FRAME
FORECASTING AND ASSESSING EUROPE'S STRATEGIC RAW MATERIALS NEEDS

DELIVERABLE D4.5

Providing Phosphate data and intelligence to EURMKB (RM1) and the GeoERA information platform

WP 4 "Critical Raw Materials in phosphate deposits and associated black shales"

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

GeoERA RAW MATERIALS

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Project:	Forecasting and Assessing Europe's Strategic Raw Materials needs
Acronym:	FRAME
Grant Agreement:	731166
Funding Scheme:	Horizon 2020
Webpage:	www.frame.lneg.pt
Work Package:	4 "Critical Raw Materials in phosphate deposits and associated black shales"
Work Package Leader:	Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium (GSB)
Deliverable Title:	Providing Phosphate data and intelligence to EURMKB (RM1) and the GeoERA information platform
Deliverable Number:	4.5
Deliverable Leader:	GSB
Involved beneficiaries:	LNEG, NGU
Dissemination level:	High
Version:	1
Status:	Draft
Authors:	GSB, LNEG, NGU
Reviewed by:	GSB, LNEG, NGU
Approved by:	LNEG
Date:	September 2021

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1. Introduction

This deliverable is devoted to the transfer of the data acquired and developed within the project WP4 "Critical Raw Materials in phosphate deposits and associated black shales" to end users. The aim of this transfer is to make all these data available and integrated into the following databases: Minerals4EU, the European Union Raw Materials Knowledge Base (EURMKB), SRT RM1, and the GeoERA Information Platform, in both web-viewer and atlas formats.

2. Methodology

The Work package 4 of the FRAME project resulted in the production three main databases which include a variety of data.

A first step in this work of data transfer – and data harmonization – was to gather, validate and produce the data the most internally consistent possible and INSPIREINSPIRE-compliant.

An important specificity of WP4 is the acquisition of numerous new mineralogical and geochemical data. Hence, it was needed to adapt the structure of the database(s) to integrate them.

Finally, maps based on these data were prepared. These different aspects of the work are detailed here below.

2.1. Data collection and harmonization

A major concern was to produce a consistent set of data that are as harmonized as possible and can be transferred in the right format and with the right vocabulary (INSPIRE-compliant) to end users.

A **first database** (Deliverable WP4-D4.1) contains information about phosphate deposits and occurrences throughout Europe. It is an integrated database, based on the literature and older data sources. As much as possible, the data included came from "reliable" database (i.e., with validated data).

Concerning data issued from the literature, efforts were made to validate them and "translate" the information available into data that fits into the INSPIRE framework (using an adequate vocabulary).

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Beside the work done for WP4 itself, the FRAME-WP4 partners took part to the "Mineral resources vocabulary" exercise (led by the FRAME-WP8, under the framework of GIP-P WP4), which aims at improving a common vocabulary when considering mineral resources.

The WP4 partners also contributed to the M4EU update/harvesting in close collaboration with MINTELL4EU. Discrepancies (i.e., no spatial join within a 1000-meter distance) were found between the database provided by FRAME-WP4 and data exported from M4EU. WP4 partners got in touch with the colleagues in the different Surveys to solve these issues of missing points/discrepancies.

2.2. Structure of the mineralogical and geochemical database

A significant part of the work done for WP4 consisted in the acquisition of new mineralogical and geochemical data. These were obtained (i) on a collection of apatite-rich samples that were as diverse as possible – i.e., being of different types and different ages – and widely distributed in Europe (Deliverable WP4-D4.2) or (ii) on a selection of samples studied in the frame of the metallogenic studies (Deliverable WP4-D4.3).

The methods used to carry out these investigations were as different as: SEM-EDS microscopy, XRD, Raman spectroscopy, whole rock analyses, electron microprobe analyses or LA-ICPMS analyses. To integrate these new data, a database with a dedicated structure was prepared in close collaboration with FRAME-WP8. The database was conceived and designed according to the FRAME data specifications to include mineralogy/geochemistry data, each column having a correspondent column in the M4EU database.

It is worth mentioning that the GIP-WP3 lead used the geochemical data issued from FRAME-WP4 to do a harmonization exercise. The final goal would be to integrate this kind of data into MIN4EU.

2.3. Preparation of the maps

The data issued from WP4, gathered and integrated in the EGDI database, were used to prepare five different maps on which are represented the phosphate mineralizations encountered in Europe: Phosphor metallogenic map of Europe, Critical raw materials occurrences, Phosphate CBA favourability map of Europe, European phosphate metallogenic area, European phosphate mineralization on land and sea.

To upload the maps to EGDI, metadata need to be created. Partners of WP4 were involved in this task, more particularly in the creation of metadata for the metallogenic maps.

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3. Outcome

3.1. Databases transferred to end users

Three databases have been transferred to FRAME-WP8, FRAME-WP3 and MINTELL4EU for further processing.

The **first database** is an integrated database, based on the literature and older data sources. The verified data sources used to fill out this new database are ProMine, FODD (Fennoscandian Mineral Deposit Database), SIORMINP (Sistema de Informação de Ocorrências e Recursos Minerais Portugueses), and Mine records database (Ireland). In addition, information extracted from about 56 references, among which very recent ones, are mentioned in the database and have been validated and "translated" – as much as possible - into an INSPIRE compliant vocabulary.

This database compiled presents 429 phosphate deposits and occurrences throughout Europe. It is meant to give information as: (i) the different commodities/CRMs associated with phosphate deposits (REE, F, V, U and Y); (ii) the size of the deposits according to their known tonnages; (iii) the type and origin of the phosphorus-phosphate mineralization and deposits; (iv) the age of the deposits/occurrences and the host rock. An extract from the table provided to FRAME-WP8 and FRAME-WP3 (with the purpose of prospectivity mapping) is presented here below (Tables 1-3). The full table is part of the Annex provided in WP4-Deliverable D4.1 "Overview of the phosphate deposits and occurrences in Europe under the form of a database and map(s)".

