Germany, others), all these use imported materials and there is currently no mine production of vanadium in Europe. The Ferrovan Co. in Finland is planning to start vanadium production in Finland by

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processing slag by-products from SSAB steel plants (www.ferrovan.com). This appears to be the next European vanadium producer using European raw materials, as the SSAB uses Swedish iron ore in their steel production.

RESOURCES BY COUNTRY

Bulgaria: Vanadium is listed as a minor commodity in five small iron occurrences in Bulgaria. These occurrences have a total resource estimate of 127 Mt of iron ore in indicated and inferred categories, however, no information on vanadium grade is included. The iron grades in these deposits vary between 6 % and 11 %, which indicates that these occurrences are uneconomic for iron production.

Estonia: Estonian Ordovician black shales and oil shales have vanadium potential according to the Minerals4EU database. The kukersite oil shale basin hosts a number of metals like vanadium, uranium, nickel and molybdenum and these metals are present in tailings, dumps and industrial wastes (slags, bottom ash). It is probable that the still unused oil shale resources also contain vanadium but it is not possible to profitably extract it with current technology. The graptolite argillite, which is comparable to the alum shale in Sweden, is also enriched in vanadium, with maximum V contents of 1600 ppm (Hade & Soesoo 2014).

Finland: Finland has 34 occurrences listed in the FODD database which contain vanadium either as the main commodity or a minor commodity (FODD 2017). The occurrences may be classified into several deposit types, with the dominant types being Fe, Fe-Ti-V, Fe-P-Ti-V and Cr-V-PGE occurrences associated with mafic-ultramafic magmatic complexes. The Mustavaara deposit in east-central Finland was a major global vanadium producer in the 1970s and early 1980s but the mine was closed in 1985. Since 2011, the company Ferrovan Co (previously Mustavaaran Kaivos Oy) has developed the deposit for re-opening. JORC-compliant reserves for the Mustavaara deposit comprise 99 Mt of ore with 14.0 wt. % of ilmenomagnetite (Mustavaaran Kaivos Oy 2018), containing 27,485 t of vanadium. Other significant vanadium occurrences in Finland include the Fe-Ti-V deposits of Koivusaarenneva and Kairineva in western Finland. These two deposits have JORC-compliant resources of 62.15 Mt @ 0.13 % V and 6.55 Mt @ 0.12 % V, respectively, containing a combined total of 88,655 t of vanadium. The Otanmäki Fe-V deposit and its satellite deposit Vuorokas, which were in production from 1940s to 1980s have a combined non-compliant resource of 20.5 Mt @ 0.26 % V, with a total of 120,464 t V. Also these deposits are currently under development, by Otanmäki Mine Oy (2015). The giant Koitelainen layered intrusion in northern Finland has a non-compliant resource of 70 Mt of ore @ 0.4 % vanadium, containing a total of 280,000 t V. Another layered complex, Akanvaara, has three different ore layers with a combined total of 140,000 t V. Non-compliant resource estimates are available for 18 other deposits, with a combined total of 181,000 t vanadium. In addition, there is about 1.3 Mt V in the Talvivaara polymetallic deposit (1.9 Gt @ 0.066 % V). However, the vanadium is not extracted during mining nor included into the JORC-compliant resource, as the metal is in mica, not in oxide, hence making the recovery uneconomic.

Greenland: Greenland is regarded as prospective for magmatic Ti-V deposits (Sørensen et al. 2016). Four areas are highlighted:

The Archaean Sinarsuk Ti-V occurrence is associated with gabbroic rocks of the Fiskenæsset anorthosite complex, West Greenland. The mineralised rocks extends for 13 km along strike. Detailed mapping and channel sampling returned grades of about 0.25 % V₂O₅ and 2.85 % TiO₂; higher-grade channel sampling includes 9.8 m @ 0.9 % V₂O₅ and 9.24 % TiO₂ (Sørensen et al. 2016, Stensgaard et al. 2016).

The Isortoq deposit, South Greenland, is hosted in a Mid-Proterozoic Fe-Ti-V-rich troctolite. The mineralisation can be traced for about 16 km along strike based on 20 drill-holes (>4,000 m) and strong magnetic anomalies;

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the deposit is open to the south. A NI 43-101 compliant, inferred resource covering one kilometre strike length at Isortoq is 70 Mt at 38 % FeO, 10.9 % TiO₂, and 0.14 % V₂O₅ (15 % Fe cut-off) (Sørensen et al. 2016).

The Paleocene, layered gabbroic Skærgaard intrusion, East Greenland, hosts titanomagnetite enriched in V. Drilling has delineated a 1,500 Mt, multi-element (PGM, Au, Ag, Cu, Ti, V) occurrence. Drilling of the Pd5-layer, the main potential source of PGMs, has revealed an inferred resource of 104 Mt grading 0.11 g/t Au, 1.91 g/t Pd, 0.16 g/t Pt, 7.8 % TiO₂, and 0.21 % V₂O₅. The Lower Zone is richer in V₂O₅ (up to 2.9 %) (Sørensen et al. 2016).

The Stendalen gabbro intrusion, South Greenland, emplaced into the Paleoproterozoic Ketilidian forearc metasediments at a syntectonic stage is considered to hold a significant Ti-V potential. A 20 m thick Fe-Ti-V layer is reported (Sørensen et al. 2016).

