FRAME
FORECASTING AND ASSESSING EUROPE'S STRATEGIC RAW MATERIALS NEEDS

DELIVERABLE D3.4

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

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

GeoERA RAW MATERIALS

Deliverable D3.4

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

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1. Introduction

The overall aim of FRAME project into the European Union Raw Materials Knowledge Base (EURMKB) is to provide data on CRM by extending the spatial coverage and higher accurate data from past and ongoing European projects on raw materials. The prime aim of work package (WP)3 in the FRAME project is to produce a map of strategic and critical raw materials (SCRM) for Europe. In cooperation with other FRAME WPs, there was a consensus on the methodology used for the identification and selection process of the SCRM to be included in that map (Arvanitidis, et al., 2019; Sadeghi et al., 2020a; Sadeghi et al, 2020b) linked mainly to information collected from existing databases, such as the ones of ProMine, Minerals4EU (M4EU), EURARE and European Geological Data Infrastructure (EGDI). WP3 also has a special focus to present the metallogenetic maps and updating databases on rare earth elements, graphite, cobalt, lithium, phosphor, niobium and tantalum in collaboration with the other work project packages (WP4, WP5 and WP6) and the Mineral Resource Expert Group (MREG) of EuroGeoSurveys. The digital version on metallogenetic areas have been prepared and delivered to EGDI (Sadeghi et al, 2020b). The occurrences dataset is harvested through national databases on *structured* data to be accessed in EDGI. A semi and *non-structured* datasets were also prepared and deliver to EGDI (EGDI, 2021a, 2021b). An overview on how this was done is given in Chapter 3 of this report – Data preparation and Delivery to EGDI.

EGDI is developed by members of EuroGeoSurveys (the organization of geological surveys in Europe) and organizes and gives access to results from several current and previous projects on mineral resources, geo-energy, groundwater, geochemistry, geophysics, geohazards, etc. EGDI is extended to support data and other results from all GeoERA projects. In the FRAME project, all partners and MREG have been involved in to updating the national databases with harmonised data and share it through the European Minerals Knowledge Data Platform (EU-MKDP). To achieve this, understand the overall technical process behind it was needed, which was undertaken through several meetings and workshops in collaboration with the Mintell4EU

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and GIP-P projects. The same information which is accessible on the EU-MKDP portal is also accessible on the EGDI portal (Šinigoj el al., 2019).

The major objectives of the European Minerals Knowledge Base (EURMKB) are:

- **Data -** to provide EU level data and information on raw materials from different sources in a harmonised and standardised way.
- **New activities –** to encourage activities in the raw materials sector such as exploration, extraction, processing, and recycling, as well as trade, development, skills, and education.
- **Increased supply –** to increase the supply of raw materials, as well as strengthen Europe's position on the forefront of the raw materials sector.

2. How the knowledge base works for the FRAME project

The information on primary and secondary sources of raw materials, together with expertise, is form according to following:

- **Data collection** - data and information have been collected from different sources, such as geological surveys in EU countries, other national and international organizations, European projects and programmes, and publication and categorized in two different *structured* and *non-structured* datasets.
- **Expertise** - selected parts of commodities (dedicated WPs in the FRAME project) were considered and in addition to data collection, information regarding the formation, classification, mineralogy, geological setting, grade, tonnage have been collected or new field campaign and sampling carried out and the samples are analyzed and then stored in databases.
- **Harmonisation** - each partner is mapping its data into a common database model with the codelists from INSPIRE which are being improved since the EuroGeoSource project. The latest version of the common database model is now known as MIN4EU DB.
- **Delivery** - metadata, tabular data, maps, documents, photos are delivered to EGDI by either direct upload or by services via a process called harvesting described hereafter.

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The EU-MKDP adopted a professional architecture with a harvesting system and a diffusion system (Figure 1). The system is divided into three parts (Cassard et al., 2014):

• The national level from which an INSPIRE compliant WFS' (Web Feature Service) delivers data to the harvesting system either from structured databases or directly from other data sources in each country

• The central harvesting system which regularly reads data from the national WFS' and stores it in the Harvesting Database. Data is subsequently being delivered to the diffusion system through a database synchronization mechanism. The Harvesting Database is optimized towards reading data from the national level and delivering this data to the diffusion system.

• The central diffusion system which is updated with data from the harvesting system at regular intervals and makes this data available to users through the EU-MKDP and the EGDI web portals.

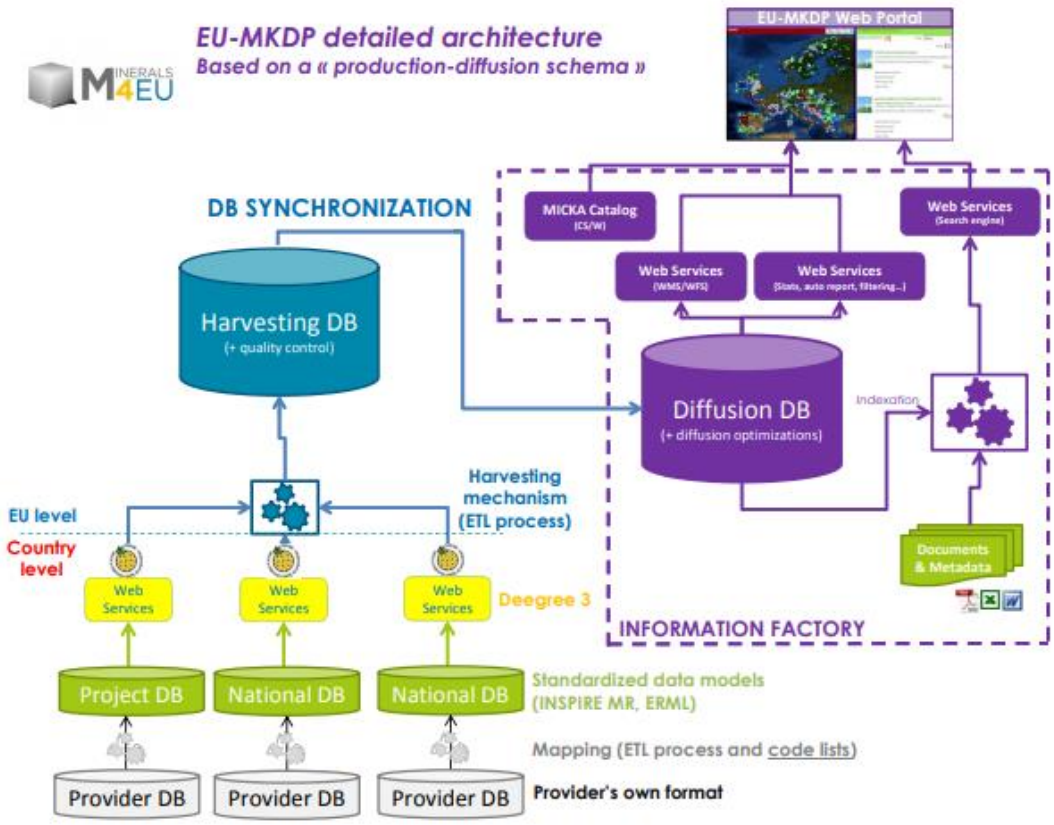

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Figure 1. The EU-MKDP detailed architecture showing the Harvesting Database, the synchronization process with the Diffusion Database, the Information factory and the indexation process of both structured and semi- and non-structured data. (source: Cassard D., 2015).

The Harvesting system

Data harvesting is a process which reads and automatically extracts large amounts of data from the Web (in form of Web pages or Web services) (Šinigoj el al., 2019). The harvesting system was set up by GeoZS and is being improved since EuroGeoSource project. This system periodically collects data from data providers and updates the harvesting database using a WFS. This database is hosted by GeoZS and connects to the diffusion database (hosted by BRGM) using SQL scripts (Figure 2).

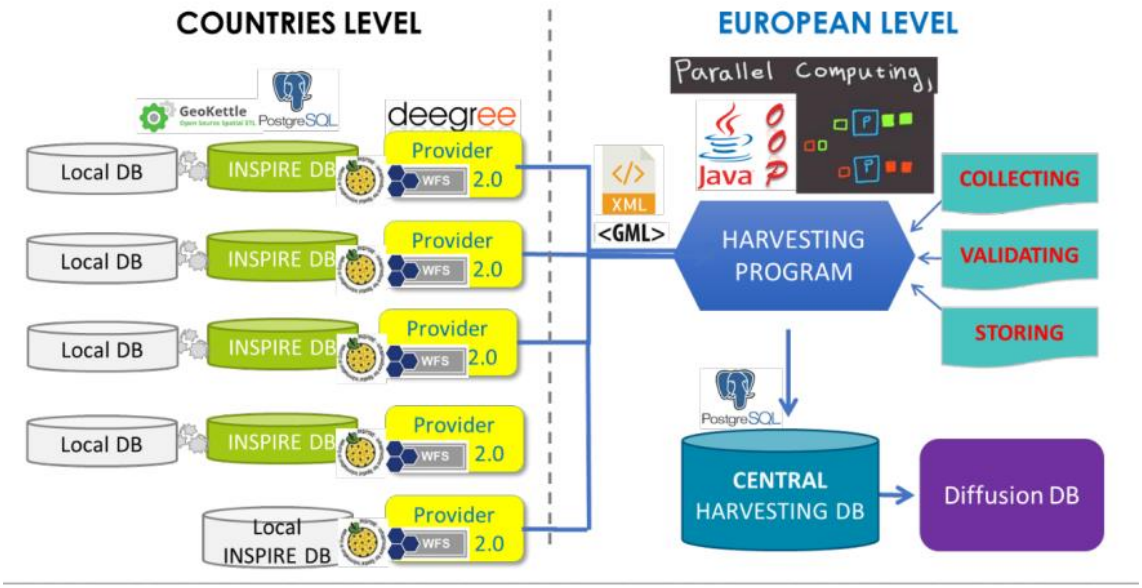

Figure 2. The harvesting system structure. (source: Šinigoj et al., 2019)

