MSP-REFRAM

Coordination and Support Action (CSA)

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Mapping the primary resources in the EU

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Summary

Mapping the primary resources in the EU

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NOTE TO THE MAP OF REFRACTORY METAL DEPOSITS IN EUROPE

MSP-REFRAM deliverable D2.1

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CONTENT

INTRODUCTION

This document describes the Map of Refractory Metal Deposits in Europe, released in April 2016 by work package 2 of the MSP-REFRAM project, how it was produced, and what information it displays. This map is the official deliverable (D2.1) of the task 2.1 of the project. It shows European mineral deposits from the ProMine, Minerals4EU, FODD and GKR databases as containing refractory metals in the scope of the project (Mo, Re, Nb, Ta and W).

The following sections briefly present:

- The MSP-REFRAM and more specifically its task 2.1;
- The scope of the deliverable;
- The world production of refractory metals from primary ore, in order to help replace the European potential and production in a more global context;
- The sources of data that were used to produce the map;
- The map itself, and data layers it displays.

THE REFRAM PROJECT

The following sections briefly describe the MSP-REFRAM project, its work package 2 and task 2.1, in order to replace the present work in its context.

OVERVIEW OF THE PROJECT

Refractory metals (tungsten, tantalum, rhenium, molybdenum and niobium) are highly strategic raw materials. Today, with the exception of rhenium, these metals are mainly imported from China (W, Mo, and Ta), Brazil (Nb and Ta), Chile (Mo and Re) but also from the USA, Canada, etc. The European primary production is only a small percentage of the global production of these metals, with only rhenium being produced in significant amounts in the EU (in Poland), and tungsten being produced in Austria, Spain and Portugal. However, refractory metals resources, either primary or secondary, exist in Europe.

In this context, MSP-REFRAM is contributing to improve the refractory metals supply chain by identifying:

- Primary and secondary resources of refractory metals available for Europe;
- New technologies that could be developed for refractory metals production, with a focus on the secondary resources;
- Substitution strategies, trends and pathways related to these metals;
- New markets and business models;
- Regulations and standards to be changed or established for facilitating new markets to emerge.

The objective of MSP-REFRAM is to establish a long-lasting multi-stakeholder platform which will carry out a comprehensive study of the whole value chain of key refractory metals including mining, processing, recycling and final applications (and potential substitution opportunities) in relation with the crosscutting aspects: policy/society, technology and market. This will contribute to strengthen the refractory metals supply-chain in Europe.

OVERVIEW OF TASK 2.1

The objective of task 2.1 of MSP-REFRAM is to produce a map of primary resources of refractory metals (including, whenever data is available, resource, reserves, mineralogy and chemistry) in Europe.

This mapping of primary resources of five refractory metals in Europe will, in turn, help in:

- identifying the available and innovative mining technologies,
- reviewing the existing technologies of mineral processing and extractive metallurgy,

- investigating the innovative technologies,
- evaluating the wastes, including mineral processing tailings and metallurgical slags, with specific attentions to the waste amount reduction, environmental impacts, recovery of valuable trace elements and potential utilisations as construction materials.

As such, task 2.1 is an upstream step of the project that will deliver critical information on primary resources of refractory metals in Europe to other tasks and work packages of the project.

TASK PARTNERS

Three partners of the MSP-REFRAM consortium are involved in the task 2.1. They are BRGM (task leader), e-Mines and GTK.

BRGM

BRGM, the French geological survey, is France's reference public institution for Earth Science applications in the management of surface and subsurface resources and risks. Its key objectives are 1) to understand geological processes and associated risks, 2) to develop new methodologies and techniques, 3) to produce and disseminate data to support the management of soils, subsoils and resources, and 4) to deliver the necessary tools for the management of soils, subsoils and their resources, risk prevention and policy responses to climate change. BRGM activities cover many topic areas that are managed by 6 operational divisions amongst which two, the Mineral Resources Division and the Environment and Ecotechnologies Division are directly involved in the MSP-REFRAM.

The Mineral Resources Division covers all aspects of knowledge on mineral raw materials and their management, including economics, assessments of reserves, substance life cycles, expert site studies and process management. The aim is to contribute to the security of supplies.

The priority areas of the Environment and Ecotechnologies Division are site surveillance and rehabilitation, polluted soils and sediments and management of household, industrial and mining waste, as well as research and development on ecotechnologies to support clean treatment processes is a key area of development.

In addition, BRGM has been strongly involved in EU-funded project related to minerals resources in Europe (ProMine, Minventory, Minerals4EU, EURARE, ProSum, MICA, …). For instance, it was leader of the work packages dedicated to the creation of the mineral deposit

database in the ProMine project and to the creation of the European Minerals Knowledge Data Pleatform (EU-MKDP) in the Minerals4EU project.

In addition of being leader of task 2.1, the main contribution of BRGM was to produce the layer of deposits containing reported amounts of refractory metals, to finalize other layers of deposits and occurrences, to provide additional layers (lithology and tectonic structures) and to edit the map and the present note.

E-MINES

E-MINES is an expert services company created in 2011. Its head office is in Ariège, southern France. Its activity includes (but is not limited to) Research & Development in metallogeny and expert services to exploration companies.

E-MINES has two main domains of activities, that are:

- research and development, essentially for its proprietary GKR software, an expert system developed with internal resources to produce expertise in the domain of mineral resources in a broad sense;
- Support activity and expertise, essentially for mining exploration companies, and environmental studies.

The company funds Ph.D. theses, in collaboration with academic partners, to strengthen its scientific and technical development. It is currently supervising two Ph.D. students. One of them works on primary tungsten resources in the Pyrenees, the other one works on antimony in Vendee. Those theses not only help strengthening the scientific development and expertise of the company, they also participate, more globally, in a better understanding of metallogeny in the French geological context.

In addition, E-MINES has set up a laboratory of analysis and is developing an X-Ray method to measure metal concentration in soils or rocks samples. This method is non-disruptive and non-destructive, and therefore allows unlimited re-analyses of the samples. It is also designed to be more eco-efficient than other analysis techniques, such as agua regia or acid attacks (no needs for water, for instance).

The company also offers management and logistic services for samples collected by geologists from client exploration companies. The laboratory follows a strict protocol for samples preparation and analyses, and has been granted the ISO 9001 quality certification in 2015.

The main contribution of E-MINES, in task 2.1 of MSP-REFRAM, was to compile in its database (GKR) the data provided by other task partners, in order to identify all known deposits and occurrences containing refractory metals across Europe and to produce the dataset of deposits and occurrences containing refractory metals.

GTK

The Geological Survey of Finland (GTK) is a European centre of excellence in assessment, research and sustainable use of natural resources. GTK provides expertise that serves the interests of its clients, stakeholders and society as a whole. Working closely with its clients and partners, it creates solutions that lead to new technologies and business areas, as well as promote sustainable growth.

GTK is an expert organisation under Finland's Ministry of Employment and the Economy. It employs approximately 460 full-time staff and is effectively engaged in tasks at the local, national and international level. Its aim is to create innovative science, technology and applications and to produce and disseminate geological information and promote viable economic activity based on natural resources.

In addition of being leader of work package 2 of MSP-REFRAM, GTK's involvement in task 2.1 was essentially to extract and provide relevant data on refractory metal deposits from the Fennoscandian Ore Deposit Database (FODD).

WORKPROGRAM OF THE TASK

The schedule of task 2.1 was extremely tight, as the present deliverable was due by month 5 of the project timeline. In order to ensure maximum efficiency, a pragmatic work program was set up in the first days of the project and was adapted during the realization of the task. Its main steps were the followings:

1) BRGM and GTK extracted relevant data from databases they have in charge (ProMine and Minerals4EU for BRGM, FODD for GTK). Relevant data was deposits and/or occurences known as containing at least one of the 5 refractory metals in scope. Database extracts were kept simple (Microsoft Excel files) to facilitate merging and compilation. This was completed before the end of January 2016.

2) the extracted datasets (excel files) were fed in the GKR system by E-MINES, in order to facilitate their compilation with the large quantity of data already in the GKR. Then, the GKR was queried to extract a dataset of all deposits and occurrences containing refractory metals in Europe. This was completed by the end of April 2016.

3) In the meantime, as the dataset extracted from the GKR was providing little information on resources and reserves, another dataset of deposits containing reported amount of refractory metals was built by BRGM. This was based on data exported from ProMine, completed by additional information from the Minerals4EU and FODD databases. This was completed by the end of April 2016.

4) In the meantime, BRGM prepared a layout for the final map, in ESRI's ArcGIS software. This was done during April 2016.

5) The final datasets were then imported in ArcGIS to be displayed on the map with the proper symbology. In the meantime, the present note was prepared. This allowed editing the final version of the deliverable by the end of April 2016, accordingly to the timeline of the task.

SCOPE OF THE DELIVERABLE

COMMODITIES

Commodities investigated in the present deliverable are the five refractory metals in scope of the MSP-REFRAM project, i.e. molybdenum, niobium, tantalum, rhenium and tungsten. The purpose of the deliverable is to identify primary mineral resources containing one or more of these five commodities, either as main commodity or as by-product.

GEOGRAPHIC COVERAGE

The geographic coverage of the present deliverable is Europe, not in the sense of the 28 member states of the European Union, but in a broader "geographic" sense. Therefore, several European countries that are not EU-28 member states, as well as "close neighbour" countries are included in the scope of this deliverable (e.g. Norway, Switzerland, Ukraine, Balkan countries, etc …). In addition, statistics on world production of the commodities in scope were collected and are presented in the following chapter, in order to help replace the European potential in a more global context.

WORLD PRODUCTION FROM PRIMARY ORE

The following sections present the primary world production for the five refractory metals in scope of MSP-REFRAM. The source of this information is the Mineral Commodity Summaries[1] published by the U.S. Geological Survey on an annual basis. For each of the five commodities, the contribution of the European Union to the world production is highlighted, in order to help replace it in a more global context.