Norway: All eight Norwegian V deposits are of the mafic intrusion-hosted Fe-Ti-V deposit type. Seven of them are located in southern Norway, within the Rogaland and Møre metallogenic areas. The eighth, Selvåg, is in the Vesterålen area in the north (Sandstad et al. 2012). The Rødsand deposit was in production from 1889 to 1981, when 15 Mt of Fe-V ore was mined. In total, the Norwegian deposits contain 531 Mt of ore with V contents varying from 0.05 % to 0.34 % (FODD 2017).

Poland: The ProMine database lists eight V deposits for Poland. Jointly, these contain about 120,000 t V. Most of the Polish V is as potential byproducts in the Kupferschiefer-type, polymetallic, copper-dominated deposits.

Sweden: The main deposit type for the vanadium deposits in Sweden is mafic intrusion-related Fe-Ti-V type, but some deposits belong to the polymetallic black shale type, in which V is enriched together with U, Mo and Ni. JORC or NI 43-101 compliant resource estimates are available for four deposits (FODD 2017). The black shale type Myrviken and Häggan deposits are large, with 3062 Mt and 1790 Mt of ore, respectively, both at 0.15 % vanadium. The Routivare malmfält deposit has historic production in the 19th century but the remaining resources are of the order of 140 Mt of ore at 0.2 % V. The Ekströmsberg deposit contains 72 Mt of ore at 0.05 % V. Non-compliant resource estimates are available for six other deposits with a total tonnage of 197 Mt of ore and vanadium contents ranging from 0.11 % to 0.3 %. A major part of this is hosted in the Smålands Tabergs gruvfält area, which had small-scale production in the late 19th and early 20th century.

United Kingdom: The phosphate deposit in the Loch Borralan alkaline igneous complex in north-west Scotland also contains vanadium, but this is not considered to be an economic resource.

PLATINUM GROUP METALS (PGM)

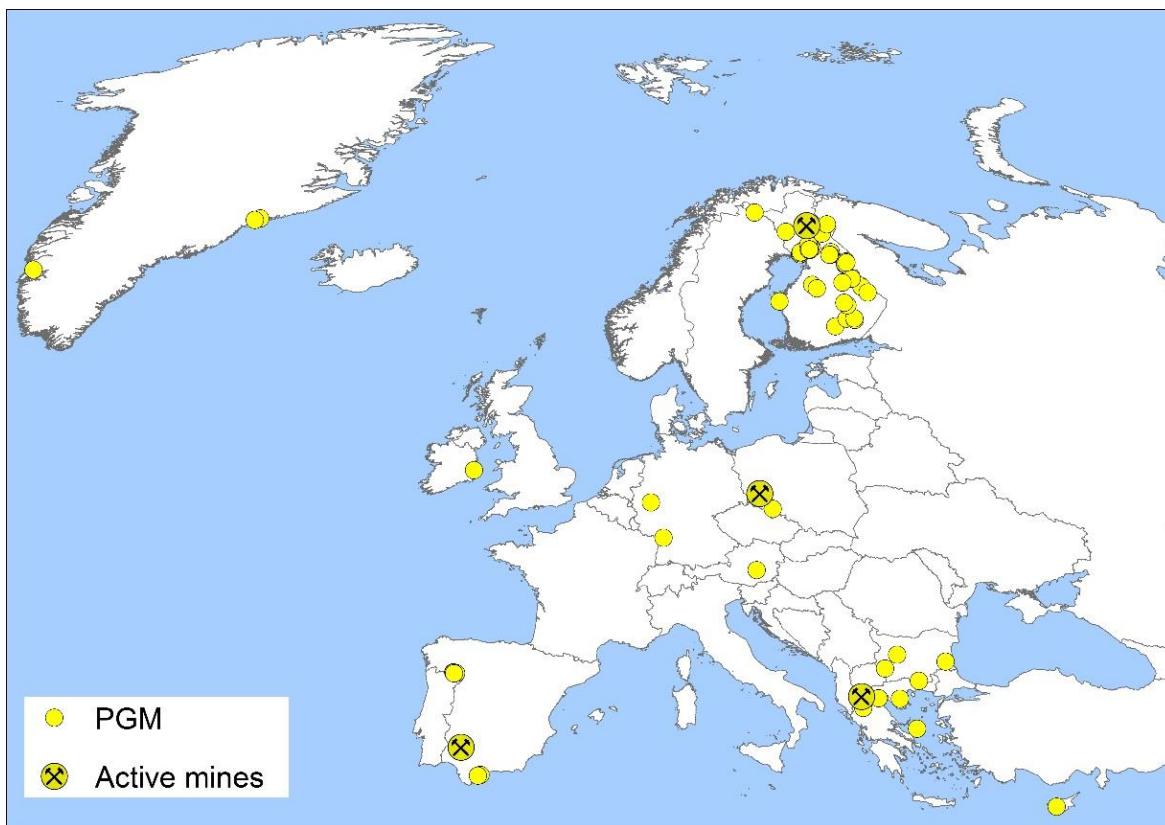


Figure 14 PGM occurrences in the EU according to the databases (FODD, ProMine, M4EU).

