A Note on the map of Critical Raw Material deposits of Europe

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Introduction

This document describes the Critical Raw Material (CRM) Map of Europe, version 3, released in December 2015 by EuroGeoSurvey's Mineral Resources Expert Group. This map is an update of previous versions that were produced during the ProMine EU funded research project. It shows European mineral deposits from the ProMine Mineral Deposit database as containing critical commodities, according to the list of critical raw materials of the European Commission (EU, 2014).

The following sections briefly present:

- EuroGeoSurveys and the Mineral Resources Expert Group.
- Critical Raw Materials in Europe.
- The ProMine project and its Mineral Deposit database.
- How CRM deposits were extracted from the ProMine database and how the map was constructed.

EuroGeoSurveys and the Mineral Resources Expert Group

EuroGeoSurveys (EGS), The Geological Surveys of Europe, is a not-for-profit organization representing 37 National Geological Surveys and some regional Geological Surveys in Europe, with an overall workforce of several thousand geoscientists, engineers and other experts.

EGS Members are public sector institutions carrying out operations and research in the field of geosciences mainly within their respective jurisdictions but in some instances in other jurisdictions, depending on their mandate. These organizations have a long tradition and experience, in many cases more than 100 years, in the collection of data, the preparation of information and in conducting research focused on their national subsurface.

EuroGeoSurveys provides the European Institutions with expert, independent , balanced and practical pan-European advice and information as an aid to problem-solving, policy, regulatory and programme formulation in areas such as:

- The use and management of on-shore and off-shore natural resources(energy, including renewable geothermal energy; minerals; water; soils; underground space; and land).
- The identification of natural hazards of geological origin, their monitoring and the mitigation of their impacts (deficit or excess of trace elements in soils and waters; earthquakes; natural emissions of hazardous gases; landslides and rockfalls; land heave; subsidence; shrinking and swelling clays).
- Environmental management; waste management and disposal; land-use planning.
- Sustainable development and safe construction.
- e- government and access to geoscientific data and metadata .
- The development of interoperable and harmonised geoscientific data at the European scale.

The EGS Mineral Resources Expert Group (MREG) is actively involved in contributing to policy and strategy-making processes aimed at identifying, characterizing and safeguarding resource potential, especially for critical raw materials through research, technological development and innovation.

The MREG mission is to provide the best available mineral expertise and information based on the knowledge of Member Geological Surveys, for policy, communication, public awareness and education purposes at European level, focusing mainly on strengthening the position of the European minerals industry towards resource sustainability and competitive growth.

EGS MREG aims to become the leading partner within a European Raw Materials Knowledge Base and Information Network, or other form of cooperation that will provide innovative tools and expertise to support a sustainable minerals supply for Europe. Mineral information provided by EGS MREG carries out its remit to standards that compare favourably to others operating in this sphere. The MREG collaborates with other organizations that have mineral intelligence capacities and expertise, with users of that information and other stakeholders.

Critical Raw Materials in Europe

The European Union aspires to reducing the import dependency of raw materials that are critical to Europe's industries by improving access to raw materials within the EU and from other sources; promoting resource efficiency, including recycling; and advancing alternatives through substitution. The EU also aims to place Europe at the forefront in raw materials innovation and mitigate negative environmental and social impacts.

In this respect, mineral resource information and data sharing and networking by European Geological Surveys is crucial . The Strategic Implementation Plan of the European Innovation Partnership on Raw Materials (SIP EIP RM) highlights the need for establishing and maintaining a common interoperable EU Geological Knowledge Base, including Minerals Intelligence Information. Such a knowledge base will facilitate a European exploration effort for mineral resources and support effective policy and decision making related to both the surface and the subsurface.

In 2010, the European Commission identified 14 critical non energy non-agricultural raw materials. Criticality is based on both the scarcity of supply and the importance of the material to European industry. This list of 14 CRM was updated and increased to 20, in 2014. The list comprises (in alphabetical order) antimony, beryllium, borates, chromium, cobalt, coking coal, fluorspar, gallium, germanium, graphite, indium, magnesite, magnesium, niobium, phosphate rock, platinum group metals, heavy rare earth elements, light rare earth elements, silicon metal and tungsten.