MOLYBDENUM

According to the statistics presented in Table 1 and Figure 1, the world mine production of molybdenum in 2014 was essentially concentrated in 3 countries: China (36.68% of the total world production), the United States (24.29%) and Chile (17.37%). Other countries played a minor yet significant role, such as Peru (6.06%) and Mexico (5.12%). The contribution of the European Union to the world mine production of molybdenum was null as no EU-28 member state is mining molybdenum.

MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of contained molybdenum)

Country[3]	2010	2011	2012	2013	2014[e]
Armenia	4 335	4 817	6 500	6 700	7 100
Canada	8 524 [r]	8 543 [r]	8 936 [r]	7 956 [r]	9 698 [4]
Chile	37 186	40 889	35 090	38 715	48 770 [4]
China[e]	96 600	103 000	105 000	101 000	103 000
Iran[e]	3 900	3 400	3 900	4 000	4 000
Mexico	10 849	10 787	11 366	12 562 [r]	14 370
Mongolia	2 198	1 960	1 903	1 815 [r]	1 999 [4]
Peru	16 963	19 141	16 790	18 140	17 018 [4]
Russia	5 777 [r]	6 014 [r]	4 939 [r]	4 753 [r]	4 800
Turkey	--	2 848	-- [r]	1 240 [r]	1 300
United States	59 400	63 700	61 500	61 000 [r]	68 200
Uzbekistan[e]	500	557 [4]	522 [4]	530	530
Total	246 000 [r]	266 000 [r]	256 000 [r]	258 000	281 000

[e]Estimated. [r]Revised. -- Zero.
[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes data available through July 20, 2015.
[3]In addition to the countries listed, the Republic of Korea, Kyrgyzstan, and Romania are thought to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.
[4]Reported figure.

Table 1 – Molybdenum, world mine production, by country (source: USGS, 2016a).

[1] Available at http://minerals.usgs.gov/minerals/pubs/mcs/

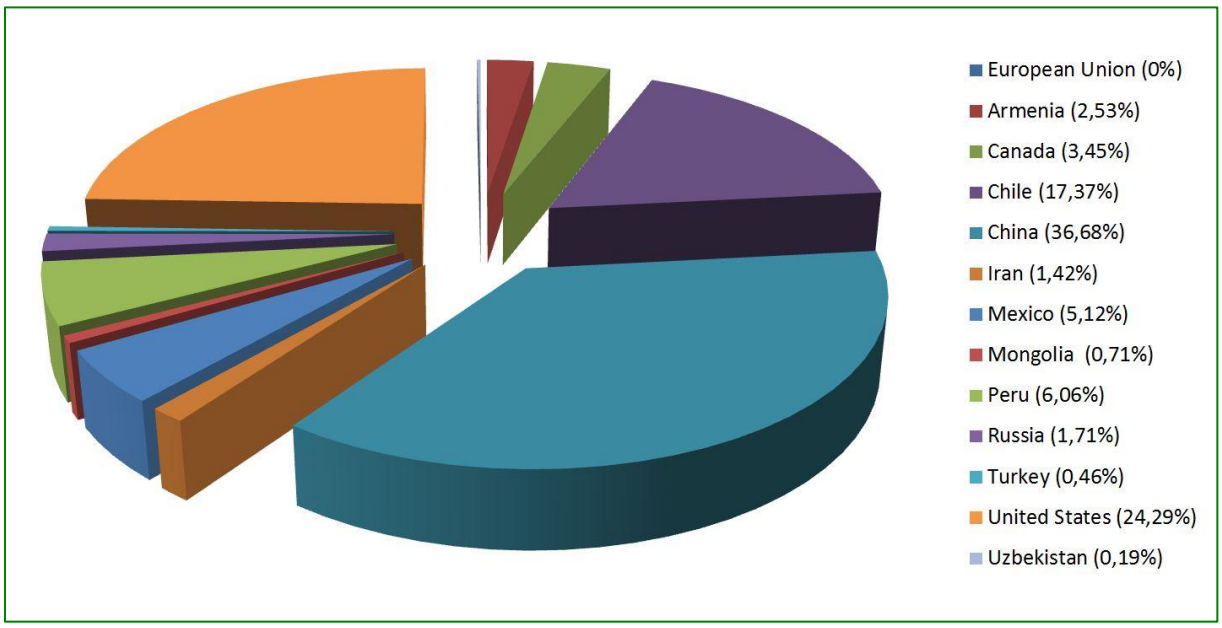

Figure 1 – Geographic distribution of the 2014 molybdenum mine production (in percent of the total world production), and contribution from the European Union.

NIOBIUM AND TANTALUM

According to the numbers presented in Table 2 and Figure 2, the production of niobium concentrate in 2013 was essentially concentrated in Brazil, with nearly 90 % of the total world production. Canada played a significant role with 9.18 % of the world production. The combined contribution of all other producing countries was negligible and amounts to less than 1 %. The contribution of the European Union to the world production of niobium concentrate was null.

Concerning tantalum (Table 2 and Figure 3), Rwanda provided almost 50 % of the 2013 world production of concentrate. Other countries, such as Congo and Brazil, played a lower but still significant role (16.56 % and 12.58 %, respectively). Similarly to niobium concentrate, the contribution of the European Union to the world production of tantalum concentrate was null.

NIOBIUM AND TANTALUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

	Gross weight[3]					Niobium content[4]					Tantalum content[4]				
Country[5]	2009	2010	2011	2012	2013[e]	2009	2010	2011	2012	2013[e]	2009	2010	2011	2012	2013[e]
Australia, columbite-tantalite[6]	318	--	--	--	--	--	--	--	--	--	86	50 [r]	50 [r]	50 [r]	50
Bolivia, tantalite	--	3	17	42	47 [7]	--	--	--	--	--	--	1	4	9	10
Brazil:															
Nb minerals[e, 8, 9]	159 000 [r]	113 000 [r]	115 000 [r]	147 000 [r]	136 000	62 159 [7]	44 270 [7]	45 198 [7]	57 471 [r, 7]	51 497 [7]	--	--	--	--	--
Ta minerals[6, 10]	473 [r, e]	587 [r, e]	453 [r, e]	393 [r, e]	400	--	--	--	--	--	116 [r]	144 [r]	111 [r]	98 [r]	152
Burundi	44	67	159 [r]	259 [r]	74	9	13	31 [r, e]	51 [r, e]	14	9	13	31 [r, e]	50 [r, e]	14
Canada:															
Nb minerals[9]	1 773 000	1 792 000	2 087 000	2 155 000	2 300 000	4 330	4 419	4 632	4 707	5 263 [7]	--	--	--	--	--
Ta minerals[e, 6, 10]	110 [7]	--	40 [r]	80 [r]	20	5	--	1 [r]	3 [r]	1	24 [r]	--	-- [r]	37 [r]	9
China[e]	NA	NA	NA	NA	NA	21	22	17	14	15	74	70	61	66 [r]	60
Congo (Kinshasa):															
Cassiterite concentrate	15 512	13 415	9 267	8 018	6 231	150	130	90	80	60	220	190	140	120	90
Columbite-tantalite[11]	464 [r]	440 [r]	536 [r]	586 [r]	500	80 [r]	80 [r, e]	90 [r, e]	100 [r, e]	90	100 [r, e]	100 [r, e]	120 [r, e]	130 [r, e]	110
Nb minerals[e]	80	--	--	-- [7]	--	40	--	--	-- [7]	--	--	--	--	-- [7]	--
Ethiopia, tantalite[12]	398	252	285	380 [r, e]	50	28	22	25	26 [r, e]	4	99	82 [8]	95 [8]	91 [r, e]	10
French Guiana, columbite tantalite[e]	2	2	2	2	2	--	--	--	--	--	(13)	(13)	(13)	(13)	(13)
Kazakhstan, niobium	NA	NA	NA	43	44	NA	NA	NA	--	--	NA	NA	NA	(13)	(13)
Mozambique[e]	405 [7]	55 [7]	139 [7]	408 [r, 7]	211	29	4	10	29 [r]	15	83 [r]	15	39	83 [r]	43
Nigeria, columbite- tantalite[e]	331	281	311	310	300	23	20	22	22	21	68	58	64	63	60
Rwanda[e]															
Cassiterite concentrate	4 210	5 290	6 950	4 640	4 900	40	50	70	50	50	60	80	100	70	70
Columbite-tantalite	952	560	890 [7]	1 145	2 466	120	70	110	140	310	200	120	190	240	530
Somalia[e, 14]	7	--	--	--	--	2	--	--	--	--	2	--	--	--	--
Uganda[e]	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)
Total	1 960 000 [r]	1 930 000 [r]	2 220 000 [r]	2 320 000 [r]	2 450 000	67 000 [r]	49 100 [r]	50 300 [r]	62 700 [r]	57 300	1 140 [r]	923 [r]	1 005 [r]	1 107 [r]	1 208

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]World total and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Except for Congo (Kinshasa) and Rwanda, excludes production of niobium and tantalum contained in tin ores. Includes data available through August 25, 2015.
[3]Gross weight is weight of concentrate before metal is extracted.
[4]Content is weight of metal produced. Nb_2O_5 is 69.904% niobium; Ta_2O_5 is 81.897% tantalum.
[5]In addition to the countries listed, Russia was thought to have produced niobium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.
[6]Tantalum production reported in Ta_2O_5 converted to tantalum content. Gross weight is concentrate assumed to be one-third Ta_2O_5.
[7]Reported figure.
[8]Niobium concentrate production reported in Nb_2O_5 content converted to niobium content. Gross weight is concentrate assumed to be one-third Nb_2O_5.
[9]Includes columbite and pyrochlore.
[10]Includes djalmaite and tantalite.
[11]Reported data includes the North Kivu and South Kivu Provinces.
[12]Data are for fiscal year beginning July 1 of that stated.
[13]Less than ½ unit.
[14]From August 2008 to April 2009, 18 metric tons of columbite-tantalite were reportedly produced in Somalia. It is unclear if production continued after early April 2009.

Table 2 - Niobium and tantalum, world production of mineral concentrates, by country (source: USGS, 2015a).