PRODUCTION IN EUROPE

Finland: Most of the European PGM production from mines comes from Finland. The sole producer, the Kevitsa Ni-Cu mine reported 889 kg Pd and 1163 kg Pt in 2016.

Poland: Several tens of kilograms of Pt+Pd slime have annually been produced from the Lubin area mines of Kupferschiefer type (Marsh et al. 2016).

Greece: PGMs may be recovered from the Ni concentrates originating from the Greek laterite nickel mines. However, no PGM recovery is reported.

Spain: The Aguablanca Ni-Cu mine contained, in 2011, about 85 t Pd and 2 t Pt in the ore (Cassard et al. 2013). The metal grade is 0.47 g/t PGE, the PGEs are dominated by Pd, and palladium-bearing minerals occur commonly enclosed within sulphides in the deposit (Pina et al. 2008). In refining, the PGMs in the nickel and copper concentrates are most certainly recovered. However, there is no information regarding how much of the Pt and Pd is retained in the concentrates and whether it is actually recovered.

RESOURCES BY COUNTRY

Bulgaria: The Elatsite porphyry Cu deposit is reported to be enriched in PGM; in the Elatsite 4 ore body (350 Mt of ore), 6.7 t of Pt+Pd is reported to occur (John & Taylor 2016). Although the PGM grade is very low (0.0197 ppm Pt+Pd), the dominant PGM minerals are closely associated with copper sulphides, hence probably will follow Cu in processing and can be recovered at a refinery. The ProMine database lists two placer occurrences with the PGMs as major commodities, but without any resource data.

Cyprus: There are a few explored Cu-Ni occurrences in the Troodos Ophiolite Complex mafic-ultramafic rocks which may also contain PGMs as potential byproducts. However, none of these have a resource reported for any metal (SNL data 28 Feb 2018).

Finland: The information given here is based on the FODD database (2017). In total, 34 deposits in Finland contain a PGM resource of 720 t Pd and 287 t Pt. Except for the Talvivaara black shale-hosted Ni-Zn-Cu-Co deposit (SSC type), these all are magmatic Ni and Ni-Cu deposits. In most cases the PGMs are potential companion or minor by-products only. However, the largest PGM resources are in the layered intrusion hosted, PGM-dominated deposits, which contain reported resources and reserves of 563 t Pd and 184 t Pt (and 38 t Au, 4000 t Co, 348,000 t Ni). The largest single resource is in the Arctic Platinum Project with two layered intrusion hosted deposits 3 km apart, jointly having 225 t Pd, 32 t Pt, and 206,000 t Ni (NI-compliant). Major reported resources not in layered intrusions are in: 1) the Kevitsa Ni-Cu mine, with current reserves + resources at 54 t Pd, 34 t Pt (NI-compliant), 2) the Sakatti deposit with indicated and inferred resource of 22 t Pd and 28 t Pt (JORC-compliant), and 3) possibly in the Talvivaara mine (39 t Pd, 29 t Pt). Note, however, that there is only a non-compliant inferred resource for the PGMs at Talvivaara. **Greece:** The Skouries porphyry Cu deposit is reported to be enriched in PGM (John & Taylor 2016). The Skouries 2 ore body is reported to have 23.1 t Pt+Pd in 568 Mt of ore (average grade 0.047 g/t Pt+Pd; John & Taylor 2016). The ProMine database suggests 26 t Pd, and no Pt, for Skouries (Cassard et al. 2013). The dominant PGM minerals are associated with copper sulphides, hence probably will follow Cu in processing and could be recovered at a refinery when the deposit goes into production. In addition, the laterite nickel deposits of Greece probably contain a PGM resource, although only the Ni and Co grades are reported for these deposits.

Greenland: Both reef-type mineralisation and dunite-related PGM occurrences are reported in Greenland.

The Paleocene tholeiitic layered gabbroic Skaergaard intrusion, East Greenland, hosts a stratiform PGM-Au occurrence – the Platinova Reef, which appears to have formed in response to silicate-sulphide liquid immiscibility in the basaltic magma and is enriched the Pd, Pt, Au and Cu (Nielsen et al. 2005, 2015). The reef includes five main levels of Pd enrichment. Pd and Au minerals are characteristically alloys (e.g., PdCu, AuPd, (Pd,Au)Cu), or intimately associated with Fe-poor Cu- sulphide minerals. Inferred resource (JORC) amounts to 203 Mt grading 0.88 ppm Au; 1.33 ppm Pd (Stensgaard et al, 2016).

The layered, tholeiitic, Kap Edward Holm complex, East Greenland, mineralised with gold and PGMs is reported to contain 0.25 ppm Pt, 0.04 ppm Pd, and 0.05 ppm Au over 3 m, with individual samples containing up to 5 ppm Pt, and 6 ppm Au (Arnason & Bird 2000).

The Archaean layered Amikoq complex, southern West Greenland, extends for 25 km and consists of norites, pyroxenites, dunites and harzburgites. NunaMinerals A/S (2009) reported the following PGM-values for the complex: I) ‘Octopus Reef’: 0.4–1.0 ppm Pt+Pd in a 2–4 m thick sheet, traced along strike for 2.5 km, open ended; II) ‘Rhodium Zone’: Up to 1.0 ppm Pt+Pd+Rh with Rh-dominated PGM patterns, traced along strike for 500 m. Drilling intersected the reef at up to 100 m depth.

