MINDeSEA

Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials

Pan-European Map of Submarine "Energy-Critical Elements"

WP1 leader: **Geological Survey of Spain (IGME) - Spain**		
Instituto Geológico y Minero de España	**Address:** C/ Ríos Rosas, 23 28003 Madrid Spain	**Telephone:** +34 91 349 58 64 (F.J. González) **Email:** fj.gonzalez@igme.es
WP1 IGME: Dr. Javier González (Coordinator)		

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

Deliverable number	**Short Title**
1.1 (Annex)	**D1-1** Annex
Long Title	
MINDeSEA_D1-1 Annex_Pan-European Map of Submarine “Energy-Critical Elements” v1	
Short Description	
This document presents the first pan-European compilation map of “energy- critical elements” based on ferromanganese deposits, status per 20.12.2018.	
Keywords	
Battery elements, cobalt, lithium, submarine mineral deposits, pan-European map	
Authors / Organisation(s)	**Editor / Organisation**
Javier González *et al.*, (IGME-Sp), Pedro Ferreira (LNEG), Vitor Magalhaes (IPMA)	IGME-Sp
File name	
MINDeSEA_ D1-1 Annex_Pan-European Map of Submarine “Energy-Critical Elements” v1.doc	
Document due date	**Deliverable submitted date (WP leader)**
28 December 2018 (M6)	
Comments	

History				
Version	**Author(s)**	**Status**	**Date**	**Comments**
01	Javier González *et al.*, (IGME-Sp), Pedro Ferreira (LNEG), Vitor Magalhaes (IPMA)	final	28 December 2018	

Dissemination level		
PU	Public	X
CO	Confidential, for project partners, GeoERA and the European Commission only	

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

FIRST COMPILATION MAP OF "ENERGY-CRITICAL ELEMENTS" IN PAN-EUROPEAN SEAS: FERROMANGANESE DEPOSITS

By Javier González, Iker Blasco, Lorena Blanco, Egidio Marino, Luis Somoza and Teresa Medialdea (IGME, Spain); Pedro Ferreira (LNEG, Portugal) and Vitor Magalhaes (IPMA, Portugal)

The term **"energy-critical elements"** (ECEs) was created by a joint committee of the American Physical Society and Materials Research Society assembled in 2009 to investigate the material resources available to support emerging energy technologies[1]. Security of mineral supply has been identified by the European Commission as a priority challenge facing the raw materials sector. The 2017 list of **Critical Raw Materials** (CRM) now reflects societies growing demand for an ever-increasing number and quantity of elements and minerals that supply the green energy and technology markets[2].
Seafloor mineral deposits represent the most important yet least explored resource of critical elements and base metals on the planet, crucial for low-carbon energy production and new technologies. **MINDeSEA** is investigating, generating and compiling data and metallogenic models on the occurrence of strategic and critical metals based on seafloor massive sulphides, ferromanganese crusts, phosphorites, polymetallic nodules and marine placer deposits, potential future resources for a wide variety of elements. The objective is to provide a better and more accurate basis for future exploration and exploitation, as well as sea-use management, and to provide high quality marine mineral intelligence data to the European data portals.

Polymetallic nodules rich in manganese, copper and nickel **(Fig. 1**); crusts rich in cobalt, tellurium, rare earth elements and platinum group elements (**Fig. 2**) makes these seafloor mineral deposits particularly interesting to both science and society. The current **map provides a first pan-European compilation of data on the occurrence of submarine cobalt- and lithium-rich ferromanganese deposits (Fig. 3)**. The map shows the resource potential for these "energy-critical elements" in nodules and crusts. The compilation of data on ferromanganese deposits consists of the following MINDeSEA partners with responsibilities for WP4 and WP6: **IGME (Spain); LNEG (Portugal); BGR (Germany); GIU (Ukraine); SGU (Sweden); IGEO (Spain); IPMA (Portugal); USGS (USA) and VNIIO (Russia)**, and they started by doing a first screening of occurrences in the different marine areas designated. The **Table 1** shows the distribution of occurrences in the European marine regions for both commodities.