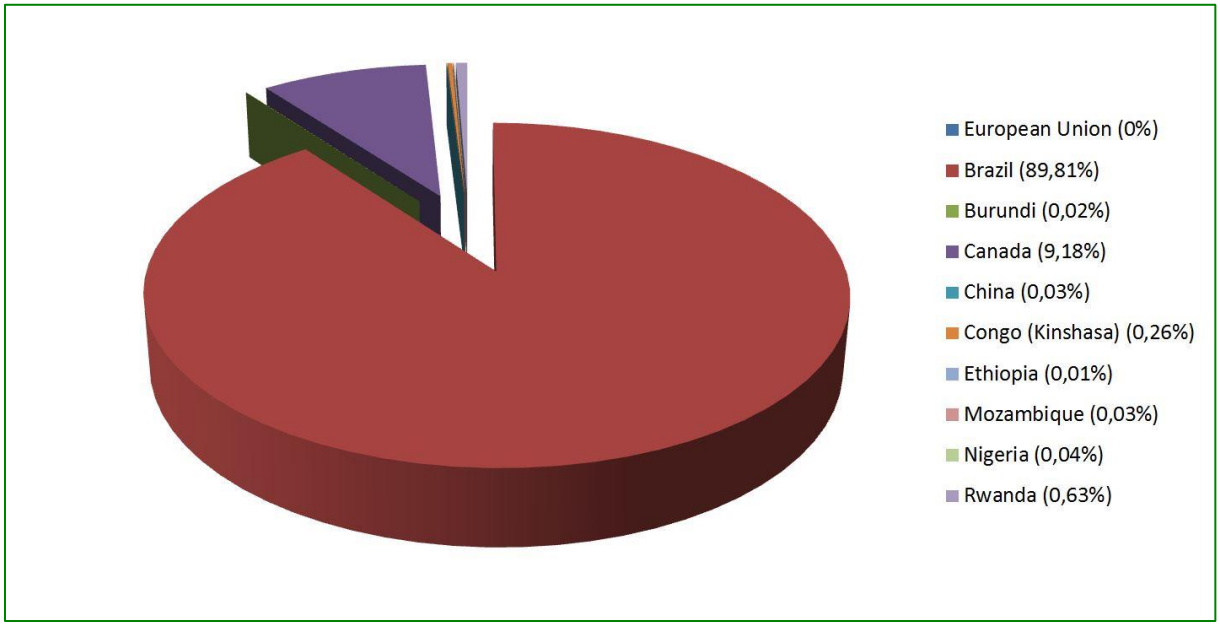

Figure 2 – Geographic distribution of the 2013 production of niobium concentrates (in percent of the total world production), and contribution from the European Union.

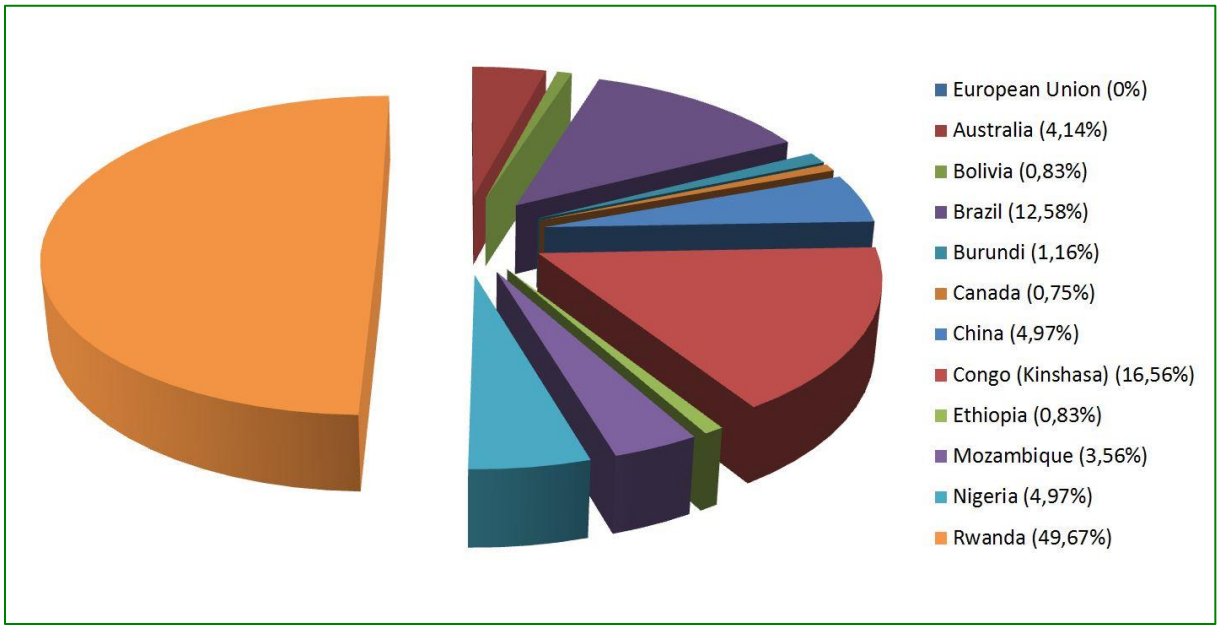

Figure 3 - Geographic distribution of the 2013 production of tantalum concentrates (in percent of the total world production), and contribution from the European Union.

RHENIUM

The world production of rhenium in 2014 (Table 3 and Figure 4) was highly concentrated in Chile (55.99 %). The two other important producers were the United States (19.04 %) and Poland (17.02 %). Therefore, owing to the Polish production, a significant amount of rhenium was produced within the European Union.

RHENIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country[3]	2010	2011	2012	2013	2014
Armenia	183 r	254 r	293 r	298 r	351
Chile[4]	25 000	24 000	27 000	25 000	25 000
Kazakhstan	3 000	3 000	3 000	2 500	300
Poland[5]	4 656 6	6 000 6	8 075 6	7 530 6	7 600
United States[6, 7]	6 100	8 600	7 900	7 100	8 500
Uzbekistan	1 200 r	1 200 r	1 200 r	900 r	900
Other[8]	1 500	1 500	1 200	1 000	2 000
Total	41 600 r	44 600 r	48 700 r	44 300 r	44 700

rRevised.
[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes data available through June 15, 2014.
[3]In addition to the countries listed, China and Russia also produce rhenium but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.
[4]Includes rhenium contained in molybdenum concentrates from Belgium, Mexico, Peru, and the United States processed at Molymet in Chile.
[5]Based on information from KGHM Ecoren S.A. Calculations based on 69.2% rhenium content of ammonium perrhenate.
[6]Reported figure.
[7]Calculated rhenium contained in molybdenite concentrates. Data are rounded to two significant digits.
[8]Includes estimates for Japan, the Republic of Korea, and Mongolia.

Table 3 - Estimated rhenium world production, by country (source: USGS, 2016b).

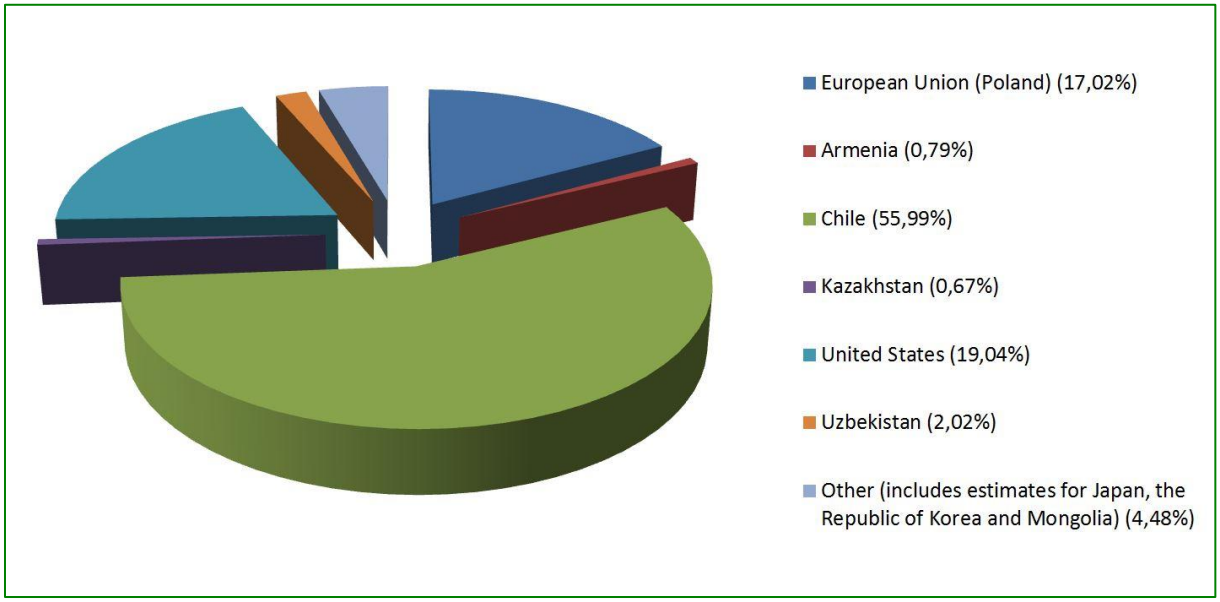

Figure 4 – Geographic distribution of the 2014 rhenium production (in percent of the total world production), and contribution from the European Union.

TUNGSTEN

The world production of tungsten concentrate in 2013 (Table 4 and Figure 5) was distributed over a quite large number of countries, although 83.58 % of it was concentrated in China. As a consequence, the contribution of other countries was limited and seldom exceed a few percent (e.g. 4.42 % in Russia, 2.62 % in Canada, 2.04 % in Vietnam,…). The contribution of the European Union was low but still significant, with 2.52 % of the world total, by combining the production of Austria, Portugal and Spain.