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The Archaean craton of the Maniitsoq area hosts a suite of noritic-gabbroic rocks (Secher 1983) known as the Maniitsoq Norite Belt. The Ni-content of the mineralised rocks is up to 2 %, with up to 0.6 ppm Pd and 2.2 ppm Pt (Secher 2001).

Germany: PGM mineralisation has been described within the Mansfeld/Sangerhausen district that appears to be similar to that in the Polish Kupferschiefer. Similar to Bulgaria, the ProMine database lists two placer occurrences with the PGMs as major commodities in Germany, but without any resource data.

Ireland: Recent geochemical mapping has revealed notable levels of platinum in stream sediments in the Leinster province of southeast Ireland (Tellus, 2016). These have not yet been quantified sufficiently to ascertain whether they represent economic resources. The ProMine database lists the Palaeogene mafic-ultramafic intrusion at Carlingford a potential PGM resource; however, no resource figures are given.

Norway: The information given here is based on the FODD database (2017). Eight deposits in Norway contain a PGM resource of 2.4 t Pd and 3.5 t Pt. Except for one clastic-hosted copper deposit (SSC type), these all are magmatic Ni-Cu deposits, and in all cases the PGMs are potential companion or minor by-products only. The largest PGM resource is in the SSC-type Cu deposit at Nussir, N Norway. In addition, there are about 20 magmatic Ni deposits which all probably do contain PGMs as potential by-products – four of these have reported unexploited resource tonnage (total about 13 Mt inferred resource), but none reported PGM grades.

Poland: The minor PGM production from the Lubin area mines indicates the PGM potential of the Polish Kupferschiefer deposits where the PGMs are concentrated in narrow zones along redox front between underlying hematitic redbeds and the overlying, organic-rich Kupferschiefer shale (Marsh et al. 2016). In addition, the Szklary serpentinite-hosted Ni deposit is reported to contain 120 platinum (Cassard et al. 2013).

Portugal: There are mafic-ultramafic intrusion-hosted nickel deposits, especially in the Ossa-Morena zone (Martins 2012), which may contain potential by-product PGMs.

Spain: The PGM grades at Aguablanca suggest that a minor PGM potential also occurs in other mafic-ultramafic intrusions in the region.

Sweden: Information given here is based on the FODD database (2017). One copper deposit (Storsjö Kapell) in Sweden contains a PGM resource of 80 kg Pd. In addition, there are about 20 magmatic Ni deposits which all probably do contain PGMs as potential by-products – most of these have reported unexploited resource tonnage (total about 430 Mt, mainly inferred resource), but none reported PGM grades. There also are two very large, but low grade, black shale-hosted, Ni-Cu-Mo-U deposits which could have a minor by-product PGM potential: Myrviken and Häggån, 3.06 Gt and 1.79 Gt (both at 0.03 % Ni) of inferred resource, respectively, but no PGM grades reported.

United Kingdom: Although the resource has not been quantified, there is reported potential for by-product PGM production from Ni-Cu-sulphide deposits associated with ultramafic rocks at Littlemill and Arthrath in Aberdeenshire, north-east Scotland (Styles et al., 2004). In addition, the ProMine database mentions the Unst island (Shetland) as a potential PGM resource, but gives no resource information.

