MINDeSEA: Seabed Mineral Deposits in European Seas

Marine minerals – Millions of years scavenging battery- and high-technology metals from the seafloor environment

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MINDeSEA Consortium (12 partners)

Project Lead

Instituto Geológico y Minero de España

WP Leads

Instituto Geológico y Minero de España

GEOLOGICAL SURVEY OF NORWAY - NGU -

Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann

Partners

BGR

SGU Sveriges geologiska undersökning Geological Survey of Sweden

(Non-Funded)

IGEO INSTITUTO DE GEOCIENCIAS

ipma instituto português do mar e da atmosfera

USGS science for a changing world

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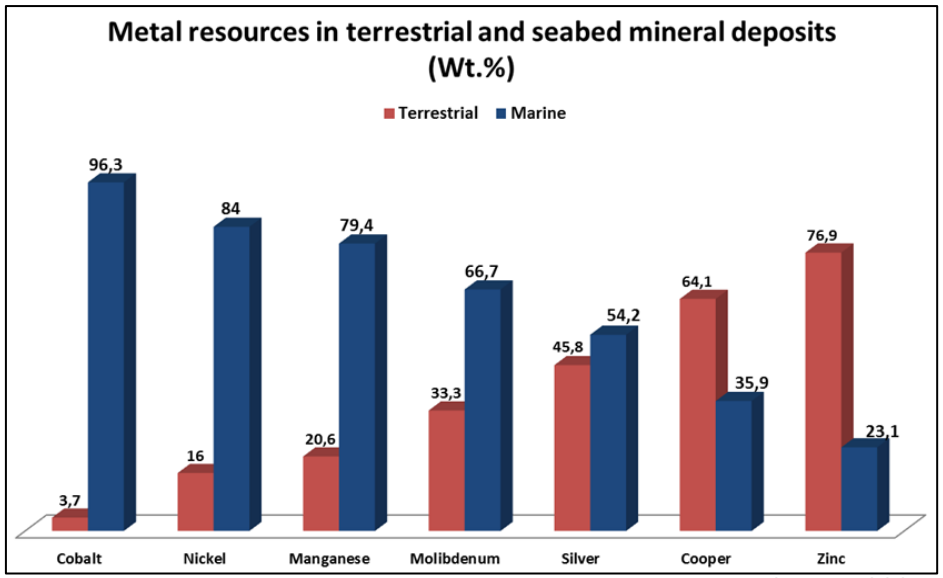
GeoERA RAW MATERIALS

Challenge

Seafloor deposits:
the most important yet least explored resource of CRM

By 2030, 10% of the world's minerals, including cobalt, copper and zinc could come from the ocean floors.

Global annual turnover of marine mineral mining can be expected to grow from virtually nothing to **€10 billion by 2030**.



Source: USGS

2020 critical raw materials (new as compared to 2017 in bold)		
Antimony	Hafnium	Phosphorus
Baryte	Heavy Rare Earth Elements	Scandium
Beryllium	Light Rare Earth Elements	Silicon metal
Bismuth	Indium	Tantalum
Borate	Magnesium	Tungsten
Cobalt	Natural graphite	Vanadium
Coking coal	Natural rubber	**Bauxite**
Fluorspar	Niobium	**Lithium**
Gallium	Platinum Group Metals	**Titanium**
Germanium	Phosphate rock	**Strontium**

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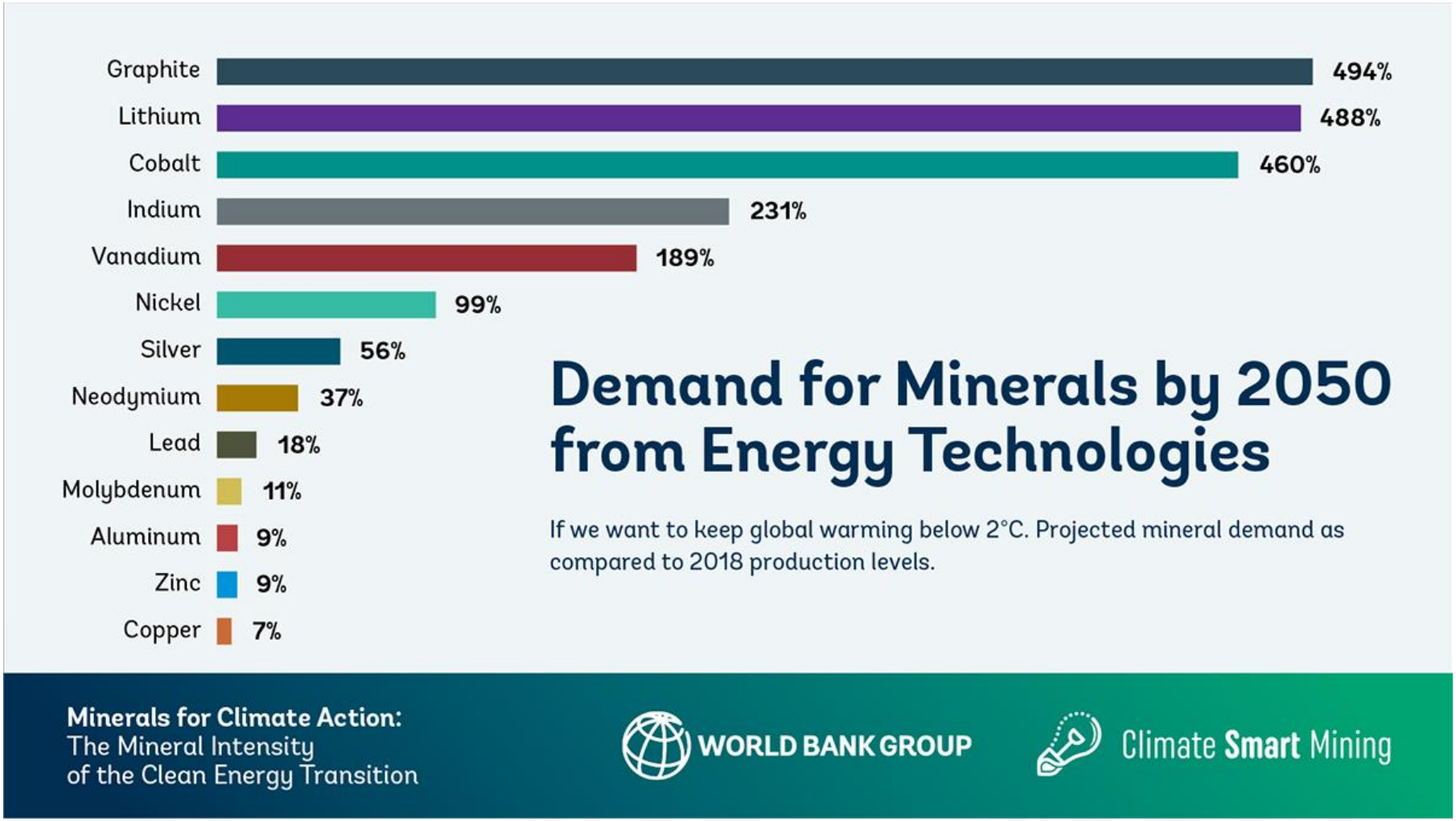

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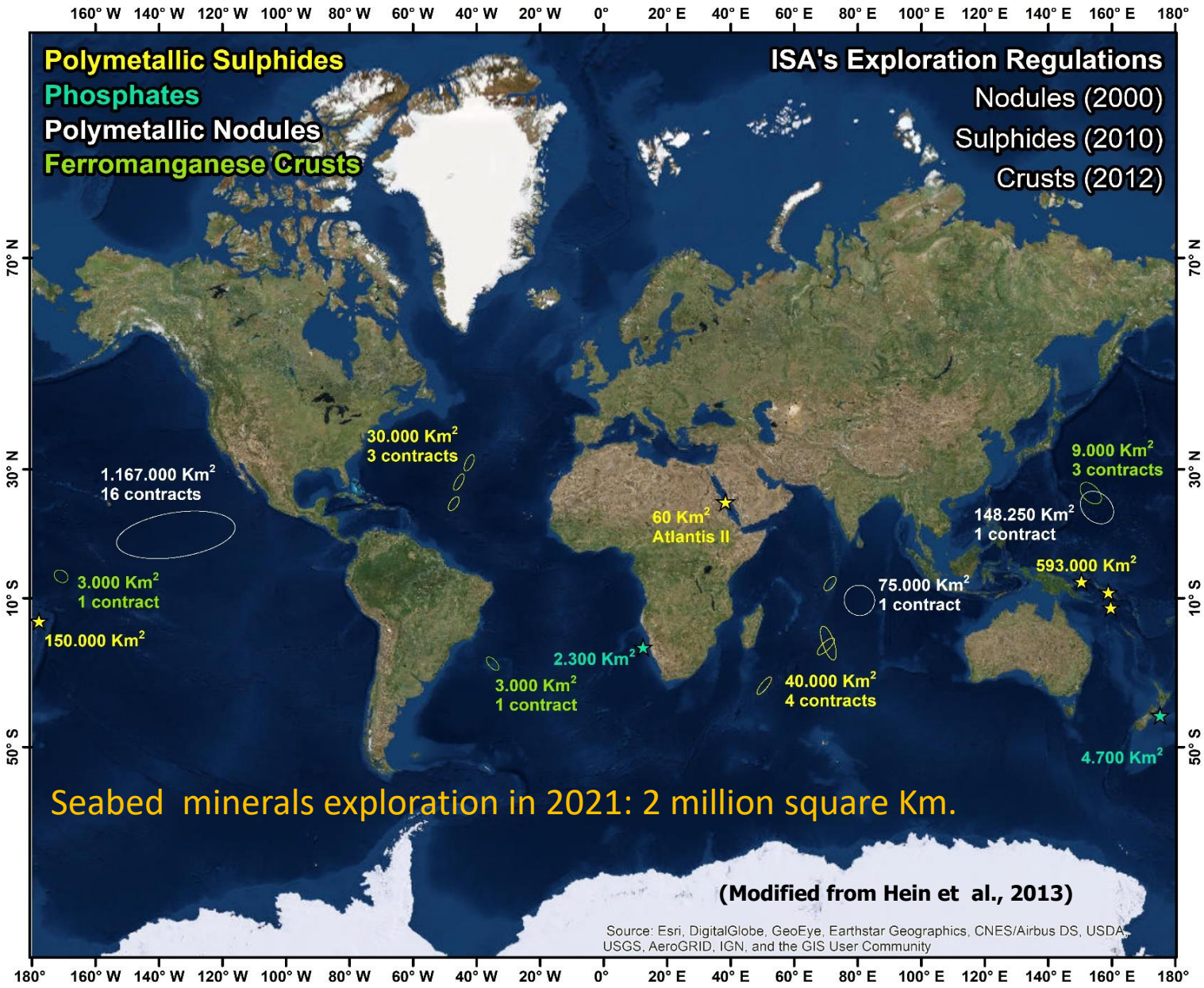
GeoERA RAW MATERIALS


Polymetallic Sulphides
Phosphates
Polymetallic Nodules
Ferromanganese Crusts
ISA's Exploration Regulations
Nodules (2000)
Sulphides (2010)
Crusts (2012)
160° W 140° W 120° W 100° W 80° W 60° W 40° W 20° W 0° 20° E 40° E 60° E 80° E 100° E 120° E 140° E 160° E 180°
70° N
30° N
10° S
50° S
1.167.000 Km² 16 contracts
30.000 Km² 3 contracts
9.000 Km² 3 contracts
60 Km² Atlantis II
148.250 Km² 1 contract
593.000 Km²
3.000 Km² 1 contract
150.000 Km²
75.000 Km² 1 contract
2.300 Km²
3.000 Km² 1 contract
40.000 Km² 4 contracts
4.700 Km²
Seabed minerals exploration in 2021: 2 million square Km.
(Modified from Hein et al., 2013)
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Characterising the European deposit types and their CRM

1- Hydrothermal mineralisations
2- Co-rich Ferromanganese Crusts
3- Phosphorites
4- Polymetallic Nodules
5- Marine Placer deposits

Pan-European seabed minerals

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Using cutting-edge technologies