The ProMine project

ProMine was a European Union (EU) co-funded project, which had as its main objective the stimulation of the extractive industry to deliver new products to manufacturing industry. The project lasted 4 years, starting in 2010 and ending in 2013. The ProMine Project Team received first Prize for the best project under

the EU Framework Programme for industrial technology at the 2014 Industrial Technologies Conference (Athens, Greece, 9-11 April 2014). The purpose of the geological element of the project was to deliver interactive GIS tools and 3D/4D models of deposits and mineralized belts (Weihed, 2015). These would in turn contribute to exploration for new resources of minerals – especially on strategic ones within the European Union. The main objectives of developing the GIS tool were:

1. To develop a geographic information system of primary and secondary mineral resources covering all European countries.
2. To produce predictive resource assessments.
3. To deliver this information through an on-line data management and visualization system.

The purpose of this was to provide a new model of European metallogeny, replacing the continental synthesis that was published by UNESCO (1984) over 25 years ago.

Three main targets were identified, implementing the latest developments in metallogeny and database management:

- Evaluation of EU primary mineral resources, including strategic and 'green' (Hocquard and Deschamps, 2008) commodities such as, for instance, Co, Ga, Ge, In, Nb, Ta, PGMs and REE.
- Evaluation of secondary mineral resources associated with metalliferous ores and industrial mineral deposits.
- Evaluation of potentially valuable mining and metallurgical residues.

These data acquisition activities and their dedicated databases allowed a homogeneous multi-layer information system to be developed and delivered online (available at http://ptrarc.gtk.fi/ProMine/default.aspx). This covered the whole European territory and included not only mineral deposit and mining wastes layers, but also geological, structural and geophysical layers. The work developing the GIS tool benefited from work already undertaken by Bureau de Recherches Géologiques et Minières (BRGM), such as the 'Geology' layer at 1:1 500 000 scale and the 'Mineral deposit' database which served as a basis for the project, reusing parts of the database architecture, the hierarchical lexicons, and records already input during various BRGM projects.

The completion of the inventory, i.e. entering missing deposits in a consistent way, ensuring that the level of knowledge and of representation was similar throughout Europe and that the mineral endowment of belts on which other tasks of the project focused was undertaken by the national geological surveys involved in the ProMine project. This GIS project provides a rational representation of Europe's mineral potential and facilitates the development of a predictive approach to Europe's mineral resource endowment.

The ProMine Mineral Deposit database

The ProMine Mineral Deposit (MD) database stores information related to mineral deposits in Europe (see Cassard et al., 2015, for detailed description of the database content). Each deposit is described in about 40 fields distributed in 8 folders (Annex A):

1. General information, including status, owner, location.
2. Deposit information, including deposit type and morphology.
3. Information on mineralization and host rocks, including age of mineralization and host rock, mineralogy of the ore, gangue, and hydrothermal alteration, host rock formation name and lithology.
4. Economic information, including the exploitation type, ore type, former production, reserves and resources; automatic assessment of potential[1], per commodity.
5. High-tech metals, characterization of high-tech metal host (mineralogy, grade) and link with the Anthropogenic Concentration (AC) database.
6. Comments (free text).
7. Iconography, including photographs, sketch maps, cross-sections, etc.
8. Bibliography, i.e. main geological and economic references related to the deposit.

Most fields that contain text values (i.e. non numerical) are lexicon guided, in order to improve the efficiency of future data processing. Lexicons are either simple (list of values), dynamic (list to which new values can be added) or hierarchical (tree-like list with parent/daughter relationships allowing storage of information according to its level of accuracy).

The total number of records in the MD database is 12,979. Records are showings, occurrences, mineral or ore deposits. The geographic distribution of records is, to a certain degree, heterogeneous as it reflects the availability and quality of knowledge of primary resources within EU Member States.