TUNGSTEN: WORLD CONCENTRATE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, tungsten content)

Country[3]	2009	2010	2011	2012	2013[e]
Australia	33	18 [r]	15	290 [r]	320 [4]
Austria	887	977	861 [r]	706 [r]	850 [4]
Bolivia[5]	1 023	1 204	1 124	1 247 [r]	1 253 [4]
Brazil	192	166	244 [r]	381 [r]	380
Burma[e, 6]	87 [4]	163 [4]	140	140	140
Burundi	110 [r]	100 [r]	165 [r]	190 [r]	50
Canada	1 964	420	1 966 [r]	2 194	2 128 [4]
China[e]	51 000	59 000	61 800	64 000	68 000
Congo (Kinshasa)[e, 7]	200	25	70	95	830
Korea, North[e, 8]	100	110	110	100	65
Mongolia	39	20	13	66 [r]	-- [4]

Peru[9]	502	571	439	276	28 [4]
Portugal	823	799	819	763	692 [4]
Russia	2 665	2 785	3 314	3 537 [r]	3 600
Rwanda[e]	380 [r]	330 [r]	520 [r]	700 [r]	730
Spain	225 [r]	240 [r]	497	542	510
Thailand[e, 10]	190	300	160	80	100
Uganda	7	44	8	21	20
United States	NA	NA	NA	NA	NA
Vietnam[11]	725	1 150	1 635	1 050	1 660 [4]
Total	61 200	68 400 [r]	73 900	76 400 [r]	81 400

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through September 3, 2014.

[3]Tungsten concentrates are thought to be produced in Colombia and Nigeria, and may be produced from tin-tungsten ores in Kyrgyzstan, but information is inadequate to make reliable estimates of production.

[4]Reported figure.

[5]Production estimated based on reported exports.

[6]Includes tungsten content of tin-tungsten concentrate produced by state-owned mining enterprises under the Ministry of Mines.

[7]Production estimated based on reported exports from NordKivu and SudKivu Provinces.

[8]Production estimated based on Chinese imports.

[9]Data for 2009–12 are based on production reported by Malaga Inc.; datum for 2013 based on production reported by the Ministry of Energy and Mines.

[10]Based upon data from the Department of Primary Industries and Mines.

[11]Mine production reported by the International Tungsten Industry Association.

Table 4 – Tungsten, world concentrate production, by country (source: USGS, 2015b).

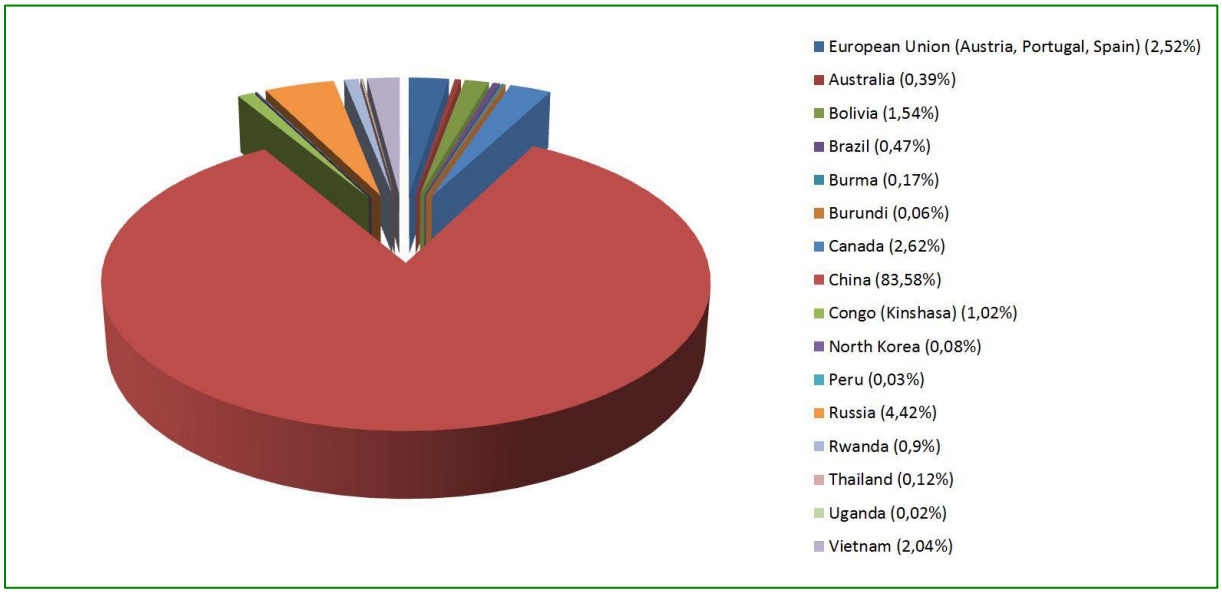

Figure 5 – Geographic distribution of the 2013 tungsten concentrate production (in percent of the total world production), and contribution from the European Union.

SOURCE OF DATA

The following sections describe the sources of data that were used to complete the present work, i.e. the ProMine, Minerals4EU, FODD and GKR databases, and how they were queried and processed. Note that the present work is inherently limited by the quality of these data sources that, despite their high level of expertise, contain information that is not exhaustive and that reflects the knowledge that prevailed at the time it was acquired.

SOURCE DATABASES

GKR

GKR stands for "Geological Knowledge Representation". It is an expert system that uses a new approach of geological data for mineral exploration and mining. Schematically, the software is based on wiki-type encyclopaedia architecture. All words of lexicon are interlinked, using ontologies. Unlike “classic” databases that are constrained by their data model, it makes it a powerful tool to make complex queries. It is able, for instance, to identify pertinent links with some concepts or words in documents even though their authors did not use them. For instance, the GKR is able to find information on rare earth elements in old documents and articles (1970’s and before) when they were not described or sought for. In this regard, the GKR was well-suited for identifying a large number of deposits and occurrences containing refractory metals across Europe.

Today, the potential for reinterpretation of thousands of occurrences is huge. For the time being, the system contains more than 700 000 occurrences worldwide. If properly used, it can produce key information to support expertise in the domain of mineral resources.

GKR is mainly used by mining companies, in order to help them organize or select relevant information to choose and evaluate projects. It is possible, for instance, to make a ranking in the huge dataset of mineral occurrences. GKR allows the user many possibilities to manage and process the information (e.g. modify content of tables, add information, link to documents or sources, etc …).

PROMINE

ProMine was a European Union (EU) co-funded project. It lasted for 4 years and ended in 2013. It was completed by a consortium of 27 partners from 11 countries, under the coordination of GTK. The purpose of the project was to develop new nano-particle products

from mineral resources, in order to stimulate the extractive industry to deliver new products to the manufacturing industry. The purpose of the geological parts of the project was to deliver interactive GIS tools and 3D and 4D models of deposits and mineralized belts. These would in turn contribute to define new reserves of minerals – with a special focus on strategic ones - in the European Union, so that the extractive industries can quantify and exploit in the future, and which could be the source of raw materials for the manufacturing industries. Therefore, one work package was dedicated to the identification of mineral resources in Europe. This was done by, amongst other tasks, developing databases of mineral deposits (MD) and anthropogenic concentrations (AC, i.e. mining and processing wastes) (Cassard et al., 2015).

The MD database stores the information related to mineral deposits in Europe. Each deposit is described in about 40 fields distributed in several folders: 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, and, per commodity, ore type, former production, reserves, and resources with associated grades; automatic calculation of the potential, per commodity; 5) High-tech metals with, per commodity, the characterization of high-tech metals hosts (mineralogy, grade, abundance) and link with the Anthropogenic Concentration (AC) database; 6) Comments (free text); 7) Iconography, including photographs, sketch maps, cross-sections, etc. and 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 father/son relationships allowing storage of information according to its level of accuracy).

The total number of records in the MD database is approximately 13,000, in 34 countries. Records are either showings, occurrences or mineral and 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. The ProMine databases and information layers can be accessed online via the ProMine portal at http://ptrarc.gtk.fi/ProMine/default.aspx

Minerals4EU was a follow-up of the ProMine project, that lasted for two years (September 2013 to August 2015). It was a project funded by the European Union under the framework of the Horizon 2020 program.

A major goal of the Minerals4EU project was to develop the European Mineral Knowledge Data Platform (EU-MKDP), an online portal and map viewer that provide harmonized and updated information on European mineral resources. This Mineral Knowledge Data Platform is designed to automatically harvest national databases, on a regular basis (weekly), in order to feed a central database that is connected to the web portal. With such a dynamic system that allows direct update of data by their providers, Minerals4EU made a significant progress compared to the ProMine project, which produced non-dynamic centralized databases with little possibility to update them.

Most of the data contained in the EU-MKDP was derived from the ProMine databases. Still, as the Minerals4EU project is more recent, it was likely that its database would be more up to date. An extraction of the Minerals4EU was then made for task 2.1 of the MSP-REFRAM.

The Minerals4EU's EU-MKDP can be accessed online at http://minerals4eu.brgm-rec.fr/

FODD

The Fennoscandian Ore Deposit Database (FODD) is a comprehensive numeric database on metallic mines, deposits and significant occurrences in Fennoscandia. It has been compiled in a joint project between the geological surveys of Finland, Norway, Russia and Sweden. The database contains information on nearly 1700 mines, deposits and significant occurrences across the region.

The FODD contains information on location, mining history, tonnage and commodity grades with a comment on data quality, geological setting, age, ore mineralogy, style of mineralisation, genetic models, and the primary sources of data. As for most databases, the resource information for a deposit in the FODD is usually scarce and not necessarily in accordance with modern industrial standards (e.g. JORC and NI 43-101 codes), as such information only exists for some deposits recently explored or presently under exploitation.

The FODD was used to feed the ProMine and Minerals4EU database. Nevertheless, to make sure no recent update could be lost, the FODD was queried for refractory metals-bearing mineralization to build the datasets of MSP-REFRAM task 2.1.

Additional information on the FODD and derived products is available online at http://en.gtk.fi/informationservices/databases/fodd/

COMPILATION AND PROCESSING OF DATA

MSP-REFRAM task 2.1 had to process and compile data coming from 4 databases, each of them having its own architecture and characteristics.

The ProMine, Minerals4EU and FODD databases are based on pre-defined and, to a certain point, relatively similar data models. They are relational databases that contain specific information stored in specific fields according to specific code lists. As such, links between information are limited by the data models, but they can be very easily queried for a specific type of data they contain.

The GKR is based on a wiki-type encyclopaedia architecture with ontology-based links. Unlike the three other databases used for this work, it is not based on a pre-defined data model. On the other hand, due to its extremely large number of record, it was a perfect tool to identify as many as possible deposits or occurrences containing refractory metals in Europe.