RARE EARTH ELEMENTS

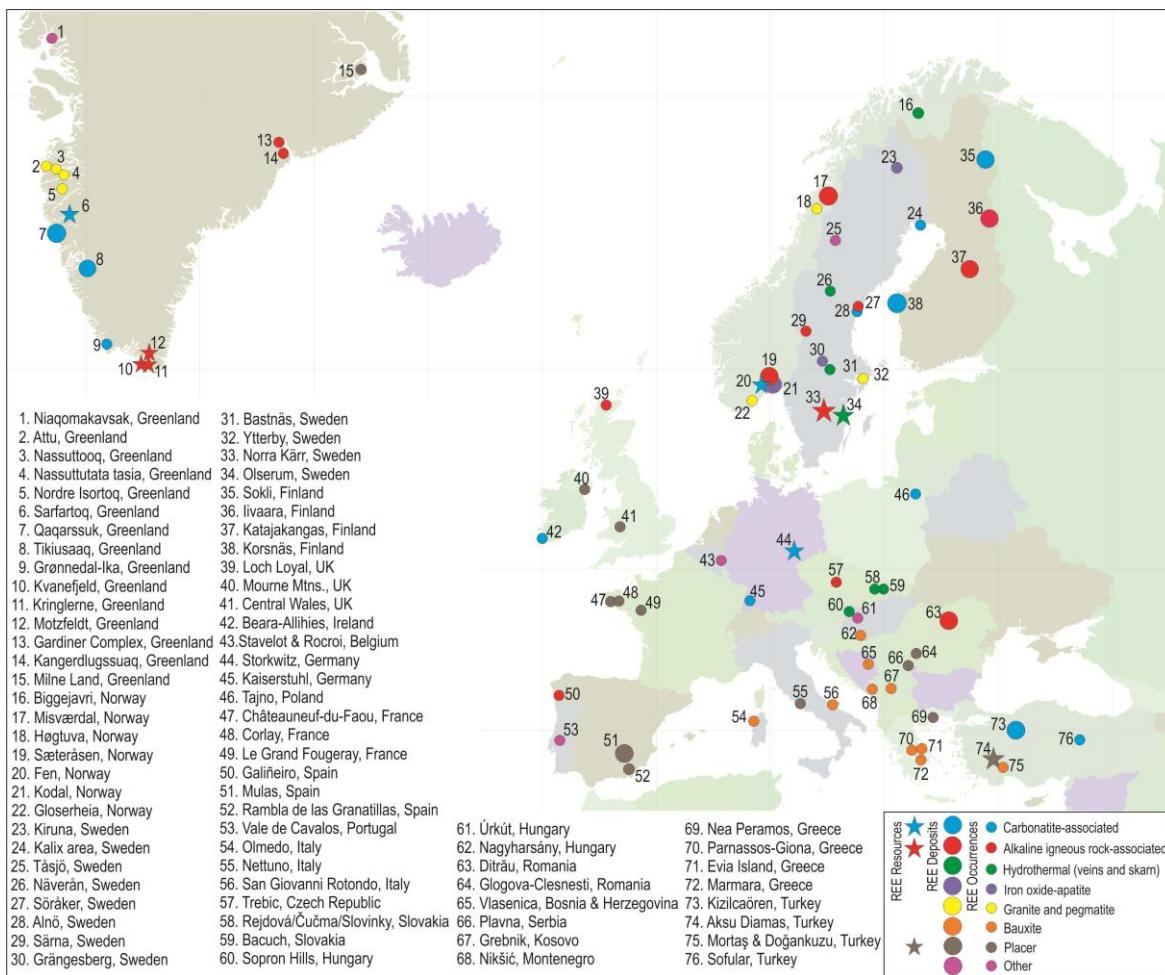


Figure 15 REE deposits in the EU according to the EURare project. Source: British Geological Survey © NERC.

All countries with a phosphate resource also have a potential for REE resources, as the REE are common enriched metals in phosphate minerals. Below, only such phosphate deposits are mentioned where there is a reported REE resource. The following chapter is mainly based on the findings of the EURare project (<http://eurare.eu/>).

RESOURCES BY COUNTRY

Belgium: The EURare database lists the Stavelot and Rocroi massifs in Belgium as placer-type REE occurrences, but no resource information is available.

Czech Republic: The Trebic alkaline pluton in the Czech Republic is listed in the EURare database as a REE occurrence, but no resource information is available.

Finland: The Sokli carbonatite in north eastern Finland, a part of the Devonian Kola alkaline province (360–380 Ma), hosts an unexploited deeply weathered phosphate deposit enriched in Nb, Ta, Zr, REE and U. Analyses from drill cores of the Sokli ring dykes show that the carbonatite has a high total REE content of 0.5–1.8 wt.%

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(Sarapää et al. 2013). The Korsnäs Pb-REE-bearing carbonatite dyke was mined from 1961 to 1972 by the Outokumpu Oy mining company, producing 45 000 tons Pb and 36 000 tons of lanthanide concentrate. The grade of the ore was 3.57 % Pb and 0.91 % RE₂O₃. A swarm of REE enriched carbonatite dykes and associated alkaline veins is found within an extensive area, covering over 100 km² in Panjavaara, eastern Finland. The dikes and veins are highly enriched in REE, with concentrations reaching 5–10 %, and even the smallest veinlets typically showing 1–2 % total REE. The studied rocks display elevated LREE to HREE ratios, with bastnäsite, aenylite, and monazite as the most important REE carriers.

The Katajakangas and Konttiaho Nb-REE occurrences in central Finland forms narrow lenses or layers within sheared quartz-feldspar alkali gneiss. They have an estimated, non-compliant, Nb-YREE resource of 0.46 Mt at 2.4 % RE₂O₃, 0.31 % Y₂O₃ and 0.76 % Nb₂O₅ (Sarapää et al. 2013). The Lamujärvi syenites in central Finland display strong enrichment in Zr (1587 ppm), Nb (up to 685 ppm), Ta (up to 82 ppm) and REE (up to 5350 ppm), but the grades and volumes of these rocks appear too small to be currently of economic potential. The Kovela monazite granite pluton in southern Finland has REE contents in drill core sections that vary from 0.6 % to 4.3 %.

The Virtasalmi kaolin deposits in SE Finland have thicknesses of 30–40 m, locally up to 100 m. The total REE content of kaolin in the basal part of the weathering profile reaches a maximum 0.1–0.2 % REE. The 200 km long Tana Belt on the southern side of the Lapland Granulite Belt shows anomalous HREE and LREE contents throughout. The REE content in the Mäkärä Au-bearing saprolite is 0.05 %, locally up to 0.4 % REE. Typical REE-rich minerals are monazite, rhabdophane and xenotime.