- ✓ On board
- ✓ At Labs

EPMA, BGR Hannover

LA-ICP-MS, Leibniz Un. Hannover

ROV LUSO 6000, EMEPC

ROV ISIS 6000, NOC

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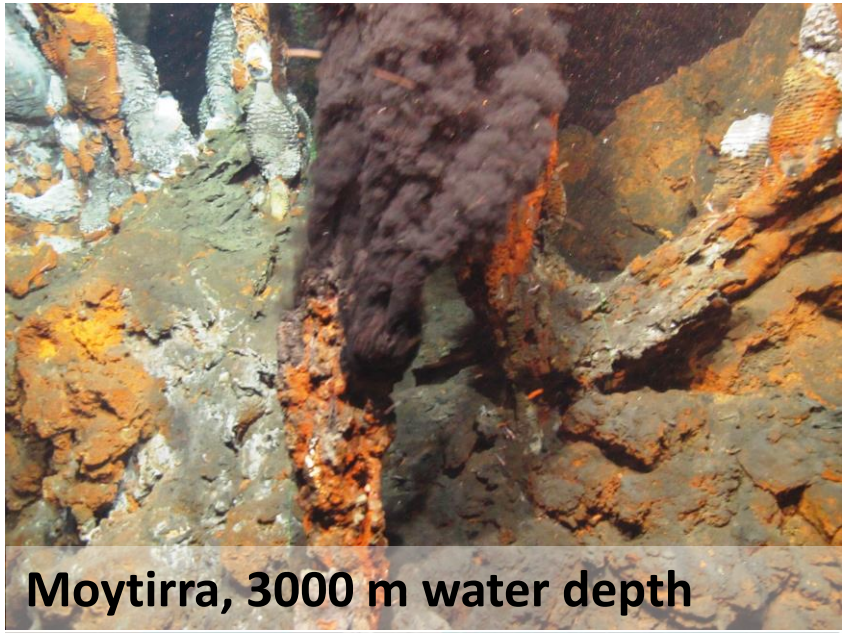
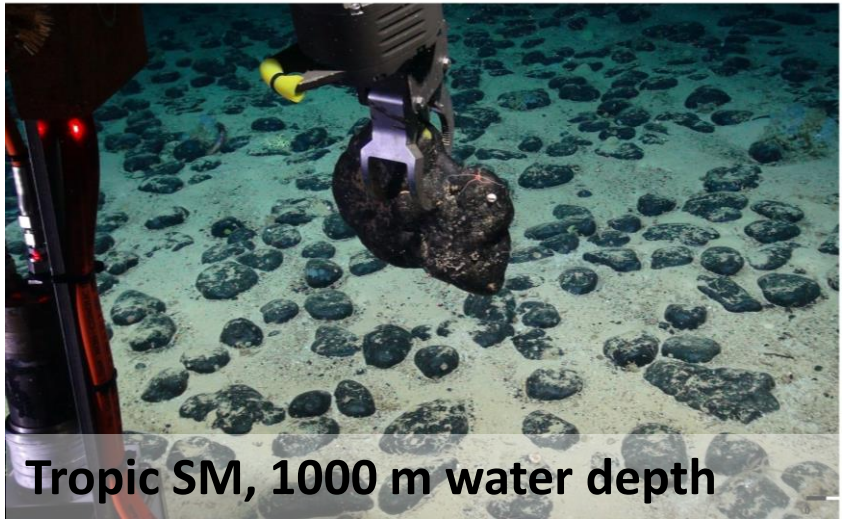
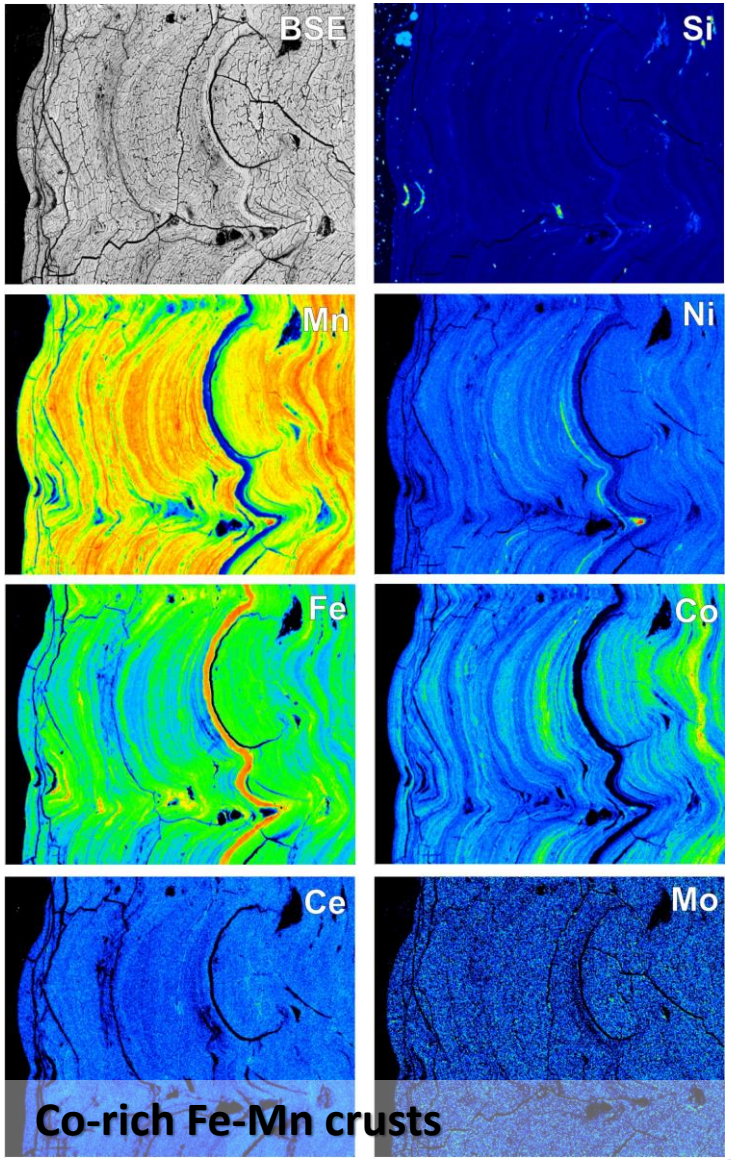
GeoERA RAW MATERIALS



Moytirra, 3000 m water depth



Tropic SM, 1000 m water depth



Co-rich Fe-Mn crusts

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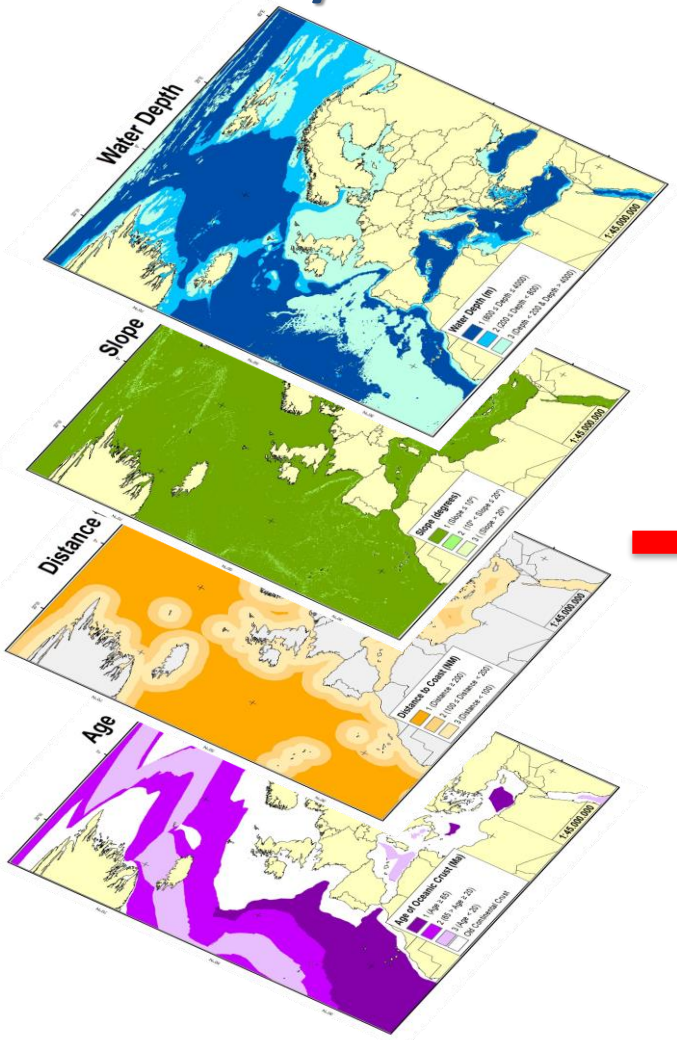
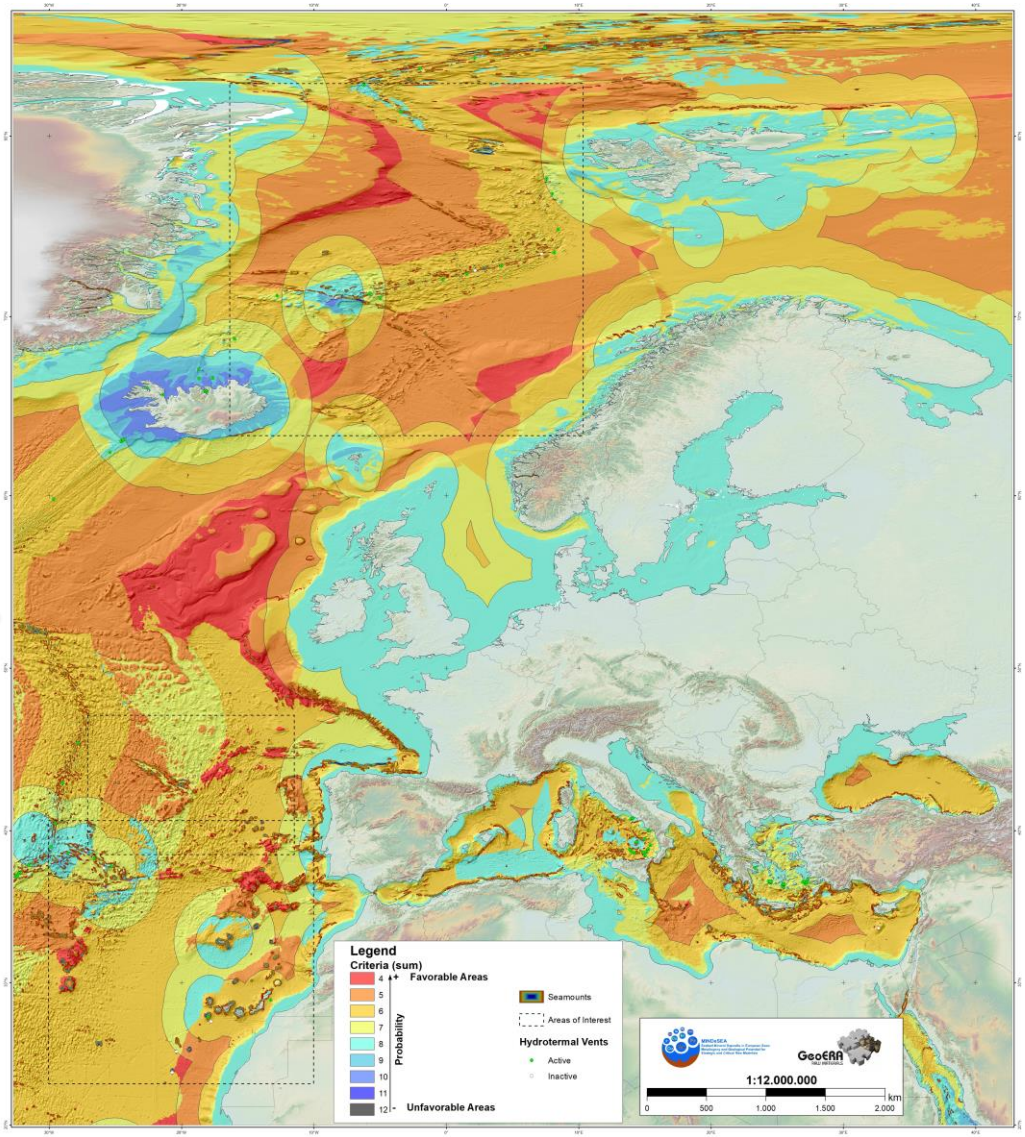
GeoERA RAW MATERIALS