Cobalt is a transition metal with application for batteries, supper-alloys and to produce cobalt-based blue pigments. Cobalt is found in the Earth's crust only in chemically combined form and is obtained as by-product in nickel, silver, lead and copper ores. The Democratic Republic of the Congo is the biggest producer in the copper belt area. In the European seas, cobalt occurs in ferromanganese crusts (up to 1%wt.) sequestered into the structure of iron-manganese oxy-hydroxides (**Fig. 2**) as well as large amounts of other minor elements like nickel or vanadium. Numerous deposits of cobalt-rich ferromanganese crusts have been discovered and mapped, in seamounts and ridges the Macaronesia area (Portugal and Spain) (**Fig. 3**). **Tellurium**, obtained as by-product of copper and lead refining to produce thin low-cost solar panels, is a potential resource in cobalt-rich ferromanganese crusts from the Canary Islands, especially in Tropic Seamount, where a very large deposit was announced in 2017 (2,600 tonnes of Tellurium metal). The Norwegian Sea, Barents Sea, Artic Ocean, Iberian margins and West Mediterranean Sea show other potential deposits and occurrences for cobalt-rich ferromanganese crusts (**Fig. 3**). In addition, cobalt is enriched in some polymetallic nodule fields like in Galicia Bank and Cantabria Knoll (NW Spain) and the Thyrrenian Sea. For mapping cobalt-rich nodules and crusts mineralization in pan-European seas (**Fig. 3**) two categories have been stablished: deposits (Co average content >500 g/t and potential resources >200Mt) and occurrences (Co average content <500 g/t and no up-to-date information about resources potential).

