



Portugal, Science and Resources in the Deep Seafloor

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BGR / Maritime Cluster of North Germany
June 10, 2013



Recursos naturais na crosta oceânica profunda: realidade ou ficção?

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JEAMB 2014 - Jornadas de Engenharia do Ambiente
IST-UL, 18 Fev 2014

RECURSOS MINERAIS DA PLATAFORMA CONTINENTAL PORTUGUESA

40° 0' W 30° 0' W 20° 0' W 10° 0' W



OCEANO ATLÂNTICO

Moytirra

ARQUIPÉLAGO DOS AÇORES

Menez Gwen

Lucky Strike

Saldanha

Rainbow

ARQUIPÉLAGO DA MADEIRA

PORTUGAL CONTINENTAL

Batimetria
0 m
-6500 m

0 250 500 km

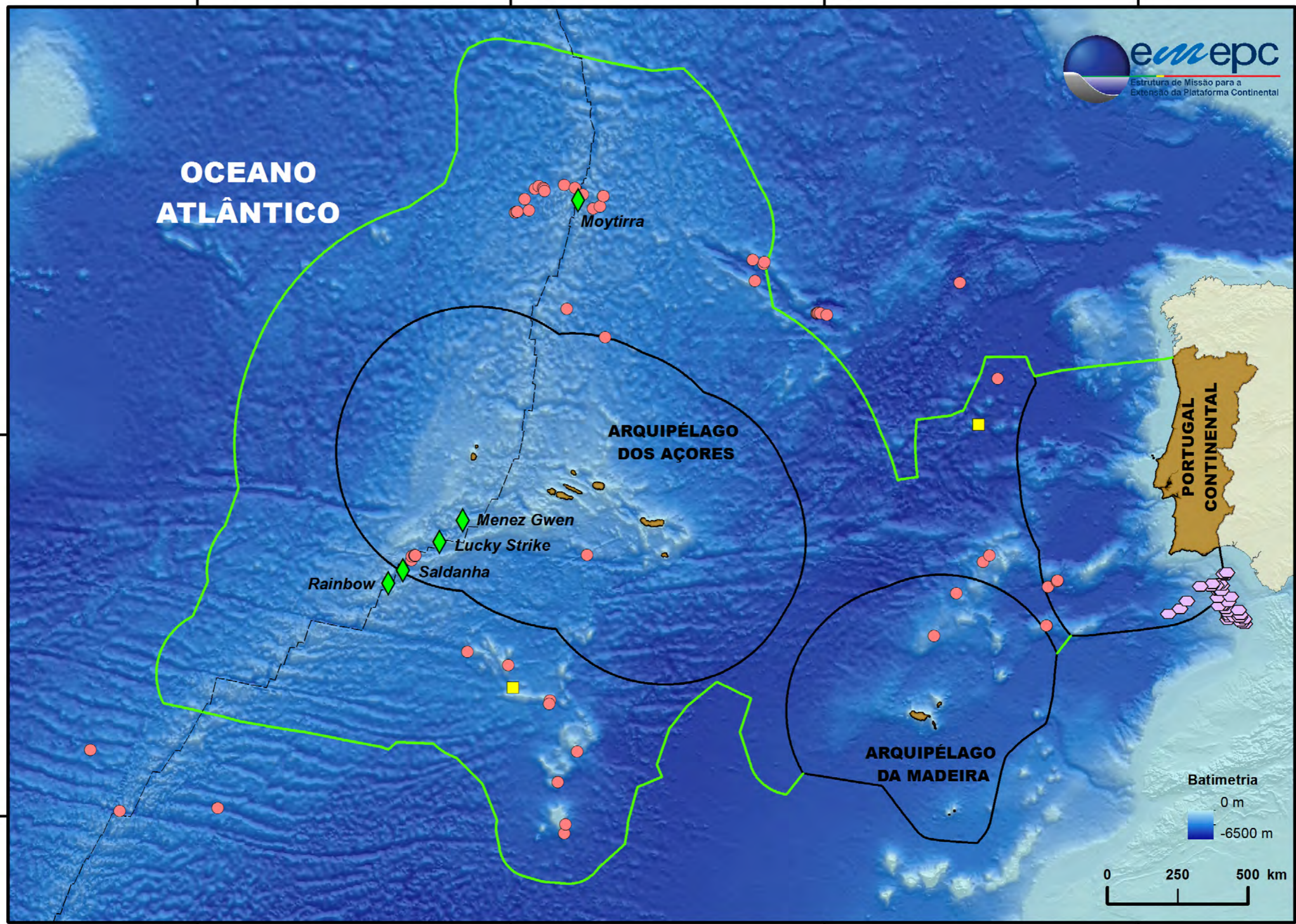
40° 0' N

40° 0' N

30° 0' N

30° 0' N