To take advantage of these specificities and maximize the diversity and amount of information delivered by the task, it was decided to produce two datasets:

- A dataset of deposits with reported amount of refractory metals in Europe. This dataset is based on data from the ProMine Mineral Deposit database, completed by additional information from the Minerals4EU, FODD and GKR databases. Query criteria were the presence of Mo or Nb or Ta or Re or W either as main or secondary commodity. This dataset provides the "total class" of a deposit (or "geological potential", that includes resources, reserves and past production), based on the ProMine commodity classes thresholds, for each refractory metal contained in a deposit. It should be kept in mind that the numbers provided reflect a certain (and often partial) degree of knowledge. They have no economic meaning and should be only considered as indication of the geological potential that was known at the time they were produced. Detail of this layer is provided in annex 1 of the present note.

- A dataset of deposits and occurrences containing refractory metals, but in unknown amount. This dataset is based on the GKR that was completed by additional information from the ProMine, Minerals4EU and FODD databases. Because of the specific architecture of the GKR, this required an important work to "de-convolute" information from other "data-model based databases" that was sometime combined in a same field (for instance, the status "abandoned mine" is in fact two informations). The GKR was then queried for all records linked to the refractory metals in scope, then filtered on the commodity (Mo or Nb or Ta or Re or W) or the mineralogy (molybdenite or wulfenite for Mo; betafite or columbite or columbo-

tantalite or euxenite or fergusonite or pyrochlore for Nb; columbite or tantalite or euxenite or microlite for Ta; ferberite or hübnerite or scheelite or wolframite for W). This dataset is less detailed than the one of deposits with reported amount of refractory metals in Europe, but it contains a much larger number of records.

Both datasets were used to produce the “mineral resources” layers in the final map.

DRAWING OF THE MAP

The following sections describe the layers on information that are displayed on the Map of Refractory Metal Deposits in Europe.

DEPOSITS AND OCCURENCES OF REFRACTORY METALS

The two datasets previously described - i.e. 1) deposits with reported amount of refractory metals, and 2) deposits and occurrences containing refractory metals, but in unknown amount – are displayed in the final map as separate data layers, with specific but coherent symbologies.

The deposits with reported amount of refractory metals are displayed in the uppermost layer (90 records). The symbology of this layer is based on dotted circles, color-coded by commodity and sized according to the class of the deposit for the displayed refractory metals (based on the ProMine commodity classes thresholds, see annex 1). Deposits in this layer are labelled, using their usual name. Note that some deposits may have several names. In such cases, the most commonly used name is displayed.

The deposits and occurences containing refractory metals in unknown amount are displayed on the map as two distinct layers (one for deposits, one for occurrences; 1120 and 3889 records, respectively), beneath the previous one. The symbology of these layers is based on squares (deposits) and triangles (occurrences), color-coded by commodity (same colors than the previous layer) and sized according to the size of the deposit or occurrence. Note however that the size refers to the mineralization as a whole and (unlike the first layer) does prejudge the amount of refractory metal it contains.

Note also that, on all layers, symbols may overlap and therefore partly hide some information. In order to minimize hidden information, layers and commodities with the smallest number of records are displayed last (i.e. on top).

OTHER LAYERS OF INFORMATION

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 Fennoscandian 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 – DEPOSITS CONTAINING REPORTED AMOUNT OF REFRACTORY METAL

The table in the following pages provides details of the map layer of deposits containing reported amount of refractory metal, including total potential, past production, resource, reserve, status, deposit type, morphology and mineralogy whenever available.

Deposit ID are from the ProMine Mineral Deposit database, except for S2887, S2888 and S5581 (Häggan, Munka and Laver-nya, respectively) that are from the FODD.

Only the most commonly used name is provided, although some deposits may have alternate names.

Class of deposits for the contained refractory metal are based on the total potential (sum of past production, resource and reserve), according to commodity class thresholds established by the ProMine project and provided in the table below:

Commodity	Class A (super large)	Class B (large)	Class C (medium)	Class D (small)
Molybdenum (metal)	500 000 t	100 000 t	5 000 t	1000 t
Niobium – columbium (Nb_2O_5)	1 000 000 t	100 000 t	10 000 t	2 000 t
Rhenium (metal)	5 000 t	500 t	50 t	5 t
Tantalum (Ta_2O_5)	25 000 t	2 000 t	1 000 t	200 t
Tungsten (WO_3)	200 000 t	50 000 t	5 000 t	500 t

Status, deposit type, morphology and mineralogy are based on the ProMine code lists.

Note that a deposit may appear on several lines if it contains several refractory metals in the scope of the MSP-REFRAM. In such cases, each line contains numbers for a specific refractory metal (indicated in brackets after the name of the deposit, and in the “contained refractory metal” column).

ID	NAME	COUNTRY	LONGITUDE	LATITUDE	MAIN COMMODITY	CONTAINED REFRACTORY METAL	TOTAL POTENTIAL FOR CONTAINED REFRACTORY METAL (metric tons)	CLASS FOR CONTAINED REFRACTORY METAL	PAST PRODUCTION (metric tons)	GRADE	YEAR	RESERVE (metric tons)	TYPE	GRADE	YEAR	RESOURCE (metric tons)	TYPE	GRADE	YEAR	CLASSIFICATION CODE	STATUS	MAIN DEPOSIT TYPE	MAIN MORPHOLOGY	MINERALOGY
AUT-00011	Mittersill	Austria	12,4859	47,2027	W	W	76000	B	45500	0,65%		30500	Proved	0,5%							Old industrial mine, abandoned deposit	Scheelite - Mo skarns	Concordant to subconcordant envelope of disseminated ore	Molybdenite, Pentlandite, Powellite, Pyrrhotite, Scheelite, Sphalerite, Wolframite
AUT-01512	Tux-Lanersbach	Austria	11,7333	47,1500	W	W	1464	D	1464	1,22%											Old industrial mine, exhausted deposit	Deposit related to sedimentary rocks	Stratiform bed: single or multi-layered (syn-depositional with host rock)	Magnesite (Giobertite), Scheelite
BEL-00019	Herzogenhügel	Belgium	6,1339	50,5725	Cu	Mo	4000	D								4000	Inferred	0,02%			Deposit of unknown status	Porphyry copper deposit	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Chalcocite, Chalcopyrite, Cobaltite, Digenite, Galena, Gersdorffite, Hessite, Ilmenite, Magnetite, Marcasite, Molybdenite, Pyrite, Pyrrhotite, Scheelite, Sphalerite, Tetradymite
BGR-00036	Elatsite	Bulgaria	24,0378	42,7519	Cu	Mo	8510	C				8510		0,0046%							Producing industrial mine	Porphyry Cu-Au deposit	Discordant envelope of disseminated ore	Azurite, Bornite, Chalcocite, Chalcopyrite, Covellite, Galena, Magnetite, Malachite, Molybdenite, Electrum, Pyrite, Sphalerite, Merenskyite, Clausthalite, Hematite, Hessite, Marcasite, Pyrrhotite, Rammelsbergite
BGR-00105	Karlievo	Bulgaria	24,1227	42,6946	Cu	Mo	3061	D								3061	Indicated	0,005%			Subeconomic deposit	Porphyry copper deposit	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Azurite, Bornite, Chalcocite, Chalcopyrite, Covellite, Copper, Galena, Goethite, Goethite (limonite), Magnetite, Malachite, Molybdenite, Pyrite, Sphalerite
CZE-00057	Cínovec	Czech Republic	13,7667	50,7300	Sn	W	24750	C				24750		0,045%	2007						Old mine workings	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Cassiterite, Wolframite, Zinnwaldite, Scheelite, Roquesite, Galena, Chalcocite, In-sphalerite, Tennantite, Bismuth, Wittichenite, Stannite, Dzhalindite, Chalcopyrite, Beudantite, Topaz, Tantalite, Bastnäsite, Uranpyrochlore, Lepidolite, Beryl, Torbernite
ESP-00134	Las Sombras	Spain	-8,0567	41,9034	Fe	W	1332	D	1332												Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Subconcordant vein, bedded vein, intraformational sheet	Wolframite, Cassiterite, Molybdenite, Scheelite

ID	NAME	COUNTRY	LONGITUDE	LATITUDE	MAIN COMMODITY	CONTAINED REFRACTORY METAL	TOTAL POTENTIAL FOR CONTAINED REFRACTORY METAL (metric tons)	CLASS FOR CONTAINED REFRACTORY METAL	PAST PRODUCTION (metric tons)	GRADE	YEAR	RESERVE (metric tons)	TYPE	GRADE	YEAR	RESOURCE (metric tons)	TYPE	GRADE	YEAR	CLASSIFICATION CODE	STATUS	MAIN DEPOSIT TYPE	MAIN MORPHOLOGY	MINERALOGY
ESP-00167	Alegría	Spain	-5,7053	40,8128	W	W	3965	D	3965												Old small-scale mine, abandoned deposit	Scheelite - Mo skarns	Stratiform bed: single or multi-layered (syn-depositional with host rock)	Scheelite
ESP-00234	los Santos	Spain	-5,7473	40,5448	Sn	W	12948	C				12948	Probable	0,26%	2006						Producing industrial mine	Scheelite - Mo skarns	Tabular-shaped mass or lens	Scheelite, Arsenopyrite, Pyrite
ESP-00327	Grupo Minero Santa Comba Filones	Spain	-8,8189	43,0982	Fe	W	8400	C	8400	1,5%											Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Subconcordant vein, bedded vein, intraformational sheet	Wolframite, Cassiterite
ESP-00652	Virgen De La Encina Mina Felipe	Spain	-6,5454	42,5080	W	W	5448	C				5448		0,0873%							Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Subconcordant vein, bedded vein, intraformational sheet	Quartz, Scheelite
ESP-00662	Almadenes	Spain	-4,2260	40,8118	Cu	W	2742	D	2742												Prospect	Sn-base metals skarn and stratiform manto	Tabular-shaped mass or lens	Sphalerite, Chalcopyrite, Magnetite
ESP-00664	Penouta Olga	Spain	-7,0190	42,1848	Sn	Ta	945	D				945		37 g/t							Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)		Quartz, Kaolin, Albite, Microcline
ESP-00794	Mina "La Lapa"	Spain	-6,5089	40,2171	W	W	22000	C				22000		0,22%	1985						Mineral occurrence	Unspecified deposit type	Subconcordant vein, bedded vein, intraformational sheet	Quartz, Arsenopyrite, Pyrite, Scheelite
FIN-00958	Sokli (Nb)	Finland	29,3086	67,8012	Phosphate	Nb	751200	B								751200	Inferred	0,3%	1983	Unknown	Prospect under (upstream) reconnaissance	Complex deposit (monometallic or polymetallic) hosted by carbonatitic complex	Breccia-pipe, funnel, chimney, column, brecciated dyke	Apatite, Pyrochlore, Magnetite, Zirconolite