GIS analyses





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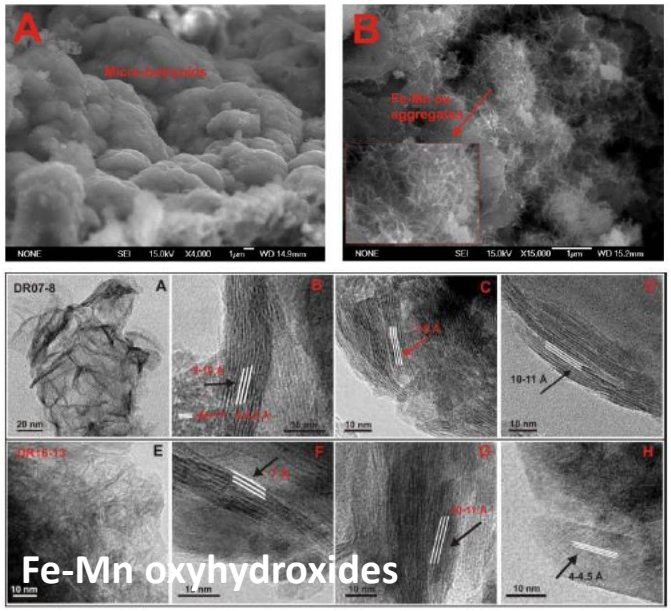
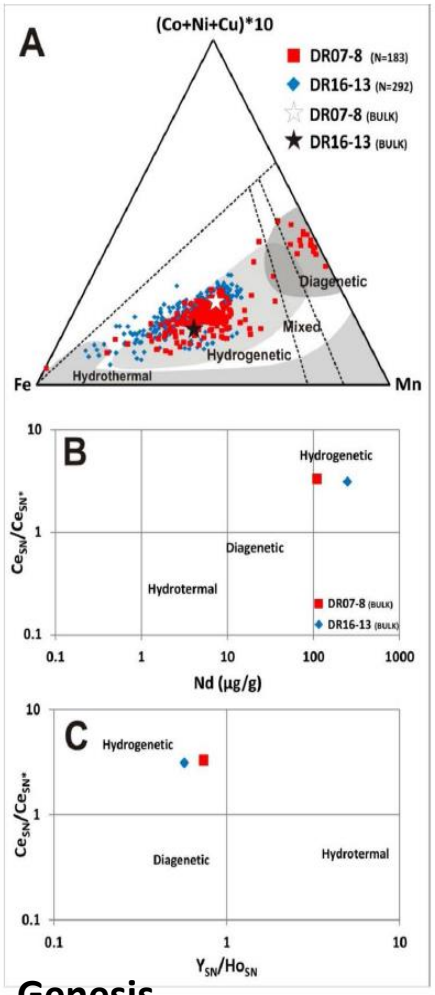
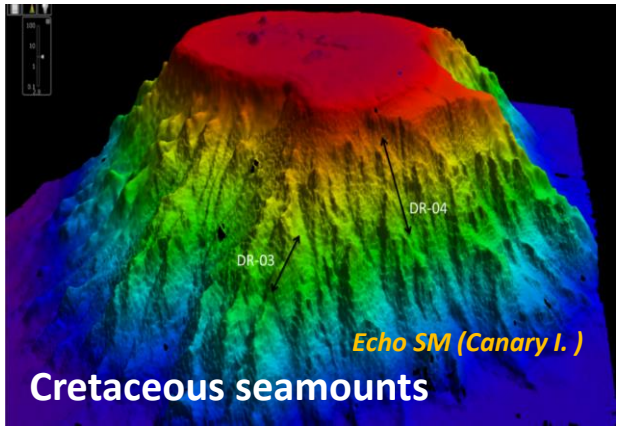
Identifying the principal metallogenic provinces

- ✓ Mineral assemblages
- ✓ Areas of distribution
- ✓ Epochs of formation
- ✓ Genetic models





Genesis



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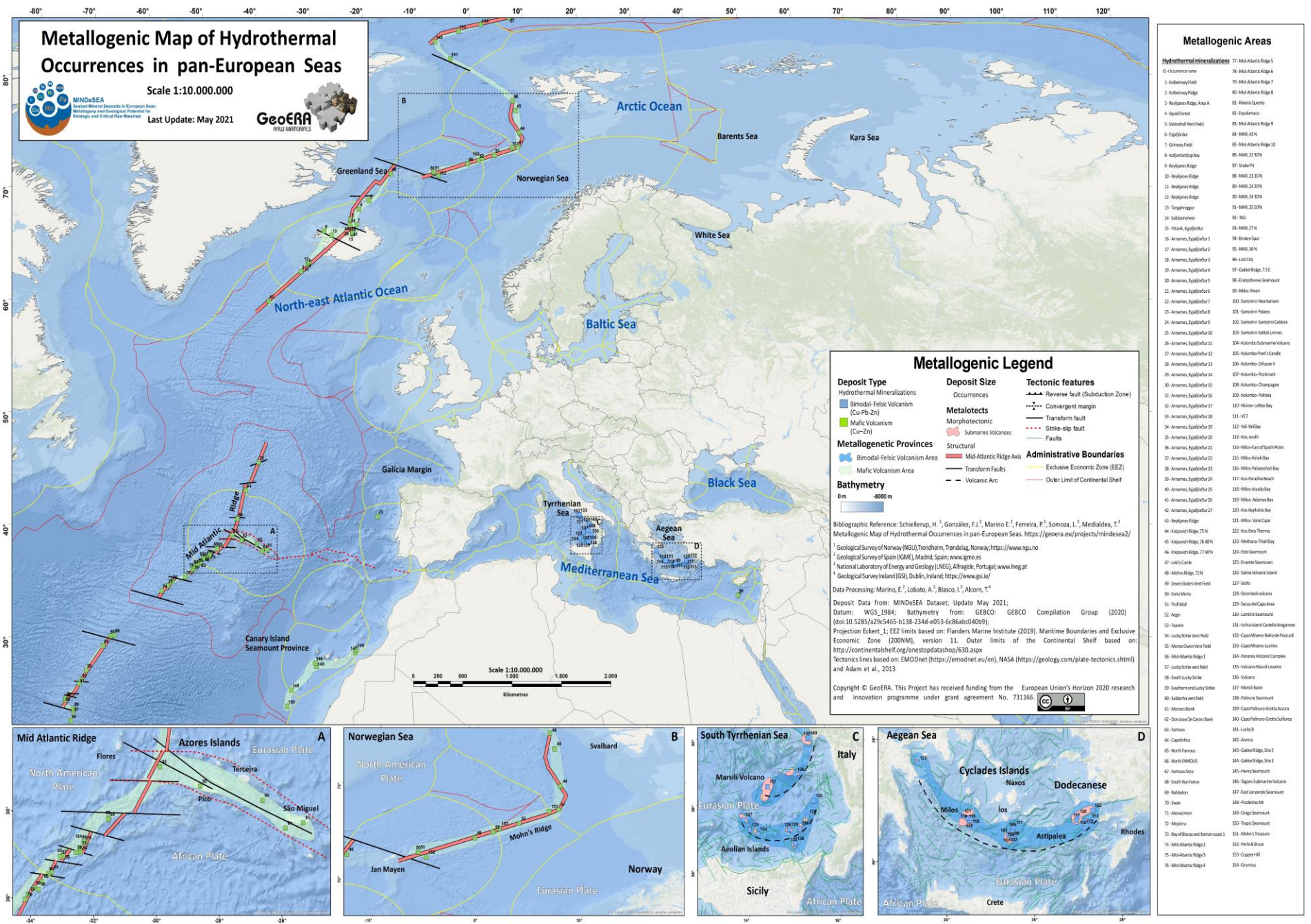
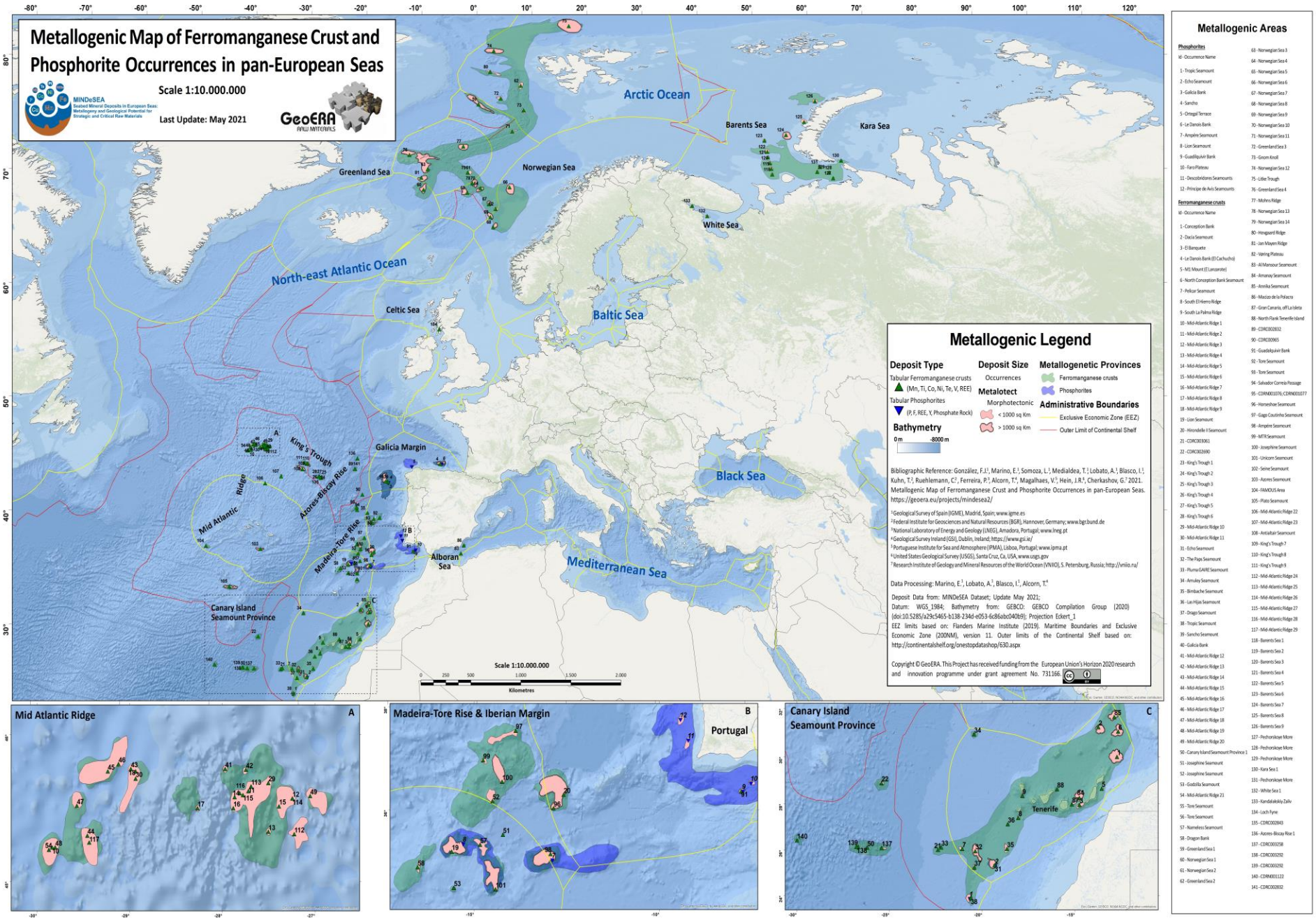