40° 0' W 30° 0' W 20° 0' W 10° 0' W



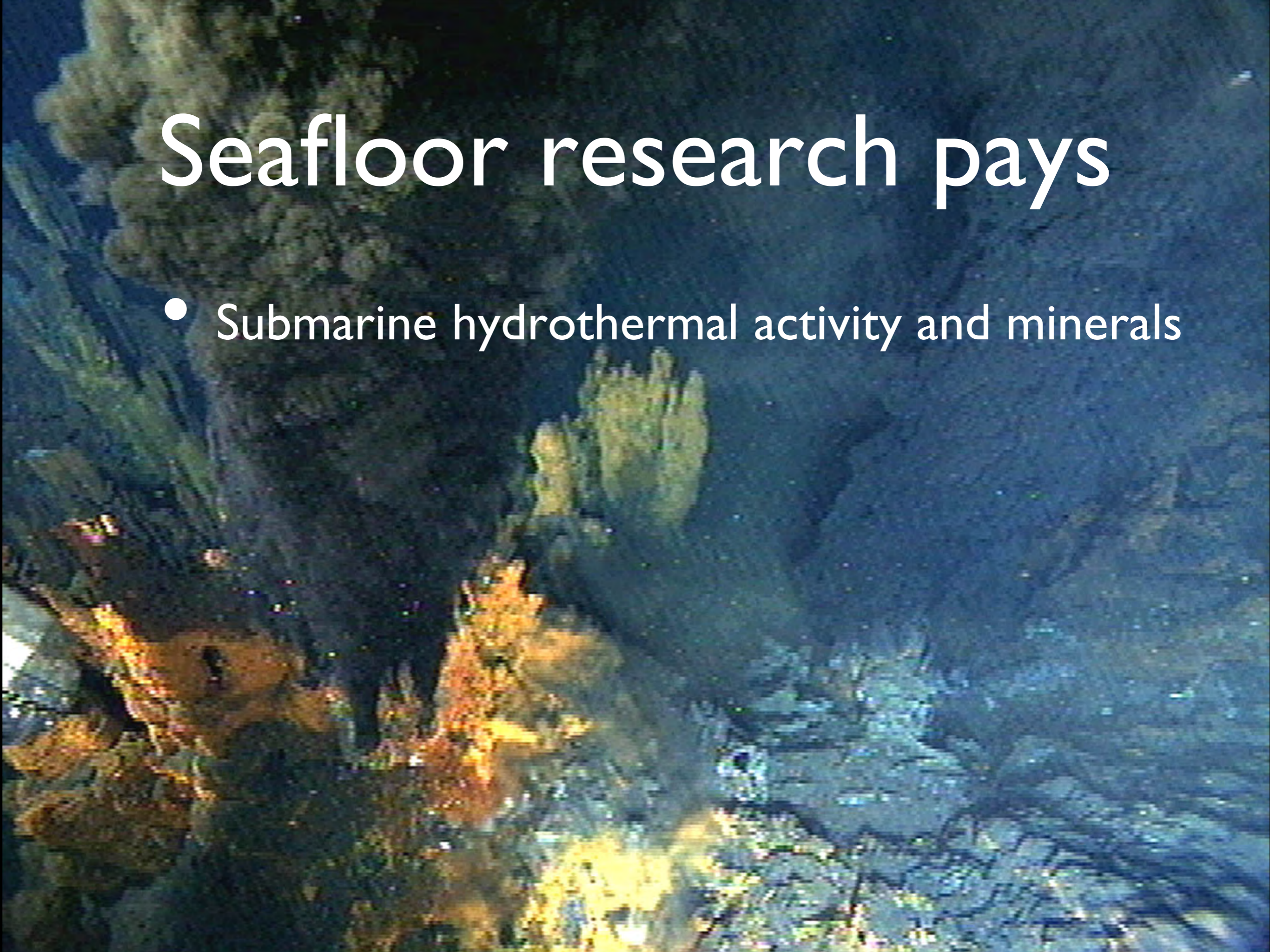
Seabed economic rights

Country	EEZ km2	Additional CS	Total seabed jurisdiction	Country area (emmerse)	Ratio seabed/country area
United States	11,351,000		11,351,000	9,629,091	1.2
France	11,035,000		11,035,000	652,090	16.9
Australia	8,505,348	2,500,000	11,005,348	7,692,024	1.4
Russia	7,566,673		7,566,673	17,098,242	0.4
UK	6,805,586		6,805,586	242,900	28.0
New Zealand	6,682,503		6,682,503	270,467	24.7
Indonesia	6,159,032		6,159,032	1,910,931	3.2
Canada	5,599,077		5,599,077	9,984,670	0.6
Brazil	3,660,955	911,847	4,572,802	8,514,877	0.5
Japan	4,479,388		4,479,388	377,930	11.9
Portugal	1,727,408	2,150,000	3,877,408	92,090	42.1
Chile	3,681,989		3,681,989	756,102	4.9