ID	NAME	COUNTRY	LONGITUDE	LATITUDE	MAIN COMMODITY	CONTAINED REFRACTORY METAL	TOTAL POTENTIAL FOR CONTAINED REFRACTORY METAL (metric tons)	CLASS FOR CONTAINED REFRACTORY METAL	PAST PRODUCTION (metric tons)	GRADE	YEAR	RESERVE (metric tons)	TYPE	GRADE	YEAR	RESOURCE (metric tons)	TYPE	GRADE	YEAR	CLASSIFICATION CODE	STATUS	MAIN DEPOSIT TYPE	MAIN MORPHOLOGY	MINERALOGY
FIN-00958	Sokli (Ta)	Finland	29,3086	67,8012	Phosphate	Ta	15250	B								15250	Inferred	0,0061%	1983	Unknown	Prospect under (upstream) reconnaissance	Complex deposit (monometallic or polymetallic) hosted by carbonatitic complex	Breccia-pipe, funnel, chimney, column, brecciated dyke	Apatite, Pyrochlore, Magnetite, Zirconolite
FIN-00959	Katajakangas	Finland	27,0223	64,1283	REE	Nb	3496	D								3496	Inferred	5300 ppm	1985	Unknown	Prospect under (upstream) reconnaissance	Rare metal and/or uranium deposit related to peralkaline complexes	Concordant to subconcordant envelope of disseminated ore	Pyrrhotite, Chalcopyrite, Pentlandite, Sperrylite, Hessite, Galena, Kotulskite, Naumannite, Fergusonite, Allanite, Columbite
FIN-00967	Ahvenlammi	Finland	24,0339	61,5790	W	W	2240	D								2240	Inferred	0,2%	1987	Unknown	Deposit or prospect of unknown status	Granitoid-controlled deposit	Discordant mass (cylinder, sheet, cone, etc.) with filling commonly brecciated	Scheelite, Arsenopyrite, Pyrite, Chalcopyrite, Sphalerite, Rutile, Stannite, Ilmenite, Cassiterite
FIN-00971	Mätäsvaara	Finland	29,5908	63,4386	Mo	Mo	1616	D	1616	0,14%	1940-1947										Dormant deposit	Porphyry Cu-Mo or Mo deposit	Discordant envelope of disseminated ore	Pyrrhotite, Chalcopyrite, Pyrite, Pentlandite, Marcasite, Mackinawite, Covellite, Violarite, Sphalerite
FIN-00973	Aittojärvi	Finland	29,2966	65,4507	Mo	Mo	8450	C								8450	Inferred	0,1%		Unknown	Deposit or prospect of unknown status	Porphyry Cu-Mo or Mo deposit	Concordant to subconcordant envelope of disseminated ore	Pyrrhotite, Pentlandite, Chalcopyrite, Magnetite, Chromite, Molybdenite, Ilmenite, Pyrite
FIN-00976	Ylöjärvi	Finland	23,5001	61,6090	Cu	W	5619	C	5619	0,14%	1943-1966										Dormant deposit	Breccia-pipe deposit	Discordant envelope of disseminated ore	Arsenopyrite, Bismuth, Chalcopyrite, Pyrrhotite, Mackinawite, Marcasite, Scheelite, Pyrite, Cubanite
FIN-00980	Rosendal	Finland	22,5548	60,1314	Ta	Ta	268	D								268	Inferred	0,0255%	2002	Unknown	Deposit or prospect of unknown status	Pegmatites: Class Abyssal	Mineralized dyke (orebody: magmatic rock)	Ferrotantalite, Ferrotapiolite, Chrysoberyl, Beryl, Cassiterite, Albite
FIN-00986	Länttä	Finland	24,1426	63,6210	Li	Ta	233	D								233	Indicated	78,9 ppm	2005	JORC code	Industrial project under development	Pegmatites: Family: LCT Class: Rare Elements Subclass: Li Type: Albite / Spodumene	Mineralized dyke (orebody: magmatic rock)	Spodumene, Petalite, Beryl, Molybdenite, Scheelite, Columbite, Analcime (analcite)

ID	NAME	COUNTRY	LONGITUDE	LATITUDE	MAIN COMMODITY	CONTAINED REFRACTORY METAL	TOTAL POTENTIAL FOR CONTAINED REFRACTORY METAL (metric tons)	CLASS FOR CONTAINED REFRACTORY METAL	PAST PRODUCTION (metric tons)	GRADE	YEAR	RESERVE (metric tons)	TYPE	GRADE	YEAR	RESOURCE (metric tons)	TYPE	GRADE	YEAR	CLASSIFICATION CODE	STATUS	MAIN DEPOSIT TYPE	MAIN MORPHOLOGY	MINERALOGY
FIN-01016	Talvivaara	Finland	28,0569	63,9931	Ni	Mo	147045	B								147045	Inferred	0,007%		JORC code	Producing industrial mine	Black shale-hosted Talvivaara-type base metal deposit	Concordant to subconcordant envelope of disseminated ore	Pyrite, Pyrrhotite, Pentlandite, Sphalerite, Alabandite, Stannite, Chalcopyrite, Ullmannite, Molybdenite
FRA-00003	Les Montmins (Echassière) (Ta)	France	2,9670	46,1830	Ta	Ta	24000	B								24000	Poorly estimated	120 g/t			Deposit under development - project	Evolved rare metals granite, aplite, rhyolite (Li, Ta, Nb, Be…)	Discordant envelope of disseminated ore	Lepidolite, Columbo-tantalite, Microlite, Cassiterite, Ferberite, Wolframite, Amblygonite, Herderite, Tapiolite, Acanthite, Arsenopyrite, Autunite, Bismuth, Bornite, Brochantite, Carnotite, Chalcopyrite, Fluorite, Francevillite, Freibergite, Galena, Linarite, Marcasite, Malachite, Molybdenite, Parsonsite, Pyrite, Pyrrhotite, Sphalerite, Stannite, Tantalite, Topaz, Torbernite, Uranocircite, Uranophane, Covellite, Curienite, Cryptomelane, Metatorbernite, Vivianite, Wavellite, Bismite, Bismutite, Cerussite, Chalcocite, Chalcosiderite, Goethite, Gorceixite, Hemimorphite (Calamine), Hinsdalite, Mawsonite, Monazite, Montebrasite, Natrojarosite, Pyromorphite, Scheelite, Tennantite, Variscite, Varlamoffite, In-cassiterite
FRA-00003	Les Montmins (Echassière) (W)	France	2,9670	46,1830	Ta	W	500	D	500												Deposit under development - project	Evolved rare metals granite, aplite, rhyolite (Li, Ta, Nb, Be…)	Discordant envelope of disseminated ore	
FRA-00009	Salau (Anglade)	France	1,1888	42,7376	W	W	15815	C	12415	1,5%	1971-1986					3400	Inferred	1,7%			Old industrial mine, exhausted deposit	Scheelite - Mo skarns	Subconcordant or stratabound mass or lens of massive to submassive ore	Scheelite, Pyrrhotite, Cobaltite, Pyrite, Arsenopyrite, Chalcopyrite, Galena, Gersdorffite, Magnetite, Sphalerite, Cerussite, Bismuthinite
FRA-00024	Leucamp	France	2,5539	44,7748	W	W	7300	C	1700	2,5%						5600	Inferred				Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Chalcopyrite, Sphalerite, Scheelite, Pyrrhotite, Pyrite, Marcasite, Covellite, Wolframite, Bismuthinite, Arsenopyrite, Goethite, Pharmacosiderite, Bismuth, Cubanite, Molybdenite, Scorodite, Tetradymite

ID	NAME	COUNTRY	LONGITUDE	LATITUDE	MAIN COMMODITY	CONTAINED REFRACTORY METAL	TOTAL POTENTIAL FOR CONTAINED REFRACTORY METAL (metric tons)	CLASS FOR CONTAINED REFRACTORY METAL	PAST PRODUCTION (metric tons)	GRADE	YEAR	RESERVE (metric tons)	TYPE	GRADE	YEAR	RESOURCE (metric tons)	TYPE	GRADE	YEAR	CLASSIFICATION CODE	STATUS	MAIN DEPOSIT TYPE	MAIN MORPHOLOGY	MINERALOGY
FRA-00034	Montbelleux - Luitré (district)	France	-1,1708	48,2899	W	W	6589	C	189	0,6%						6400	Inferred				Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Wolframite, In-cassiterite, Pyrite, Chalcopyrite, Sphalerite, Digenite, Galena, Melnicovite, Covellite, Tungstite, Cassiterite, Arsenopyrite, Molybdenite
FRA-00061	Puy les Vignes	France	1,5310	45,8263	W	W	5260	C	4000	0,85%						1260	Inferred	0,3%			Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Discordant lode or vein (thickness > 50 cm), in clusters or isolated	Pyrite, Wolframite, Sphalerite, Scheelite, Marcasite, Galena, Ferberite, Chalcopyrite, Bismuthinite, Arsenopyrite, Siderite
FRA-00065	Montredon-Labessonnié	France	2,3279	43,7327	W	W	21590	C	500	1,08%	1951-1960	10500	Probable	0,7%		10590	Inferred	0,6%			Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Covellite, Wolframite, Arsenopyrite, Cassiterite, Cubanite, Galena, Goethite, Goethite (limonite), Pyrite, Pyrrhotite, Scheelite, Sphalerite, Fluorite, Hematite, Chalcopyrite, Stannite, Molybdenite, Bismuthinite
FRA-00066	Enguialès	France	2,5282	44,6668	W	W	6300	C	1300	0,6%	1969-1978					5000	Inferred				Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Wolframite, Scheelite, Pyrite, Molybdenite, Chalcopyrite, Arsenopyrite, Bismuthinite
FRA-00083	La Favière (La Baisse)	France	6,8161	43,5338	W	W	2945	D	1145							1800	Inferred				Old industrial mine, abandoned deposit	Scheelite - Mo skarns	Concordant to subconcordant envelope of disseminated ore	Loellingite, Scheelite, Pyrrhotite, Marcasite, Hematite, Chalcopyrite, Bismuth, Apatite, Pyrite
FRA-00144	Auxelles-Haut	France	6,7736	47,7419	W	W	8500	C								8500	Inferred	0,3%			Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Pyrite, Sphalerite, Pyrrhotite, Molybdenite, Galena, Fluorite, Barite, Arsenopyrite, Scheelite, Apatite, Chalcopyrite
FRA-00158	Costabonne	France	2,3524	42,4105	W	W	5044	C								5044	Inferred	0,4%			Old prospect	Scheelite - Mo skarns	Concordant to subconcordant envelope of disseminated ore	Chalcopyrite, Sphalerite, Scheelite, Pyrite, Magnetite, , Bismuthinite, , Apatite, Molybdenite
FRA-00226	Beauvain	France	-0,3234	48,6254	Mo	Mo	60000	C								60000	Inferred	0,02%			Old prospect	Porphyry Cu-Mo or Mo deposit	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Molybdenite