Metallogenic Areas

Hydrothermal mineralizations	
ID - Occurrence name	77 - Mid-Atlantic Ridge 5
1 - Kolbeinsey Field	78 - Mid-Atlantic Ridge 6
2 - Kolbeinsey Ridge	79 - Mid-Atlantic Ridge 7
3 - Reykjanes Ridge, Area A	80 - Mid-Atlantic Ridge 8
4 - Squid Forest	81 - Ribeira Quente
5 - Steinahóll Vent Field	82 - Espalamaca
6 - Eyjafjördur	83 - Mid-Atlantic Ridge 9
7 - Grimsey Field	84 - MAR, 43 N
8 - Isafjardardjup Bay	85 - Mid-Atlantic Ridge 10
9 - Reykjanes Ridge	86 - MAR, 22 30'N
10 - Reykjanes Ridge	87 - Snake Pit
11 - Reykjanes Ridge	88 - MAR, 23 35'N
12 - Reykjanes Ridge	89 - MAR, 24 20'N
13 - Tangahryggur	90 - MAR, 24 30'N
14 - Saltsteinshver	91 - MAR, 25 50'N
15 - Ystavik, Eyjafjörður	92 - TAG
16 - Arnarnes, Eyjafjördur 1	93 - MAR, 27 N
17 - Arnarnes, Eyjafjördur 2	94 - Broken Spur
18 - Arnarnes, Eyjafjördur 3	95 - MAR, 30 N
19 - Arnarnes, Eyjafjördur 4	96 - Lost City
20 - Arnarnes, Eyjafjördur 5	97 - Gakkel Ridge, 7.5 E
21 - Arnarnes, Eyjafjördur 6	98 - Eratosthenes Seamount
22 - Arnarnes, Eyjafjördur 7	99 - Milos - Rivari
23 - Arnarnes, Eyjafjördur 8	100 - Santorini - Nea Kameni
24 - Arnarnes, Eyjafjördur 9	101 - Santorini - Paleea
25 - Arnarnes, Eyjafjördur 10	102 - Santorini - Santorini Caldera
26 - Arnarnes, Eyjafjördur 11	103 - Santorini - Kalliste Limnes
27 - Arnarnes, Eyjafjördur 12	104 - Kolumbo Submarine Volcano
28 - Arnarnes, Eyjafjördur 13	105 - Kolumbo - Poet's Candle
29 - Arnarnes, Eyjafjördur 14	106 - Kolumbo - Diffuser II
30 - Arnarnes, Eyjafjördur 15	107 - Kolumbo - Rockmark
31 - Arnarnes, Eyjafjördur 16	108 - Kolumbo - Champagne
32 - Arnarnes, Eyjafjördur 17	109 - Kolumbo - Polittea
33 - Arnarnes, Eyjafjördur 18	110 - Nisiros - Lefkos Bay
34 - Arnarnes, Eyjafjördur 19	111 - VC7
35 - Arnarnes, Eyjafjördur 20	112 - Yali - Yali Bay
36 - Arnarnes, Eyjafjördur 21	113 - Kos, south
37 - Arnarnes, Eyjafjördur 22	114 - Milos - East of Spathi Point
38 - Arnarnes, Eyjafjördur 23	115 - Milos - Kiriaki Bay
39 - Arnarnes, Eyjafjördur 24	116 - Milos - Palaeochori Bay
40 - Arnarnes, Eyjafjördur 25	117 - Kos - Paradisa Beach
41 - Arnarnes, Eyjafjördur 26	118 - Milos - Voudia Bay
42 - Arnarnes, Eyjafjördur 27	119 - Milos - Adamas Bay
43 - Reykjanes Ridge	120 - Kos - Kephalos Bay
44 - Reykjanes Ridge, 75 N	121 - Milos - Vani Cape
45 - Reykjanes Ridge, 76 48'N	122 - Kos - Bros Thrma
46 - Reykjanes Ridge, 77 40'N	123 - Methana - Thiafi Bay
47 - Loki's Castle	124 - Eolo Seamount
48 - Mohns Ridge, 72 N	125 - Enarete Seamount
49 - Seven Sisters Vent Field	126 - Salina Volcanic Island
50 - Soria Moria	127 - Stolfo
51 - Troll Wall	128 - Stromboli volcano
52 - Aegir	129 - Secca del Capo Area
53 - Fauvne	130 - Lamitini Seamount
54 - Lucky Strike Vent Field	131 - Ischia Island-Castello Aragonese
55 - Menez Gwen Vent Field	132 - Capo Miseno-Bahia de Pozzuoli
56 - Mid-Atlantic Ridge 1	133 - Capo Miseno-Lucrino
57 - Lucky Strike vent field	134 - Panarea Volcanic Complex
58 - South Lucky Strike	135 - Vulcano-Baia di Levante
59 - Southern end Lucky Strike	136 - Vulcano
60 - Saldanha vent field	137 - Marsili Basin
61 - Monaco Bank	138 - Palinuro Seamount
62 - Don Joao De Castro Bank	139 - Capo Palinuro-Grotta Azzura
63 - Famous	140 - Capo Palinuro-Grotta Sulfurea
64 - Capelinhos	141 - Lucky B
65 - North Famous	142 - Aurora
66 - North FAMOUS	143 - Gakkel Ridge, Site 2
67 - Famous Area	144 - Gakkel Ridge, Site 3
68 - South Kurchatov	145 - Henry Seamount
69 - Bubbylon	146 - Tagoro Submarine Volcano
70 - Ewan	147 - East Lanzarote Seamount
71 - Menez Hom	148 - Piccoletino Mt
72 - Moytirra	149 - Drago Seamount
73 - Bay of Biscay and Iberian coast 1	150 - Tropic Seamount
74 - Mid-Atlantic Ridge 2	151 - Mohn's Treasure
75 - Mid-Atlantic Ridge 3	152 - Perle & Bruse
76 - Mid-Atlantic Ridge 4	153 - Copper Hill
	154 - Grunnus


Metallogenic Map of Ferromanganese Crust and Phosphorite Occurrences in pan-European Seas
Scale 1:10.000.000
Last Update: May 2021
MINDeSEA
Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials
GeoERA RAW MATERIALS
Arctic Ocean
Barents Sea
Kara Sea
Greenland Sea
Norwegian Sea
White Sea
North-east Atlantic Ocean
Celtic Sea
Baltic Sea
Galicia Margin
King's Trough
Azores-Biscay Rise
Mid Atlantic Ridge
Madeira-Tore Rise
Alboran Sea
Black Sea
Mediterranean Sea
Canary Island Seamount Province
Scale 1:10.000.000
Kilometres
Metallogenic Legend
Deposit Type
Tabular Ferromanganese crusts (Mn, Ti, Co, Ni, Te, V, REE)
Tabular Phosphorites (P, F, REE, Y, Phosphate Rock)
Bathymetry
0m -8000 m
Deposit Size
Occurrences
Metalotect
Morphotectonic
< 1000 sq Km
> 1000 sq Km
Metallogenetic Provinces
Ferromanganese crusts
Phosphorites
Administrative Boundaries
Exclusive Economic Zone (EEZ)
Outer Limit of Continental Shelf
Bibliographic Reference: González, F.J.[1]; Marino, E.[1]; Somoza, L.[1]; Medialdea, T.[1]; Lobato, A.[1]; Blasco, I.[1]; Kuhn, T.[2]; Ruehlemann, C.[2], Ferreira, P.[3], Alcorn, T.[4]; Magalhaes, V.[5]; Hein, J.R.[6], Cherkashov, G.[7] 2021. Metallogenic Map of Ferromanganese Crust and Phosphorite Occurrences in pan-European Seas. https://geoera.eu/projects/mindesea2/
[1]Geological Survey of Spain (IGME), Madrid, Spain; www.igme.es
[2]Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany; www.bgr.bund.de
[3]National Laboratory of Energy and Geology (LNEG), Amadora, Portugal; www.lneg.pt
[4]Geological Survey Ireland (GSI), Dublin, Ireland; https://www.gsi.ie/
[5]Portuguese Institute for Sea and Atmosphere (IPMA), Lisboa, Portugal; www.ipma.pt
[6]United States Geological Survey (USGS), Santa Cruz, Ca, USA, www.usgs.gov
[7]Research Institute of Geology and Mineral Resources of the World Ocean (VNIIO), S. Petersburg, Russia; http://vniio.ru/
Data Processing: Marino, E.[1], Lobato, A.[1], Blasco, I.[1], Alcorn, T.[4]
Deposit Data from: MINDeSEA Dataset; Update May 2021;
Datum: WGS_1984; Bathymetry from: GEBCO: GEBCO Compilation Group (2020) (doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9); Projection Eckert_1
EEZ limits based on: Flanders Marine Institute (2019). Maritime Boundaries and Exclusive Economic Zone (200NM), version 11. Outer limits of the Continental Shelf based on: http://continentalshelf.org/onestopdatashop/630.aspx
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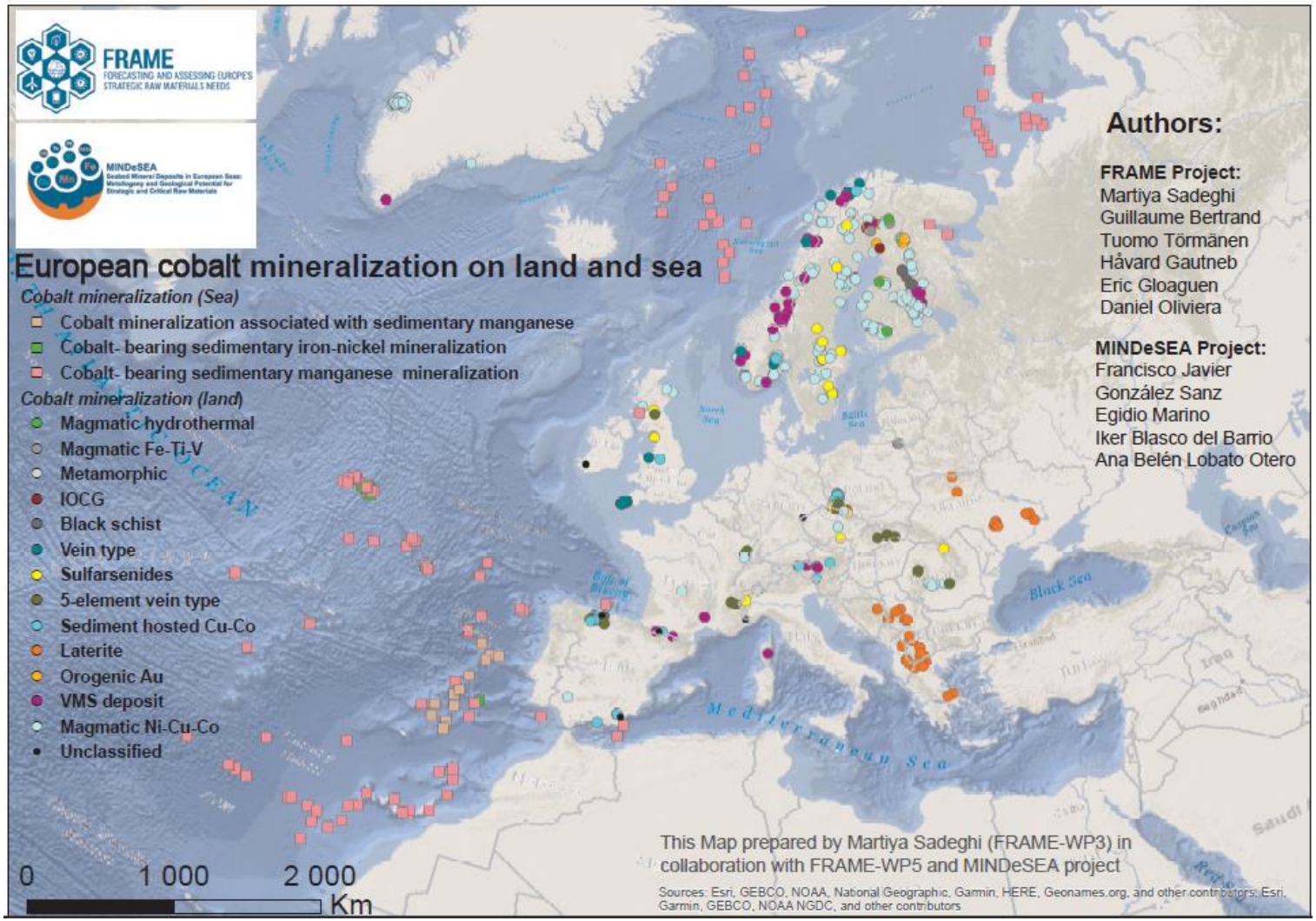
Metallogenic Areas
Phosphorites
Id - Occurrence Name
1 - Tropic Seamount
2 - Echo Seamount
3 - Galicia Bank
4 - Sancho
5 - Ortegal Terrace
6 - Le Danois Bank
7 - Ampère Seamount
8 - Lion Seamount
9 - Guadalquivir Bank
10 - Faro Plateau
11 - Descubridores Seamounts
12 - Principe de Avis Seamounts
Ferromanganese crusts
Id - Occurrence Name
1 - Conception Bank
2 - Dacia Seamount
3 - El Banquete
4 - Le Danois Bank (El Cachucho)
5 - M1 Mount (E Lanzarote)
6 - North Conception Bank Seamount
7 - Pelicar Seamount
8 - South El Hierro Ridge
9 - South La Palma Ridge
10 - Mid-Atlantic Ridge 1
11 - Mid-Atlantic Ridge 2
12 - Mid-Atlantic Ridge 3
13 - Mid-Atlantic Ridge 4
14 - Mid-Atlantic Ridge 5
15 - Mid-Atlantic Ridge 6
16 - Mid-Atlantic Ridge 7
17 - Mid-Atlantic Ridge 8
18 - Mid-Atlantic Ridge 9
19 - Lion Seamount
20 - Hirondelle I Seamount
21 - CDRC003061
22 - CDRC002690
23 - King's Trough 1
24 - King's Trough 2
25 - King's Trough 3
26 - King's Trough 4
27 - King's Trough 5
28 - King's Trough 6
29 - Mid-Atlantic Ridge 10
30 - Mid-Atlantic Ridge 11
31 - Echo Seamount
32 - The Paps Seamount
33 - Pluma GAIRE Seamount
34 - Amulay Seamount
35 - Bimbache Seamount
36 - Las Hijas Seamount
37 - Dragon Seamount
38 - Tropic Seamount
39 - Sancho Seamount
40 - Galicia Bank
41 - Mid-Atlantic Ridge 12
42 - Mid-Atlantic Ridge 13
43 - Mid-Atlantic Ridge 14
44 - Mid-Atlantic Ridge 15
45 - Mid-Atlantic Ridge 16
46 - Mid-Atlantic Ridge 17
47 - Mid-Atlantic Ridge 18
48 - Mid-Atlantic Ridge 19
49 - Mid-Atlantic Ridge 20
50 - Canary Island Seamount Province 1
51 - Josephine Seamount
52 - Josephine Seamount
53 - Gadolla Seamount
54 - Mid-Atlantic Ridge 21
55 - Tore Seamount
56 - Tore Seamount
57 - Nameless Seamount
58 - Dragon Bank
59 - Greenland Sea 1
60 - Norwegian Sea 1
61 - Norwegian Sea 2
62 - Greenland Sea 2
63 - Norwegian Sea 3
64 - Norwegian Sea 4
65 - Norwegian Sea 5
66 - Norwegian Sea 6
67 - Norwegian Sea 7
68 - Norwegian Sea 8
69 - Norwegian Sea 9
70 - Norwegian Sea 10
71 - Norwegian Sea 11
72 - Greenland Sea 3
73 - Gnom Knoll
74 - Norwegian Sea 12
75 - Litke Trough
76 - Greenland Sea 4
77 - Mohns Ridge
78 - Norwegian Sea 13
79 - Norwegian Sea 14
80 - Hovgaard Ridge
81 - Jan Mayen Ridge
82 - Vøring Plateau
83 - Al Mansour Seamount
84 - Amanay Seamount
85 - Annika Seamount
86 - Macizo de la Polacra
87 - Gran Canaria, off La Isleta
88 - North Flank Tenerife Island
89 - CDRC002832
90 - CDRC00965
91 - Guadalquivir Bank
92 - Tore Seamount
93 - Tore Seamount
94 - Salvador Correia Passage
95 - CDRN001076; CDRN001077
96 - Horseshoe Seamount
97 - Gago Coutinho Seamount
98 - Ampère Seamount
99 - MTR Seamount
100 - Josephine Seamount
101 - Unicorn Seamount
102 - Seine Seamount
103 - Azores Seamount
104 - FAMOUS Area
105 - Plato Seamount
106 - Mid-Atlantic Ridge 22
107 - Mid-Atlantic Ridge 23
108 - Antialtair Seamount
109 - King's Trough 7
110 - King's Trough 8
111 - King's Trough 9
112 - Mid-Atlantic Ridge 24
113 - Mid-Atlantic Ridge 25
114 - Mid-Atlantic Ridge 26
115 - Mid-Atlantic Ridge 27
116 - Mid-Atlantic Ridge 28
117 - Mid-Atlantic Ridge 29
118 - Barents Sea 1
119 - Barents Sea 2
120 - Barents Sea 3
121 - Barents Sea 4
122 - Barents Sea 5
123 - Barents Sea 6
124 - Barents Sea 7
125 - Barents Sea 8
126 - Barents Sea 9
127 - Pechorskoye More
128 - Pechorskoye More
129 - Pechorskoye More
130 - Kara Sea 1
131 - Pechorskoye More
132 - White Sea 1
133 - Kandalakshiy Zaliv
134 - Loch Fyne
135 - CDRC002843
136 - Azores-Biscay Rise 1
137 - CDRC003758
138 - CDRC003292
139 - CDRC003292
140 - CDRN001122
141 - CDRC002832
Mid Atlantic Ridge
A
Madeira-Tore Rise & Iberian Margin
B
Portugal
Canary Island Seamount Province
C
Tenerife