Seafloor research pays

Seafloor research pays

- Submarine hydrothermal activity and minerals



Seafloor research pays

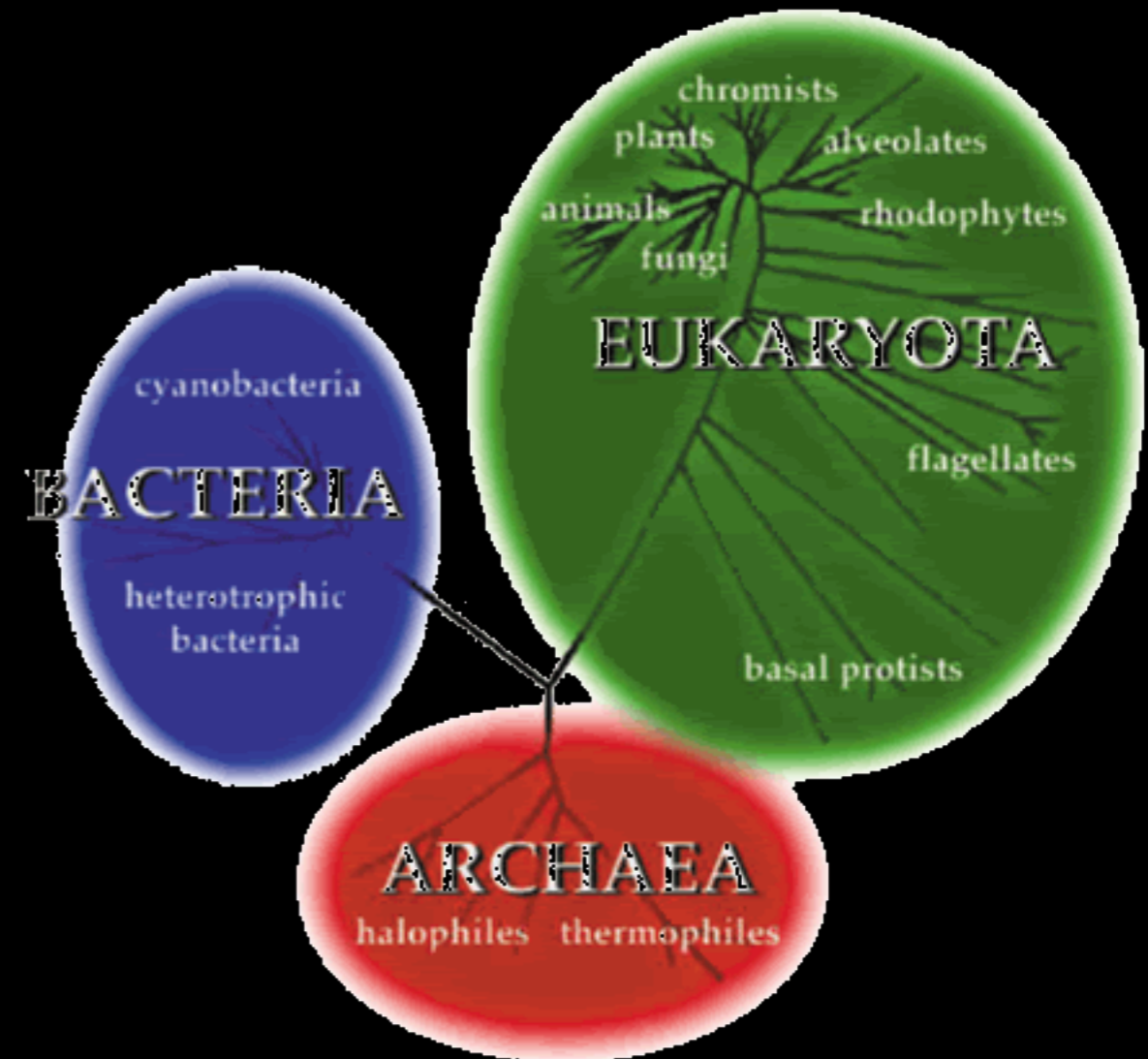
- Submarine hydrothermal activity and minerals

- Gas hydrates



Seafloor research pays

- Submarine hydrothermal activity and minerals
- Gas hydrates
- The deep biosphere



Seafloor research pays

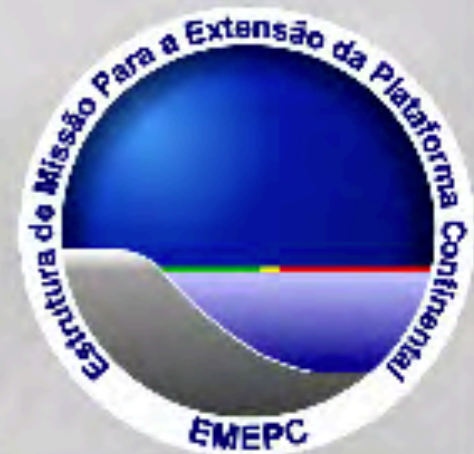
- Submarine hydrothermal activity and minerals
- Gas hydrates
- The deep biosphere
- Older stuff revisited (nodules and crusts)
- Non-resource related (climate, hazards)
- Plate Tectonics

What else is out there?

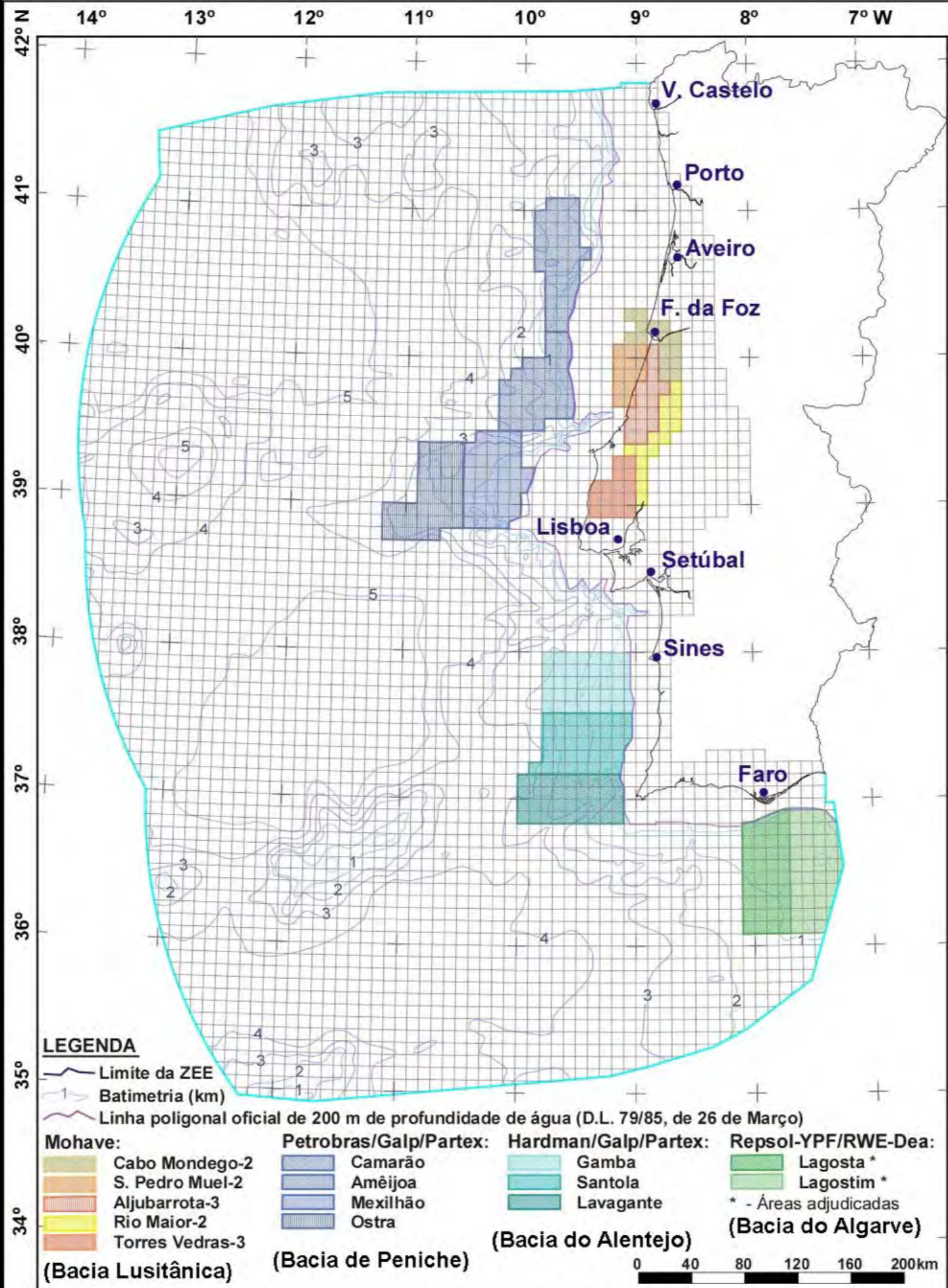
- New tools and observatories
- Systems research