During the harvesting phase data collected from WFS, implemented by the national data providers, is checked mainly:

a) if the nomenclature used conforms to the INSPIRE list of values
b) if data have the correct format according to standards (e.g., dates, numbers…).
c) if the geometry data is correct

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Significant improvements to the overall system were done in ORAMA project and more recently ongoing through Mintell4EU and GIP-P projects. Now all data providers can get information about the harvesting and database status from a newly developed web page available at https://harvesting.geo-zs.si/main. Several different technical solutions are provided in one place:

- Service monitoring page. – web page with the smiley and sadly faces color green and red near the country name of data provider
- Count reports - to check the number of records harvested. The ability to compare two count reports performed at different dates is also present.
- Alert report – a list of possible errors in SQL so now it's easy to identify what is wrong from national providers side
- Chart reports - to check provider progression in amount of data inserted in national databases over time
- Quality Control Application – to check the data from each provider before publishing it in EGDI

Data Harmonisation

FRAME data providers should harmonise their data according to INSPIRE data specifications as far as it is possible. Some outlines from the Mintell4EU project need to be highlighted with regard to its key challenges (Šinigoj et al., 2019):

1. Partners are encouraged to provide the latest version of the common database model and the latest data. The ability to identify the version of the database was added to the model.

2. Each national provider should follow the technical guidelines to harmonise their data, available at the GEUS repository. These documents describe, extend and detail the main steps of the harmonisation process: a) how to implement the common database model, b) how to set up the WFS service, c) how to insert data into the database model (primary and secondary data). An open source software tool stack is also available along with database install scripts and code lists.

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3. The quality of the data inserted depends on each partner quality assurance procedures. The FRAME project is not aware of the procedures at each Geological Survey, but recommendations were sent to each partner to check the quality of the data and the contents.
Special attention should be paid to the requirements:

a) INSPIRE IDs should not change in time,
b) When a modification is made in the database change the *versionID* and the *begin/end lifespan* fields;
c) *Voidreason* fields only need to be filled to justify the absence of data with the following legal codes: unpopulated, unknown or withheld;
d) the eXclusive OR (XOR) table connections should be respected as they are not implemented as database constraints.

Code lists

At national level each data provider should map their own data to the INSPIRE code lists. This means that correspondences between terms used by each provider and the ones established by INSPIRE should be done. However not always this is possible and when it is there are always different interpretations made by each data provider. Three distinct situations must be considered when mapping to the INSPIRE code lists: i) a complete match, ii) a partial match and iii) no match.

In the FRAME project no matching terms were identified mainly in WP5. Table 1 shows a matching table between the terms to classify genetic types of ore deposits.

Table 1. *Matching table between INSPIRE Deposit Type code list and WP5 code list*

Code list v1.1.2	WP 5 code list
DepositTypeType	Deposit type
	Brines
	Graphite (amorph)
	Graphite (flake)

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	Graphite (vein)
	Graphite (unclassified)
greisen	Greisen
iron oxide copper gold (IOCG)	IOCG
laterite	Laterite
	Lithium Phosphate Quartz Vein
mafic to ultramafic intrusion	Magmatic Ni-Cu-Co, Magmatic Fe-Ti-V
	Magmatic hydrothermal
	Metamorphic
orogenic gold	Orogenic Au
	Pegmatite-aplite
	Rare metal granite
	Sediment hosted Cu-Co
shale-hosted (incl. SEDEX)	Black schist
vein, including polymetallic and 5 element vein (Bi, Co, Ni, Ag, U)	5-element vein type, Vein type, Sulfarsenides
	VMS deposit
	unclassified

Only 9 of 23 different genetic types of Li, Co and Graphite deposits have an INPIRE equivalent code (Gautneb et al., 2020). Therefore, a proposal for new additions to the list of deposit types was made by WP5. As result ten new genetic types were added to the list of types of deposits (Table 2).

Table 2. *New genetic types added to the latest INSPIRE Deposit Type codelist (v2020.8.01)*

Deposit type	Description	Deposit Group
Graphite (flake)	Flake graphite (crystal size > 100 micron) https://doi.org/10.2113/gselements.10.6.415	metamorphic

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Deposit type	Description	Deposit Group
Graphite (amorph)	Amorphous graphite (crystal size < 1 micron usually https://doi.org/10.2113/gselements.10.6.415	metamorphic
Graphite (vein)	Vein graphite (hydrothermally deposited graphite) https://doi.org/10.2113/gselements.10.6.415	metamorphic
Lithium Phosphate Quartz Vein	Amblygonite-Montebrasite quartz veins of hydrothermal origin frequently spatially associated with Rare Metal Granites. https://doi.org/10.1016/j.oregeorev.2019.103215	felsicIntermediateIgneousRockRelated
Pegmatite-aplite	Pegmatites are texturally complex igneous rocks marked by extremely large but variable crystal size, spatial zonation of minerals, prominent anisotropy of crystal orientations from the margins inward, or skeletal, radial, and graphic intergrowth habits of crystals. Any one attribute is sufficient, none is necessary, and they commonly occur in combination within a single pegmatite body. https://doi.org/10.1016/B978-0-12-409548-9.12489-3	felsicIntermediateIgneousRockRelated
Magmatic hydrothermal	Ore deposits associated with hydrothermal fluids associated with magmatic activity. Robb, L. 2005 Introduction to ore forming processes chapter two, Blacwell Publishing	metasomaticReplacementOrHydrothermalShearOrVein
metamorphic	Mineral deposit formed by regional or contact metamorphism. https://doi.org/10.5382/Rev.11	metamorphic
Rare metal granite	Rare metal granites are relatively quartz-poor albite-rich granites hosting a disseminated essentially magmatic mineralisation. They are generally emplaced at a high crustal emplacement level with frequent volcanic equivalents. https://doi.org/10.5382/AV100.12	felsicIntermediateIgneousRockRelated

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Deposit type	Description	Deposit Group
Volcanogenic Massive Sulphide	Volcanogenic Cu-Zn-Pb deposits in general. https://doi.org/10.3133/sir20105070C	marineVolcanicAssociation
Sediment Hosted Copper	Sediment hosted Cu deposits, such as Central African Copper Belt and Kupferschiefer. https://pubs.usgs.gov/sir/2010/5090/j/sir2010-5090j_text.pdf	sedimentHosted

Still the codelist latest version (v2020.8.01) is simply not detailed enough to accomodate some genetic types compared to WP5 codelist and in some other few cases is more detailed.

3. Providing CRM data to EURMKB

Data collection

In the FRAME project data and information have been collected from SCRM mineral deposits including any available geological knowledge, classification deposit types involved. Data currently residing in the EU-MKDP has been the core for data collection in the FRAME project, especially when there was not dedicated work packages to work with specific commodities, based mainly on the methodology and the instructions provided by the Mintell4EU project.

Several EU projects addressed objectives and issues related to CRM and other strategic minerals at the various levels of details (Table 3). The information available from their websites varies a lot and have been used in updating data on CRM and strategic minerals.

Table 3. *Some of the EU projects (completed and on-going projects addressing the CRM from mineral-based waste).*

Project	Full name	Status	Links	Strategic mineral relevance	Digital data platform
PROMINE	Nano-particle products from new mineral resources in Europe	Finished project	http://promine.gtk.fi	yes	yes

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Project	Full name	Status	Links	Strategic mineral relevance	Digital data platform
MINERALS4EU	Minerals Intelligence Network for Europe	Finished project	http://www.minerals4eu.eu/, http://minerals4eu.brgm-rec.fr/	yes	yes (incomplete, not all countries represented)
EuroGeoSource	EuroGeoSource	Finished project	http://www.eurogeosource.eu	partly	not operational for the moment
EURARE	EURARE (Development of a sustainable exploitation scheme for Europe's Rare Earth ore deposits)	Finished project	http://www.eurare.eu/	yes	Integrated Knowledge Management System (IKMS) for REE resources in Europe.
EGDI	European Geological Data Infrastructure	on-going	http://www.europe-geology.eu/	yes	yes
MINVENTORY	The Minventory metadata portal Minventory Portal	Finished project	http://www.minventory.eu/ https://ec.europa.eu/jrc/en/scientific-tool/minventory	partly	Yes Final Report: Minventory - EU raw materials statistics on resources and reserves
ERA-MIN	ERA-NET Cofund on Raw Materials (ERA-MIN 2)	on-going	https://www.era-min.eu/	yes	no
PROSUM	ProSUM – Prospecting Secondary raw materials from the Urban Mine and Mining waste	Finished project	http://www.prosumproject.eu/	yes	yes

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Project	Full name	Status	Links	Strategic mineral relevance	Digital data platform
MICA	Mineral Intelligence Capacity Analysis	Finished project	http://www.mica-project.eu/	yes	yes (under construction)
SCRREEN	Solutions for Critical Raw materials-a European Expert Network	Finished project	http://scrreen.eu/	yes	Preliminary version (prototype) of the EUCRMKDP (EUROPEAN UNION CRITICAL RAW MATERIALS KNOWLEDGE DATA PLATFORM)
MINDeSEA	Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials	Ongoing project	GeoERA Comunidad de Madrid MINDeSEA (wixsite.com)	yes	Seabed Mineral Deposits in European Seas

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Project	Full name	Status	Links	Strategic mineral relevance	Digital data platform
GIP-P	GeoERA Information Platform Project (GIP-P)	Ongoing project	GeoERA Information Platform Project (GIP-P) | GeoERA	yes	The platform will be based on a coherent architecture which will take into account experiences gained in previous EU-funded data harmonization projects and be built as an extension to the European Geological Data Infrastructure EGDI.