In addition to this database, the ProMine project produced 'added-value' products such as mineral potential maps or a map of the distribution of the 14 critical raw materials, as defined by the European Commission (2010).

Extracting CRM from the ProMine Mineral Deposit database

In order to extract data to be displayed on the CRM map of Europe, the ProMine Mineral Deposit database was queried (based on its commodity code-list) as detailed below for each commodity:

- Antimony: query for extracting significant (medium, large or super-large) antimony deposits was "(contained commodity = Sb) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Sb" is the code for antimony (metal) in the ProMine commodity code-list.
- Beryllium: query for extracting significant (medium, large or super-large) beryllium deposits was "(contained commodity = Be) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Be" is the code for beryllium (BeO) in the ProMine commodity code-list.
- Borates: query for extracting significant (medium, large or super-large) borates deposits was "(contained commodity = Bor) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where

1 Tonnage of commodity (metric tons of metal) in the ore body, based on its grade and the tonnage of ore.

"Bor" is the code for borates (B_2O_3) in the ProMine commodity code-list.

- Chromium: query for extracting significant (medium, large or super-large) chromium deposits was "(contained commodity = Cr) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Cr" is the code for chromium oxide (Cr_2O_3) in the ProMine commodity code-list.
- Cobalt: query for extracting significant (medium, large or super-large) cobalt deposits was "(contained commodity = Co) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Co" is the code for cobalt (metal) in the ProMine commodity code-list.
- Coking coal: the ProMine MD database contains information on coal deposits but does not specify whether they are of coking coal or other types. Therefore, coal deposits from the ProMine MD database were not displayed on the map. Only a few deposits (3) explicitly described as being coking coal by MREG members are displayed on the map.
- Fluorspar: query for extracting significant (medium, large or super-large) fluorspar deposits was "(contained commodity = Fl) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Fl" is the code for fluorspar (CaF_2), or fluorite, in the ProMine commodity code-list.
- Gallium: query for extracting significant (medium, large or super-large) gallium deposits was "(contained commodity = Ga) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Ga" is the code for gallium (metal) in the ProMine commodity code-list.
- Germanium: query for extracting significant (medium, large or super-large) germanium deposits was "(contained commodity = Ge) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Ge" is the code for germanium (metal) in the ProMine commodity code-list.
- Graphite: query for extracting significant (medium, large or super-large) graphite deposits was "(contained commodity = Gr) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Gr" is the code for graphite (substance) in the ProMine commodity code-list.
- Indium: query for extracting significant (medium, large or super-large) indium deposits was "(contained commodity = In) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "In" is the code for indium (metal) in the ProMine commodity code-list.
- Magnesite and magnesium: magnesite and magnesium are considered in the ProMine code-list as a unique commodity; therefore they are displayed in the CRM map as a unique commodity and the query for extracting significant (medium, large or super-large) Mg deposits from the ProMine MD database was "(contained commodity = Mg) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Mg" is the code for magnesium and magnesite ($MgCO_3$) in the ProMine commodity code-list.
- Niobium: query for extracting significant (medium, large or super-large) niobium deposits was "(contained commodity = Nb) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where

"Nb" is the code for niobium-columbium (Nb_2O_5) in the ProMine commodity code-list.

- Phosphate rock: query for extracting significant (medium, large or super-large) phosphate deposits was "(contained commodity = Phos) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Phos" is the code for phosphate (P_2O_5) in the ProMine commodity code-list.

- Platinum group metals: PGMs (platinum group metals) is a group of 6 elements (ruthenium, rhodium, palladium, osmium, iridium and platinum) that are listed in the ProMine MD database either as a group or as individual elements; query for extracting significant (medium, large or super-large) PGM deposits was "((contained commodity = Pltd) OR (contained commodity = Ru) OR (contained commodity = Rh) OR (contained commodity = Pd) OR (contained commodity = Osir) OR (contained commodity = Pt)) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "Pltd", "Ru", "Rh", "Pd", "Osir" and "Pt" are the codes for platinoids group (metal), ruthenium (metal), rhodium (metal), palladium (metal), osmiridium (metal) and platinum (metal), respectively, in the ProMine commodity code-list. Note however that the ruthenium commodity query criteria did not return any deposits, as the class thresholds are not defined for ruthenium in the ProMine commodity code list. This query could not extract any Ru-bearing medium to super-large deposits.