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

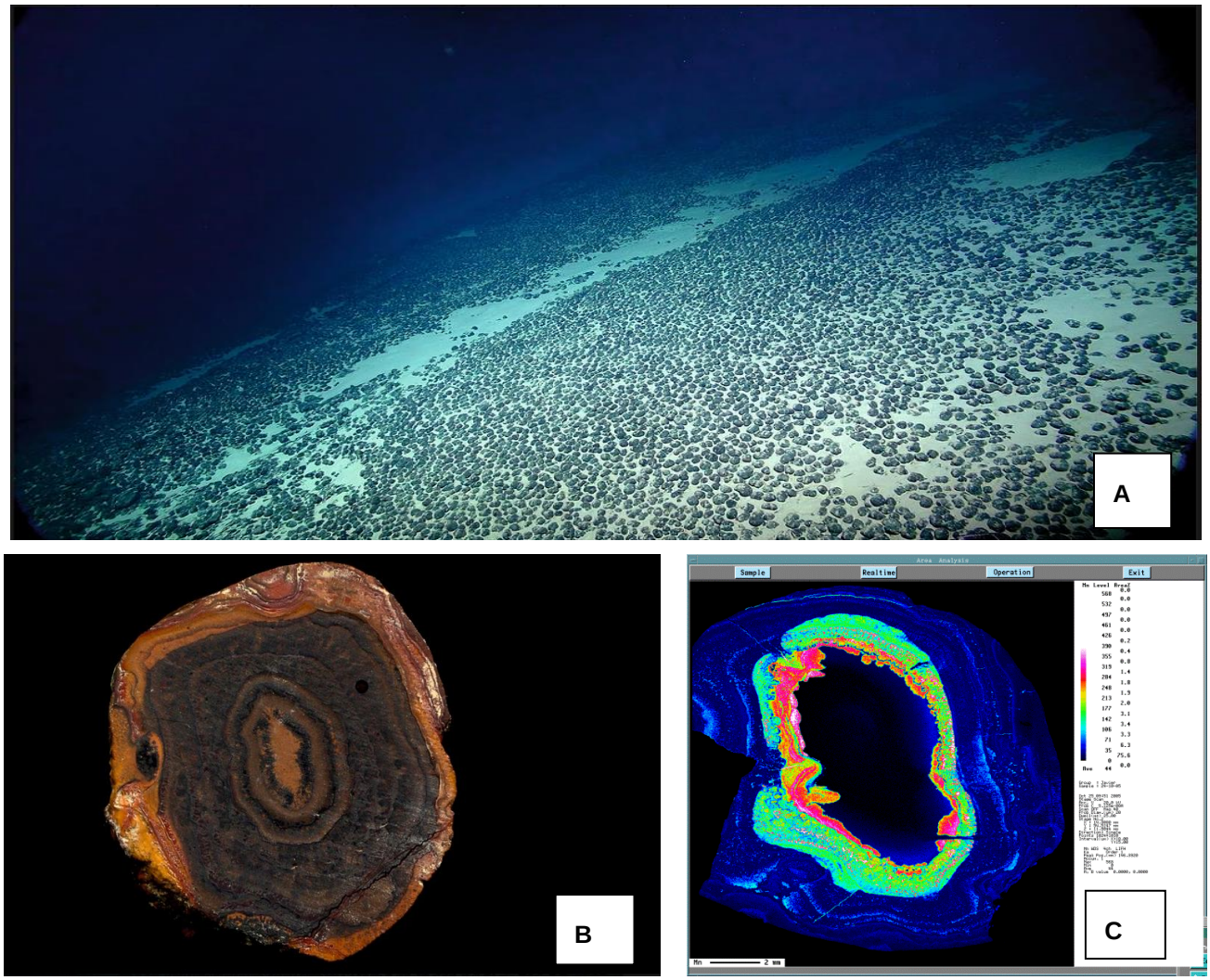

Figure 1. *A) Underwater image showing polymetallic nodules field, Tropic Seamount (Canary Islands, Central East Atlantic Ocean). Photo: ROV ISIS 6000, NOC. B and C) Spherical small Fe-Mn nodules, sections and Electron Probe Micro Analyzer mapping distribution of manganese in a nodule from the Gulf of Cadiz (Gulf of Cádiz, NE Atlantic Ocean). Cool colors indicate low contents, warm colors indicate high contents of manganese. Photos: IGME.*

Lithium is soft alkali metal used in modern batteries. In nature is forming part of silicate minerals like pegmatite lepidolite and spodumene as well as in brines. It is extracted today from saline deposits forming "salars" in North and South America (eg., Chile, Bolivia, and Brazil). In the European seas, lithium occurs essentially in polymetallic nodules (up to 200g/t) sequestered into the structure of manganese oxy-hydroxides as well as large amounts of other minor elements like copper or nickel. The contents of lithium in ferromanganese crusts usually are less than 35g/t. he Baltic Sea, Barents Sea, Kara Sea, Iberian margins, the Thyrrenian Sea and the Black Sea (**Fig. 3**) have the higher potential for Li-rich occurrences in polymetallic nodule fields. For mapping lithium-rich mineralization in pan-European seas (**Fig. 1**) just one category has been stablished as occurrences (Li_2O average content <660 g/t and potential resources <5,000Mt).