EGDI gives access to datasets and services from several pan-European data harmonisation and infrastructure projects, either entirely funded by EGS members or co-funded by the EU, including OneGeology-Europe (geological mapping), EuroGeoSource (energy and minerals), ProMine (minerals), PanGeo (Earth Observation and geohazards), TerraFirma (Earth Observation and geohazards), GeoMind (geophysics), GEMAS (soils and geochemistry) and EMODNet (seabed mapping).

The FRAME project-WP3 has classified and organized the latest data, back then, on CRM harvested by GeoZS and send to the respective partners involved in the FRAME project as well the members of the MREG in respective countries for evaluation and updating the missing information on CRM and strategic commodities.

Mineral Resources Expert Group (MREG)

The MREG has a task team with the functional role to register the project activities carried out by European Geological Surveys at national level and monitor the progress of ongoing national projects addressing mineral resources and any other topics and issues of relevance. The MREG group has a great impact in data collection in cooperation with specific WP's in the FRAME project or incorporate and update the national databases.

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Data received from other GeoERA raw materials projects and FRAME WPs.

Mintell4EU- Mineral Intelligence for Europe

Data collection and related information of strategic minerals carried out during the FRAME project will address and implement the harvesting methodology, instructions and guidelines provided by the Mintell4EU project in order to improve the overall EURMKB.

FRAME WPs 4, 5, 6 & 7

There are obvious and clear linkages between WP3, WP4, WP5, WP6 and WP7 of the FRAME project when it comes to collect respective strategic minerals data and information based on common harvesting methodology and being compliant to INSPIRE.

The data of all strategic minerals raw materials is collected by respective WPs the following way:

- WP 3 coordinates and provides overall view on the critical raw materials and strategic minerals and produces metallogenic area maps and prospectivity maps related to selected CRMs.
- WP 4 (Critical Raw Materials associated with phosphate deposits and associated black shales) collects data on P, F, REE, Be, Sb, Co, PGM, V and Cr associated phosphate deposits and black shales
- WP 5 (Energy Critical Elements) collects mineral data of Li, Co and graphite
- WP 6 (Conflict Minerals) collects mineral data of Nb and Ta
- WP 7 (Historical mine sites revisited) collects mineral data from mining wastes

Each partner joining the WPs mentioned above and close collaboration of MREG is requested to provide a filtered raw data export from their national mineral deposit database, that is or should be INSPIRE harmonised. At this stage only points were considered, not any areas for the occurrences.

The following data was requested as mandatory from each occurrence that is considered a resource for the critical and strategic minerals mentioned above (according to the INSPIRE data specifications):

1. Id = your national database id to occurrence and INSPIRE ID if available
2. Country code
3. Name= the occurrence name
4. Latitude and longitude in decimal degrees EPGS 4258
5. The commodity type: e.g., Li, graphite or Co

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6. The occurrence type: occurrence, prospect or deposit, as defined by INSPIRE. To be a deposit a resource and grade estimate is required. Information about geological setting, age, grades and mineralogy to be also provided if available.
7. Deposit type hosting strategic minerals and metals as associated commodities (e.g. Re in porphyry Cu-Mo deposits or Ga in bauxite deposits).
8. Status of the occurrence in terms of exploration activities

Based on the obtained data it was possible to produce mineral occurrences/deposits spatial distribution maps on associate CRM (e.g., REE; Figure 3).

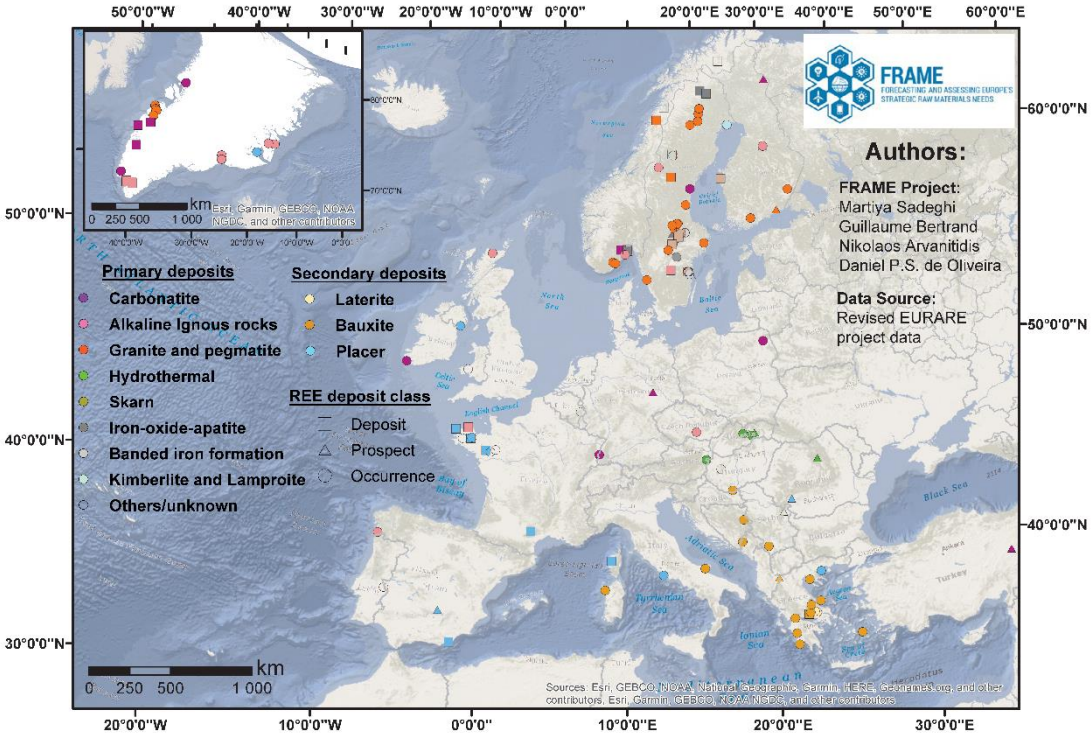

Figure 3. An example of the produced mineralisation map presented and delivered to the EGDI.

WP 4 collected data on phosphor in compliance with the INSPIRE requirements. The partners of this WP have provided information from their own countries and data from other European countries have been collected by WP4 partners from readily available literature and data source (Decree et al., 2018). The data sources used to fill this new database were Promine, FODD (Fennoscandian Mineral Deposit Database), SIORMINP (Portuguese Mineral Occurrences and

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Resources Information System), and Mine records database (Ireland). More details can be read in the deliverable reports related to WP4 (Decree et al., 2018; 2020).

WP 5 collected data on energy minerals (graphite, lithium and cobalt). From the project partner, MREG members and from several individuals the data on the mineral occurrences' lithium cobalt and graphite were collected. In addition to standard geographical information such as occurrence name and location, information on the individual occurrence's deposit type (genetic types), occurrence type and mine status were gathered. The genetic types are based on standard ore petrology, with a small adaptation to the WP specific needs, the occurrences and status follow the INSPIRE codes (Gautneb et al., 2019; 2020; 2021).

WP 6 focuses on the chemically related elements niobium (Nb) and tantalum (Ta). An important objective of this WP is to collect and integrate geological and mineralogical/metallogenetic data on Nb-Ta in Europe. The existing knowledge base has been used as a starting point for developing an updated overview of the European Nb-Ta mineralisations. Of significance in this context was the results and databases produced by the Minerals4EU, EURARE and ProMine. and projects (Reginiussen et al., 2021a; b). Additional datasets, including e.g. exploration reports and data from websites of exploration companies have been used. Data from the existing pan-European sources have been integrated with verified data from national geological survey databases. New data have been produced within WP6.
In order to produce a consistent dataset for FRAME, it was decided in cooperation with GiP-P project that the M4EU DB (prior to the MIN4EU DB) shall be used as the main source of data. At early stage of the FRAME project, because of limitations in content on Nb and Ta in the M4EU DB, it was decided that WP 6 should also collect data directly from GeoERA partners. In addition, important data has been produced outside the GeoERA system, e.g., by exploration companies and universities and this data may never be included in the MIN4EU DB.

WP 7 collected data from the deposits that have already been discovered and for which general geological data is available. These deposits are part of former mining activities, meaning that they have been mined or are previously untouched ore bodies, which are part of an ancient mine or mining district (Sievers et al., 2019).
The data collection on historic mines sites in WP 7 will include the following raw material sources:

- Abandoned/closed mines
- Mining region/districts with various (abandoned/closed) mines
- Active mines, that have been operating for decades (>25 years)Ore deposits linked to former mining activities, that have not been mined, yet
- Mine wastes (tailings from mineral processing, unprocessed waste rock)

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The project partners started to review and collect site-specific data on historic mine sites and their potential for CRM. Different sources of data like national databases, literature, previous projects and company reports were used. The main source of information at this stage of the project were national databases.