France: Relatively few REE occurrences are known in France, although the presence of alkaline magmatism in the Massif Central, the Pyrénées and Corsica raises the possibility that further occurrences remain to be discovered. The most significant REE enrichments are located in low grade metamorphosed black shales in Brittany that commonly contain 50 to 200 g/t of monazite nodules. Le Grand-Fougeray monazite placer is the largest and the best documented of the placers in Brittany. Estimated tonnages in alluvium of the Aron and Gras rivers are modest (1900 t of monazite in clayey gravels with a grade of 2 to 2.6 kg of monazite per ton, and a cut-off at 1 kg/t). However, this monazite is exceptionally rich in europium (0.2–1 % Eu₂O₃); it also contains neodymium (13–14 % Nd₂O₃) and is poor in thorium (<1 % ThO₂). Exploitation tests were carried out at a site in the Aron river in 1967–1968, and 78 t of monazite were extracted and marketed. New analyses have indicated interesting grades in dysprosium (0.25 % Dy) and terbium (0.1 % Tb). Similar monazite nodules occur also in the southern Massif Central, in the Ardennes and in the French Pyrénées.

Cambrian dolomites contain thick but discontinuous phosphate-enriched layers with 0.1–0.22 % U, 0.1–0.18 % Th and 0.17–0.25 % REE. In the Montagne Noire, approximately 30 cm thick layers of limestone and black shale contain clasts and phosphate-enriched nodules with 5–20 ppm Th, 10–40 ppm U and 0.03–0.21 % REE (Laval et al. 1990). Other known REE occurrences in France are of mineralogical interest only.

Germany: The Kaiserstuhl and Storkwitz REE-Nb occurrences are listed in the EURare database, but no resource data is available.

Greece: In Greece, exploitable deposits of bauxites exist mainly in the regions of Mt Parnassus, Mt Ghiona and Mt Helikon (central Greece) and on Evia Island. Bauxite reserves are approximately 70 Mt. These deposits are currently exploited for aluminium by a number of producers. Tsirambides and Filippidis (2012) report total REE values in the bauxites and lateritic bauxites of central Greece as 3275 to 6378 ppm. Although these concentrations are significant, they are unlikely to be reflective of all Greek bauxite deposits. High values are

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likely to result from the sampling of localised areas with REE enrichment along the footwall limestone, and are not representative of average REE concentrations in the bauxite.

Greenland: The Mesoproterozoic Ilímaussaq intrusion, South Greenland, hosts two of world's largest REE-deposits; Kvanefjeld (REE-U-Zn-F) and Kringlerne (REE-Nb-Ta-Zr) (also known as TANBREEZ). In Kvanefjeld, steenstrupine is the main REE-mineral. The license holder, Greenland Minerals and Energy A/S (GMEL), reports a measured JORC resource of 143 Mt grading 1.21% TREO and 303 ppm U₃O₈. Substantial additional resources were identified. In the Kringlerne deposit, eudialyte is the main REE-mineral. The inferred resource amounts to 4,700 Mt, grading 0.653 % TREO and 1.8 % ZrO₂. Both projects have reached feasibility stage and negotiations for mining leases are in progress.

The bulk of the REE occurrences within the Motzfeldt Sø intrusion, South Greenland, are related to pegmatite intrusions at depth. Main REE-minerals are zircon, monazite, and bastnäsite.

In the REE occurrence at the Sarfartoq carbonatite complex, West Greenland, bastnäsite, synchysite, and monazite are the main REE minerals. Based on the 'ST-1' prospect, a 14 Mt inferred resource grading 1.53 % TREO was identified (Stensgaard et al. 2016). The average thorium grade is about 500 ppm; U is very low.

The Jurassic Tikiusaaq carbonatite, West Greenland, is enriched in REE in the latest intrusive phases, and the main REE-mineral is ancyllite. Drill core samples have yielded up to 9.6 % TREO (predominantly LREE). Interpretation of radiometric and magnetic data indicates a 750 m x 100 m body, extending to a depth of at least 500 m.

The Jurassic Qeqertaasaq carbonatite complex, West Greenland, consists of steeply dipping concentric carbonatite sheets. Exploration focus by NunaMinerals A/S has been on the core of complex. The dominant REE mineral is ancyllite; the average grade for a 1.5 km² area is 2.4 % TREO, LREE dominated.

Ireland: The EU-funded EURare project identified just one occurrence of REE in Ireland, a Permian-aged carbonatite at Beara-Allahies in the south west of the country. This deposit has previously been mined for copper and has minor enrichment in REE (EURare, 2017).

Italy: Olmedo and San Giovanni Rotondo bauxites, Nettuno placer. Rare earth elements in bauxites have been recorded and studied since early researchers in the 1970s identified authigenic minerals occurring in lower layers of bauxites in the San Giovanni Rotondo bauxite in Italy (Bárdossy and Pantó, 1973).

Hungary: Sopron Hills vein, Urkút, Nagyharsány bauxite

Norway: The present knowledge of Norwegian REE deposits is primarily based on data collected during exploration and exploitation for uranium (U), beryllium (Be) and niobium (Nb) mineralisation and from the quarrying of quartz and feldspar in pegmatites. REE mineralisation in Norway includes examples related to magmatic and to hydrothermal-metasomatic processes. Apatite-rich iron oxide mineralisation in Kodal contains >6000 parts per million (ppm) total REE in apatite.