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FRA-00240	Coat-An-Noz (B)	France	-3,3900	48,5122	W	W	11000	C								11000	Inferred	1%			Old prospect	Scheelite - Mo skarns	Varied synchronous to sub-synchronous primary orebodies	Arsenopyrite, Chalcopyrite, Pyrite, Pyrrhotite, Scheelite, Sphalerite
FRA-00249	Fumade	France	2,4990	43,6597	W	W	10000	C								10000	Inferred	1%			Old prospect	Scheelite - Mo skarns	Stratiform mass or lens of massive to semimassive ore (syn-depositional with host rock)	Arsenopyrite, Pyrite, Pyrrhotite, Scheelite, Sphalerite
FRA-00306	Neuf-Jours	France	2,2424	45,5991	W	W	2500	D								2500	Inferred	0,5%			Old prospect	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Bismuth, Wolframite, Scheelite, Pyrrhotite, Cassiterite, Arsenopyrite, Molybdenite, Chalcopyrite, Cubanite
FRA-00312	Pinardeau - Pierre Bergère	France	0,6362	46,0768	W	W	1000	D								1000	Poorly estimated	0,2%			Old prospect	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Scheelite, Wolframite, Stannite, Sphalerite, Molybdenite, Cubanite, Chalcopyrite, Bismuthinite, Pyrite, Cassiterite, Mackinawite, Bismuth, Wittichenite, Emplectite, Aikinite
FRA-00328	Tréguennec	France	-4,3485	47,8752	Ta	Ta	1950	C								1950	Inferred	232 g/t			Old prospect	Evolved rare metals granite, aplite, rhyolite (Li, Ta, Nb, Be…)	Discordant envelope of disseminated ore	Amblygonite, Cassiterite, Lepidolite, Columbite, Microlite, Tantalite
FRA-00867	Périssac	France	0,6867	46,0384	W	W	523	D	3							520	Inferred				Old small-scale mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Discordant lode or vein (thickness > 50 cm), in clusters or isolated	Wolframite, Arsenopyrite, Sphalerite, Cassiterite, Chalcopyrite, Galena, Pyrite
FRA-01349	La Bosse (Echassières)	France	2,9569	46,1775	W	W	3900	D	3900	0,8%	up to 1954										Old small-scale mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Ferberite
GBR-00073	Carrock Fell	United-Kingdom	-3,0688	54,6824	W	W	529	D	271	1,29%	1901-1943	258	reserve documentation	1,29%	1993						Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Discordant lode or vein (thickness > 50 cm), in clusters or isolated	Wolframite, Scheelite, Arsenopyrite, Pyrrhotite, Sphalerite, Galena, Molybdenite, Chalcopyrite, Bismuth, Joseite

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GBR-00105	Cornwall (Province)	United-Kingdom	-4,8833	50,3667	Sn	W	5600	C	5600												Abandoned industrial mining district	Sn-specialised granite (greisen) and porphyry deposit enriched in indium	Field of discordant lodes	In-sphalerite, Sphalerite, Cassiterite, In-cassiterite, In-stannite, In-chalcopyrite, Stannite, Chalcopyrite, Fluorite, Barite, Wolframite, Stibnite, Arsenopyrite, Siderite, Hematite
GBR-00191	Hemerdon	United-Kingdom	-4,0000	50,4054	W	W	75600	B								75600	Inferred	0,18%			Deposit of unknown status	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Cassiterite, Wolframite, Chalcopyrite, Arsenopyrite, Pyrite, Chalcocite
GBR-00353	South Crofty, East Pool and Agar mines	United-Kingdom	-5,2333	50,2167	Sn	W	2135	D	2135												Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Wolframite, Arsenopyrite, Cassiterite, Stannite, Sphalerite, Chalcopyrite
GBR-00480	Carrock fell mine	United-Kingdom	-3,0503	54,6872	W	W	720	D	720	1%	1977-1981										Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)		Aikinite, Apatite, Arsenopyrite, Azurite, Barite, Beryl, Bismuth, Bismuthinite, Bornite, Cassiterite, Cerussite, Chalcocite, Chalcopyrite, Columbite, Fluorite, Galena, Gold, Joseite, Ferberite, Jamesonite, Mimetite, Molybdenite, Scheelite, Scorodite, Sphalerite, Stibnite, Sylvanite, Tungstite, Uraninite, Vanadinite, Wolframite, Wulfenite, Zinkenite
GRC-00744	Kimmeria (north-east) (Mo)	Greece	24,9331	41,1506	Cu	Mo	10000	C				10000									Unexploited deposit	Cu skarn	Discordant mass or lens of massive to submassive ore	Chalcopyrite, Pyrite, Magnetite, Seelite, Galena, Powellite, Molybdenite, Pyrrhotite, Cosalite, Sphalerite, Mackinawite, Cubanite, Gold, Argyrose
GRC-00744	Kimmeria (north-east) (W)	Greece	24,9331	41,1506	Cu	W	7600	C				7600		0,38%							Unexploited deposit	Cu skarn	Discordant mass or lens of massive to submassive ore	Chalcopyrite, Pyrite, Magnetite, Seelite, Galena, Powellite, Molybdenite, Pyrrhotite, Cosalite, Sphalerite, Mackinawite, Cubanite, Gold, Argyrose
HUN-00039	Recsk (Cu-Au-Pb-Zn)	Hungary	20,0535	47,9466	Cu	Mo	15930	C								15930	Poorly estimated	0,01%			Dormant deposit	Porphyry Cu-Au deposit	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Bornite, Chalcopyrite, Molybdenite, Pyrite, Pyrrhotite, Sphalerite, Enargite, Gold, Magnetite, Luzonite, Tetrahedrite, Tennantite, Re-molybdenite

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NOR-00582	Sæteråsen	Norway	10,0001	59,2938	Zr	Nb	28040	C								28040	Inferred	2450 ppm			Unexploited deposit	Rare metal and/or uranium deposit related to peralkaline complexes	Concordant to subconcordant envelope of disseminated ore	Pyrochlore, Chessexite, Fergusonite, Euxenite, Apatite, Zircon, Chevkinite
NOR-00583	Nordli	Norway	11,0211	60,4809	Mo	Mo	189000	B								189000	Inferred	0,09%		Unknown	Unexploited deposit	Porphyry Cu-Mo or Mo deposit	Discordant envelope of disseminated ore	Molybdenite, Pyrite, Hematite, Wolframite
NOR-00606	Knaben	Norway	7,0837	58,6879	Mo	Mo	16000	C	16000	0,2%	1885-1973; 2007-2011										Old industrial mine, abandoned deposit	Scheelite - Mo skarns	Atypical, unspecified or ill-defined form	Molybdenite
POL-00007	Polkowice (Lubin district)	Poland	16,0211	51,5071	Cu	Mo	4890	D	150			4740	Proved								Producing industrial mine	Kupferschiefer (or Cu shale) deposit	Stratiform mass or lens of massive to semimassive ore (syn-depositional with host rock)	Chalcocite, Chalcopyrite, Bornite, Pyrite, Galena, Tetrahedrite, Sphalerite, Enargite, Silver, Cobaltite, Smaltite, Loellingite, Polkovicite, Morozeviczite, Marcasite, Tennantite, Digenite, Covellite, Gersdorffite, Clausthalite, Electrum
POL-00008	Sieroszowice (Lubin district)	Poland	16,0212	51,5071	Cu	Mo	13710	C	190			13520	Proved								Producing industrial mine	Kupferschiefer (or Cu shale) deposit	Stratiform mass or lens of massive to semimassive ore (syn-depositional with host rock)	Chalcocite, Chalcopyrite, Bornite, Pyrite, Sphalerite, Galena, Tetrahedrite, Enargite, Loellingite, Silver, Smaltite, Cobaltite
POL-00009	Rudna (Lubin district)	Poland	16,1461	51,5174	Cu	Mo	18290	C	470			17820	Proved								Producing industrial mine	Kupferschiefer (or Cu shale) deposit	Stratiform mass or lens of massive to semimassive ore (syn-depositional with host rock)	Chalcocite, Chalcopyrite, Bornite, Pyrite, Sphalerite, Galena, Tetrahedrite, Enargite, Loellingite, Silver, Smaltite, Cobaltite
POL-00501	Gaworzyce	Poland	15,8825	51,6285	Cu	Mo	1260	D				1260										Unspecified deposit type		(no data)
POL-00502	Lubin-Małomice	Poland	15,9333	51,6375	Cu	Mo	22580	C	380			22200	Proved									Unspecified deposit type		(no data)