Known resources

- Sand and gravel
- Co-rich Mn crusts (+ phosphorites)
- sms deposits



Oil and gas



Fonte: Direcção Geral de Geologia e Energia http://www.dgge.pt/dpep/intro_pt.htm

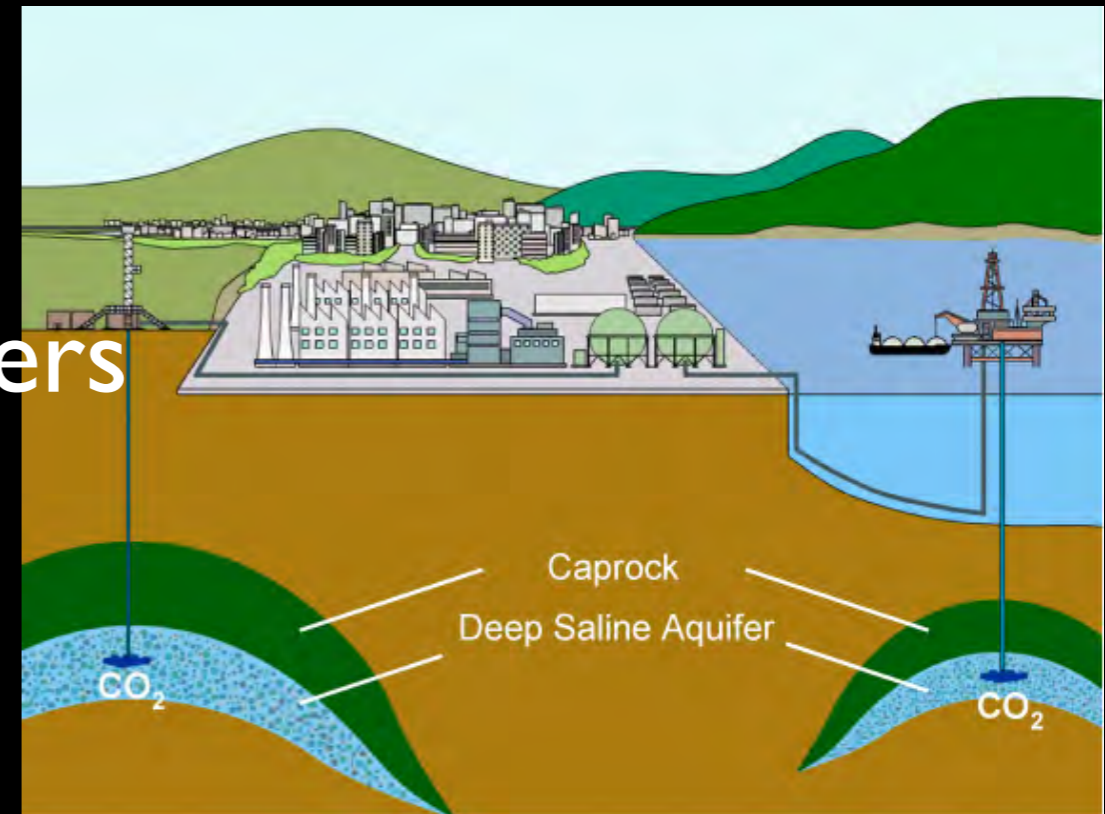
Microbes & biomolecules



- Extremophile microbes / biomolecules
- Biomass=0.1-1 conventional biosphere
- Being produced for economic use (e.g. Seahma)
- Portuguese companies