Maps (metallogenic area and prospectivity maps)

WP 3 presented a general overview of the main metallogenetic provinces in Europe and, in more detail, the metallogenetic maps and their description for rare earth elements, graphite, cobalt, lithium, phosphor, niobium and tantalum with the contribution from the other FRAME work packages (WP4, WP5 and WP6) and the MREG on land based, cobalt and phosphor metallogenic areas in the European seas with the contribution from the MINDeSEA project. The digital version on the metallogenetic areas have been prepared and delivered in D3.2 (Sadeghi et al., 2020a). The methodology and some examples of prospectivity maps were presented in D3.3 (Sadeghi et al., 2020b) while all final prospectivity maps for selected CRM commodities will be presented in report D3.5.

In this regard, WP 3 provided a template with minimum requirements for metallogenic maps which includes, commodity, class (deposit type classification), thematic_c (representing thematic classification), ID_area, Group_(commodity group), and area_name. The original shape file prepared by FRAME and accordingly, the metadata, keywords, references, completed and delivered to the EDGI by WP 8. Simultaneously, a pdf map was also prepared by WP3 and uploaded to the EDGI in addition to digital version (Figure 4).

Table 2. An example of the structure of the attribute table prepared and filled in for metallogenic map.

Table

REE

OBJECTID	commodity	class	SHAPE_Leng	SHAPE_Area	Thematic_c	ID_area	Group_	area_name
1	REE	Placer	2970.712687	233040.220703	Secondary resources	REE_14	CRM	North Atlantic Igneous Province_1_Greenland
13	REE	Carbonatite and alkaline	291.958019	4551.538788	Carbonatite and alkaline	REE_11	CRM	Fen
14	REE	Carbonatite	348.207641	4329.198007	Carbonatite	REE_5	CRM	Hartug-Pottäng
17	REE	Carbonatite	1728.702438	119370.173918	Carbonatite	REE_10	CRM	Greenland_North Gardar province_Safartoq
19	REE	Carbonatite	287.824258	4448.496218	Carbonatite	REE_2	CRM	Gräddmanshållan -Storö
20	REE	Alkaline ignous rock	966.450829	64794.806623	Alkaline ignous rocks	REE_12	CRM	Gardar Province
24	REE	Alkaline ignous rock	2897.59813	260100.276762	Alkaline ignous rocks	REE_13	CRM	North Atlantic Ignous Province_2_Greenland
26	REE	Alkaline ignous rock	450.775439	7321.74765	Alkaline ignous rocks	REE_1	CRM	Langesundsfjord
28	REE	Iron-oxide-apatite	400.594806	7232.929644	Iron oxide apatite, Iron skarn & hydrothermal	REE_15	CRM	Kiruna- Malmberg
29	REE	Iron-oxide-apatite and Skarn	483.774764	8245.537437	Iron oxide apatite, Iron skarn & hydrothermal	REE_17	CRM	REE line in Bergslagen
32	REE	Carbonatite and alkaline	919.811461	24365.83824	Carbonatite and alkaline	REE_32	CRM	Kola Alkaline province
21	REE	Alkaline ignous rock	448.40025	11584.920379	Alkaline ignous rocks	REE_16	CRM	Olserum- Norra kärr

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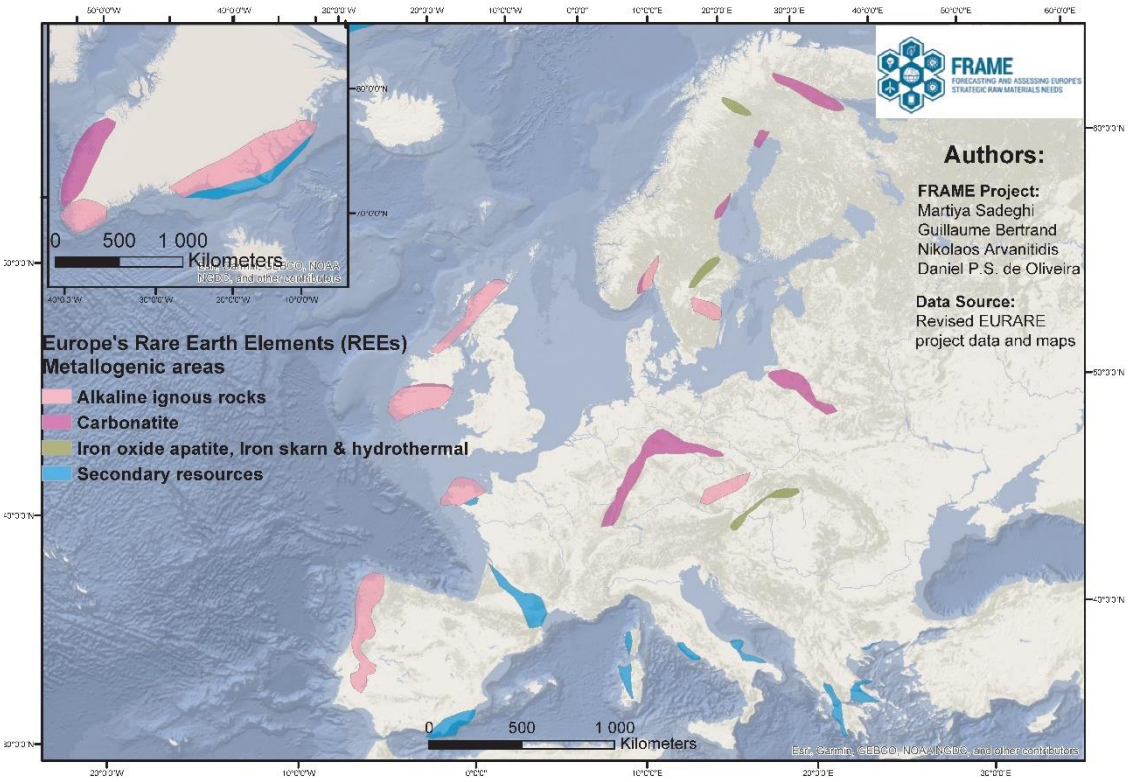

Figure 4. An Example of the metallogenic map presented and delivered to EDGI.

An objective of WP3 in the FRAME project was also to produce predictive assessments – in the form of prospectivity maps (favourability maps) - of CRM based on GIS exploration tools at the continental scale, in order to identify high potential mineral provinces and mining districts.
When it comes to mineral prospectivity mapping at continental scale (which is the goal of this work), encompassing huge geographic coverage, numerous geological environments and large volumes of data, data driven methods are well appropriate. In this work, we have used a data driven approach – the Cell Based Association (CBA) – that has been recently developed by BRGM (Tourlière et al., 2015). Preliminary results on prospectivity mapping have been presented and published in different events (e.g. Bertrand et al., 2020, Sadeghi et al., 2020c and Sadeghi et al., 2020d)

The CBA prospectivity maps were calculated with the deposit datasets compiled by WP 4 (phosphate), 5 (lithium, cobalt and natural graphite) and 6 (niobium and tantalum) of the FRAME project and the final maps and description will be presented in deliverable report D3.5. The 1 to 1.5 million geological map (1/1,500,000) compiled by BRGM (Billa et al., 2008) and a regular grid of 10 by 10 km cell size. 10 by 10 km may seem rather coarse, and it certainly is, but it is in the order of size of an exploration permit, and it was a good compromise between "geological

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reality", and "computing constrains" at pan-european scale. Note that the CBA prospectivity maps do not include Greenland, although it is a highly strategic region for mineral exploration. The reason is that the input 1 to 1.5 million (1/1,500,000) geological map of Europe does not cover Greenland. However, the fuzzy weight of evidence approach, in the present work, uses different data sources and includes Greenland and example of this method will be reported in D3.5.

To ease the reading of the prospectivity maps, favourability scores have been color coded in five classes, going from "very low" to "very high" favourability (Figure 5). Note that it is a relative classification. Note also that the visual result significantly depends on the method used to classify the scores.

Finally, note that only the geology (lithology) was used to characterize the associations in grid cells and deposit buffers. No geochemical or geophysical datasets were used because no such dataset is available at the scale of the whole European continent. Anyway, further developments of the present work could be done to refine the CBA prospectivity mapping at regional scale, in favourable areas, with additional pertinent datasets.