Table 1. Structure of the first database (D4.1) - part 1. Data for Belgian phosphate deposits and occurrences

	A	B	C	D	E	F	G	H	I	J
1	Longitude	Latitude	Deposit Name	Identifiant	Locality	Country	Main Commodity	Mineral occurrence type	All commodities	Importance
2	3.94605	50.42445	Mons basin		Hainaut	Belgium	Phosphate	District	Phosphate	Large
3	3.73759	50.73678	Flobecq		Flobecq	Belgium	Phosphate	Occurrences	Phosphate	Occurrence
4	5.54338	50.67591	Rocourt		Rocourt	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
5	5.48163	49.52591	Lamorteau		Lamorteau	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
6	5.5007	49.53543	Harnoncourt		Harnoncourt	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
7	5.83458	49.56298	Athus		Athus	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
8	5.79842	49.57166	Aubange		Aubange	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
9	5.90585	50.32609	Grand-Halleux		Grand-Halleux	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
10	5.56667	50.63333	Liège- Meuse Valley		Liège- Meuse Valley	Belgium	Phosphate	District	Phosphate	Small
11	4.86667	51.20000	Demer (bassin de la)		Demer (bassin de la)	Belgium	Iron	Occurrence	Iron, Phosphate	Occurrence
12	5.03333	51.28330	Nethe (fleuve) Petite et Grande		Nethe (fleuve) Petite et Grande	Belgium	Iron	Occurrence	Iron, Phosphate	Occurrence
13	3.83333	50.48333	Baudour		Baudour	Belgium	Phosphate	Occurrence	Phosphate, Uranium	Occurrence
14	5.35000	50.66670	Momalle		Momalle	Belgium	Phosphate	Occurrence	Phosphate	Occurrence
15	3.95667	50.41667	Saint Symphorien		Saint Symphorien	Belgium	Phosphate	Occurrence	Phosphate, Uranium	Occurrence

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Table 2. Structure of the first database (D4.1) - part 2. Data for Belgian phosphate deposits and occurences

	A	B	C	K	L	M	N
1	Longitude	Latitude	Deposit Name	Host-rock	Host-rock age	Mineral Deposit Group	Mineralization age
2	3.94605	50.42445	Mons basin	Chalk, Craie de Ciply and Tuffeau de Ciply	Upper Cretaceous and Palaeocene	phosphorite	Upper Cretaceous and Palaeocene
3	3.73759	50.73678	Flobecq	Clays and sands	Upper ypresian	phosphorite	Upper Ypresian
4	5.54338	50.67591	Rocourt	Clays and sands	Maastrichtian	phosphorite	Maastrichtian
5	5.48163	49.52591	Lamorteau	Ferruginous limestone	Lias	oolitic iron/ironstone	Lias
6	5.5007	49.53543	Harnoncourt	Ferruginous limestone	Lias	oolitic iron/ironstone	Lias
7	5.83458	49.56298	Athus	Ferruginous limestone	Lias	oolitic iron/ironstone	Lias
8	5.79842	49.57166	Aubange	Ferruginous limestone	Lias	oolitic iron/ironstone	Lias
9	5.90585	50.32609	Grand-Halleux	Dark shales and silty quartzites	Middle Cambrian	phosphorite	Middle Cambrian
10	5.56667	50.63333	Liège- Meuse Valley	Clays and sands	Maastrichtian	phosphorite	Maastrichtian
11	4.86667	51.20000	Demer (bassin de la)	Oolitic ferruginous limestone	Lias	oolitic iron/ironstone	Lias
12	5.03333	51.28330	Nethe (fleuve) Petite et Grande	Oolitic ferruginous limestone	Lias	oolitic iron/ironstone	Lias
13	3.83333	50.48333	Baudour	Chalk, Craie de Ciply and Tuffeau de Ciply	Upper Cretaceous and Palaeocene	phosphorite	Upper Cretaceous and Palaeocene
14	5.35000	50.66670	Momalle	Chalk, Craie de Ciply and Tuffeau de Ciply	Upper Cretaceous and Palaeocene	phosphorite	Upper Cretaceous and Palaeocene
15	3.95667	50.41667	Saint Symphorien	Chalk, Craie de Ciply and Tuffeau de Ciply	Upper Cretaceous and Palaeocene	phosphorite	Upper Cretaceous and Palaeocene

Table 3. Structure of the first database (D4.1) - part 3. Data for phosphate deposits and occurrences in Belgium

	A	B	C	O	P	Q	R	S	T	U
1	Longitude	Latitude	Deposit Name	Mine status	Reserves	Resources	Code, commodity	Avg. Grade - Reserves	Avg. Grade - Resources	Grade unit
2	3.94605	50.42445	Mons basin	closed		600-900.000.000			8-10.5	%
3	3.73759	50.73678	Flobecq	not operating						
4	5.54338	50.67591	Rocourt	closed					21	%
5	5.48163	49.52591	Lamorteau	not operating						
6	5.5007	49.53543	Harnoncourt	not operating						
7	5.83458	49.56298	Athus	not operating						
8	5.79842	49.57166	Aubange	not operating						
9	5.90585	50.32609	Grand-Halleux	not operating						
10	5.56667	50.63333	Liège- Meuse Valley	closed		5.000.000				
11	4.86667	51.20000	Demer (bassin de la)	not operating						
12	5.03333	51.28330	Nethe (fleuve) Petite et Grande	not operating						
13	3.83333	50.48333	Baudour	not operating						
14	5.35000	50.66670	Momalle	not operating						
15	3.95667	50.41667	Saint Symphorien	not operating						

Table 4. Structure of the first database (D4.1) - part 4. Data for phosphate deposits and occurrences in Belgium

	A	B	C	V	W	X	Y	Z	AA
1	Longitude	Latitude	Deposit Name	Petrography	Mineralogy	Whole rock analyses	Isotope analyses	Microanalyses	References
2	3.94605	50.42445	Mons basin	Yes	Yes	Yes	O and Sr isotopes	Yes	Robaszynski, 1989; ; Jacquemin et al., 2019; Decrée et al., in prep
3	3.73759	50.73678	Flobecq						Notholt et al., 1979
4	5.54338	50.67591	Rocourt						Notholt et al., 1979
5	5.48163	49.52591	Lamorteau						Notholt et al., 1979
6	5.5007	49.53543	Harnoncourt						Notholt et al., 1979
7	5.83458	49.56298	Athus						Notholt et al., 1979
8	5.79842	49.57166	Aubange						Notholt et al., 1979
9	5.90585	50.32609	Grand-Halleux	Yes	Yes	Yes	O and Sr isotopes	Yes	Graulich, 1980; Decrée et al., in prep
10	5.56667	50.63333	Liège- Meuse Valley						ProMine database
11	4.86667	51.20000	Demer (bassin de la)						ProMine database
12	5.03333	51.28330	Nethe (fleuve) Petite et Grande						ProMine database
13	3.83333	50.48333	Baudour						ProMine database
14	5.35000	50.66670	Momalle						ProMine database
15	3.95667	50.41667	Saint Symphorien	Yes	Yes	Yes	O and Sr isotopes	Yes	Robaszynski, 1989; ; Jacquemin et al., 2019; Decrée et al., in prep