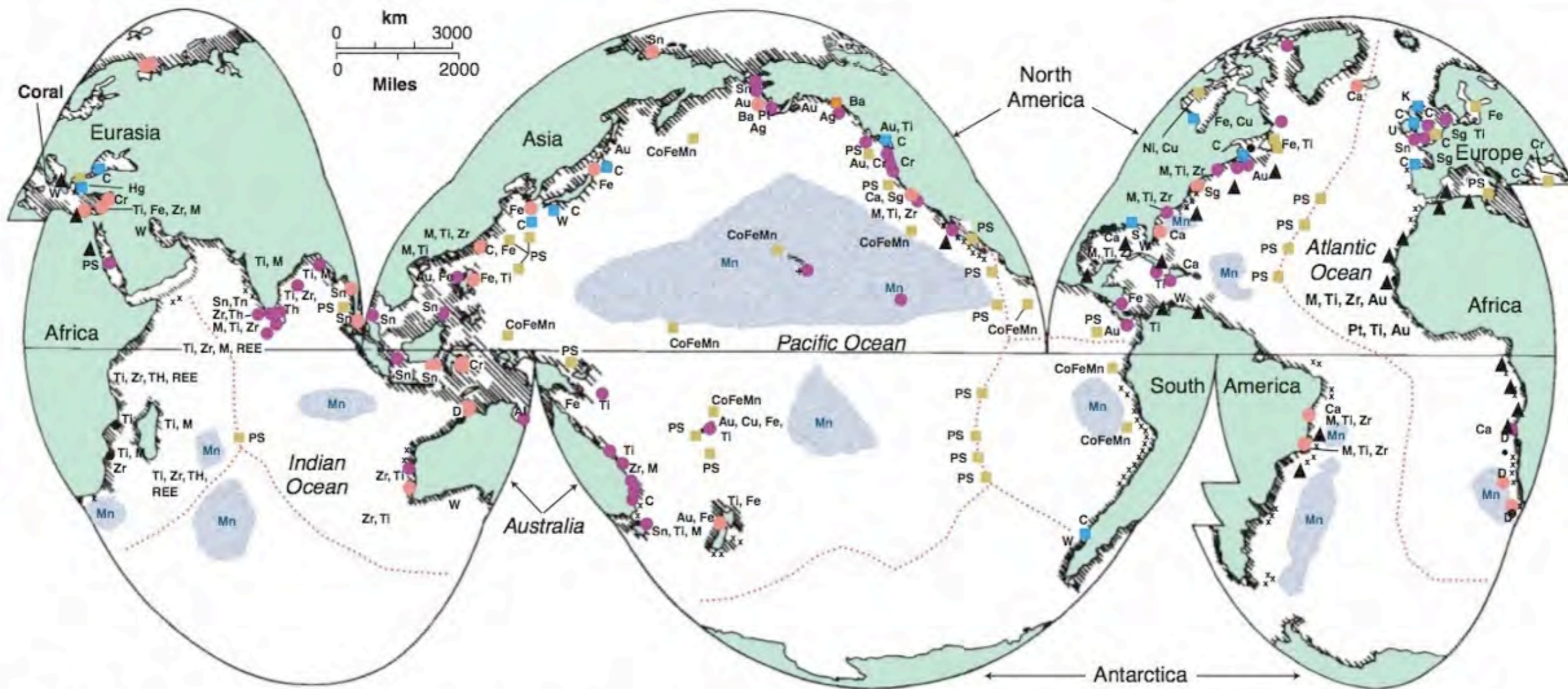
CO₂ sequestration

- Sub-seafloor saline aquifers



CO₂ sequestration

- Sub-seafloor saline aquifers
- Carbonates of Ca, Mg, Fe and Mn
- Already under consideration