GeoERA projects cooperation: onshore-offshore



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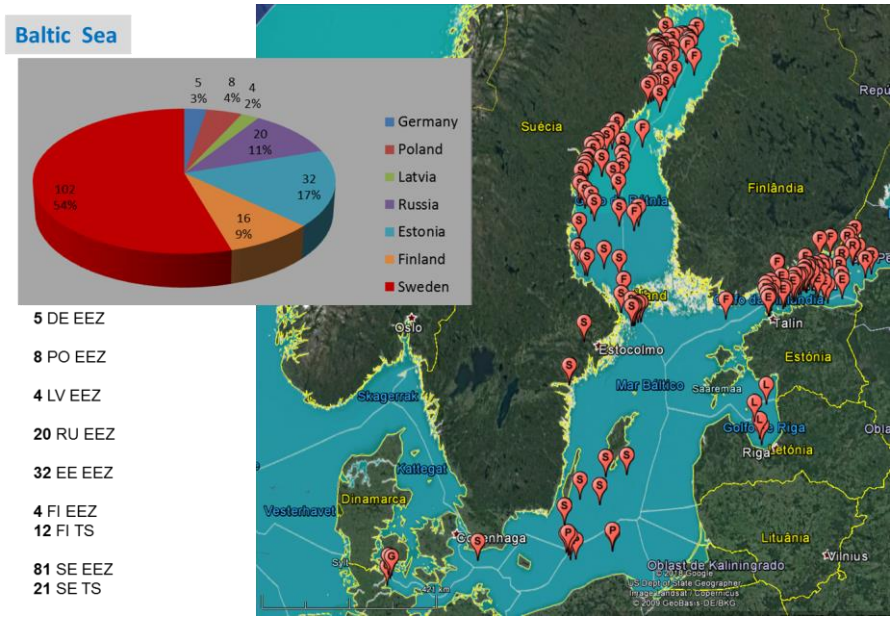
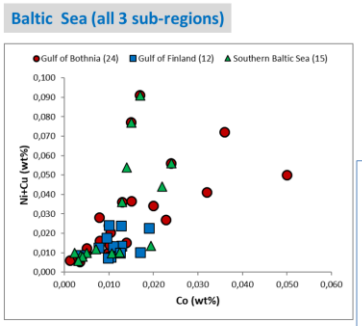
GeoERA RAW MATERIALS

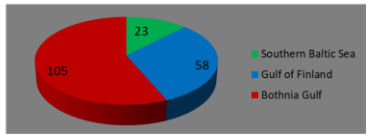
Demonstrating the efficiency of the case study results

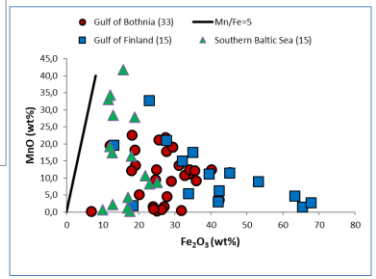
- ✓ **Offshore minerals exploration**
- ✓ **Critical metals assessment**

Areas: Baltic, Mediterranean and Atlantic









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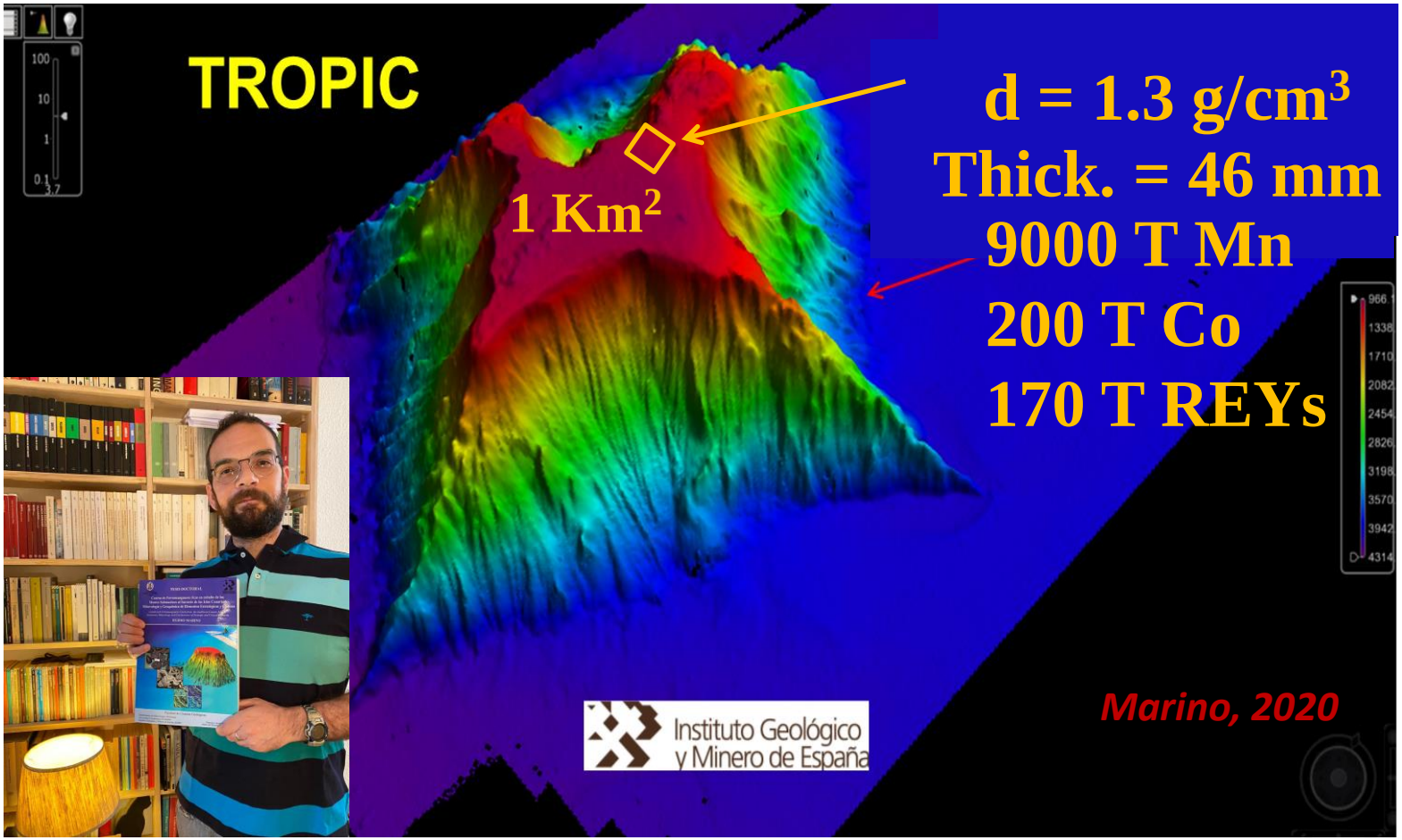
GeoERA RAW MATERIALS