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The **second database** contains and presents new mineralogical and geochemical data obtained on about 90 samples representative of ~75 phosphate occurrences and deposits throughout Europe. It provides key information about the samples investigated, with a short petrographic description and identification of the minerals constituting the rock (XRD, SEM). Further information about the determination of Raman peaks is provided. Chemistry may include (depending on the samples) whole rock analysis, electron microprobe analyses and LA-ICPMS analyses (including analyses of the most crucial CRMs in apatite). The database was compiled using the template provided by WP8, as described in section 2.2. An extract from the table provided to FRAME-WP8 is presented here below (Tables 5-7). The full table is part of the Annex provided in WP4-Deliverable D4.2 "New mineralogical and geochemical data on samples from phosphate deposits/occurrences".

Table 5. Structure of the second database (D4.2) - part 1 (mineralogy). Data for Belgian phosphate deposits and occurrences

ID (mineralOccurrence)	Country	X	Y	Sample Number	Description	Mineralogy XRD	Raman spectra description (only fluorescence : OF, phosphate peak : ~963 cm-1 : v1, or all phosphate peaks + REE-induced fluorescence REE-F)
Grand Halleux (boring)	Belgium	5.906557	50.32599	GH 2743	phosphate nodules (mm-size) in a silty quartzite	Clinochlore 35%, Muscovite 24%, Quartz 20%, Apatite 11%, Pyrrhotite 10%	v1, REE-F
Grand Halleux (boring)	Belgium	5.906557	50.32599	GH 2952	phosphate nodules (mm-size) in a silty quartzite	Muscovite 37%, clinochore 36%, Calcite 16%, Quartz 7%, Apatite 4%	v1, REE-F
Thy-le-Chateau	Belgium	4.4328	50.280789	Thy 1	Conglomerate bed: phosphate nodules (mm-size) with inclusions of garnet in a silty matrix	Clinochlore 54%, Apatite 23%, Quartz 23%	v1, REE-F
Thy-le-Chateau	Belgium	4.4328	50.280789	Thy 1	Conglomerate bed: phosphate nodules (mm-size) with inclusions of garnet in a silty matrix	Clinochlore 54%, Apatite 23%, Quartz 23%	v1, REE-F
Berchem	Belgium	4.433187	51.189882	Berch 1	Cm-size phosphate nodule in the "Sables d'Anvers", Berchem Fm.	Quartz 40%, Apatite 39%, Glauconite 19%, Albite 3%	OF
Berchem	Belgium	4.433187	51.189882	Berch 2	Cm-size phosphate nodule in the "Sables d'Anvers", Berchem Fm.	Apatite 78%, Quartz 10%, Glauconite 10%, Goethite 2%	OF
Sint Niklaas	Belgium	40147764	51.165109	STN 1	Fossil moulds replaced by phosphates in the "Boom clay"	Apatite 74%, Quartz 26%	OF
Sint Niklaas	Belgium	40147764	51.165109	STN 2	Fossil moulds replaced by phosphate in the "Boom clay"	Apatite 58%, Quartz 36%, Microcline 6%	OF
Moen, Bossuit Canaal	Belgium	3.394251	50.767645	MO	Cm-size phosphate nodule under a glauconitic layer	Apatite 76%, Quartz 16%, Glauconite 3%, Albite 3%, Montmorillonnite 2%	OF
Marke, Kockelberg	Belgium	3.219493	50.803869	MA	Cm-size phosphate nodule under a glauconitic layer	Apatite 76%, Quartz 19%, Glauconite 5%	OF
La Malogne	Belgium	3.932322	50.435506	LM1	Matrix-supported carbonate rock with silt- and sand-sized peloidal phosphatic grains	Calcite 64%, Apatite 34%, Quartz 2%	OF
La Malogne	Belgium	3.932322	50.435506	LM4	Weakly consolidated conglomeratic carbonate rock with abundant phosphatic pebbles	Apatite 50%, Calcite 47%, Quartz 3%	OF
La Malogne	Belgium	3.932322	50.435506	LM3	Unconsolidated to very weakly consolidated silt- and sand-sized peloidal phosphatic grains. Carbonates almost totally absent-Enriched pocket	Apatite 70%, Quartz 15%, Illite 10%, Goethite 3%, Nontronite 2%	OF
Hyon (boring)	Belgium	3.960824	50.439202	Hb56.76	Matrix-supported carbonate rock with silt- and sand-sized peloidal phosphatic grains	Calcite 93%, Apatite 6%, Quartz 1%	OF
Hyon (boring)	Belgium	3.960824	50.439202	Hb79.06	Matrix-supported carbonate rock with silt- and sand-sized peloidal phosphatic grains	Calcite 72%, Apatite 27%, Quartz 1%	OF
Hyon (boring)	Belgium	3.960824	50.439202	Hb90.2	Grain-supported carbonate rock with peloidal phosphatic grains	Calcite 81%, Apatite 18%, Quartz 1%	OF

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Table 6. Structure of the second database (D4.2) - part 2 (whole rock chemistry). Data for Belgian phosphate deposits and occurrence