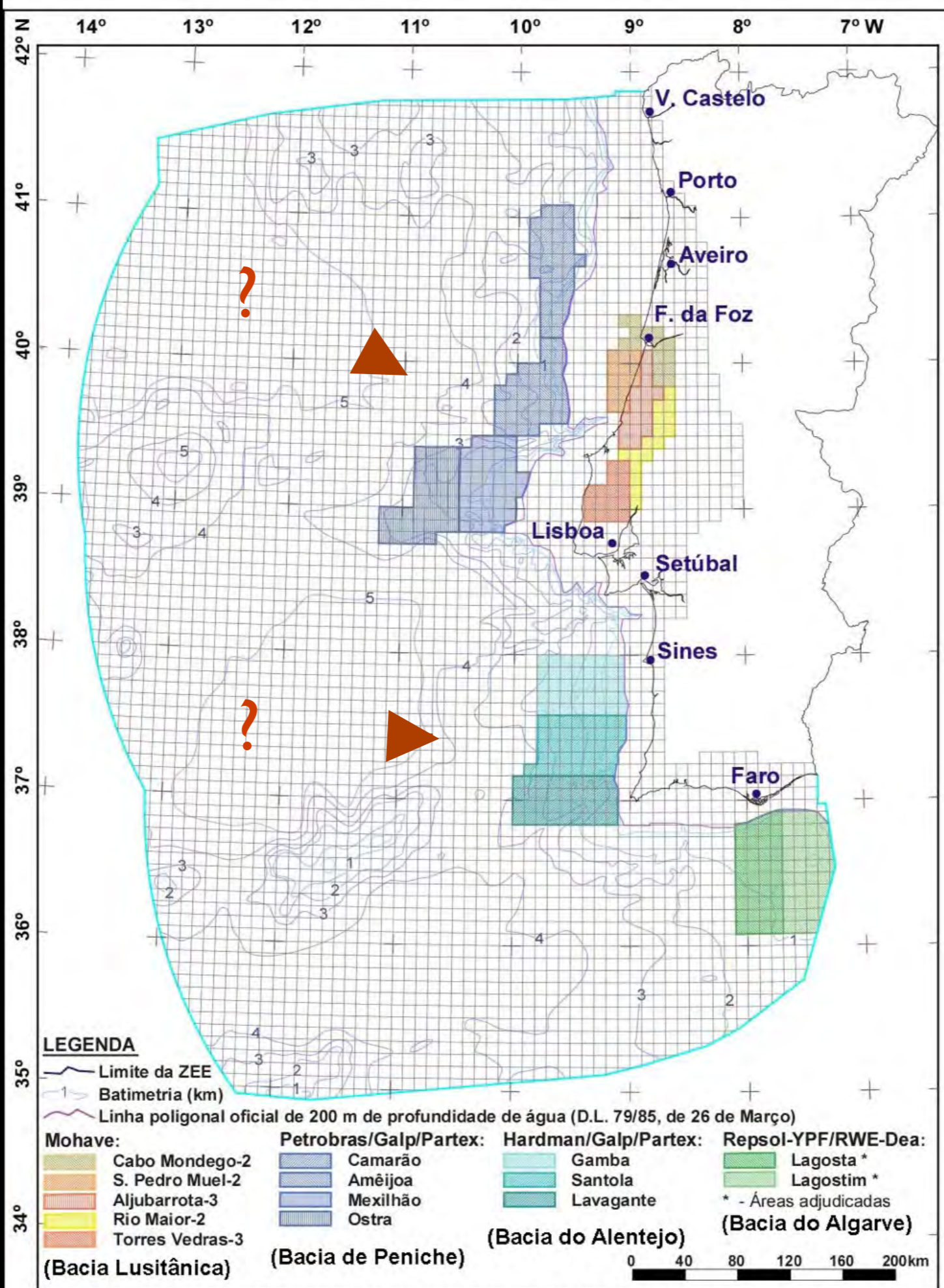


- | | | | | | | |
|--|----------------------------------|-----------------------------|---------------------------------|----------------------------------|--------------------------------|---|
| Ag Silver | Ca Lime mud, sand, shells | Hg Mercury | Ni Nickel | Sg Siliceous sand, gravel | Unconsolidated deposits | Ocean ridges (Geothermal potential) |
| Al Bauxite | Cr Chromite | K Potash | Pt Platinum | Sn Tin | ● Developmental | ▨ Petroleum potential |
| Au Gold | Cu Copper | M Monazite | PS Polymetallic sulfides | Ti Ilmenite, rutile | ● Operational | xxxxx Phosphorite |
| Ba Barite | D Diamonds | Mg Magnesium | REE Rare earth elements | U Uranium | ■ Developmental | ▲ Salt |
| C Coal | Fe Iron, magnetite | Mn Manganese nodules | S Sulfur | W Fresh water | ■ Operational | |
| Co Cobalt-rich ferromanganese crust | G Gems | | | Zr Zircon | | |

Global distribution of marine mineral resources known at this early stage of ocean exploration.

Unconventional HC's

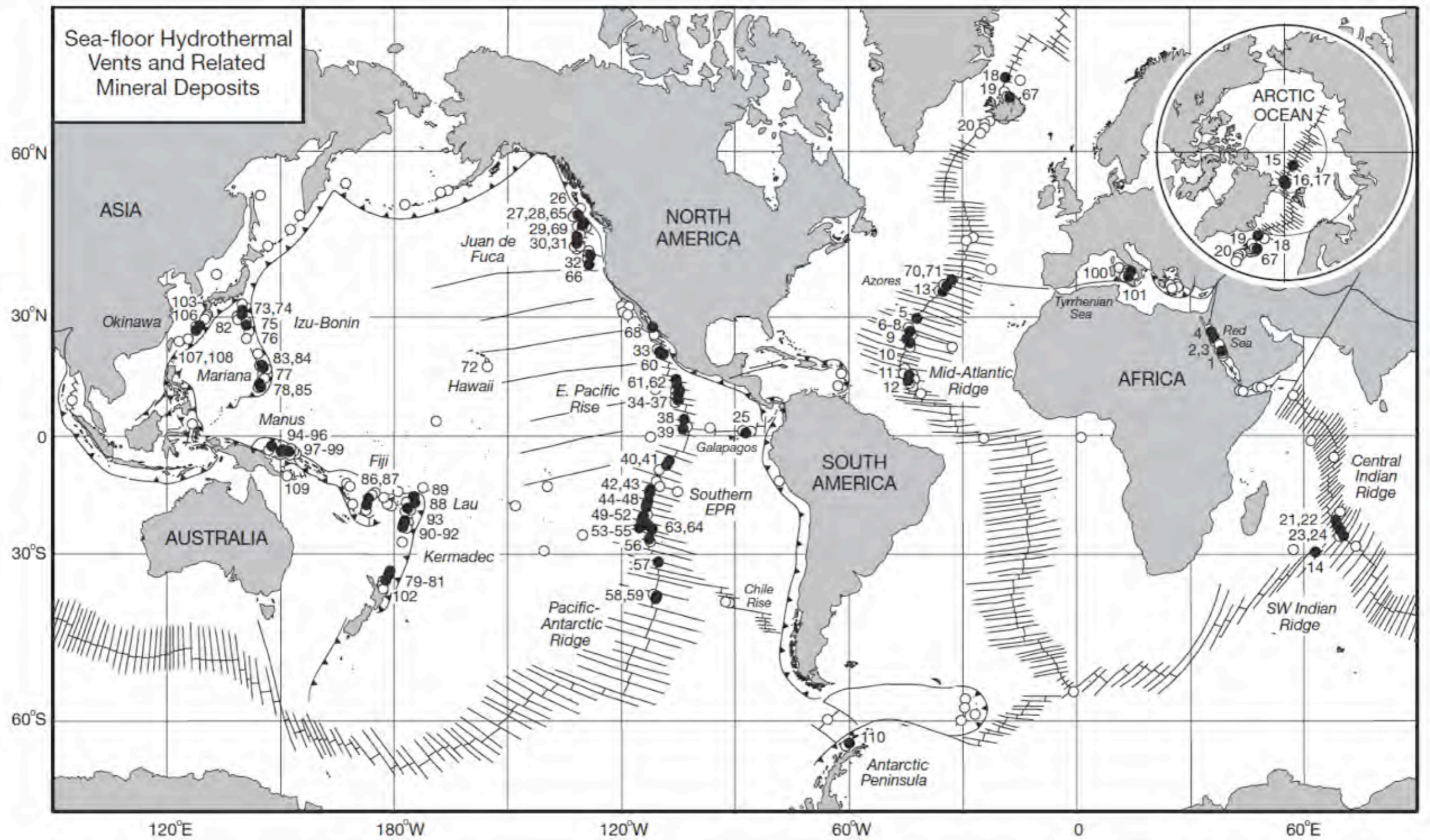
- The deep biosphere & the origin of oil
- Serpentinization HC's
- Both from the crystalline crust
- Sediments needed chiefly as cover rocks