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

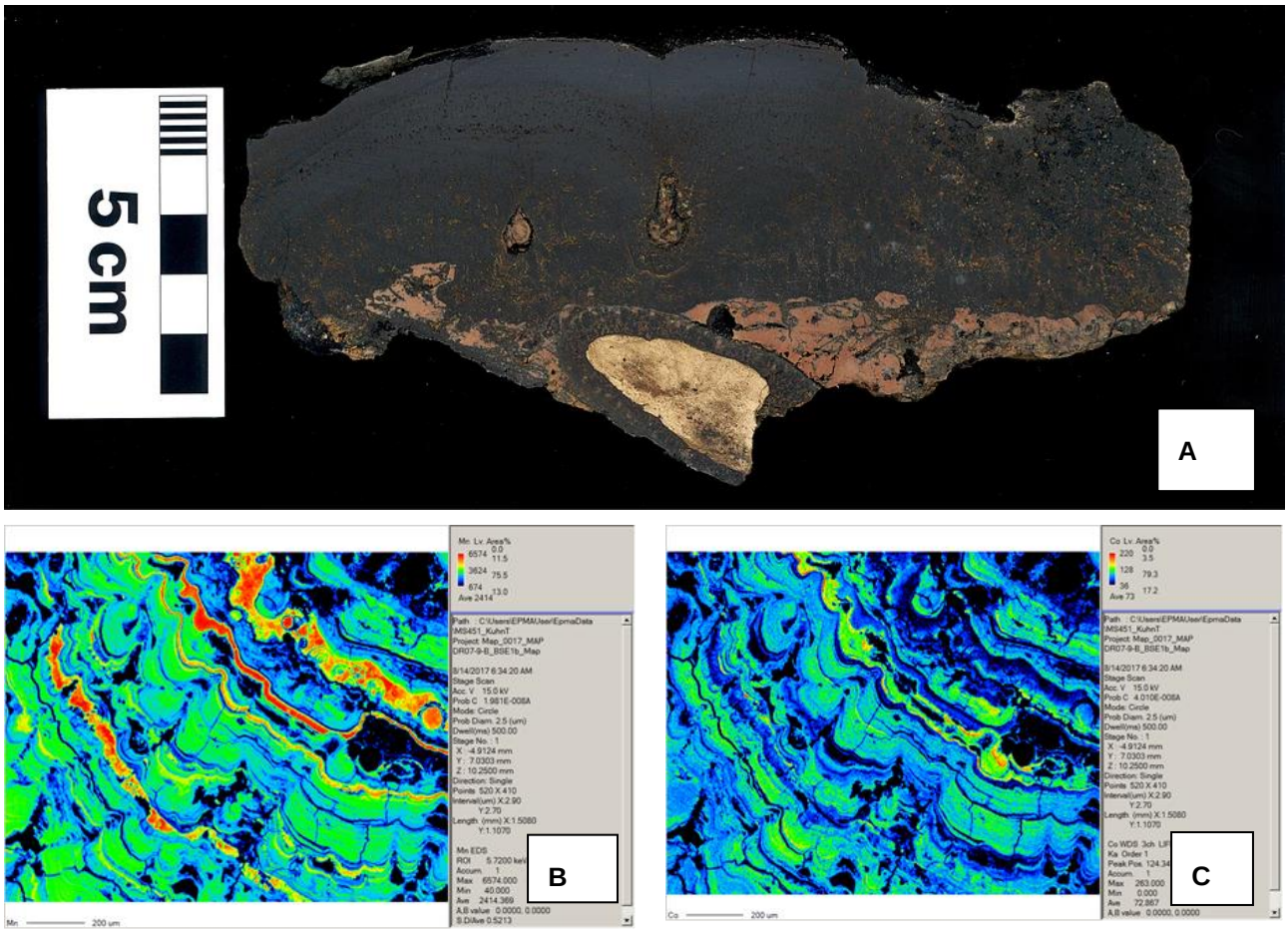

Figure 2. *A) Cobalt-rich ferromanganese crust recovered on Echo Seamount, Canary Island Seamount Province (Central East Atlantic). Photo: IGME. B and C) Electron Probe Micro Analyzer mapping distribution of manganese (left) and cobalt (right) in a ferromanganese crust from the Canary Islands. Cool colors indicate low contents, warm colors indicate high contents of these elements. Photos: IGME-BRG.*