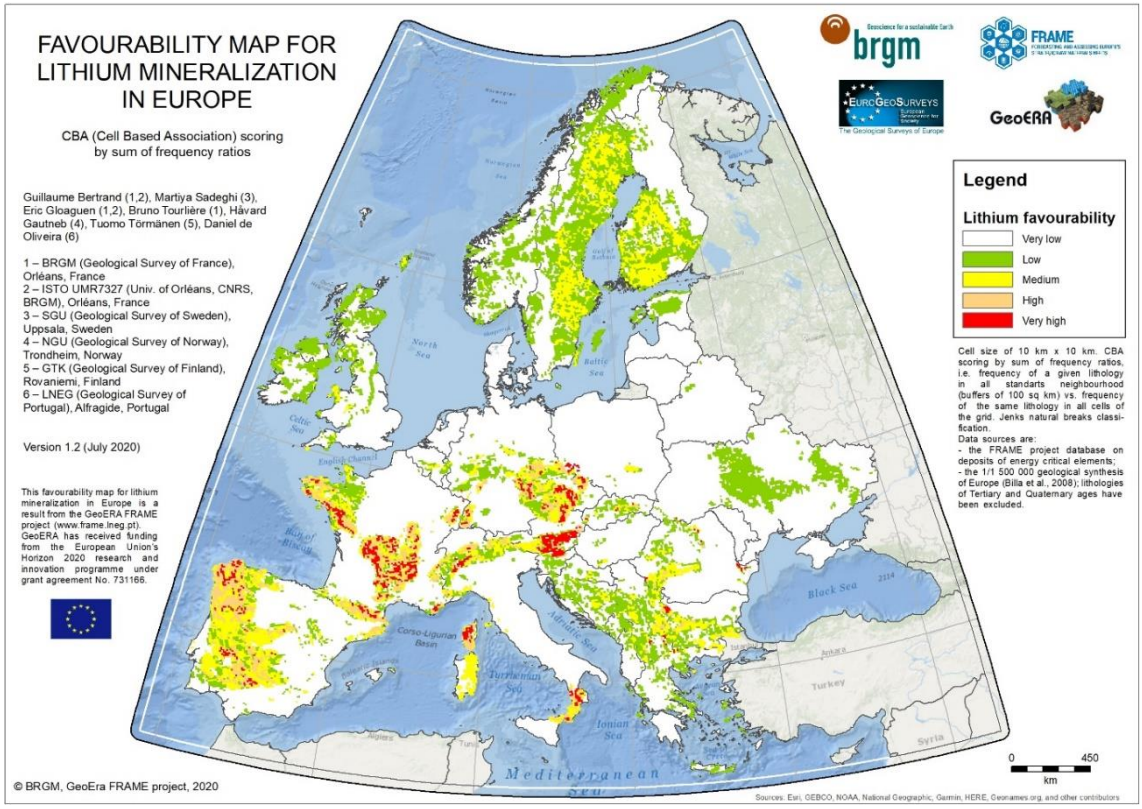

Figure 5. An example of the CBA favourability map (lithium in Europe here). This map will be delivered to EGDI together with D3.5.

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EGDI Document Repository

EGDI Document Repository (production version 1.6.4) (https://search.europe-geology.eu/) is a platform to make easier for user to search, select and access information, documents and maps stored in EGDI (unstructured data). The following search functions are available:

Basic search

Users can search for all the selected or typed keywords. Example:
Start typing, choose one keyword from the list of the autosuggested keywords (e.g lithium). Start typing again, the complete word this time (e.g. FRAME), press Enter, then press Basic Search (Figure 6).

Semantic Search

Users can search for all the selected or typed keywords including all semantically related keywords in selected languages. Languages for semantic search can be selected from the languages menu. 22 languages are available for now. Example: Start typing, choose one keyword from the list of the autosuggested keywords (e.g rare earth element). Start typing again, the complete word this time (e.g. FRAME), press Enter, then press Semantic Search (Figure 6).

Advanced Search

Users type all keywords and search conditions . No autoselection list and semantic is given. Example: Type "FRAME AND rare earth element" and then press Enter.

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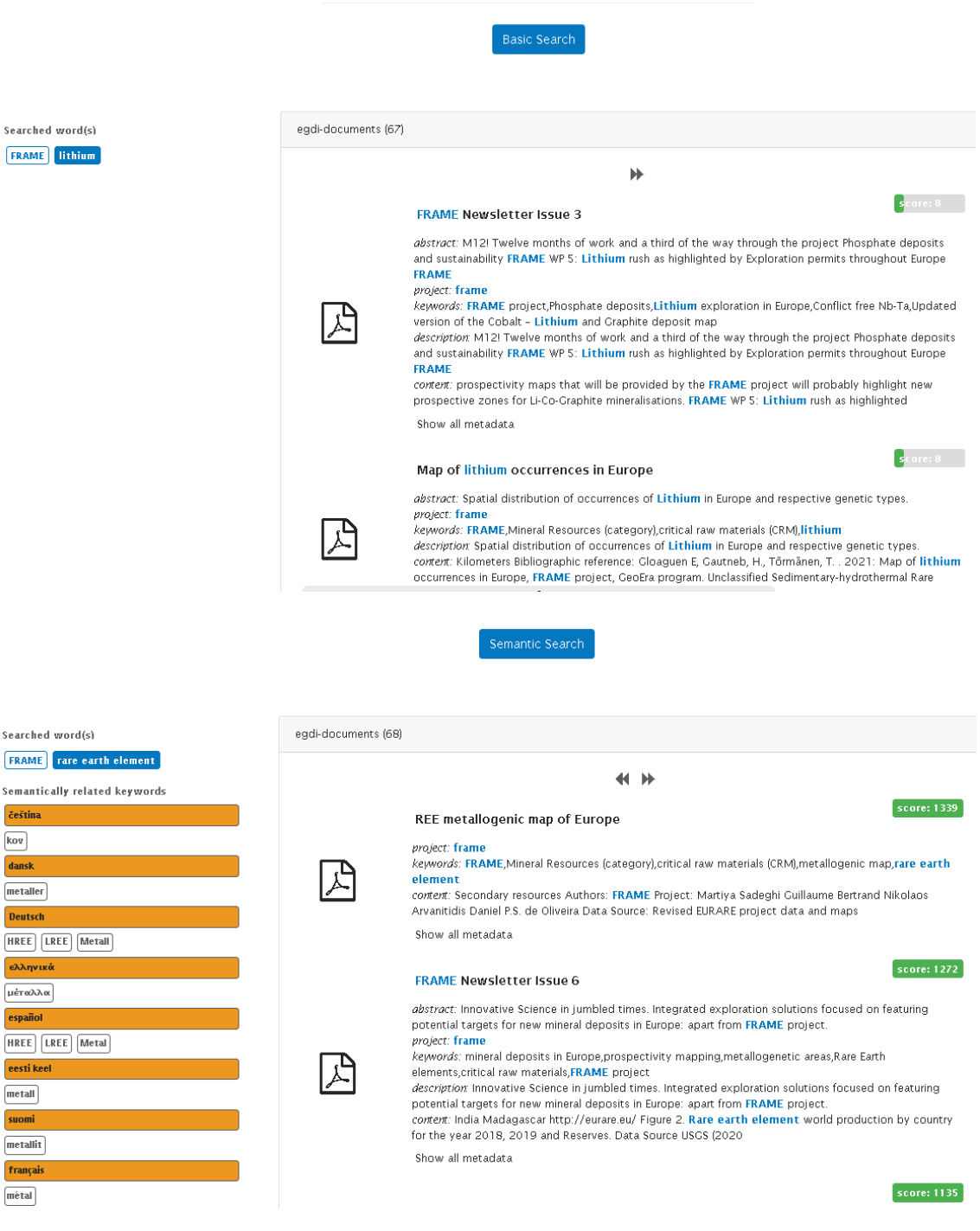

Figure 6. Two examples of search in EGDI Document Repository. A basic and semantic search functions for the keywords: Lithium, rare earth element and FRAME.

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Data preparation and delivery to EGDI (WP8)

The objective of the WP 8 in FRAME project is to provide and disseminate spatial information on the respective resources and underpinning geological data identified in the technical work packages of the FRAME project (WP 3, WP 4, WP 5, WP 6 and WP 7). WP 8 has to ensure that the maps, documents and data produced by the other WPs are uploaded to EGDI platform in accordance with GIP-P requirements.

Until now WP 8 upload to EGDI platform 19 maps from a total of 25. Three of them are prototypes maps prepared at an early stage of delivery with the purpose of testing the overall system (Quental, L. & Pereira, A., 2020). During this stage it was essential the GIP-P team support as well as FRAME WP 3. These prototypes maps are representative of the main maps produced by WPs (3, 4, 5 and 6):

- REE mineral occurrences/deposits spatial distribution (prototype)
- REE metallogenic map of Europe (prototype)
- Cobalt CBA favourability map of Europe (prototype)

After the prototyping phase WP 8 uploaded 16 final maps, following the EGDI documentation provided by GIP-P on:

a) how to create spatial data sets to deliver to EGDI
b) how to create metadata for spatial data sets, as mandatory for every map
c) how to upload data to EGDI (spatial and non-spatial datasets)

Description on how to create spatial data sets, metadata and upload data to EGDI are given:

Create spatial data sets

GeoPackage is the preferred format to deliver spatial data sets to EGDI because it is an open standard. The default coordinate reference system is the EPSG 3034.

FRAME WP 3 in collaboration with other WPs (4, 5 and 6) delivered their maps to WP 8 as map packages (.mpk) as all members are ArcGIS users. A map package contains a map document (.mxd) with one or two layers (maximum), the data itself (.shp) and the lyr files with appropriate symbology. From each mpk a GeoPackage (.gpkg) is created and data is projected to the required coordinate system. Each dataset is a map and each map is a GeoPackage. A GeoPackage is in fact a simple file database (SQLite) that stores the spatial features and tables (Figure 7).