Alkaline to peralkaline complexes in the Palaeozoic Oslo graben are generally enriched in REE and Nb, Th ± Zr. In the Sæteråsen deposit, fine-grained disseminations of complex REE-Nb-Th silicates and oxides occur in trachytic lava. In the Misværdal alkaline-ultrapotassic complex the REE-bearing apatite constitutes up to 10 wt.% in pyroxenite. The Fen complex carbonatite carries low-grade Nb ores and REE- and Th-enriched iron oxide ores, which were mined in the past. It is the deposit with the highest economic potential for REE in

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Norway, but the depth extension of the mineralization is poorly known. There is current exploration activity in the Fen complex.

Rare metal pegmatites with accessory REE-, Nb-, Ta-, Be-, Th- and/or U-bearing minerals occur in the Sveconorwegian orogenic belt in south Norway and in Proterozoic granites in north Norway. Metasomatic albitites with U-REE mineralisation occur in the Palaeoproterozoic Kautokeino greenstone belt. Highly-fractionated Paleoproterozoic granitic orthogneisses in basement windows in the Caledonides show local enrichments in allanite, LREE-bearing titanite, and fluorite. The Høgtuva Be deposit is also enriched in REE, U and Zr. The possible exploitation of any of these occurrences is dependent on the market as well as on grade and tonnage. In total, the REO resources in the Norwegian deposits are of the order of 4.7 Mt, most of them residing in the Fen carbonatite complex.

Poland: The Tajno carbonatite in Poland hosts a LREE occurrence according to the EURare database, but no resource estimate is available.

Portugal: Significant REE enrichments are associated with radioactive, heavy-mineral rich quartzites in the Vale de Cavalos-Portalegre area of Portugal, which extend across the Spanish border. Locally, total REE concentrations in the most enriched quartzites are in the order of 0.65 wt.%. A resource estimate of 2.4 Mt at an average total REE grade of 0.46 wt.%, has been suggested by Inverno et al. (1998).

Romania: Two REE occurrences are listed for Romania. The Glogova-Clesnesti is a placer with monazite concentrations. The Ditrău occurrence is hosted by alkaline igneous rocks. No resource information is available for Romania.

Slovakia: The REE occurrences in Slovakia are associated with uranium, but no resource information is available.

Spain: The Galiñeiro Complex is composed largely of aegirine-riebeckite gneiss with some amphibole-biotite gneiss with patchy areas of hydrothermally altered, F and Th-rich 'radioactive' albite gneisses. Significant REE enrichments are found in the 'radioactive' and aegirine-riebeckite gneisses, with concentrations up to more than 1 wt.% total REE, and notable HREE-enrichments. The REE are hosted by REE-carbonates (bastnäsite and parisite), REE-niobotantalates (fergusonite, samarskite, pyrochlore and aeschynite), REE-silicates (allanite, zircon), and REE-phosphates (monazite and xenotime) (Montero et al., 1998).

Sweden: Sweden is known to host a large number of REE occurrences of different genetic types, and numerous REE-bearing minerals were originally discovered in this country. The Norra Kärr REE deposit comprises a small agpaitic intrusion in southern Sweden. Recent data from the concession holder, Tasman Metals Ltd, indicate that the deposit contains resources of REE, Y and Zr with eudialyte as the main REE ore mineral. The NI 43-101 compliant REE resource is estimated as 41.6 Mt at 0.57 % TREO, with 51 per cent of that being heavy rare earth oxides (Jonsson 2013). Other alkaline intrusives with potential for REE are the Särna and Almunge nepheline syenites.

Some of the highest concentrations of REE as a whole in Sweden, and some of the most LREE-enriched compositions, have been identified in sövite from the Alnö alkaline complex in Sweden, which includes both silicic (syenitic) and carbonatitic rocks, with higher potential for REE enrichment in the carbonatitic rocks.

The Kiruna type apatite-iron ores generally exhibit anomalously high concentrations of REE. Total REE contents in the fluorapatite may reach up to weight-percent levels. Important examples of this deposit type include

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Kirunavaara and Malmberget in northernmost Sweden, and Grängesberg-Blötberget-Idkerberget in Bergslagen, south central Sweden.

The Bastnäs-type deposits are located in the Bergslagen ore province of south central Sweden, where they form a discontinuous, narrow belt of approximately 100 km length, the so-called REE-line. LREE-enriched deposits are located mainly in the Riddarhyttan-Bastnäs area, whereas those in the Norberg district may also have HREE enrichment. Typical host minerals comprise cerite-(Ce), törnebohmite-(Ce) and allanite, as well as REE-fluorocarbonates such as bastnäsite-(Ce).

The Tåsjö U-REE mineralisation contains 0.03–0.07 % U_3O_8 and 0.11–0.24 % total REE (Gustafsson, 1979). In the Olserum area are several vein-hosted, REE-rich mineralisations associated with iron ore. These contain abundant monazite-(Ce) and xenotime-(Y) in addition to e.g. apatite, biotite and magnetite, and exhibit a relatively high proportion of HREE. Tasman Metals' Olserum deposit comprises lower grade placer material with higher grade apatite-magnetite veins. Using a TREO cut-off of 0.4 %, Olserum hosts an indicated mineral resource of 4.5 Mt at 0.6 % TREO, with 34 % of that being HREO.