- Rare earth elements (light and heavy): the ProMine MD database does not make the distinction between light and heavy rare earth elements, so they are grouped in the CRM map; query for extracting significant (medium, large or super-large) rare earth elements-deposits was "(contained commodity = REE) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "REE" is the code for undifferentiated rare earth elements oxide (RE_2O_3) in the ProMine commodity code-list.

- Silicon metal: silicon metal is not listed in the ProMine commodity code-list; only silica and silica sands are. Therefore, potential silicon deposits are not displayed in the CRM map.

- Tungsten: query for extracting significant (medium, large or super-large) tungsten deposits was "(contained commodity = W) AND ((deposit size class = A) OR (deposit size class = B) OR (deposit size class = C))", where "W" is the code for wolfram (WO_3) in the ProMine commodity code-list.

Note that the deposit size classes A, B and C in the ProMine MD database are super large, large and medium deposits, respectively. These classes are based on thresholds that are defined for each commodity. Thresholds for classes A to C are listed, per commodity, in Annex B below.

After this dataset was extracted from the ProMine MD database, it was been circulated to the Mineral Resources Expert Group in order to update and complete it. This final listing was the database used to compile the CRM Map.

Drawing the CRM map

Deposits containing CRM are displayed on the map with symbols of different shapes and color, according to the commodities. Note that if a deposit contains several critical commodities, only the uppermost displayed is visible on the map. Symbols are sized according to the class ("size") of the deposit for the commodity concerned. Deposits displayed on the map are labeled, using their usual name. Note that some deposits may have several names. In such cases, the most commonly used name is displayed.

The background map, for inland Europe, is the 1:1,500,000 Geological Synthesis of Europe (Billa et al., 2008). This map is one of the 'deliverables' of the BRGM R&D project 'GIS Europe' that was initially undertaken as part of the ESF (European Science Foundation) GEODE (Geodynamics and Ore Deposit Evolution) programme, ABCD (Alpine-Balkan-Carpathian-Dinarides) sub program. The first synthesis produced within this programme (Metallogenic Map of Central and Southeastern Europe) was later completed with scientific input from several projects,e.g. SIG Mines France (BRGM);, GIS Karelia (RFML – Russian-French Metallogenic Laboratory), GIS Caucasus (BRGM – CNRS) . The coverage has mainly been created by digitization and synthesis of published national geological maps after applying a standardized legend based on the age and the lithology of the mapped units. The input maps from all countries have been published at a 1:500,000 scales or less and permits verification of the synthesis at a 1:1,500,000 scale. Some key areas, such as the Alps, have been completely redrawn. The Fenno-Scandinavian part of the map has been produced by the Geological Surveys of Finland, Norway, Russia and Sweden.

The background map for offshore areas is the ESRI's Ocean basemap (Sources: ESRI, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors). According to the ESRI description, this map "was compiled from a variety of best available sources from several data providers, including General Bathymetric Chart of the Oceans GEBCO_08 Grid version 20091120, IHO-IOC GEBCO Gazetteer of Undersea Feature Names, August 2010 version National Oceanic and Atmospheric Administration (NOAA), National Geographic, and Esri. The base map currently provides coverage for the world down to a scale of ~1:1m. The base map was designed and developed by ESRI."

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Annex A

ProMine Mineral Deposit database fields

1. General Information

- Lexicon guided fields:
- Status: detailed information on mine, deposit, occurrence, showing.
- Country: link to list of countries.

Free text fields:

- Mining company (owner); Mining District.
- Longitude (xx.xxx° and xx°xx'xx''), Latitude (xx.xxx° and xx°xx'xx'') (WGS 84).
- Ore deposit name(s): multi-entry field to list all possible names of the same deposit.
- Free comment field.
- Author, date of entry, Controller and date of control.
- Links to other databases and numbering in these databases.
- URL + source of the mine site (if any).