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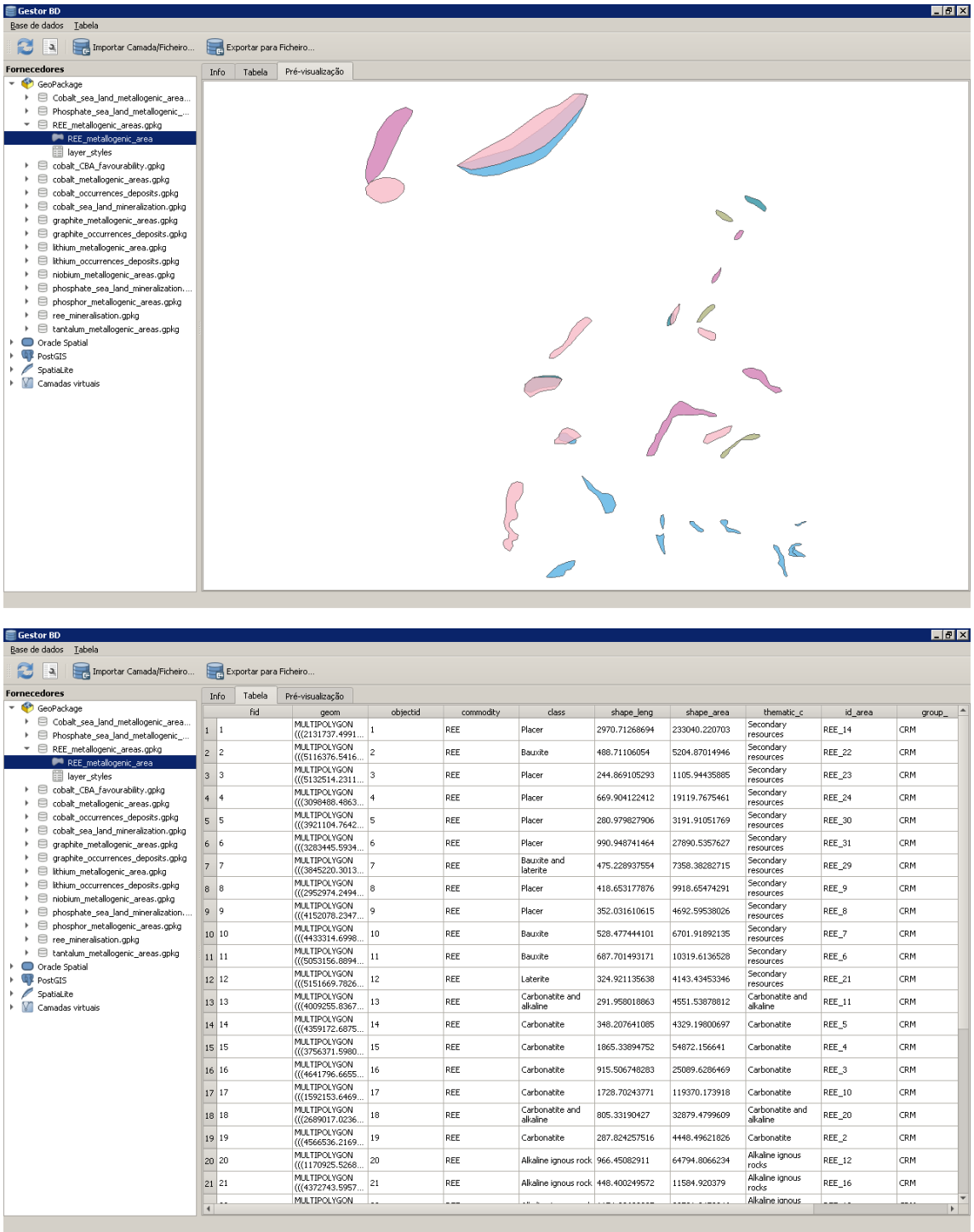

	fid	geom	objectid	commodity	class	shape_leng	shape_area	thematic_c	id_area	group_
1	1	MULTIPOLYGON (((2131737.4991...	1	REE	Placer	2970.71268694	233040.220703	Secondary resources	REE_14	CRM
2	2	MULTIPOLYGON (((5116376.5416...	2	REE	Bauxite	488.71106054	5204.87014946	Secondary resources	REE_22	CRM
3	3	MULTIPOLYGON (((5132514.2311...	3	REE	Placer	244.869105293	1105.94435885	Secondary resources	REE_23	CRM
4	4	MULTIPOLYGON (((3098488.4863...	4	REE	Placer	669.904122412	19119.7675461	Secondary resources	REE_24	CRM
5	5	MULTIPOLYGON (((3921104.7642...	5	REE	Placer	280.979827906	3191.91051769	Secondary resources	REE_30	CRM
6	6	MULTIPOLYGON (((3283445.5934...	6	REE	Placer	990.948741464	27890.5357627	Secondary resources	REE_31	CRM
7	7	MULTIPOLYGON (((3845220.3013...	7	REE	Bauxite and laterite	475.228937554	7358.38282715	Secondary resources	REE_29	CRM
8	8	MULTIPOLYGON (((2952974.2494...	8	REE	Placer	418.653177876	9918.65474291	Secondary resources	REE_9	CRM
9	9	MULTIPOLYGON (((4152078.2347...	9	REE	Placer	352.031610615	4692.59538026	Secondary resources	REE_8	CRM
10	10	MULTIPOLYGON (((4433314.6998...	10	REE	Bauxite	528.477444101	6701.91892135	Secondary resources	REE_7	CRM
11	11	MULTIPOLYGON (((5053156.8894...	11	REE	Bauxite	687.701493171	10319.6136528	Secondary resources	REE_6	CRM
12	12	MULTIPOLYGON (((5151669.7826...	12	REE	Laterite	324.921135638	4143.43453346	Secondary resources	REE_21	CRM
13	13	MULTIPOLYGON (((4009255.8367...	13	REE	Carbonatite and alkaline	291.958018863	4551.53878812	Carbonatite and alkaline	REE_11	CRM
14	14	MULTIPOLYGON (((4359172.6875...	14	REE	Carbonatite	348.207641085	4329.19800697	Carbonatite	REE_5	CRM
15	15	MULTIPOLYGON (((3756371.5980...	15	REE	Carbonatite	1865.33894752	54872.156641	Carbonatite	REE_4	CRM
16	16	MULTIPOLYGON (((4641796.6655...	16	REE	Carbonatite	915.506748283	25089.6286469	Carbonatite	REE_3	CRM
17	17	MULTIPOLYGON (((1592153.6469...	17	REE	Carbonatite	1728.70243771	119370.173918	Carbonatite	REE_10	CRM
18	18	MULTIPOLYGON (((2689017.0236...	18	REE	Carbonatite and alkaline	805.33190427	32879.4799609	Carbonatite and alkaline	REE_20	CRM
19	19	MULTIPOLYGON (((4566536.2169...	19	REE	Carbonatite	287.824257516	4448.49621826	Carbonatite	REE_2	CRM
20	20	MULTIPOLYGON (((1170925.5268...	20	REE	Alkaline ignous rock	966.45082911	64794.8066234	Alkaline ignous rocks	REE_12	CRM
21	21	MULTIPOLYGON (((4372743.5957...	21	REE	Alkaline ignous rock	448.400249572	11584.920379	Alkaline ignous rocks	REE_16	CRM

Figure 7. Example of a GeoPackage shown in QGIS. Polygons are REE metallogenic areas. Each polygon links to a row on the table of attributes.

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Until now, WP 8 organized, prepared and delivered to EGDI platform 16 GeoPackages from a total of 22 (prototypes not included) as shown in figure 8. The maps are distributed by three main groups of products on critical raw materials in Europe:

1) Metallogenic maps (total of 9)
2) Mineral occurrences/deposits spatial distribution on land and the marine environment (total of 6)
3) Potential/ prospectivity maps (total of 7)

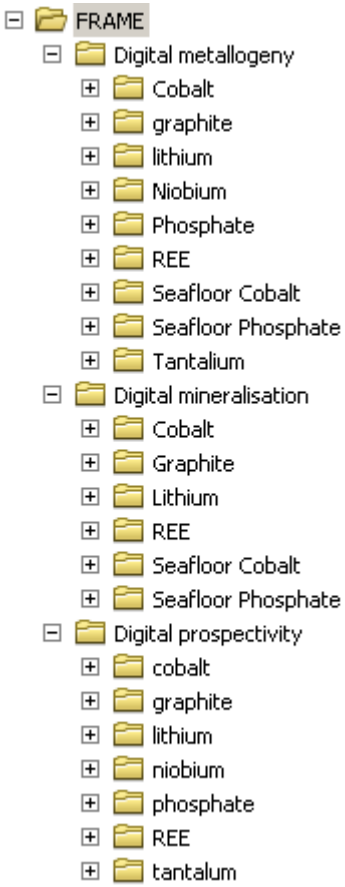

Figure 8. Sketch of digital maps folder structure for FRAME project in ArcCatalog. Each folder contains the GeoPackage, metadata, map PDFs, legends and all the related documents on critical raw materials: Cobalt, Graphite, Lithium, Niobium, Phosphate, REE and Tantalum.

Create metadata

Each map delivered to EGDI has its own metadata entry in EGDI Metadata Catalog (MIcKA, version 6.0). That's why metadata was created in the first place.

Only authorized users can create and edit metadata. WP 8 access the metadata catalog through the Web and uses LNEG credentials to create FRAME metadata. The required minimum fields of

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information provided for each map is: title, abstract, type, responsible party, metadata point of contact, identifier, Keywords, reference date, lineage, spatial resolution, conditions applying to access and use, coordinate reference system, spatial representation type and purpose. All the metadata are then completed and validated by each responsible WP's lead.