	ICP-MS															ICPOES											
	LREE							HREE																			
ID (mineralOccurrence)	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Y (ppm)	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	LOI %	TOTAL %
Grand Halleux (boring)	46.60	95.80	10.60	41.30	8.80	2.80	9.30	1.50	8.40	1.60	4.40	0.64	4.10	0.60	46.00	50.47	0.98	23.74	8.03	0.15	1.59	2.65	1.05	4.57	1.95	4.86	90.32
Grand Halleux (boring)	45.00	102.00	12.00	51.30	14.40	2.74	18.80	3.00	16.10	2.70	6.80	0.87	5.10	0.71	80.00	60.50	0.64	11.77	14.11	0.61	1.62	2.21	0.47	1.71	1.31	5.33	89.62
Thy-le-Chateau	165.38	335.28	36.16	139.00	26.81	8.77	22.79	3.10	18.33	3.42	9.89	1.27	8.62	1.08	105.62	34.07	0.40	9.68	17.13	3.34	1.74	14.17	0.00	0.05	12.02	8.73	83.86
Thy-le-Chateau	165.38	335.28	36.16	139.00	26.81	8.77	22.79	3.10	18.33	3.42	9.89	1.27	8.62	1.08	105.62	34.07	0.40	9.68	17.13	3.34	1.74	14.17	0.00	0.05	12.02	8.73	83.86
Berchem	16.91	50.10	4.24	16.14	3.12	0.72	2.44	0.32	1.75	0.32	0.78	0.11	0.71	0.09	9.50	12.02	0.10	2.13	5.59	0.05	0.63	39.52	0.80	0.47	25.53	11.82	75.01
Berchem	18.38	60.87	4.74	18.43	3.59	0.76	3.28	0.41	2.21	0.40	1.00	0.16	0.85	0.15	10.70	15.27	0.09	2.22	5.97	0.02	0.74	40.25	0.72	0.98	15.41	10.93	70.73
Sint Niklaas	46.49	96.66	10.01	40.72	9.18	2.13	10.81	1.56	8.90	1.90	4.99	0.73	4.41	0.68	54.12	20.39	0.10	1.29	2.21	0.04	0.35	41.45	0.88	0.36	15.89	9.60	73.36
Sint Niklaas	53.43	114.82	11.70	48.33	10.26	2.42	12.00	1.73	9.90	2.11	5.57	0.80	4.64	0.76	57.81	29.55	0.14	1.57	2.18	0.03	0.38	36.38	0.86	0.45	12.95	8.94	75.56
Moen, Bossuit Canaal	207.76	405.53	44.89	176.41	32.60	6.89	28.88	3.65	21.56	4.38	11.63	1.42	9.04	1.29	148.80	15.09	0.24	2.12	1.32	0.07	0.42	40.59	0.87	0.29	26.05	9.26	77.81
Marke, Kockelberg	154.51	312.33	34.74	149.84	33.32	8.70	44.52	6.73	40.23	8.73	22.27	2.88	15.94	2.53	247.07	20.79	0.35	2.83	1.90	0.11	0.53	39.43	1.04	0.70	15.22	9.69	73.22
La Malogne	23.80	10.84	3.85	16.45	2.91	0.72	4.17	0.52	3.21	0.74	2.01	0.28	1.49	0.22	30.72	0.70	0.01	0.10	0.24	0.01	0.51	61.18	0.32	0.03	0.81	38.51	25.39
La Malogne	45.15	21.49	7.88	31.90	5.75	1.36	8.17	1.00	6.33	1.45	3.84	0.52	2.77	0.47	57.06	1.72	0.03	0.31	0.61	0.01	0.50	57.81	0.49	0.10	5.83	34.81	32.60
La Malogne	397.41	619.14	101.71	396.51	73.64	16.96	71.94	8.91	47.18	9.08	22.29	2.95	16.33	2.52	283.33	16.59	0.13	4.89	13.83	0.14	0.79	30.11	0.83	0.60	11.13	14.30	64.74
Hyon (boring)	25.76	12.76	4.44	18.38	3.30	0.77	4.44	0.59	3.44	0.78	2.07	0.27	1.53	0.25	32.21	0.74	0.01	0.11	0.20	0.01	0.41	60.75	0.23	0.03	1.61	41.05	23.07
Hyon (boring)	133.71	64.20	24.43	99.85	18.50	4.31	24.75	3.21	19.28	4.45	11.25	1.44	7.68	1.20	172.33	1.64	0.03	0.24	0.34	0.01	0.34	58.82	0.55	0.10	5.73	31.06	36.75
Hyon (boring)	157.84	77.12	29.19	121.95	21.52	5.24	29.37	3.73	22.61	5.07	13.28	1.67	9.10	1.48	197.29	6.16	0.04	0.47	0.40	0.01	0.38	55.20	0.63	0.16	6.71	28.02	42.12

Table 7. Structure of the second database (D4.2) - part 3 (electron microprobe analyses). Data for Belgian phosphate deposits and occurrence

	electron microprobe															
ID (mineralOccurrence)	Number of samples	SiO_2 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	P_2O_5 %	Cl %	F %	SrO %	BaO %	La_2O_3 %	Ce_2O_3 %	TOTAL %	Other Elements
Grand Halleux (boring)	gh2743-4	2.870	3.189	0.000	0.013	48.978	0.099	36.622	0.098	3.630	0.080	0.056			95.64	0.026
Grand Halleux (boring)	gh2952-1	0.123	0.137	0.088	0.010	54.481	0.000	40.904	0.000	4.374	0.259	0.043			100.42	2.060
Thy-le-Chateau	thy1-1	1.914	2.127	0.151	0.021	40.139	0.201	35.909	0.007	1.668	0.318	0.000			82.46	1.637
Thy-le-Chateau	thy1-3	1.885	2.095	0.189	0.000	43.929	0.176	38.467	0.016	2.597	0.186	0.071			89.61	1.358
Berchem	berch1	3.288	3.654	0.034	0.080	48.273	0.628	30.931	0.018	4.669	0.240	0.000			91.81	1.339
Berchem																
Sint Niklaas	stn1-2	1.124	1.249	0.085	0.100	48.631	1.086	30.007	0.027	3.774	0.371	0.000			86.45	0.000
Sint Niklaas																
Moen, Bossuit Canaal																
Marke, Kockelberg	ma-2	2.334	2.594	0.132	0.006	48.273	1.191	31.495	0.040	4.330	0.216	0.000			90.61	1.518
La Malogne	lm1-2	0.007	0.008	0.000	0.063	51.116	0.881	32.832	0.026	4.338	0.179	0.018			89.47	0.079
La Malogne	lm4-1	0.297	0.330	0.000	0.051	50.276	1.028	31.912	0.007	4.921	0.278	0.000			89.10	0.832
La Malogne	lm3-1	0.031	0.034	0.000	0.052	51.167	0.679	32.896	0.048	4.392	0.215	0.097			89.61	1.535
Hyon (boring)																
Hyon (boring)																
Hyon (boring)	hb90.2-2	0.072	0.080	0.000	0.253	51.074	0.571	31.322	0.058	4.564	0.217	0.000			88.21	0.075

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

The **third database** was prepared for the deliverable WP4-D4.3 "Detailed metallogenic studies of key phosphate deposits in Europe". Its general structure is the same as the second database. Hundreds of mineralogical data and chemical analyses (whole rock, electron microprobe and LA-ICPMS) were acquired or gathered from the literature in order to carry out metallogenic studies on a selection of representative phosphate deposits in Europe. These deposits comprise the igneous phosphate deposits encountered in Norway, the carbonatite related Siilinjarvi deposit (Finland), the phosphatic chalk of the Mons basin (Belgium), the phosphate deposits of the Salento Peninsula (Italy), the phosphorites of the Bohemian Cretaceous Basin (Czech Republic), and the Moncorvo deposit (Portugal).