2. Deposit information

Lexicon guided fields:

- Deposit type(s): multi-entry field of deposit type hierarchical listing.
- Main morphology and Deposit morphologies: multi-entry field of deposit morphology hierarchical listing.

Free text fields:

- Azimuth, dip, length, width, down dip information associated with ore morphology.

3. Information on mineralization and host rocks

Lexicon guided fields:

- Mineralization stratigraphic age (upper and lower limit).
- Ore mineralogy, Gangue mineralogy, Hydrothermal alteration: multi-entry fields.
- Host rock lithologies: multi-entry field and Host rock stratigraphic age (upper and lower limit).

Free text fields:

- Mineralization absolute age, Host rock absolute age (with error and dating method from lexicon).
- Host rock formation name.

4. Economic information

Lexicon guided fields:

- Exploitation type(s): multi-entry field.
- Main commodity.
- Multi-commodity window: per commodity:
  - ore type; production and grade units.
  - former production, grade of former production, duration of former production.
  - reserve, type of reserve (proven, probable, measured, ...), grade of reserve, year of estimate, classification code used.
  - resource, type of resource (proven, probable, measured, ...), grade of resource, year of estimate, classification code used.
  - automatic calculation of i) former production, ii) reserves, iii) resources and iv) deposit size class.

5. High-Tech Metals

Lexicon guided fields:

Per commodity

- Characterization of high-tech metals hosts (mineralogy, grade, abundance).

➔ Possibility to create a link with the Anthropogenic Concentration (AC) database.

6. Comments

- General comments on geology, General comments on economy, Mine site infrastructure.

7. Iconography

- Illustrations (photographies, schemas, cross-sections, etc.) related to the deposit.

8. Bibliography

- Geological reference(s), Economic reference(s).

Annex B

Class thresholds for critical raw materials in the ProMine Mineral Deposit database.