Until now 25 metadata were created for FRAME project (including the metadata for the three prototypes maps) as shown in Figure 9:

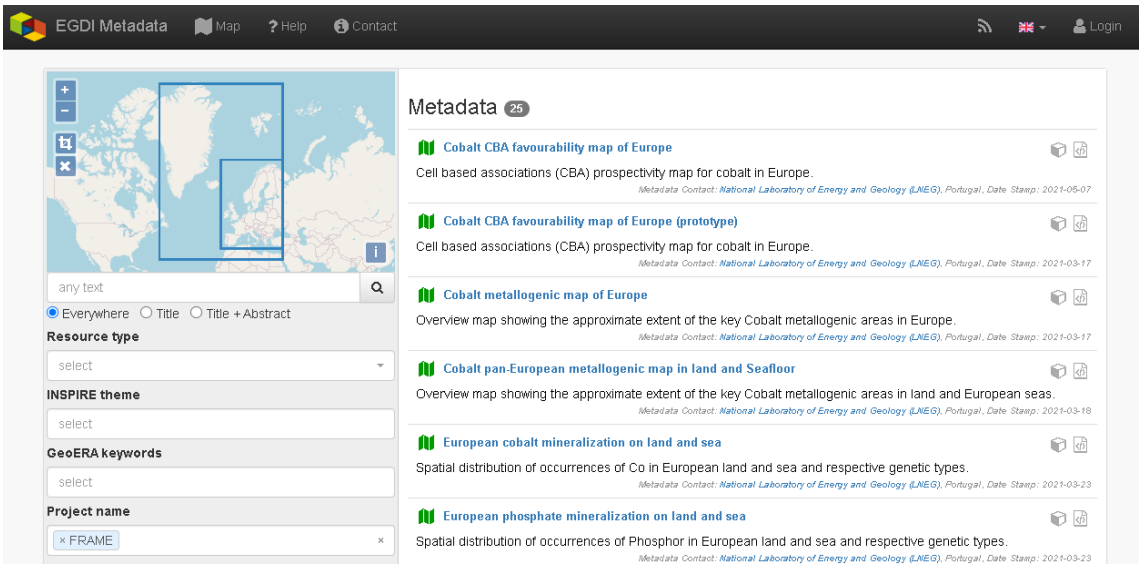

Figure 9. **EGDI Metadata catalogue with the search interface (left side) and the list of records for FRAME project (right side)**

Upload data

The upload of data to EGDI is done remotely by authorized users only via the EGDI Administration Module (Figure 10).

From the EGDI Administration Module WP 8 uploads:

- Unstructured data as PDF and DOI
- Structured data as GeoPackages

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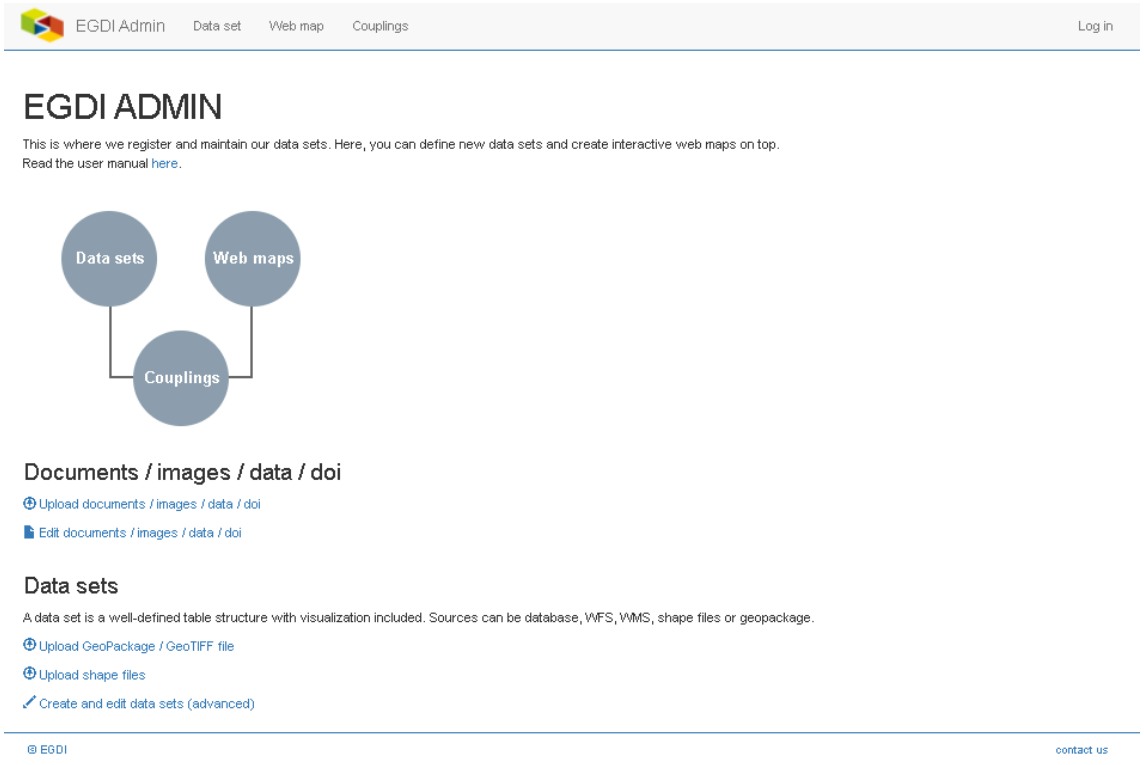

Figure 10. The home page of the EGDI Administration Module (https://data.geus.dk/egdiadmin/)

Unstructured data

Only open access documents were uploaded by WP 8. When uploading a document fill in metadata was required. The minimum fields of information are title, abstract, keywords, reference date, authors, accessibility, language, spatial coverage. At the end of the upload each PDF gets a URL to the EGDI Document Repository where it is possible to download the PDF. Example of the URL for the PDF file of the Lithium metallogenic map of Europe:

https://repository.europe-geology.eu/egdidocs/frame/lithium_metalogeny_final2021.pdf

All PDFs uploaded by WP 8 has on its URL the name of the project and the file name of the PDF.

All the PDF documents are accessible for searching and downloading at the EGDI Document Repository (as explained above). FRAME maps are also available as PDF files. Until now WP 8 uploaded 33 PDFs freely available for download and 23 references to documents/scientific articles (DOI) that might / might not be freely available.

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Structured data

Examples of the upload of three different maps is given, as representatives of the main maps produced by FRAME.

The workflow to upload the maps to EGDI is:

1 - upload the GeoPackage

2 – define the layers

3 – change the layer configuration (e.g. add descriptions, disclaimers and legends, link to a document in the repository, add logos, create views, setting up colors)

When uploading the maps to EGDI data goes to a PostgreSQL /PostGIS database. The layers are defined during the upload. All layers start with the word "frame" to easily locate the FRAME project layers in the long list of layers at EGDI (Figure 11).

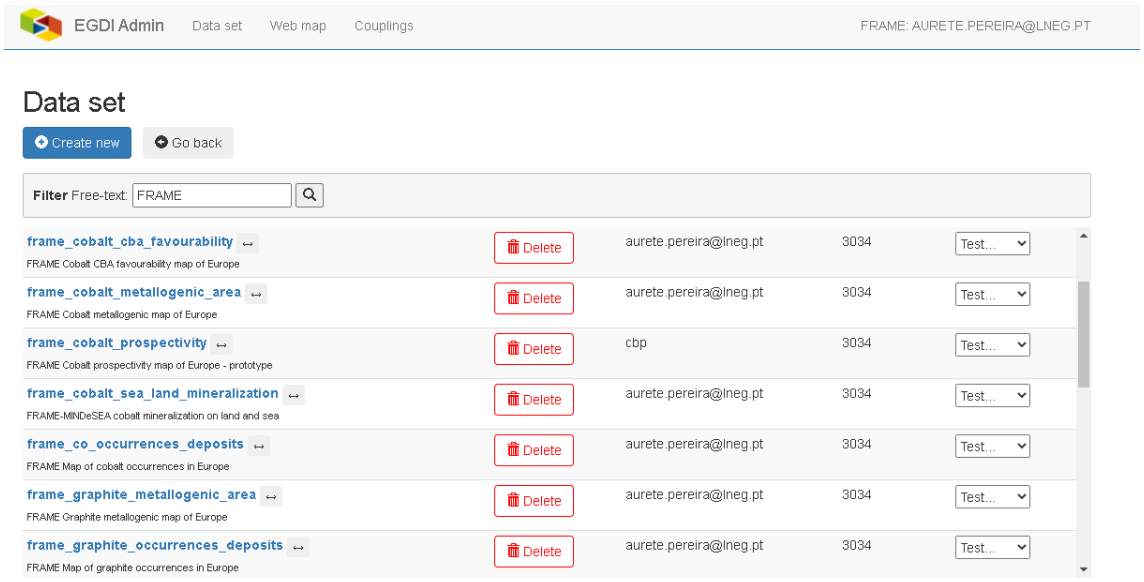

Figure 11. List of layers in production for FRAME project (total of 16)

REE metallogenic map of Europe

This map contains only one layer based on one spatial table (see Figure 7 above). The layer shows polygons with different colors that identify the type of deposit. Colors were defined for the different classes of deposits based on the content of the field "Thematic_c" like this:

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```
CASE
 WHEN f.Thematic_c IN ('Carbonatite') THEN '211,128,181'
 WHEN f.Thematic_c IN ('Alkaline ignous rocks') THEN '248,186,199'
 WHEN f.Thematic_c IN ('Carbonatite and alkaline') THEN '49,146,163'
 WHEN f.Thematic_c IN ('Iron oxide apatite, Iron skarn & hydrothermal') THEN '176,180,126'
 WHEN f.Thematic_c IN ('Secondary resources') THEN '87,177,228'
END rgb_hidden,
```

Logos, descriptions and a disclaimer were added next to the layer. A link to the PDF of the map stored in the EGDI document repository was also provided (Figure 12).