LEGENDA

- Limite da ZEE
 - 1 Batimetria (km)
 - Linha poligonal oficial de 200 m de profundidade de água (D.L. 79/85, de 26 de Março)
- | | | | |
|-----------------|-------------------------------|-----------------------------|----------------------------|
| Mohave: | Petrobras/Galp/Partex: | Hardman/Galp/Partex: | Repsol-YPF/RWE-Dea: |
| Cabo Mondego-2 | Camarão | Gamba | Lagosta * |
| S. Pedro Muel-2 | Amêijoia | Santola | Lagostim * |
| Aljubarrota-3 | Mexilhão | Lavagante | * - Áreas adjudicadas |
| Rio Maior-2 | Ostra | | |
| Torres Vedras-3 | | | |
- (Bacia Lusitânica) (Bacia de Peniche) (Bacia do Alentejo) (Bacia do Algarve)

sms deposits

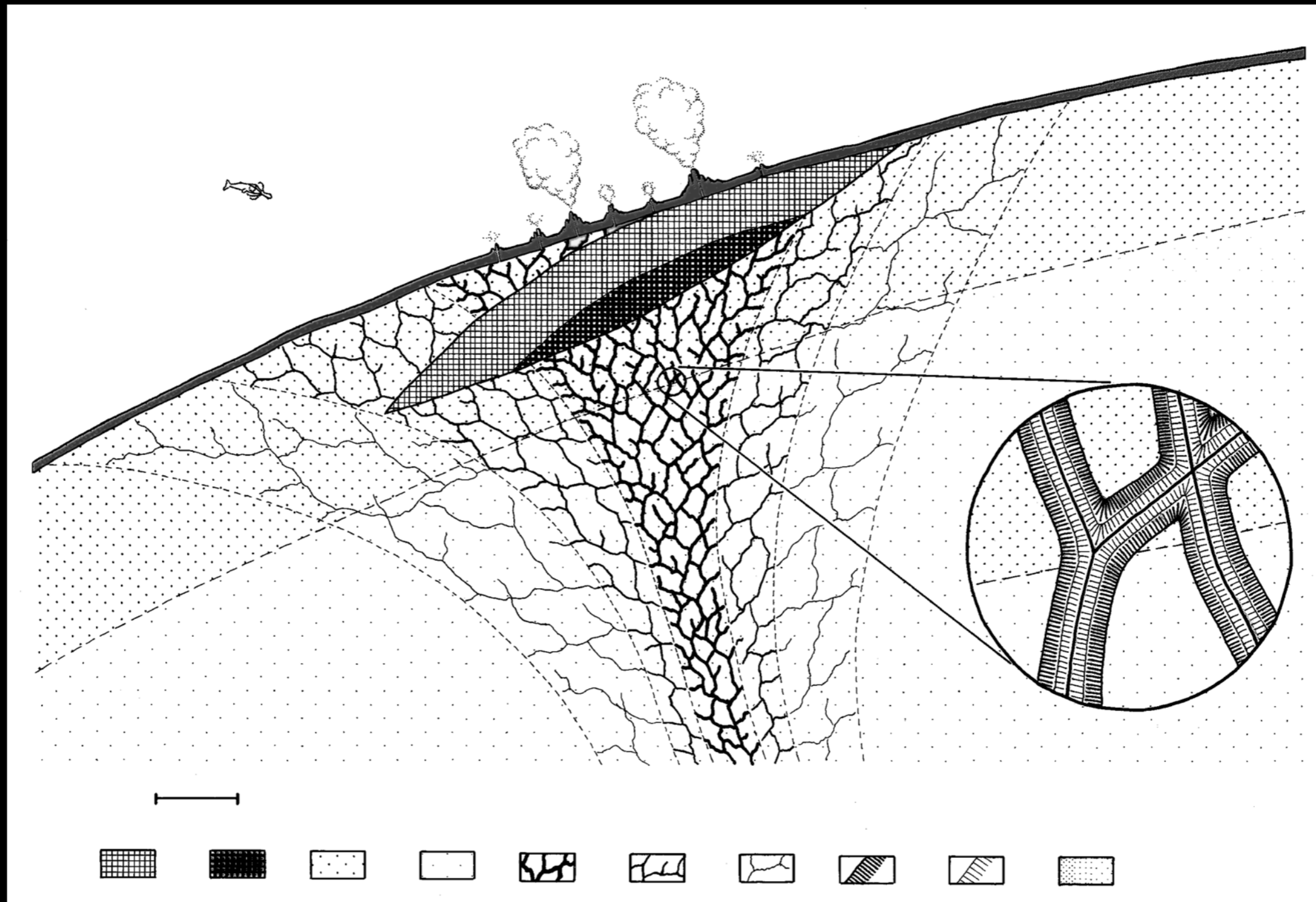


sms deposits

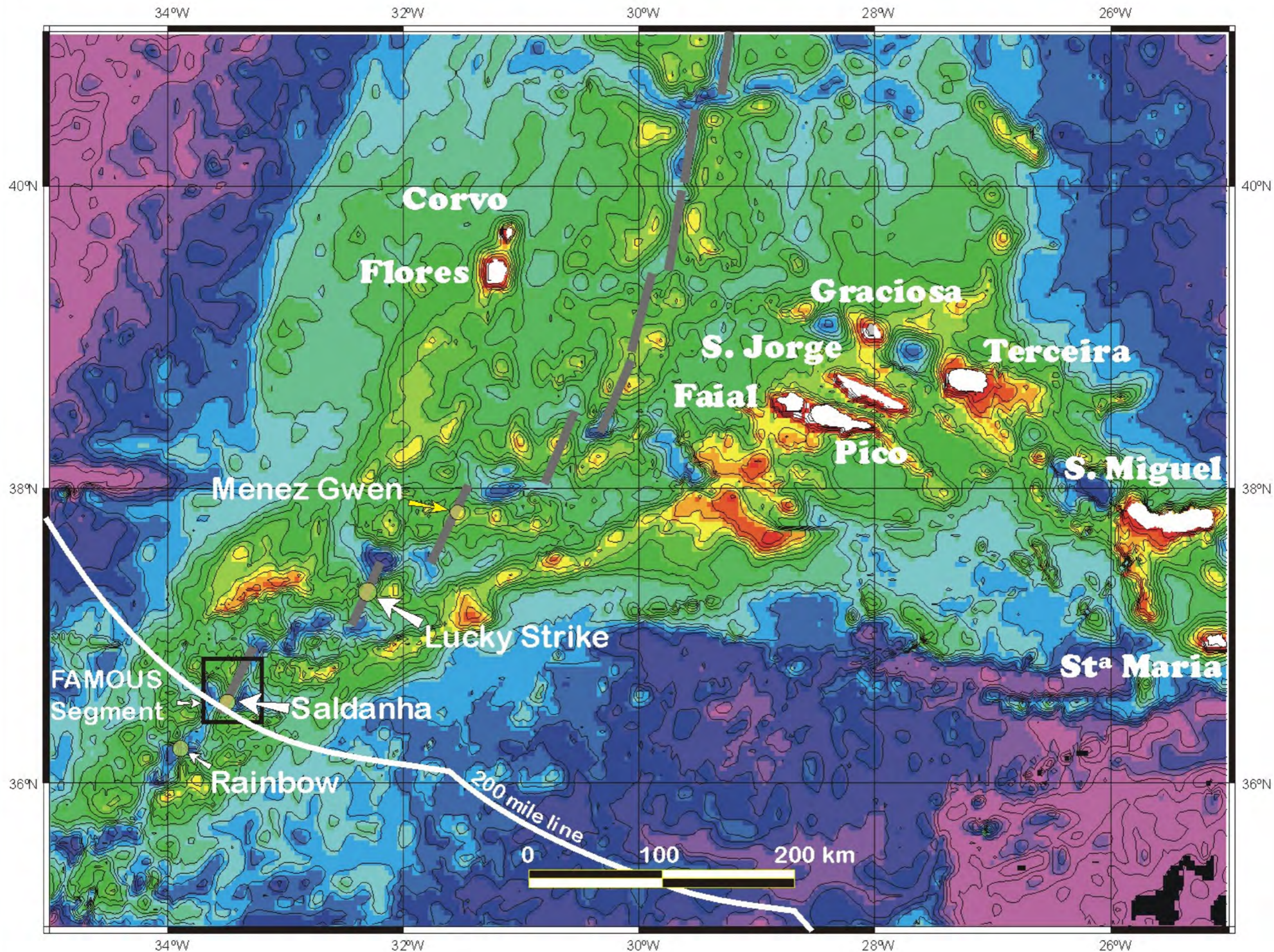


- Exposed on land
- Few ophiolites
- Obducted under exceptional conditions
- Representative?
- Present mid-ocean ridges
- Back-arc basins
- Sub-seafloor massive sulphide deposits
- Very large potential

ssms deposits



After Carvalho, Barriga & Munhá, 1999



Exploration

- Provinces with sms activity