Assesment to Policy Makers

✓ **Tropic Seamount (Canary Island Seamount Province)**



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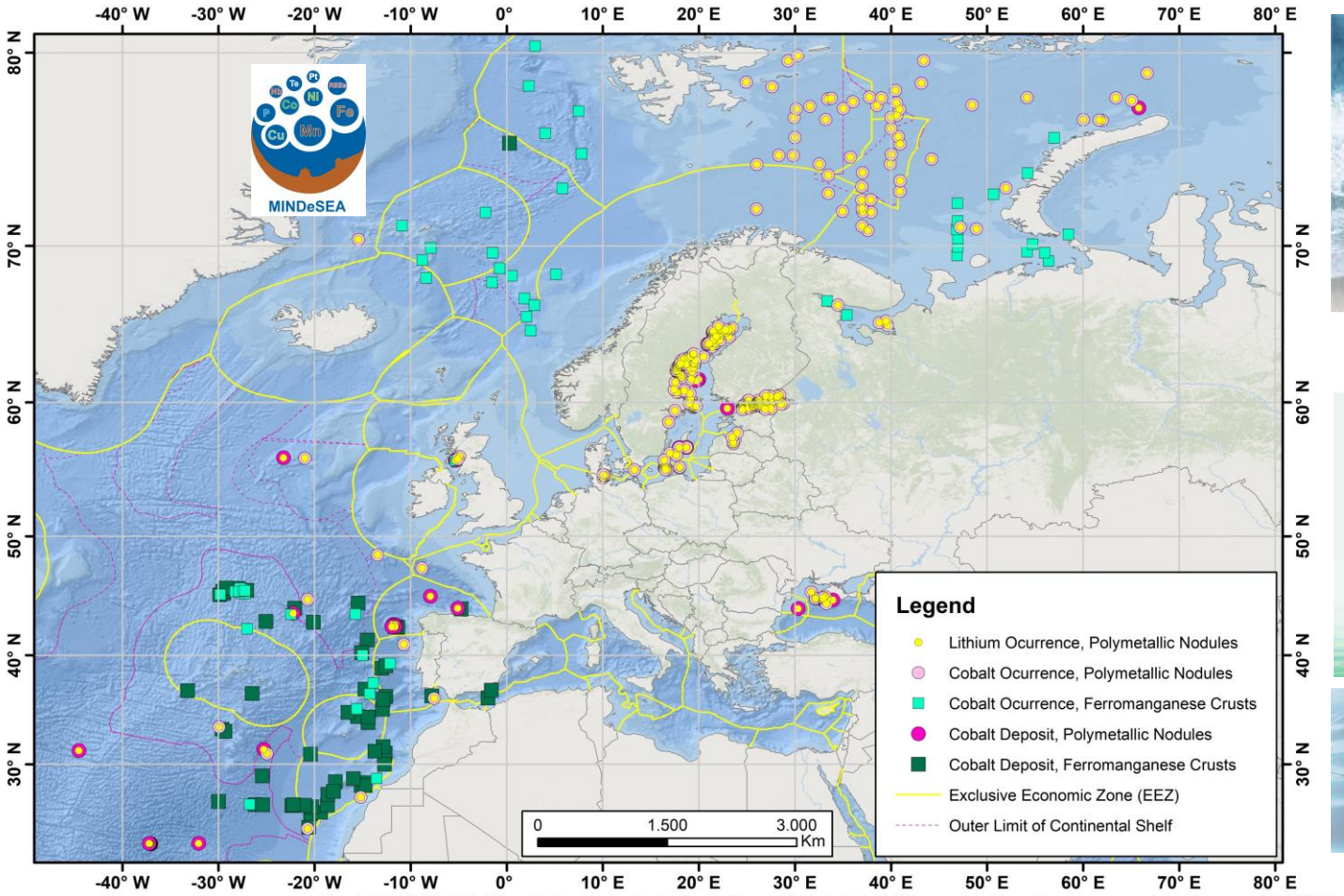
Supporting EC and outreach activities

✓ Pan-European map of Energy-critical elements Co and Li



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GeoERA RAW MATERIALS

Analysing present-day exploration and exploitation status

✓ **Regulation, legislation, environmental impacts, exploitation and future directions**

D6-6: Present-day status of regulation, legislation and exploitation of placer deposits

MINDeSEA

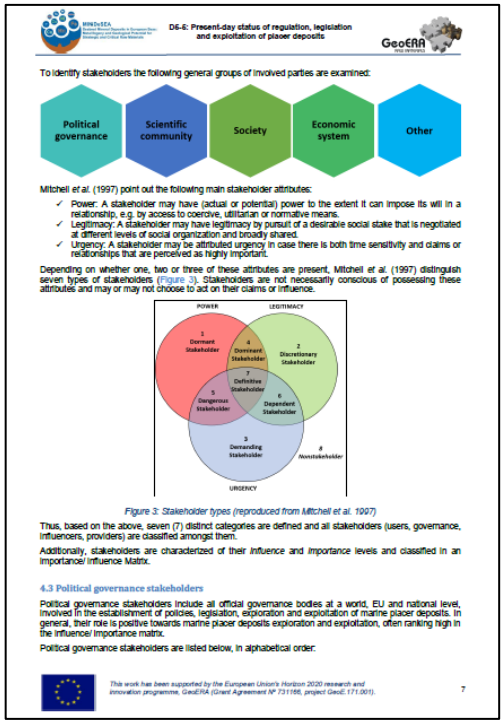
Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials

MINDeSEA

Deliverable 5.5: WP5 Literature review report on present-day status of regulation, legislation and exploitation of placer deposits, with emphasis on the impact of a pan-European research approach

WP5 leader: Hellenic Survey of Geology & Mineral Exploration (HSGME) - Greece		
	Address: 1 Spirou Loui str. Olympic Village 13677 Acharnae Attica Greece	Telephone: +30 213 133 7000 +30 213 133 7194 (I.Zananiri) Email: izanan@gme.gr
WP5 HSGME Team: Dr. Irene Zananiri (scientific responsible) Vaggelis Zimianitis – Martiza Thomadaki – Nikolaos Georgakopoulos		

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



D6-6: Present-day status of regulation, legislation and exploitation of placer deposits

To identify stakeholders the following general groups of involved parties are examined:

Mitchell *et al.* (1997) point out the following main stakeholder attributes:

- Power: A stakeholder may have (actual or potential) power to the extent it can impose its will in a relationship, e.g. by access to coercive, utilitarian or normative means.
- Legitimacy: A stakeholder may have legitimacy by pursuit of a desirable social stake that is negotiated at different levels of social organization and broadly shared.
- Urgency: A stakeholder may be attributed urgency in case there is both time sensitivity and claims or relationships that are perceived as highly important.

Depending on whether one, two or three of these attributes are present, Mitchell *et al.* (1997) distinguish seven types of stakeholders (Figure 3). Stakeholders are not necessarily conscious of possessing these attributes and may or may not choose to act on their claims or influence.

Figure 3: Stakeholder types (reproduced from Mitchell et al. 1997)

Thus, based on the above, seven (7) distinct categories are defined and all stakeholders (users, governance, influencers, providers) are classified amongst them.

Additionally, stakeholders are characterized of their *influence* and *importance* levels and classified in an Importance/ Influence Matrix.

4.3 Political governance stakeholders

Political governance stakeholders include all official governance bodies at a world, EU and national level, involved in the establishment of policies, legislation, exploration and exploitation of marine placer deposits. In general, their role is positive towards marine placer deposits exploration and exploitation, often ranking high in the Influence/ Importance matrix.

Political governance stakeholders are listed below, in alphabetical order:

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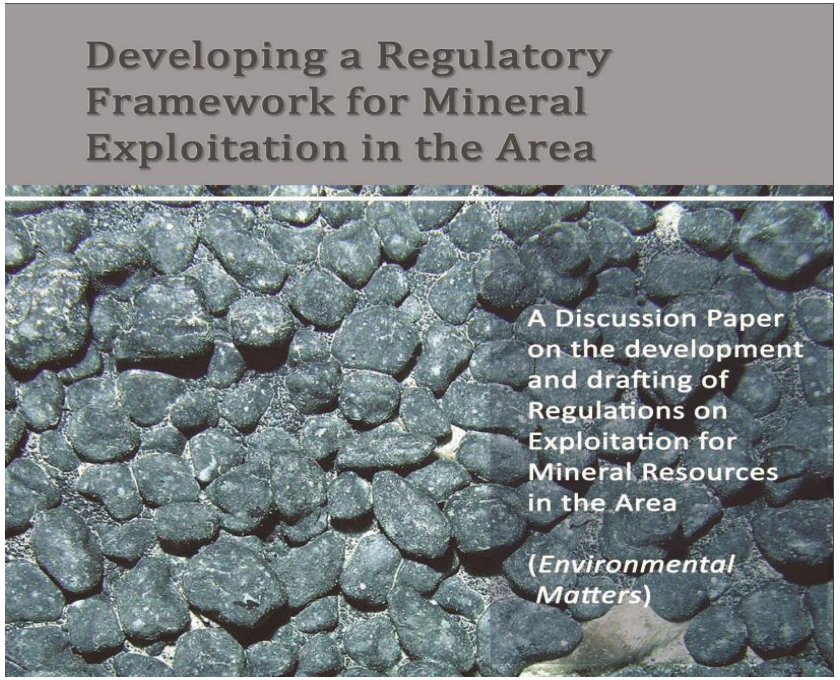
OCEANS & LAW OF THE SEA
UNITED NATIONS
DIVISION FOR OCEAN AFFAIRS AND THE LAW OF THE SEA

United Nations Convention on the Law of the Sea of 10 December 1982
Overview and full text



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GeoERA RAW MATERIALS

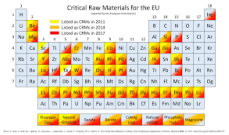
Developing harmonized mineral maps and datasets

- ✓ **Geological Survey Organizations datasets**
- ✓ **Mineral potential and prospectivity maps**

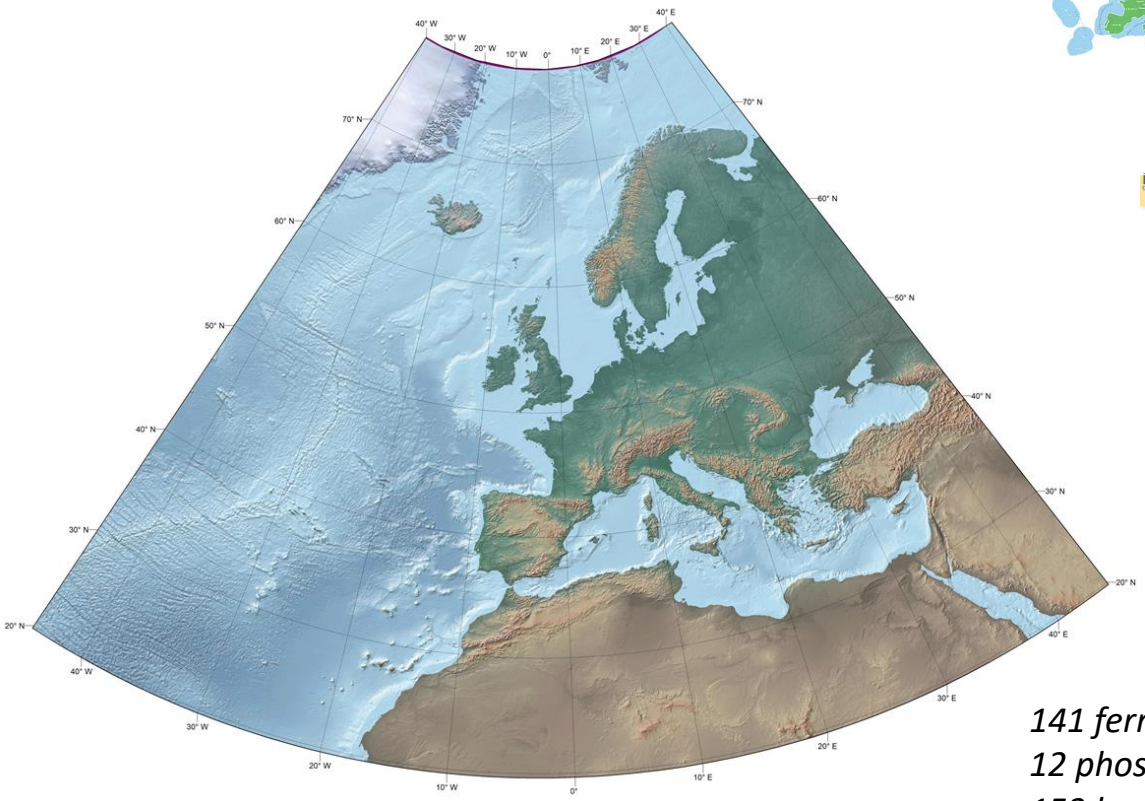
23 European countries

14 marine regions

Scale 1:250.000



23 CRM
5 deposit types



691 occurrences

141 ferromanganese crusts; 89 marine placers;
12 phosphorites; 296 polymetallic nodules;
153 hydrothermal mineralisation