```
<p>
 <a href="https://geoera.eu/projects/frame2/" target="_blank">
  <img src="https://geoera.eu/wp-content/uploads/2021/03/FRAME-logo_color_print__300dpi.jpg" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="Project webpage">
 </a>
 <a href="https://www.sgu.se/" target="_blank">
  <img src="https://www.sgu.se/globalassets/itp308/logo/sgu-bla-vanlig-eng.png" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="SGU webpage">
 </a>
 </p>
<p>
REE metallogenic map of Europe
</p>
<p>
 <i class="fa fa-file-pdf-o" style="color:red"> </i><a href="https://repository.europe-geology.eu/egdidocs/frame/ree_metalogeny.pdf" target="_blank">Download REE metallogenic map of Europe</a>
</p>
<div class="alert alert-warning alert-dismissible" role="disclaimer">
 <button type="button" class="close" data-dismiss="alert" aria-label="Close">
  <span aria-hidden="true">&times;</span>
 </button>
 <h5>Disclaimer</h4>
 <p style="font-size:90%;">This map is produced within FRAME project using a series of pan European Geological information and maps with scale of 1:1.5 million to 1:5 million.
 Users are encouraged to examine the documentation or metadata associated with the data on which this map is based for information related to its
 accuracy, correctness, and limitations.</p>
</div>
```

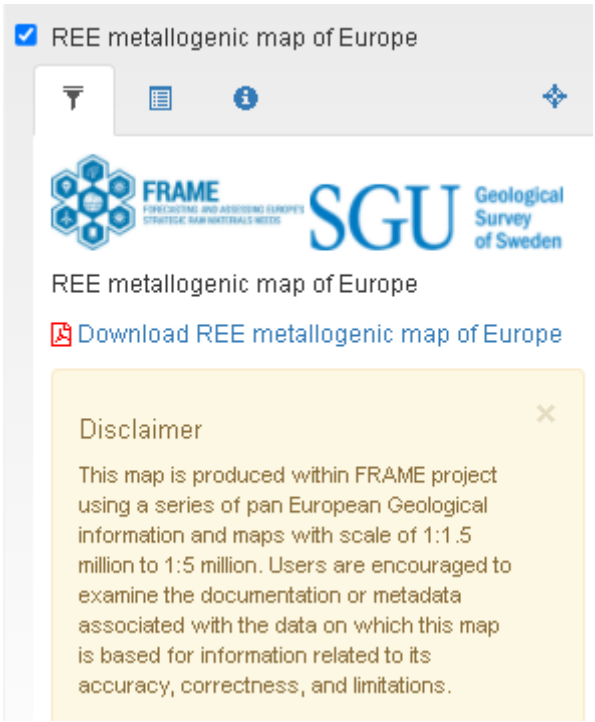

Figure 12. HTML code lines and the obtained results next to the layer

The results can be seen at EGDI by clicking on the link of [REE metallogenic map of Europe].

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REE mineral occurrences/deposits spatial distribution

This map contains only one layer based on one spatial table. The layer shows circles, triangles and squares filled in with different colors to identify the deposits types and at the same time the type of occurrences (circle for occurrence, triangle for prospect and square for deposit). Colors were defined for the different classes of deposits based on the content of the field “Deposittyp” and the geometric forms attributed based on the content of the field “Occurrence” like this:

```
CASE
  --Primary deposits
  WHEN f.deposittyp = 'carbonatite' THEN '123,73,160' --Carbonatite
  WHEN f.deposittyp = 'unsaturatedAndSaturatedSyeniticAlkaliGraniticIgneousRocksPegmatites' THEN '236,110,174' --Alkaline Ignous rocks
  WHEN f.deposittyp = 'graniticIgneousRocksAndPegmatites' THEN '243,80,51' --Granite and pegmatite
  WHEN f.deposittyp = 'veinPolymetallic' THEN '72,187,83' --Hydrothermal
  WHEN f.deposittyp = 'skarnAndCarbonateReplacement' THEN '147,156,70' --Skarn
  WHEN f.deposittyp = 'ironOxideApatite' THEN '131,131,131' --Iron-oxide-apatite
  WHEN f.deposittyp = 'bandedIronFormation' THEN '204,204,204' --Banded iron formation
  WHEN f.deposittyp = 'kimberliteAndLamproite' THEN '183,229,209' --Kimberlite and Lamproite
  WHEN f.deposittyp IN ('maficToUltramaficEffusiveVolcanism','maficToUltramaficIntrusion','sandstoneHosted','sedimentaryManganese','sedimentaryPhosphorite','shaleHosted','veinPolymetallic') THEN '225,225,225' --Others/unknown
  --Secondary deposits
  WHEN f.deposittyp = 'laterite' THEN '248,228,165' --Laterite
  WHEN f.deposittyp = 'bauxite' THEN '213,137,61' --Bauxite
  WHEN f.deposittyp IN ('alluvialPlacer','paleoplacer','shorelineOrMarinePlacer') THEN '102,210,238' --Placer
END rgb_hidden,

CASE
  WHEN f.occurrence = 'deposit' THEN 'box'
  WHEN f.occurrence IN ('prospect','field') THEN 'triangle'
  WHEN f.occurrence = 'occurrence' THEN 'circle'
END symbol_hidden,
```

Logos and descriptions were added next to the layer. A link to the PDF of the map stored in the EGDI document repository was also provided (Figure 13).

```
<p>
 <a href="https://geoera.eu/projects/frame2/" target="_blank">
  <img src="https://geoera.eu/wp-content/uploads/2021/03/FRAME-logo_color_print__300dpi.jpg" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="Project webpage">
 </a>

 <a href="https://www.sgu.se/" target="_blank">
  <img src="https://www.sgu.se/globalassets/itp308/logo/sgu-bla-vanlig-eng.png" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="SGU webpage">
 </a>
</p>
<p>
REE mineral occurrences/deposits spatial distribution map of Europe
</p>
<p>
 <i class="fa fa-file-pdf-o" style="color:red"> </i><a href="https://repository.europe-geology.eu/egdidocs/frame/ree_mineralisation.pdf" target="_blank">Download REE mineral occurrences/deposits spatial distribution map of Europe</a>
</p>
```

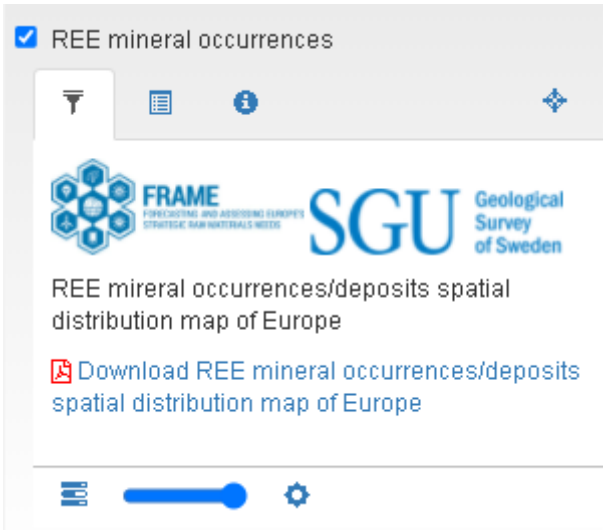

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Figure 13. HTML code lines and the obtained results next to the layer

The results can be seen at EGDI by clicking on the link of REE mineral occurrences/deposits spatial distribution.

Cobalt CBA favourability map of Europe

This map contains only one layer based on one spatial table. The layer shows five different classes defined taking ranges of values from the field “score” like this:

```
CASE
    WHEN (f.score) <= '4.18' THEN '255 255 255'
    WHEN (f.score) > '4.18' AND (f.score) <= '8.36' THEN '139 209 0'
    WHEN (f.score) > '8.36' AND (f.score) <= '12.54' THEN '255 255 0'
    WHEN (f.score) > '12.54' AND (f.score) <= '16.72' THEN '255 201 127'
    WHEN (f.score) > '16.72' AND (f.score) <= '20.90' THEN '255 0 0'
  END rgb_hidden,
```

Logos, descriptions and a disclaimer were added next to the layer. A link to the PDF of the map stored in the EGDI document repository was also provided (Figure 14).

```
<p>
 <a href="https://geoera.eu/projects/frame2/" target="_blank">
  <img src="https://geoera.eu/wp-content/uploads/2021/03/FRAME-logo_color_print__300dpi.jpg" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="Project webpage">
 </a>
 <a href="https://www.sgu.se/" target="_blank">
  <img src="https://www.sgu.se/globalassets/itp308/logo/sgu-bla-vanlig-eng.png" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="SGU webpage">
 </a>
 <a href="https://www.brgm.fr/en" target="_blank">
  <img src="https://www.securegeoenergy.eu/sites/default/files/BRGM-resized.png" style="max-height:100px;max-width:140px;vertical-align:bottom" alt="BRGM webpage">
 </a>
</p>
<p>
Cobalt favourability map of Europe.
</p>
<p>
 <i class="fa fa-file-pdf-o" style="color:red"> </i><a href="https://repository.europe-geology.eu/egdidocs/frame/frame_cba_prospectivity_co_equal+intervals.pdf" target="_blank">Download Co favourability map map of Europe</a>
</p>
<div class="alert alert-warning alert-dismissible" role="disclaimer">
 <button type="button" class="close" data-dismiss="alert" aria-label="Close">
  <span aria-hidden="true">&times;</span>
 </button>
 <h5>Disclaimer</h4>
 <p style="font-size:90%;">This map is produced within FRAME project using a series of pan European Geological information and maps with scale of 1:1.5 million.
  Users are encouraged to examine the documentation or metadata associated with the data on which this map is based for information related to its accuracy, correctness, and limitations.</p>
</div>
```


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Figure 14. **HTML code lines and the obtained results next to the layer**

The results can be seen at EGDI by clicking on the link of Cobalt CBA favourability map of Europe.

4. References

Arvanitidis, N., Gautneb, H., Jonsson, E., Lynch, E., Reginiussen, H., Sadeghi, M., 2019. Producing a report describing the methodology used for the identification and selection process of the CRM to be included in the metallogenetic map. FRAME Deliverable 3.1

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