United Kingdom: Although of unknown extent REE-mineralised veins associated with the Silurian Loch Loyal Syenite Complex in north-west Scotland grade up to 2 % total rare earth oxides (TREO). The primary ore mineral in these enriched veins is allanite (Walters et al. 2013).

CONCLUSIONS AND RECOMMENDATIONS

Europe has been a significant mining region in the past and some commodities are still being mined, but opening of new mines in the EU is presently nowadays rare. The mine production of CRM within the EU28 + Norway covers from 3 % (helium) to 40 % (tungsten) of the EU supply for those commodities that are mined in Europe (EC 2017). Refinery production is larger for some commodities (boron chemicals, cobalt, gallium, germanium, hafnium, indium and silicon metal), but the raw materials are largely produced outside EU.

Occurrences and deposits of all non-biotic CRM are known in the EU28 countries, Norway and Greenland. Although quite a few of these have been in production at some time, most of them are currently considered as mined out, uneconomic, or not just explored at such detail that a feasibility study can be performed. New exploration activities are mainly taking place in the countries that still have active mines – the Nordic countries, Ireland, Spain, Portugal, Greece and Eastern Europe – but also in Germany and the United Kingdom, of which tungsten production has recently re-started in the UK. However, finding a potential ore deposit and investigating it to the knowledge level that is required for the mining decision is a time and money-consuming process that may take even decades. In addition to the financial and technical obstacles, the establishment of new mines is hindered by prolonged permitting procedures, increasing environmental activism, and NIMBY attitudes in most EU28 countries. These are issues that also need to be taken into account when discussing exploration and mining.

Table 3 shows the current status of CRM potential in the EU28, Norway and Greenland. What needs to be remembered when investigating Table 3 is that the amount of data available varies hugely between the different countries. Reliable resource data for most commodities is generally very sparse and new data generated by exploration and mining companies is not collected in most member states, excluding the Nordic countries. The current report gives a strong support for CRM exploration and extraction within the EU, as it shows the large potential for such raw materials to exist in potentially economic concentrations within the European bedrock.

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Table 3 CRM primary resource potential in EU, Norway and Greenland. Question marks indicate cases where a commodity may be recovered in current mining, but no data exist to confirm this. Mg indicates a potential raw material for Mg metal production (no Mg metal is produced in Europe). Si indicates quartz resources which form potential raw material for silicon metal production.

Country	Current mine production	Known unexploited resources (tonnage data exists)	Assumed unexploited resources only (no tonnage data)
Austria	Mg, W	Sb, In, Mg, Graphite, P, W	Baryte, Bi, Co, Fluorspar, Ga, Ge, Nb-Ta, Sc, Si, REE
Belgium		Baryte, P	REE
Bulgaria		Sb, Baryte, In, Mg, Nb-Ta, PGM	Bi, Fluorspar, Si, W, V
Croatia			Baryte, P
Cyprus			Co, PGM
Czech Republic		W, REE	Sb, Fluorspar, In, Nb-Ta
Denmark/Greenland		Sb, Co, Fluorspar, Ga, Graphite, Nb, Ta, Hf, REE, PGM, V	Be, Ge, P, W
Estonia		P	V, REE
Finland	Co, Mg, P, PGM	Sb, Be, Co, Nb-Ta, P, Sc, W, V, PGM, REE, Hf	Baryte, Bi, Mg, Graphite, Si,
France		Sb, Baryte, Be, Fluorspar, Ge, Mg, Nb-Ta, P, W, REE, Hf	Bi, Co, Graphite
Germany	Baryte, Fluorspar, In(?)	Baryte, Fluorspar, In, Si	Sb, Be, Bi, Co, P, W, PGM, REE
Greece	Co(?), Mg, PGM(?)	Sb, Co, In, Graphite, P, Sc, W, PGM, REE	Bi, Mg, Si
Greenland		Fluorspar, Ga, Graphite, Nb-Ta, W, V, PGM, REE	Sb, Be, Co, Ge, P
Hungary			Sb, Fluorspar, In, Sc, REE
Ireland		In, Mg, P	Baryte, Fluorspar, W, PGM, REE
Italy		Sb, Baryte, Fluorspar, P	Mg, Graphite, Si, W, REE
Latvia			
Lithuania			
Luxembourg			Sb
Malta			P
Netherlands	Mg		Mg
Norway	Graphite	Be, Co, Nb-Ta, P, Sc, Si, V, PGM, REE, Hf	Bi, Fluorspar, Graphite
Poland	Co(?), He, PGM(?)	Baryte, Co, Fluorspar, Ga, Ge, Mg, Si, V	He, Mg, P, PGM, REE
Portugal	In(?), W	Sb, Be, In, Nb-Ta, W, REE	Si, PGM
Romania		P	Sb, Baryte, Bi, B, Co, Graphite, REE
Slovakia	Mg	Sb, Mg	Co, REE, Nb, Ta
Slovenia			Sb
Spain	Fluorspar, Mg, W, PGM(?)	Baryte, Co, Fluorspar, Mg, Nb-Ta, P, W	Sb, PGM, REE
Sweden		Sb, Co, Fluorspar, Graphite, Nb-Ta, P, Si, W, V, REE, Hf	Be, Bi, Sc, W, PGM
United Kingdom	Baryte, Fluorspar, W	Baryte, Fluorspar, P, W, Hf	PGM, REE

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