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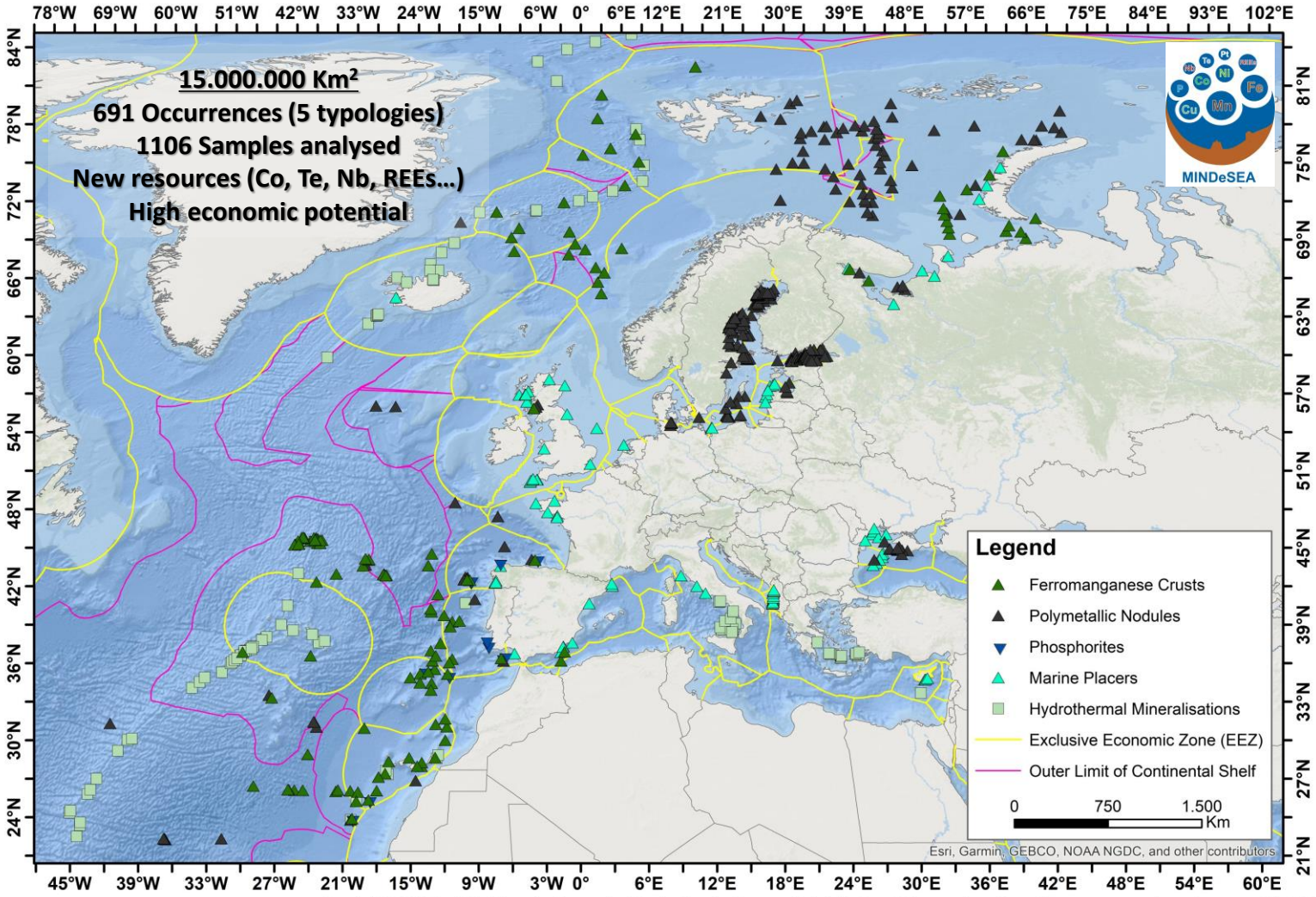
GeoERA RAW MATERIALS

pan-European research approach for seabed mineral deposits



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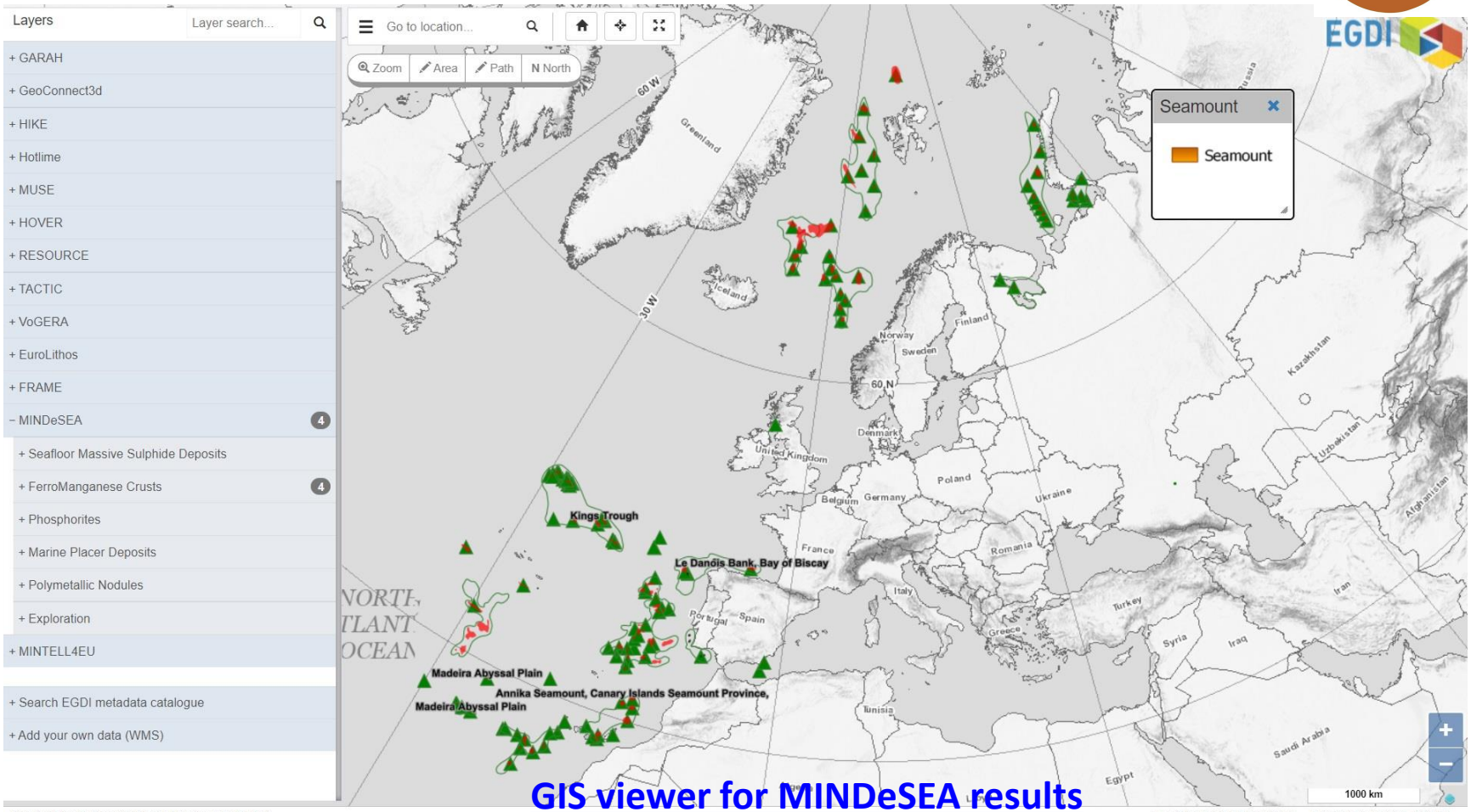
GeoERA RAW MATERIALS

European Geological data Infrastructure (EGDI)

http://www.europe-geology.eu/



GIS viewer for MINDeSEA results

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Seabed mineral deposits potential for Critical Raw Materials

✓ **Assessment to EC (DG- GROW, MARE)**

Sustainable development
Energy transition
Environmental protection and spatial planning

Mapping critical and strategic raw materials in European seas
Maps for 14 CRM (Co, Li, REE, Te, Ni, V, Sb, PGE, Au, Ag, Ti, P, Mn, Cu)
5 deposit types (hydrothermal, ferromanganese crusts, phosphates, placers and polymetallic nodules)
Geochemistry :
- **Mean content**
- **N samples**
- **Range of contents**

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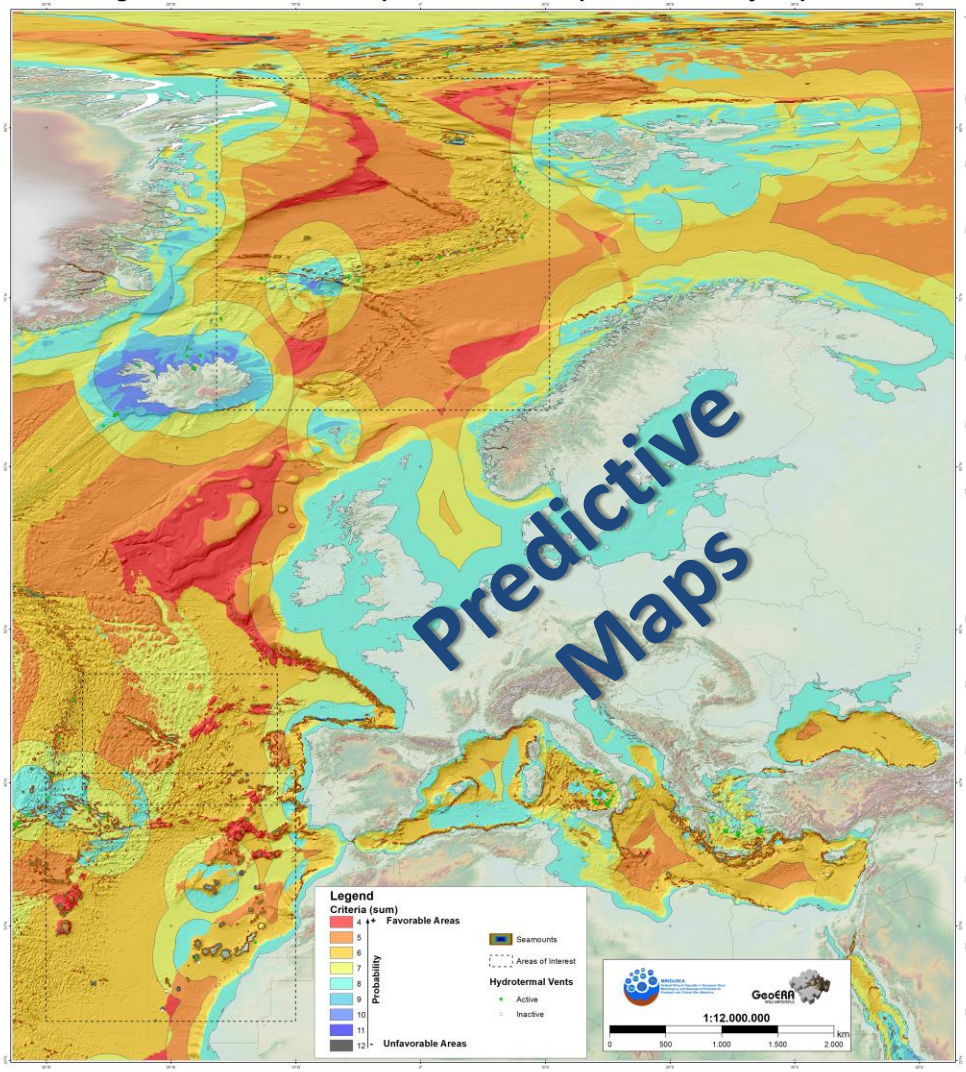
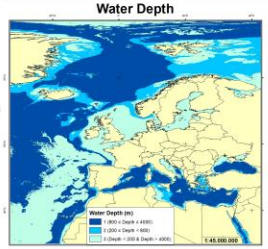
GeoERA RAW MATERIALS

Ferromanganese Crusts and Phosphorites Pan-European Predictivity Map

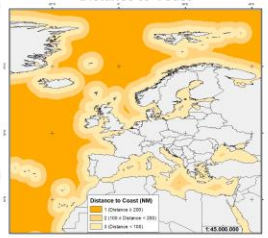


Evaluation Criteria

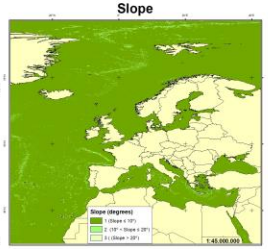
Water Depth



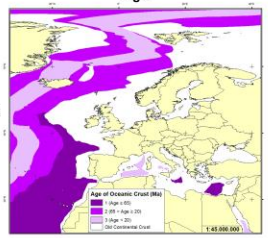
Distance to Coast



Slope

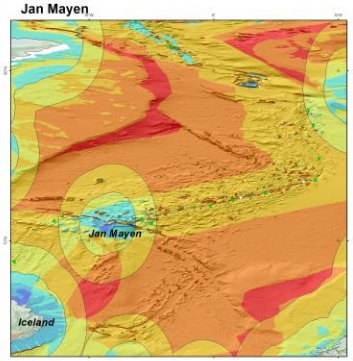


Age

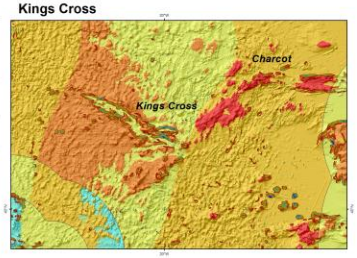


Areas of Interest

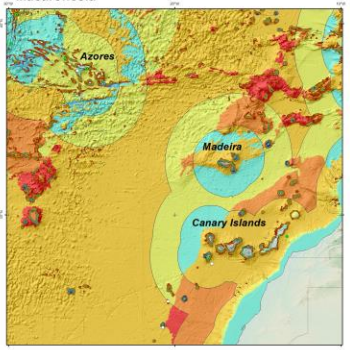
Jan Mayen



Kings Cross



Macaronesia



Legend Explanation

Potential Areas

4: Areas with all the evaluation criteria very favorable

5: Areas with 3 very favorable evaluation criteria and one semi favorable factor

6:
- -Areas that could have three very favorable evaluation criteria and an unfavorable criteria
- -Areas with two very favorable evaluation criteria and 2 semi favorable criteria

7: Areas with only one or two very favorable evaluation criteria

8: Areas with one or two very favorable evaluation criteria and one or two unfavorable criteria

9 - 12: Areas with just one on none very favorable evaluation criteria

Evaluation Criteria

-The physical evaluation criteria have been performed on the GEBCO bathymetry.