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

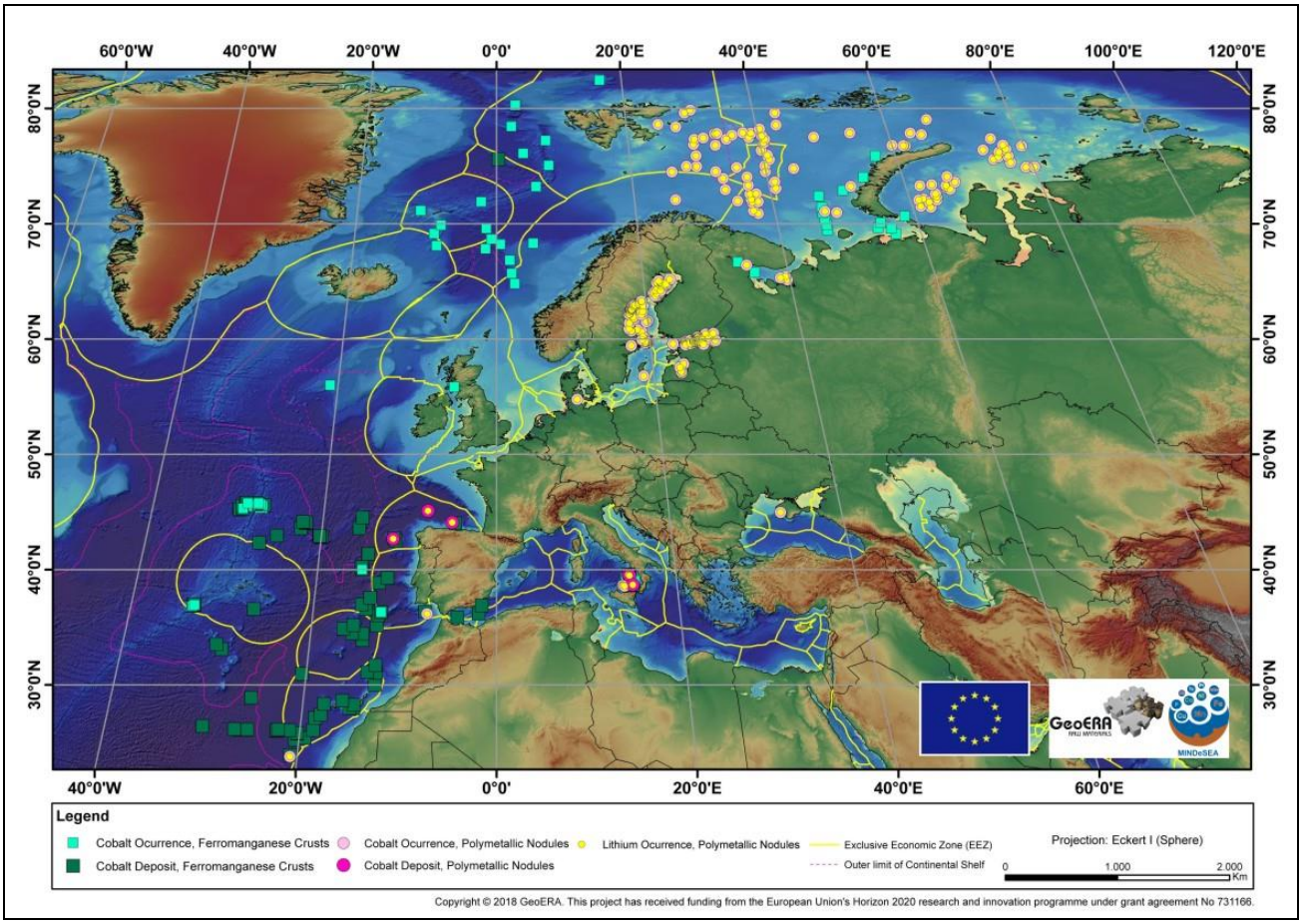

Figure 3. *Distribution of occurrences of Cobalt and Lithium in pan-European seas: ferromanganese deposits, status per 20.12.2018. Extended Continental Shelfs are presented in the map as submissions to the CLCS (Commission on the Limits of the Continental Shelf, United Nations).*

Future work and challenges

Future work will have four major challenges:

1. Only a minority of the EU35 countries are partners in MINDeSEA, a complete overview of the energy-critical elements in European seas is not possible without data as large part of EU coastal States as possible.

2. The map of "energy-critical elements" will be continuously updated with new data and additional information on REEs, tellurium and other critical raw materials on seabed deposits. The WP leads look forward to co-operate with everybody both internal and external people and institutions.

3. The maps and datasets produced by MINDeSEA for strategic and critical raw materials in pan-European seas will be shared in the FRAME project-WP3: "Critical and Strategic Raw Materials Map of Europe" and the EMODnet-Geology project-WP7: "Mineral Occurrences".

4. It will be important to integrate the data that has been collected in to a common information platform for GeoERA.

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

Marine Region/Commodity	Number of deposits/occurrences
Arctic Ocean	**114**
Co	114
Li	90
Baltic Sea	**113**
Co	113
Li	113
Black Sea	**1**
Co	1
Li	1
Bay of Biscay and the Iberian Coasts	**13**
Co	13
Li	4
Celtic Sea	**1**
Co	1
Macaronesia	**87**
Co	87
Li	1
North East Atlantic Ocean	**16**
Co	16
Norwegian Sea	**13**
Co	13
Western Mediterranean Sea	**21**
Co	21
Li	6
TOTAL	**379 (164 crusts, 215 nodules)**

Table 1. *The data is grouped according to marine regions-subregions and commodity. http://marine.discomap.eea.europa.eu/arcgis/rest/services/Marine/Marine_regions_subregions_v1/MapServer*

References:

[1]. Energy Critical Elements: Securing Materials for Emerging Technologies (Materials Research Society/American Physical Society, Washington, DC, 2011).

[2]. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. On the 2017 list of

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

Critical Raw Materials for the EU. Brussels, 13.9.2017. COM(2017) 490 final. https://ec.europa.eu/transparency/regdoc/rep/1/2017/EN/COM-2017-490-F1-EN-MAIN-PART-1.PDF

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).