The database was compiled using the template provided by WP8, as described in section 2.2. An extract from the table provided to FRAME-WP8 is presented here below (Tables 8-11). The full table is part of the Annex provided in WP4-Deliverable D4.2.

Table 8. Structure of the third database (D4.3) - part 1 (mineralogy). Data for the Siilinjarvi deposit (Finland)

ID (mineralOccurrence)	Country	X	Y	Sample Number	Description	Raman spectra description (only fluorescence : OF, phosphate peak at ~963 cm-1 : v1, or all phosphate peaks + REE-induced fluorescence : REE-F)	References
Siilinjarvi	Finland	27.733294	63.141931	Si8	fenite (amph)	v1, v2, v3, V4, REE-F	Decrée et al. (2020) for GeoERA-FRAME-D.4.3
Siilinjarvi	Finland	27.733294	63.141931	Si11	fenite (amph)	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si7 (UCS R713 L-128_577-577.60)	carbonate glimmerite	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si3	fenite (pyrox)	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si9 (UCS R713 L-136_614.85-615.35)	fenite (pyrox)	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si4	fenite (pyrox)	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si5	silica carbonatite	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si6	carbonatite	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si1	glimmerite	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si2 (R713 L-114_513.95-514.45)	fenite (amph)	v1, v2, v3, V4, REE-F	
Siilinjarvi	Finland	27.733294	63.141931	Si10	carbonatite (apatite rock)	v1, v2, v3, V4, REE-F	

Table 9. Structure of the third database (D4.3) - part 2 (whole rock analyses). Data for the Siilinjarvi deposit (Finland)

	ICP-MS															ICP-OES											
	LREE							HREE																			
Sample Number	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Y (ppm)	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	LOI %	TOTAL %
Si8	441.9	1050.6	135.2	520.6	74.5	18.79	48.01	4.595	22.19	3.07	6.91	0.75	4.37	0.59	81.33	0.27	0.01	0.00	0.45	0.13	0.81	54.69	0.08	0.00	11.42	32.32	100.19
Si11	523.3	1407.6	192.9	784.3	117.1	29.21	72.64	6.451	27.61	3.58	6.84	0.60	3.05	0.33	85.68	0.06	0.01	0.00	0.37	0.07	1.17	54.09	0.19	0.00	34.18	10.59	100.71
Si7 (UCS R713 L-128_577-577.60)	73.0	176.6	23.3	89.5	13.6	3.49	8.77	0.879	4.12	0.58	1.29	0.16	0.83	0.09	15.31	28.24	0.09	6.53	6.96	0.10	17.45	17.14	0.08	5.27	2.32	15.15	99.34
Si3	12.3	30.6	3.9	15.5	2.3	0.57	1.23	0.135	0.49	0.09	0.20	0.02	0.12	0.02	2.25	36.94	0.20	8.07	9.91	0.05	21.51	4.10	0.16	6.89	0.23	7.39	95.46
Si9 (UCS R713 L-136_614.85-615.35)	205.6	534.9	72.9	294.0	42.7	10.68	26.88	2.431	9.73	1.38	2.50	0.24	1.18	0.11	31.54	27.24	0.11	5.32	7.84	0.04	14.92	18.60	0.33	4.91	14.01	2.22	95.55
Si4	21.3	49.9	6.7	26.4	4.5	1.11	2.86	0.272	1.45	0.23	0.55	0.08	0.66	0.16	6.04	52.88	0.22	8.19	7.90	0.13	5.49	10.83	2.76	5.53	0.55	3.98	98.46
Si5	87.9	204.8	26.3	99.7	14.2	3.41	9.08	0.888	3.99	0.57	1.32	0.16	1.42	0.26	15.86	44.97	0.50	3.73	11.34	0.20	5.24	19.08	3.66	2.02	1.40	7.76	99.90
Si6	56.3	135.2	17.5	68.9	10.0	2.44	6.03	0.563	2.60	0.32	0.70	0.07	0.45	0.06	8.78	56.77	0.08	12.87	2.68	0.05	2.67	7.63	2.01	7.66	2.93	1.41	96.75
Si1	23.9	62.7	8.9	36.8	5.4	1.32	3.46	0.318	1.58	0.23	0.46	0.06	0.34	0.07	5.37	55.65	0.27	6.56	9.40	0.12	10.61	6.39	2.85	3.69	1.43	1.79	98.74
Si2 (R713 L-114_513.95-514.45)	63.5	150.1	19.5	74.9	11.0	2.95	7.27	0.650	3.08	0.44	1.05	0.11	0.94	0.14	11.12	47.98	0.25	4.81	6.58	0.18	9.87	13.12	3.23	4.06	2.38	6.07	98.54
Si10	81.7	185.5	23.9	91.3	13.5	3.41	9.10	0.944	4.42	0.67	1.49	0.17	1.01	0.13	18.42	26.65	0.05	2.32	5.68	0.17	11.77	28.03	0.89	1.71	1.22	19.32	97.83

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

Table 10. Structure of the third database (D4.3) - part 3 (electron microprobe analyses). Data for the Siilinjarvi deposit (Finland)