-Data on Oceanic crust age have been obtained from the NOAA: www.ngdc.noaa.gov/mgg/mggd.html

-Areas located near the Mid Atlantic Ridge and active vents could accumulate great thickness of hydrothermal Fe-Mn crusts rich in different strategic and critical elements (eg. Li).

-Phosphorites occurrences in MINDeSEA database are limited to Atlantic Iberian Margins and Macaronesia and normally associated with the presence of thick Fe-Mn crusts on old substrates.

-Evaluation criteria could be consulted in the D4.5 Case of Study report (http://geoera.eu/projects/mindesea2/).

Areas of Interest

Areas of interest have been selected as areas in which are present both seamounts detected with the predictive method as areas with a good potential of presence of thick and metal-rich Fe-Mn crusts.

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[4] Geological Survey Ireland (GSI), Dublin. Ireland. www.gsi.ie

[5] Portuguese Institute for Sea and Atmosphere (IPMA), Lisboa. Portugal. www.ipma.pt

[6] United States Geological Survey (USGS), Santa Cruz, Ca. USA. www.usgs.gov

[7] Research Institute of Geology and Mineral Resources of the World Ocean (VNIIO), St. Petersburg. Rusia. http://vniio.ru

Data Processing: Marino, E.[2], Lobato, A.[2], Blasco, I.[2], Alcorn, T.[4]

Deposit Data from: MINDeSEA Dataset; Update May 2021; Bathymetry from: GEBCO: GEBCO Compilation Group (2020) (doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9); Projection: Compact Miller World (Potential and Zoomed-in Areas), WGS84 (Evaluation Criteria).

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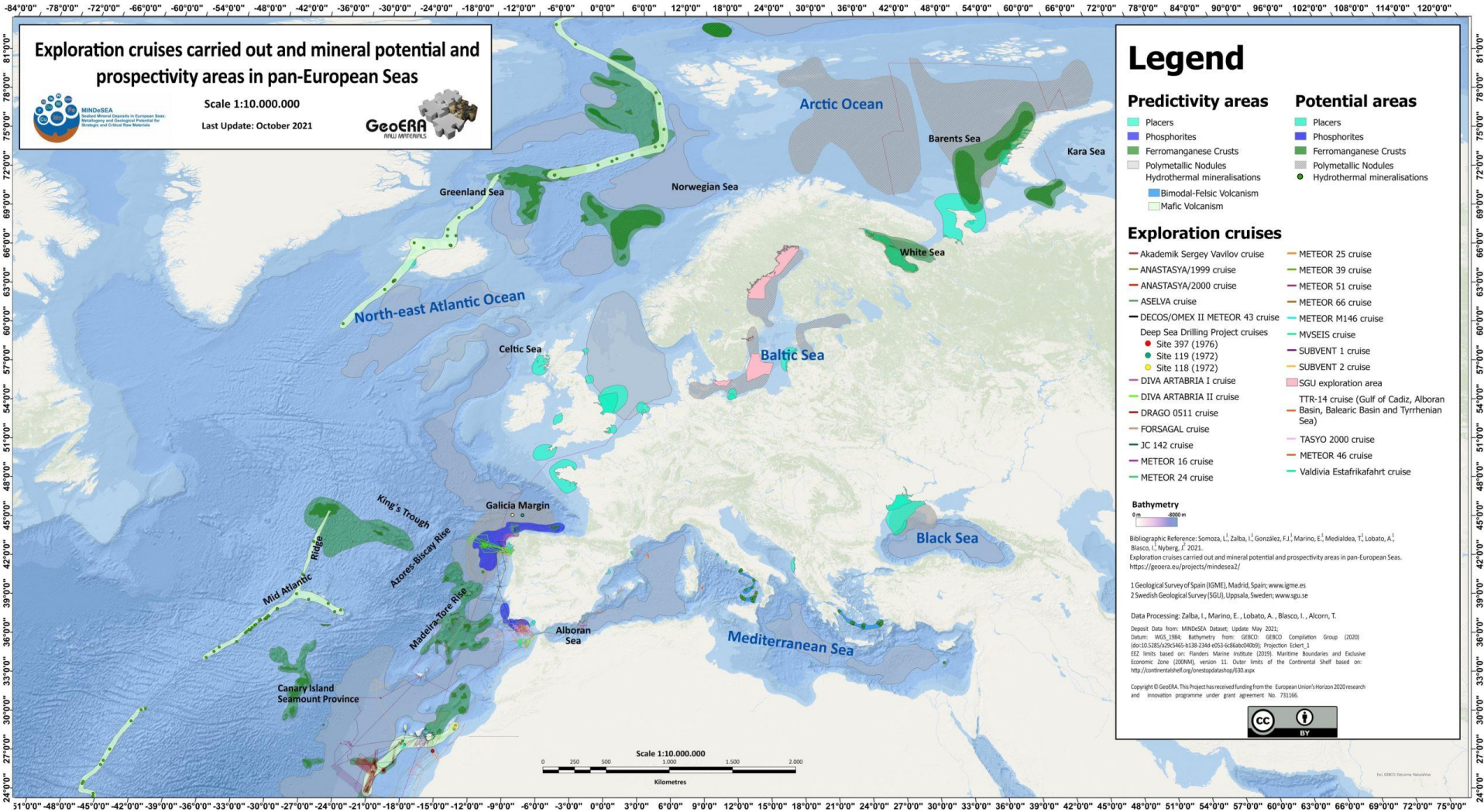
Potential and Prospectivity Resume Map



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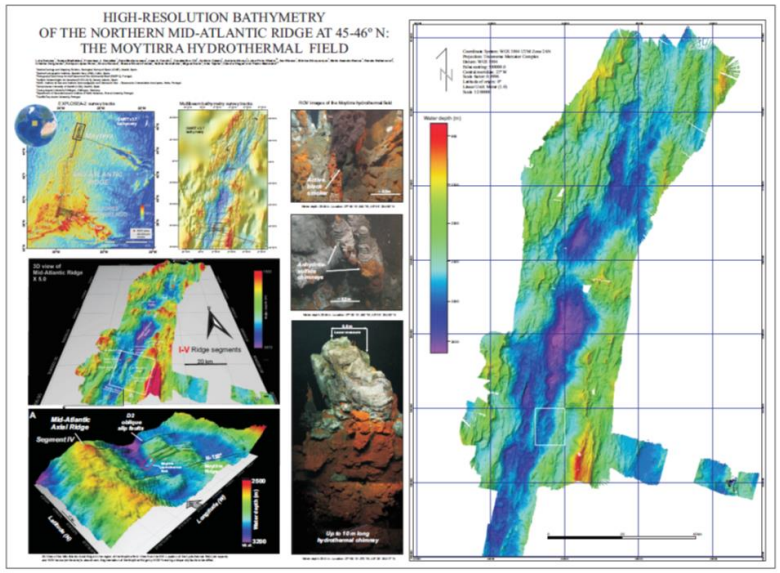
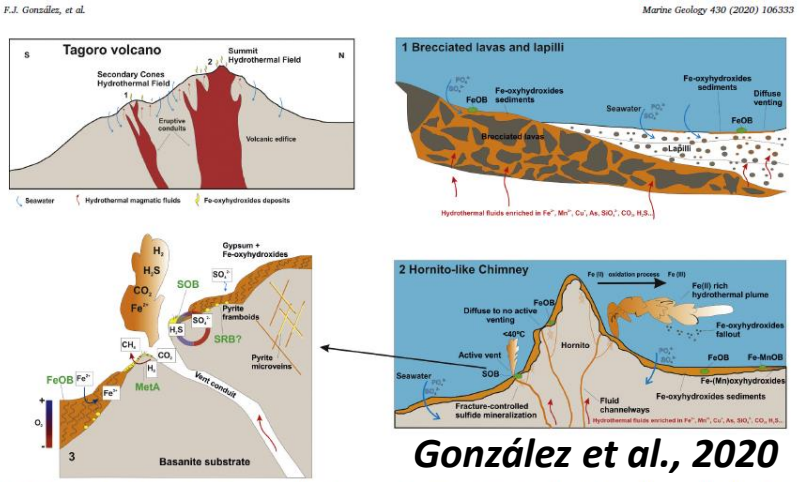
MINDeSEA in SCI journals:

https://geoeramindesea.wixsite.com/mindesea/publications



Somoza et al., 2020, 2021



González et al., 2020

Fig. 13. Schematic model, not to scale, showing geologic setting and formation of Tagoro volcano hydrothermal deposits: (1) Secondary cones hydrothermal field with development of microbial-mediated Fe-oxyhydroxide mineralization on brecciated lavas and lapilli; (2) Summit hydrothermal field with mineralization on a hornito-like chimney; formation temperatures for the Fe-oxyhydroxide sediments are inferred to have varied below 40 °C; a host of elements (e.g., Fe, Si, P, Mn, As, Cu, Mo) were derived from leaching of basanite basement, sorbed from seawater, and to a lesser extent, magmatic fluids; Fe(II)-rich hydrothermal plumes allowed for the precipitation of Fe-Si-(Mn) mineralized sediments far away the vent sites; breakdown of the volcanic rock due to lava cooling or seismicity allowed for the precipitation of sulfides (pyrite ± chalcopyrite) from the hydrothermal fluids; (3): diversity of metabolic processes carried out by microorganisms related to diffuse venting. FeOB = iron-oxidizing bacteria, MetA = methanogenic archaea, SOB = sulfur-oxidizing bacteria, SRB = sulfate reducing bacteria.

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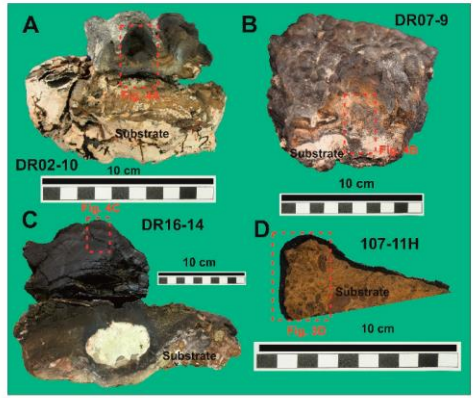

Figure 2. Image of selected Fe-Mn crust samples for this study. (A) Crust DR02-10 was dredged from Echo Sm., (B) crust DR07-9 from The Paps Sm., (C) DR16-14 and (D) 107-11H from Tropic Sm. Red discontinuous squares mark the areas where thin sections were taken for further investigations (Figure 4).

Marino et al., 2018, 2019

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GeoERA RAW MATERIALS

MINDeSEA Team members at Geominero Museum (IGME-CSIC), Madrid

Instituto Geológico y Minero de España