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POL-00503	Niecka Grodziecka (Re)	Poland	16,1592	51,4415	Cu	Re	60	C								60	Poorly estimated					Unspecified deposit type		(no data)
POL-00503	Niecka Grodziecka (Mo)	Poland	16,1592	51,4415	Cu	Mo	2540	D								2540	Inferred					Unspecified deposit type		(no data)
POL-00506	Retków	Poland	16,1982	51,5892	Cu	Mo	2380	D								2380	Poorly estimated					Unspecified deposit type		(no data)
POL-00507	Wartowice	Poland	15,6500	51,2167	Cu	Mo	1210	D								1210	Poorly estimated					Unspecified deposit type		Chalcocite, Bornite, Pyrite
PRT-00003	Panasqueira	Portugal	-7,7447	40,1494	W	W	93000	B								93000	Measured			UNFC code	Producing industrial mine	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Wolframite, Cassiterite, Arsenopyrite, Chalcopyrite, Sphalerite, Stannite, Marcasite, Pyrite, Pyrrhotite, Goethite, Galena, Hematite, Magnetite, In-cassiterite
PRT-00013	Almendra	Portugal	-7,0147	41,0011	Sn	Ta	290	D								290	Indicated	31,65 g/t		UNFC code	Old industrial mine, abandoned deposit	Pegmatites	Discordant primary orebody (vein, reef, mass, lens, pipe, column, etc.)	Cassiterite, Columbite, Tantalite, Pyrite, Arsenopyrite, Beryl
PRT-00024	Argozelo	Portugal	-6,6028	41,6437	Sn	W	2333	D	1816		1958-1985					517	Measured	1752,8 g/t		UNFC code	Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Discordant lode or vein (thickness > 50 cm), in clusters or isolated	Cassiterite, Wolframite, Scheelite, Silver, Pyrite, Arsenopyrite, Marcasite
PRT-00035	Bejanca, Carvalhal	Portugal	-8,0207	40,6985	Sn	W	2531	D	178		1960-1985					2353	Indicated	460 g/t		UNFC code	Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Cassiterite, Wolframite, Scheelite, Blende (Sphalerite), Chalcopyrite, Stannite, Arsenopyrite, Pyrite
PRT-00041	Borralha	Portugal	-7,9687	41,6528	W	W	15050	C	12950		1903-1985					2100	Inferred	1050 g/t		UNFC code	Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Wolframite, Scheelite, Cassiterite, Chalcopyrite, Pyrite, Molybdenite, Blende (Sphalerite), Pyrrhotite

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PRT-00079	Covas (Viana do Castelo district)	Portugal	-8,7132	41,8739	W	W	8272	C	566		1955-1979					7706	Indicated	0,692%	1979	UNFC code	Old industrial mine, abandoned deposit	Replacement deposit (skarn, manto)	Stratiform envelope of disseminated ore	Scheelite, Wolframite, Ferberite, Pyrrhotite, Pyrite, Arsenopyrite, Chalcopyrite, Blende (Sphalerite)
PRT-00101	Góis	Portugal	-8,0815	40,1559	Sn	W	852	D								852	Measured	1460 g/t		UNFC code	Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Discordant lode or vein (thickness > 50 cm), in clusters or isolated	Cassiterite, Wolframite, Gold, Silver
PRT-00118	Lagoaça (Fonte Santa)	Portugal	-6,7657	41,2320	W	W	35392	C	281		1955-1983					35111	Indicated	0,05%			Old industrial mine, abandoned deposit	Pegmatites	Field of discordant lodes	Scheelite, Wolframite, Pyrite, Siderite
PRT-00212	Valdarcas mine	Portugal	-8,7089	41,8694	W	W	1403	D	228		1954-1960					1175	Indicated	0,67%	1979		Old industrial mine, abandoned deposit	Replacement deposit (skarn, manto)	Concordant to subconcordant mass, lens or pod of massive to submassive ore	Wolframite, Scheelite, Ferberite, Pyrite, Pyrrhotite, Arsenopyrite, Chalcopyrite, Blende (Sphalerite)
PRT-00213	Vale das Gatas	Portugal	-7,5827	41,3041	W	W	2314	D	794		1960-1986					1520	Indicated	2500 g/t			Old industrial mine, abandoned deposit	Granitic and peri-granitic veins and stockworks (greisen)	Field of discordant lodes	Wolframite, Cassiterite, Scheelite, Arsenopyrite, Pyrrhotite, Sphalerite, Chalcopyrite, Galena, Sabatierite
PRT-00230	Vale dos Porros (Riba d´Alva)	Portugal	-6,8769	41,0330	W	W	1843	D				1843	Proved	0,53%							Old industrial mine, abandoned deposit	Replacement deposit (skarn, manto)	Concordant to subconcordant mass, lens or pod of massive to submassive ore	Scheelite, Cassiterite, Fluorite, Apatite, Tourmaline, Chalcopyrite, Pyrite, Pyrrhotite
SWE-00359	Aitik	Sweden	20,9589	67,0717	Cu	Mo	95284	C								95284		0,0026%		JORC code	Producing industrial mine	Porphyry Cu-Au deposit	Discordant envelope of disseminated ore	Bornite, Chalcopyrite, Magnetite, Molybdenite, Pyrite, Pyrrhotite
SWE-00361	Björntjärn	Sweden	17,6923	66,3296	Mo	Mo	2160	D								2160	Inferred	0,12%		Unknown	Unexploited deposit	Unspecified deposit type		Molybdenite
SWE-00431	Svärtträsk	Sweden	17,2507	65,1687	W	W	546	D								546	Inferred	0,21%		Unknown	Unexploited deposit	Unspecified deposit type		Scheelite, Galena, Sphalerite

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SWE-00810	Baggetorpsgruvan	Sweden	15,4635	58,7196	W	W	702	D	702	0,2%	1944-1958										Old industrial mine, abandoned deposit	Unspecified deposit type	Discordant lode or vein (thickness > 50 cm), in clusters or isolated	Wolframite
SWE-00840	Myrviken	Sweden	14,4057	62,9734	V	Mo	734880	A								734880	Inferred	0,024%		NI 43-101	Industrial project under development	Uraniferous black shale	Stratiform bed: single or multi-layered (syn-depositional with host rock)	Pitchblende (Uraninite)
SWE-00990	Yxsjöbergsfältet	Sweden	14,7734	60,0414	W	W	24838	C	24838	0,48%	1897-1989										Old industrial mine, abandoned deposit	Scheelite - Mo skarns		(no data)
S2887	Häggan	Sweden	14,2943	63,0378	U	Mo	387757	B								387757		0,022%		Unknown	Unexploited deposit	Uraniferous black shale		(no data)
S2888	Munka	Sweden	17,8795	66,5646	Mo	Mo	2652	D								2652	Poorly estimated	0,156%		Unknown	Unexploited deposit	Epigenetic Mo		Molybdenite
S5581	Laver-nya	Sweden	20,2486	65,7632	Cu	Mo	36637	C								36637		0,0034%		SveMin	Unexploited deposit			(no data)
UKR-00041	Mazurovskoe (Nb)	Ukraine	37,5181	47,5136	Zr	Nb	230000	B								230000	Inferred	0,118%			Dormant deposit	Rare metal and/or uranium deposit related to peralkaline complexes	Mineralized dyke (orebody: magmatic rock)	Zircon, Ilmenorutile, Columbite, Pyrochlore, Fersmite, Nepheline, Britholite
UKR-00041	Mazurovskoe (Ta)	Ukraine	37,5181	47,5136	Zr	Ta	12500	B								12500	Inferred	0,0065%			Dormant deposit	Rare metal and/or uranium deposit related to peralkaline complexes	Mineralized dyke (orebody: magmatic rock)	Zircon, Ilmenorutile, Columbite, Pyrochlore, Fersmite, Nepheline, Britholite

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YUG-00058	Majdanpek	Former Yugoslavia, Republic of Macedonia	21,9497	44,3761	Cu	Mo	30000	C				30000		0,005%							Producing industrial mine	Porphyry Cu-Au deposit	Discordant envelope of disseminated ore	Chalcopyrite, Bornite, Molybdenite, Telluride, Gold, Pyrite, Magnetite, Tellurite, Stannite, Re-molybdenite, Arsenopyrite, Bismuth, Enargite, Galena, Marcasite, Pyrrhotite, Sphalerite, Tetrahedrite, Tennantite
YUG-00076	Veliki Krivelj	Former Yugoslavia, Republic of Macedonia	22,0972	44,1309	Cu	Mo	122000	B	2000		1991	120000									Producing industrial mine	Porphyry Cu-Au deposit	Discordant envelope of disseminated ore	Chalcopyrite, Molybdenite, Pyrite, Magnetite, Scheelite, Fluorite, Chalcocite, Covellite, Cubanite, Enargite, Galena, Hematite, Pyrrhotite
YUG-00087	Mackatica (Mo)	Former Yugoslavia, Republic of Macedonia	22,2171	42,7472	Mo	Mo	141180	B								141180	Inferred	0,078%			Dormant deposit	Porphyry Cu-Mo or Mo deposit	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Molybdenite, Pyrite, Hematite, Chalcopyrite, Sphalerite, Galena, Hübnerite
YUG-00087	Mackatica (Re)	Former Yugoslavia, Republic of Macedonia	22,2171	42,7472	Mo	Re	43	D								43	Poorly estimated				Dormant deposit	Porphyry Cu-Mo or Mo deposit	Stockwork (or network) of stringers or veinlets (thickness < 50 cm), discordant on the strata	Molybdenite, Pyrite, Hematite, Chalcopyrite, Sphalerite, Galena, Hübnerite
YUG-00134	Borska Reka	Former Yugoslavia, Republic of Macedonia	22,0880	44,0819	Cu	Mo	19869	C				11456		35,8 g/t		8413		35,8 g/t			Dormant deposit	Porphyry Cu-Au deposit	Stratabound envelope of disseminated ore	Chalcopyrite, Pyrite, Magnetite, Telluride, Molybdenite, Chalcocite, Covellite, Bornite