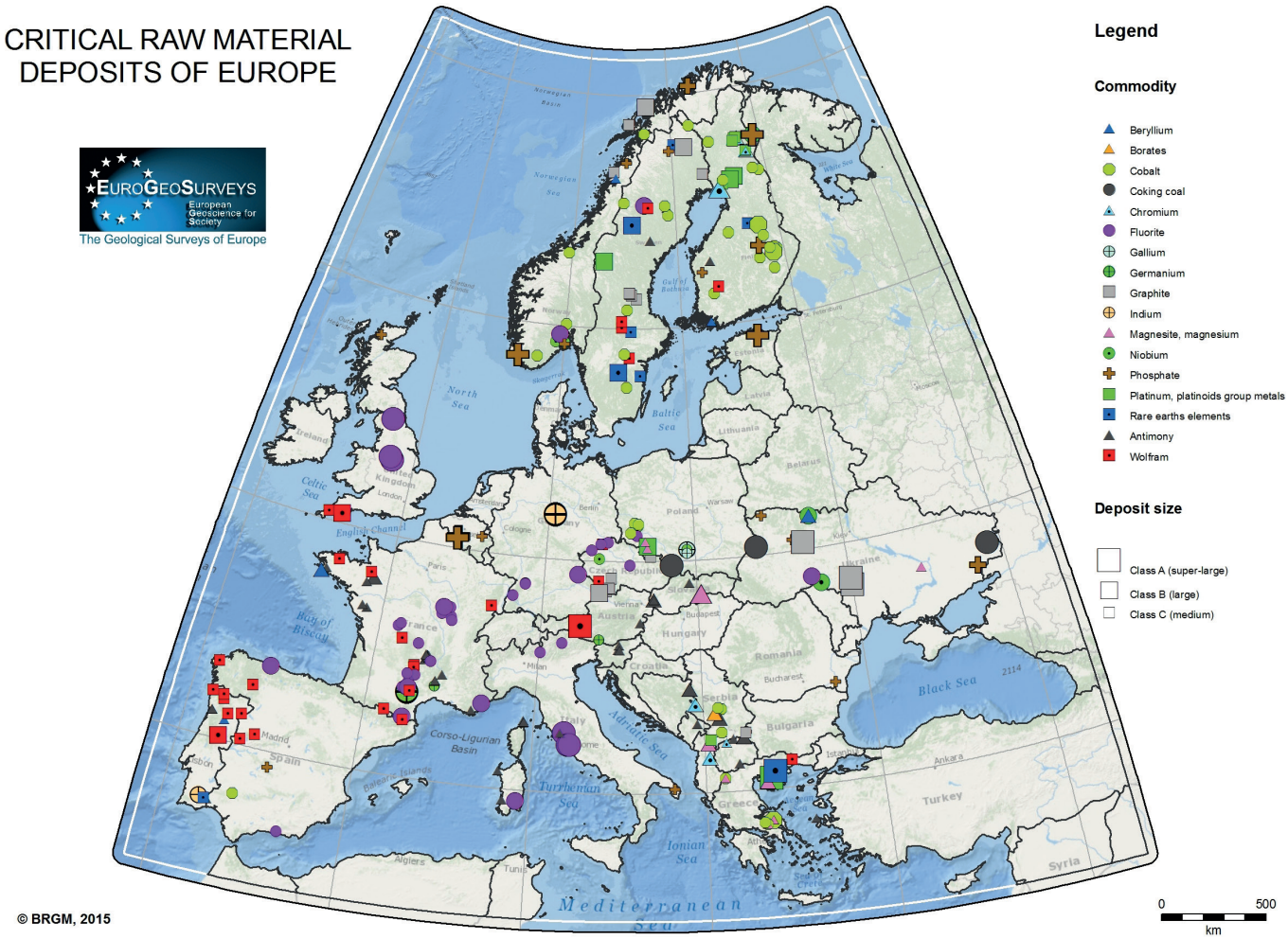
Commodity code	Commodity name (from the ProMine commodity code list)	Class A deposits (super large)*	Class B deposits (large)*	Class C deposits (medium)*
Be	Beryllium (BeO)	20,000	2,000	200
Bor	Borates (B_2O_3)	25,000,000	2,000,000	100,000
Co	Cobalt (metal)	500,000	50,000	2,000
Coal	Coal, lignite (sub-stance)	1E+10	1,000,000,000	100,000,000
Cr	Chrome (Cr_2O_3)	25,000,000	5,000,000	1,000,000
Fl	Fluorite (CaF_2)	5,000,000	1,000,000	200,000
Ga	Gallium (metal)	100	50	10
Ge	Germanium (metal)	500	100	20
Gr	Graphite (substance)	10,000,000	1,000,000	100,000
In	Indium (metal)	500	100	25
Mg	Magnesium, magnesite ($MgCO_3$)	100,000,000	10,000,000	1,000,000
Nb	Niobium - columbium (Nb_2O_5)	1,000,000	100,000	10,000
Osir	Osmiridium (metal)	25	5	1

Commodity code	Commodity name (from the ProMine commodity code list)	Class A deposits (super large)*	Class B deposits (large)*	Class C deposits (medium)*
Pd	Palladium (metal)	1,000	100	10
Phos	Phosphate (P_2O_5)	200,000,000	20,000,000	2,000,000
Pltd	Platinoids, group (metal)	1,000	100	10
Pt	Platinum (metal)	1,000	100	10
REE	Rare Earths (RE_2O_3)	1,000,000	100,000	10,000
Rh	Rhodium (metal)	25	5	1
Ru	Ruthenium			Not defined
Sb	Antimony (metal)	100,000	25,000	2,000
W	Wolfram (WO_3)	200,000	50,000	5,000

*in metric tonnes of commodity

Annex C

Map of critical raw materials deposit of Europe



Annex D

List of EuroGeoSurveys Mineral Resource Expert Group (MREG) members

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Czech Republic	CGS	Ivo Sitensly
		Petr Rambousek
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		Diogo Rosa
		Karen Hanghoj
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