		electron microprobe													
Sample Number	**Number of samples**	**SiO_2 %**	**Fe_2O_3 %**	**MnO %**	**MgO %**	**CaO %**	**Na_2O %**	**P_2O_5 %**	**Cl %**	**F %**	**SrO %**	**BaO %**	**La_2O_3 %**	**Ce_2O_3 %**	**TOTAL %**
Si8	3	0.034	0.028	0.032	0.000	55.022	0.066	40.164	0.005	2.534	0.818	0.032			97.705
Si11	2	0.054	0.035	0.013	0.013	55.423	0.082	39.298	0.017	2.652	0.726	0.061			97.319
Si7 (UCS R713 L-128_577-577.60)	4	0.029	0.017	0.032	0.012	55.098	0.172	40.574	0.014	3.008	0.897	0.004			98.615
Si3	2	0.048	0.081	0.050	0.008	55.293	0.093	41.114	0.003	3.010	0.669	0.004			99.151
Si9 (UCS R713 L-136_614.85-615.35)	4	0.024	0.078	0.015	0.038	55.047	0.134	40.998	0.000	2.843	0.878	0.060			98.973
Si4	4	0.099	0.053	0.029	0.000	55.207	0.113	41.606	0.000	2.902	0.907	0.010			99.747
Si5	4	0.071	0.020	0.064	0.032	55.342	0.090	41.043	0.020	2.740	0.743	0.012			99.090
Si6	4	0.072	0.045	0.052	0.006	53.887	0.106	40.896	0.006	3.114	0.686	0.014			97.611
Si1	4	0.063	0.020	0.047	0.012	51.910	0.107	39.413	0.011	3.106	0.739	0.009			94.231
Si2 (R713 L-114_513.95-514.45)	3	0.061	0.031	0.009	0.022	54.669	0.123	39.451	0.006	2.521	0.954	0.034			96.916
Si10	5	0.056	0.041	0.011	0.024	53.428	0.199	40.765	0.013	2.947	0.871	0.036			97.271
B2	1	0.003	0.003	0.000	0.053	49.197	1.177	30.159	0.166	4.362	0.258	0.000			85.38
PR1	1	2.903	3.226	0.015	0.169	48.359	0.772	20.658	0.032	3.634	0.196	0.012			79.98
C3	1	1.262	1.402	0.050	0.081	48.218	1.077	29.695	0.031	4.452	0.260	0.051			86.58
L10b	1	0.323	0.359	0.003	0.081	46.939	1.029	27.006	0.043	4.269	0.162	0.012			80.23
C2	1	0.251	0.279	0.081	0.045	49.826	1.180	32.585	0.033	4.526	0.261	0.000			89.07

Table 11. Structure of the third database (D4.3) - part 4 (LA-ICPMS analyses). Data for the Siilinjarvi deposit (Finland)

						LA-ICPMS															
						LREE								HREE							
Sample Number	**U (ppm)**	**V (ppm)**	**W (ppm)**	**Zn (ppm)**	**Zr (ppm)**	**La (ppm)**	**Ce (ppm)**	**Pr (ppm)**	**Nd (ppm)**	**Pm (ppm)**	**Sm (ppm)**	**Eu (ppm)**	**Gd (ppm)**	**Tb (ppm)**	**Dy (ppm)**	**Ho (ppm)**	**Er (ppm)**	**Tm (ppm)**	**Yb (ppm)**	**Lu (ppm)**	**Y (ppm**
Si8	0.201667	#DIV/0!				914.9667	2798	334.3	1356		202.7333	46.45333	120.3667	10.98333	49.83	6.603333	13.02	1.256667	5.673333	0.607	154.5
Si11	0.2395	3.555				562.5	1717	218	916		140.55	32.85	82.45	7.67	32.25	4.16	7.46	0.6715	3.04	0.2835	96.25
Si7 (UCS R713 L-128_577-577.60)	0.624	3.7675				656.375	2026	245.125	998.75		155.025	36.71	96.2	8.935	40.0575	5.13	9.8475	0.90625	4.345	0.4145	123.8
Si3	0.3275	5.645				512.45	1447.5	197	857		133.3	32.135	84.2	7.935	35.12	4.5955	8.48	0.771	3.35	0.331	110.2
Si9 (UCS R713 L-136_614.85-615.35)	0.305	2.425				529.325	1550.75	196.65	812.5		123.25	29.2075	73.375	6.58	28.695	3.675	6.9375	0.63825	2.9525	0.30075	86.35
Si4	1.9695	1.19175				991.8	2651.5	300.225	1181.15		170.775	38.885	104.25	9.645	43.7925	5.985	11.98	1.2105	6.2725	0.70575	143.8
Si5	1.054	185.7425				188.125	629.425	96.575	454.1		77.1	17.0725	53.35	4.675	21.485	3.1	6.6425	0.7205	4.2675	0.647	79.75
Si6	1.28825	2.99				370.775	1141.75	153.625	662.525		105.15	24.07	65.5	5.8825	25.9725	3.5175	6.8325	0.6635	3.1525	0.3515	87.025
Si1	0.66675	2.395				391.425	1178.5	161.275	698.75		107.9	22.8975	66.675	6.03	27.045	3.5725	7.105	0.71825	3.415	0.38175	87.25
Si2 (R713 L-114_513.95-514.45)	1.447	0.483667				792	2133.667	247.0333	1001		146.1667	32.99333	86.06667	8.08	35.36667	4.8	9.603333	0.991	5.396667	0.646667	110.6
Si10	0.8241	6.27				665.6833	2015	259.2167	1114.75		168.6333	39.53167	100.2667	8.903333	37.6	4.744	8.648333	0.766	3.331667	0.340333	109.0

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

3.2. Maps produced using the databases provided by WP4

The maps presented here were produced using the databases described in section 3.1. The **Phosphor metallogenic map of Europe** (Fig. 1) aims at illustrating the diversity and potential regarding phosphate mineralization in Europe. It further helps at identifying new areas of interest for CRMs in Europe. A metadata file was prepared to upload this map to EGDI (Table 12). This task involved the FRAME-WP4 partners.

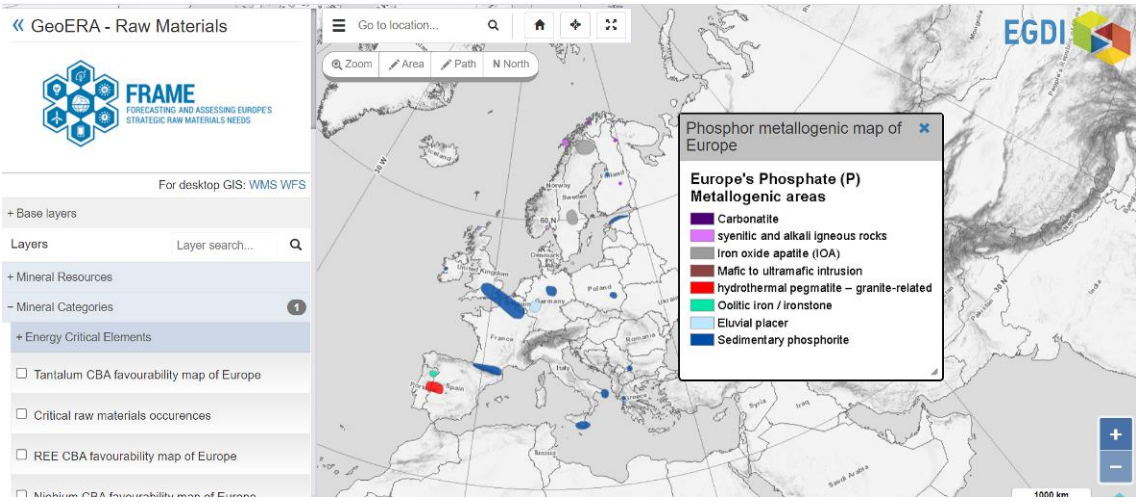

Figure 1. Phosphor metallogenic map of Europe (FRAME project)