- Structure and geomorphology
- “Airborne” geophysics (with AUV’s)
- Definition of favorable areas
- Detailed geophys, geochem, mineralogy
- Shallow drilling (sea-floor rigs)
- Via partnerships/joint ventures

Areas requested by Nautilus in the Azores Sea

Nautilus Minerals Inc	MNPPP0309 Verdelho	<u>WGS8405</u>	<u>Nº 196 de 10-10-2012</u>
Nautilus Minerals Inc	MNPPP0313 Moreto	<u>WGS8404</u>	<u>Nº 195 de 09-10-2012</u>
Nautilus Minerals Inc	MNPPP0312 Arinto	<u>WGS8403</u>	<u>Nº 195 de 09-10-2012</u>
Nautilus Minerals Inc	MNPPP0311 Famous	<u>WGS8402</u>	<u>Nº 219 de 13-11-2012</u> <u>Nº 195 de 09-10-2012</u>
Nautilus Minerals Inc	MNPPP0310 Saldanha	<u>WGS8401</u>	<u>Nº 195 de 09-10-2012</u>

Next

- Interaction between
 - Crystalline crust
 - Sedimentary cover

Seafloor mining

- Pilot deep sea mining installation
- Area under Portuguese jurisdiction
- Joint ventures (exploration & mining)

Seafloor ecosystems

- Deep seafloor sustainable mining
- There's reasons for hope
- Environmental scientists needed
 - Monitoring
 - Modeling
 - Validation