Table 12. Metadata provided for the Phosphor metallogenic map of Europe

Metadata element	item descriprion	metadata in English
Required minimum for uploading metadata to the EGDI platform and for saving metadata record in Metadata Catalogue		
Resource title	Name by which the cited resource is known	Phosphor metallogenic map of Europe
Resource abstract	Brief narrative summary of the content of the resource(s).	Overview map showing the approximate extent of the key Phosphor metallogenic areas in Europe.
Resource type	Valid values for the EGDI projects are dataset, series, non-geographic dataset, service. For 3D models choose "dataset".	dataset
Responsible party	Contact person responsible for the content of the data, name, email, organisation	Daniel Oliveira. National Laboratory of Energy and Geology, I.P. servicos.urmg@lneg.pt. Point of contact. Martiya Sadeghi, Mineral resource Department, Geological survey of Sweden (SGU); martiya.sadeghi@sgu.se. Custodian. Sophie Decree. Author
Metadata point of contact	Contact person responsible for the metadata, name, email, organisation	Aurete Pereira, geoportal@lneg.pt, National Laboratory of Energy and Geology, I.P.
Identifier		
Keyword	At least GeoERAProject name required	FRAME Mineral Resources (category), critical raw materials (CRM), metallogenetic map, phosphor
Free Keyword		EGDI, WP4 (FRAME), WP3 (FRAME)
Reference date	Date of creation/publication of the cited resources	13-11-20
Lineage	Description of the history of processing and the overall quality of the dataset, including information on the input data, SW used, if the data/model has been approved etc.	Data from the national database of the project partners' countries; data from data sources: ProMine, FODD, SIORMINP, and Mine records database; verified data extracted from references issued from the literature; verified data resulting from mineralogical and chemical studies performed on samples from various collections and sampled in the field
Spatial resolution	Can be described by equivalent scale or a distance	Pan european scale; 1/5 000 000
Coordinate reference system	Coordinate reference system(s) used in the dataset	ETRS-LCC (3034)
Spatial represenatation type	Method used to spatially represent geographic information (vector, grid, vid	vector
Purpose	Summary of purposes for which the data source was created (internal projec	Comprehensive database and maps illustrating the diversity and potential regarding phosphate mineralization in Europe; help at identifying new areas of interest for CRMs in Europe

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The aim of the **Phosphate CBA favourability map of Europe** (Fig. 2) is to highlight the areas the most favourable to find phosphate deposits.

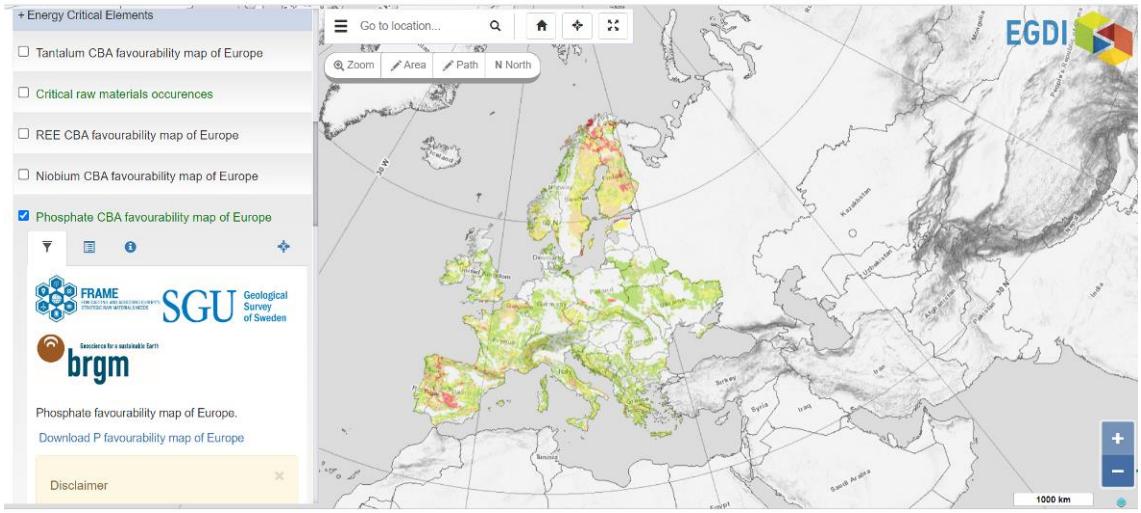

Figure 2. Phosphate CBA favourability map of Europe (FRAME project)

The pan-European map presenting the **European phosphate metallogenic area** (Fig. 3) was drawn gathering the data from FRAME and MINDeSEA. It shows polygons highlighting the potential regarding onshore and offshore phosphate mineralization in Europe.

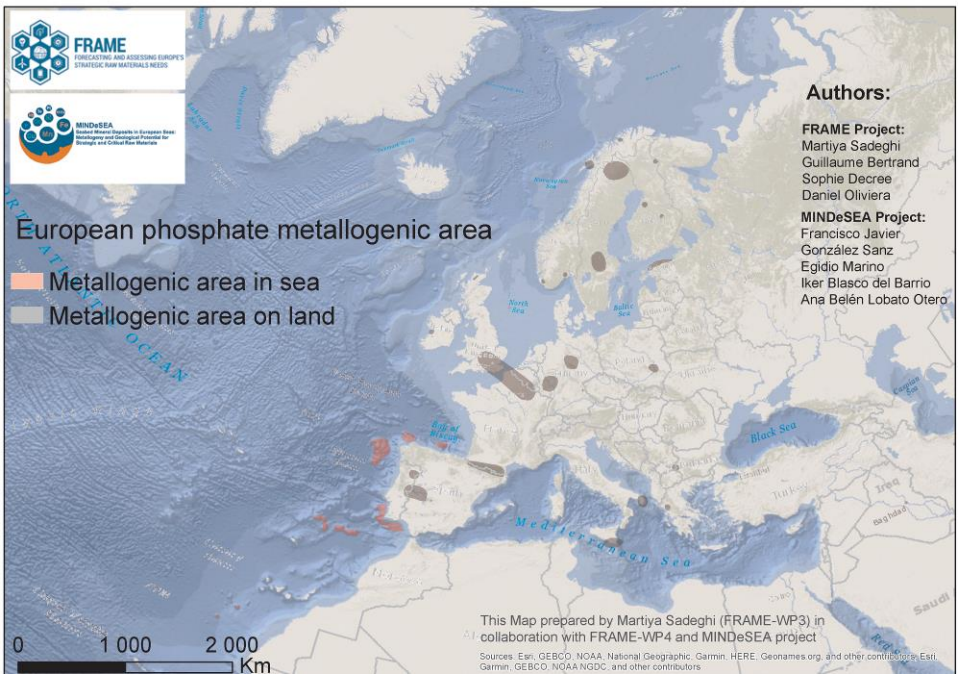

Figure 3. European phosphate metallogenic area (FRAME and MINDeSEA project)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

A last map shows the **European phosphate mineralization on land and sea** (Fig. 4). This map emphasizes the diversity of the phosphate deposits off- and onshore.

To upload to EGDI these two maps combining data from FRAME and MINDeSEA, a new metadata file was created thanks to the contribution of the WP4 partners, among others.

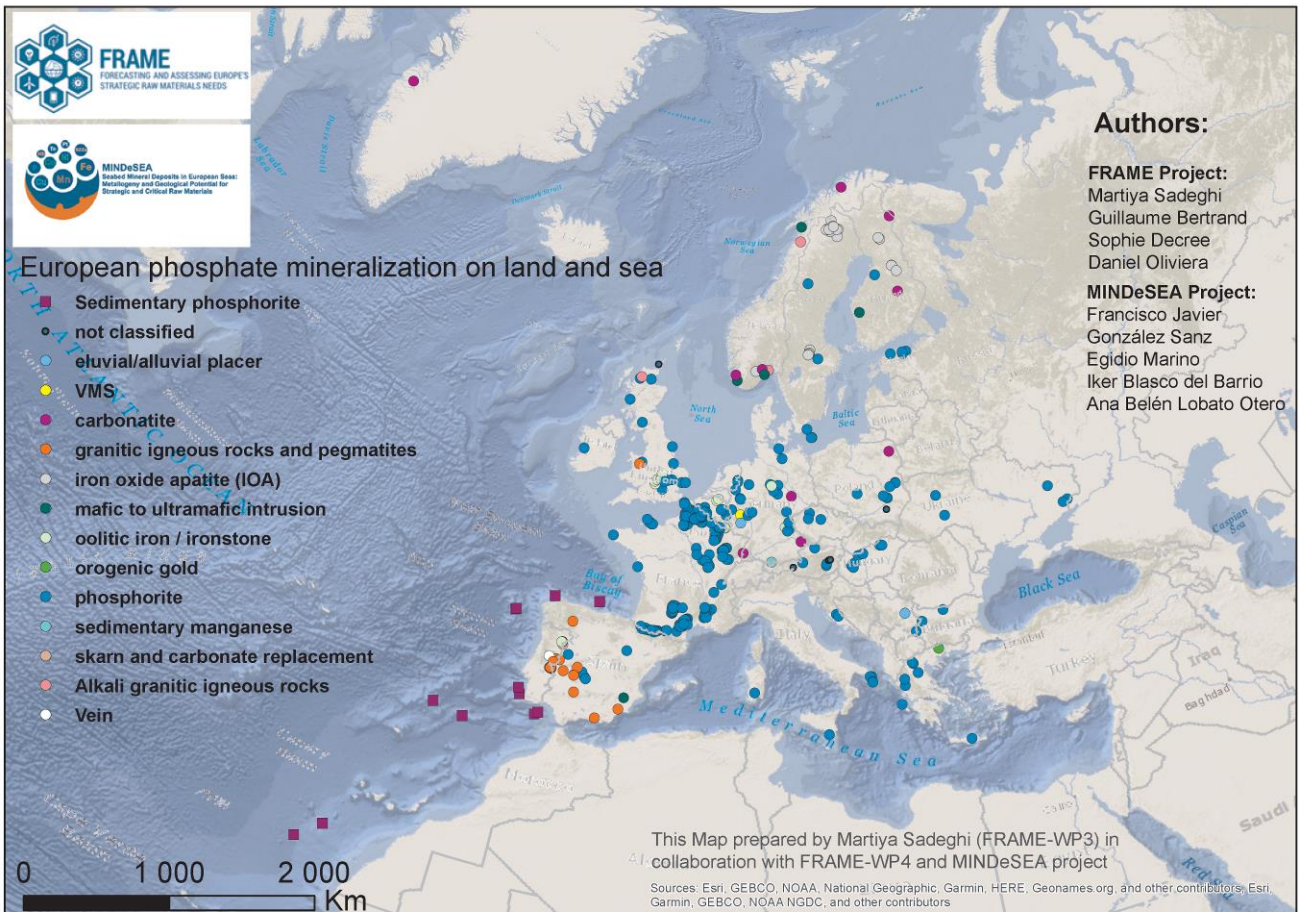

Figure 4. European phosphate mineralization on land and sea (FRAME and MINDeSEA project)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

4. Conclusions

Many data were delivered to FRAME-WP8, FRAME-WP3 and MINTELL4EU through three databases, that comprise:

- 429 entries relating to phosphate deposits and occurrences throughout Europe in the database (overview of the phosphate mineralization in Europe; Deliverable D4.1),
- new mineralogical and geochemical data obtained on about 90 samples representative of ~75 phosphate occurrences and deposits throughout Europe (Deliverable D4.2),
- hundreds of new mineralogical and geochemical (whole rock, electron microprobe, LA-ICPMS) data compiled in the framework of the metallogenic studies (Deliverable D4.3).

Owing to the goals aimed by WP4 and the diversity of data collected, the major challenge regarding the data transfer was to design databases with a structure that can accommodate a variety of mineralogical data and geochemical analyses.

The excellent collaboration between FRAME-WP4, FRAME-WP8 (and FRAME-WP3 for the work about prospectivity mapping) and MINTELL4EU made possible the integration of these new data, both in the EGDI, MIN4EU databases and under the form of maps.

These data – considered into larger and well-designed databases and maps – contribute to highlight promising areas regarding phosphate deposits (and related CRMs) in Europe.

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