



Gestão Sustentável de Recursos Geológicos em Fundos Oceânicos

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Sustentabilidade na Terra: Desafios à Geologia e à Biologia

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INSTITUTO DOM LUIZ
LABORATÓRIO ASSOCIADO



Ciências
ULisboa

Sumário



- 1 – Recursos minerais: um tema de todos
- 2 – Recursos minerais no mar profundo
 - Sulfuretos maciços
 - Nódulos manganésíferos
 - Crostras polimetálicas
- 3 – Necessidade urgente de regulação
- 4 – Dois exemplos relevantes: Solwara 1 e Rainbow
- 5 – A Tecnologia é só um custo; não um real obstáculo
- 6 – Ecossistemas marinhos e questões ambientais
- 7 – Mensagens a levar para casa





SUSTAINABLE DEVELOPMENT GOALS

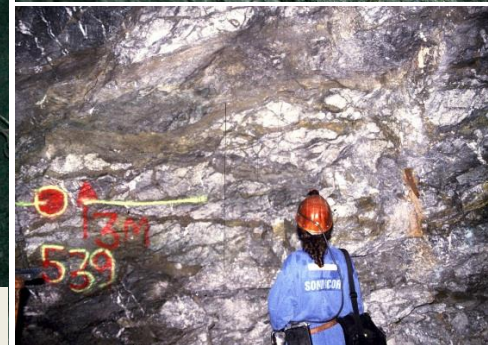
17 GOALS TO TRANSFORM OUR WORLD



Se não é plantado, tem de ser minerado

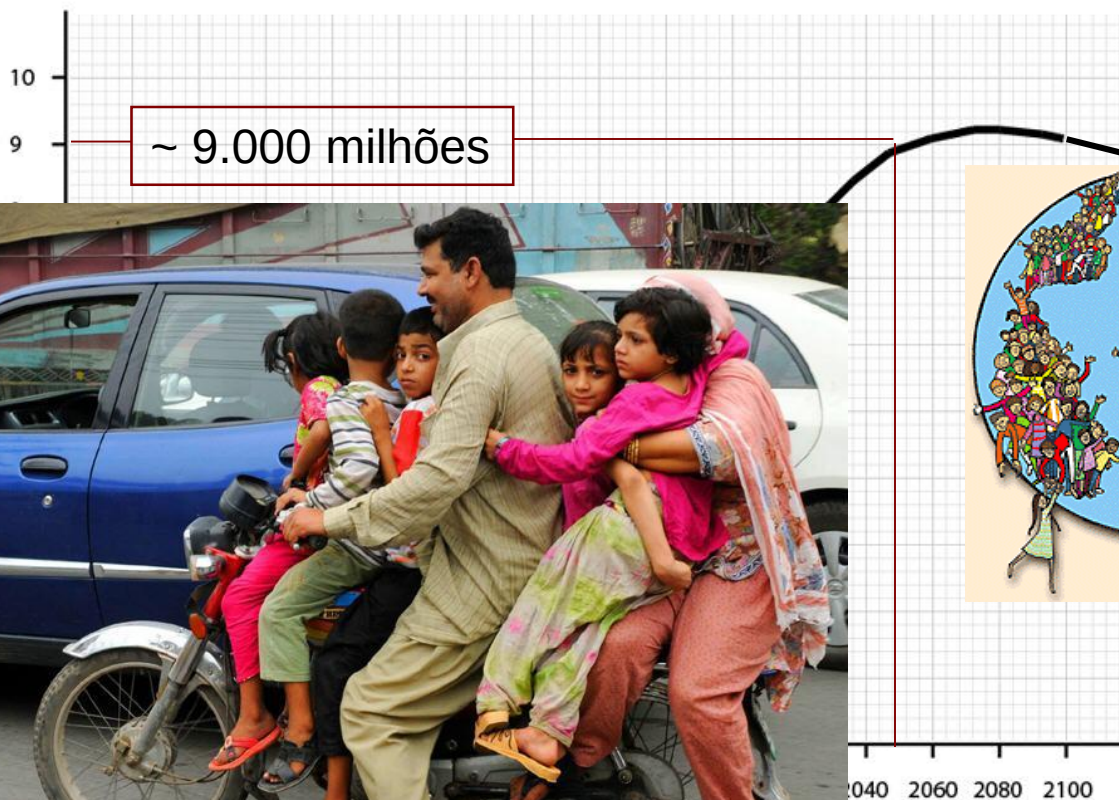


Photos J Relvas





Recursos Minerais e Sociedade

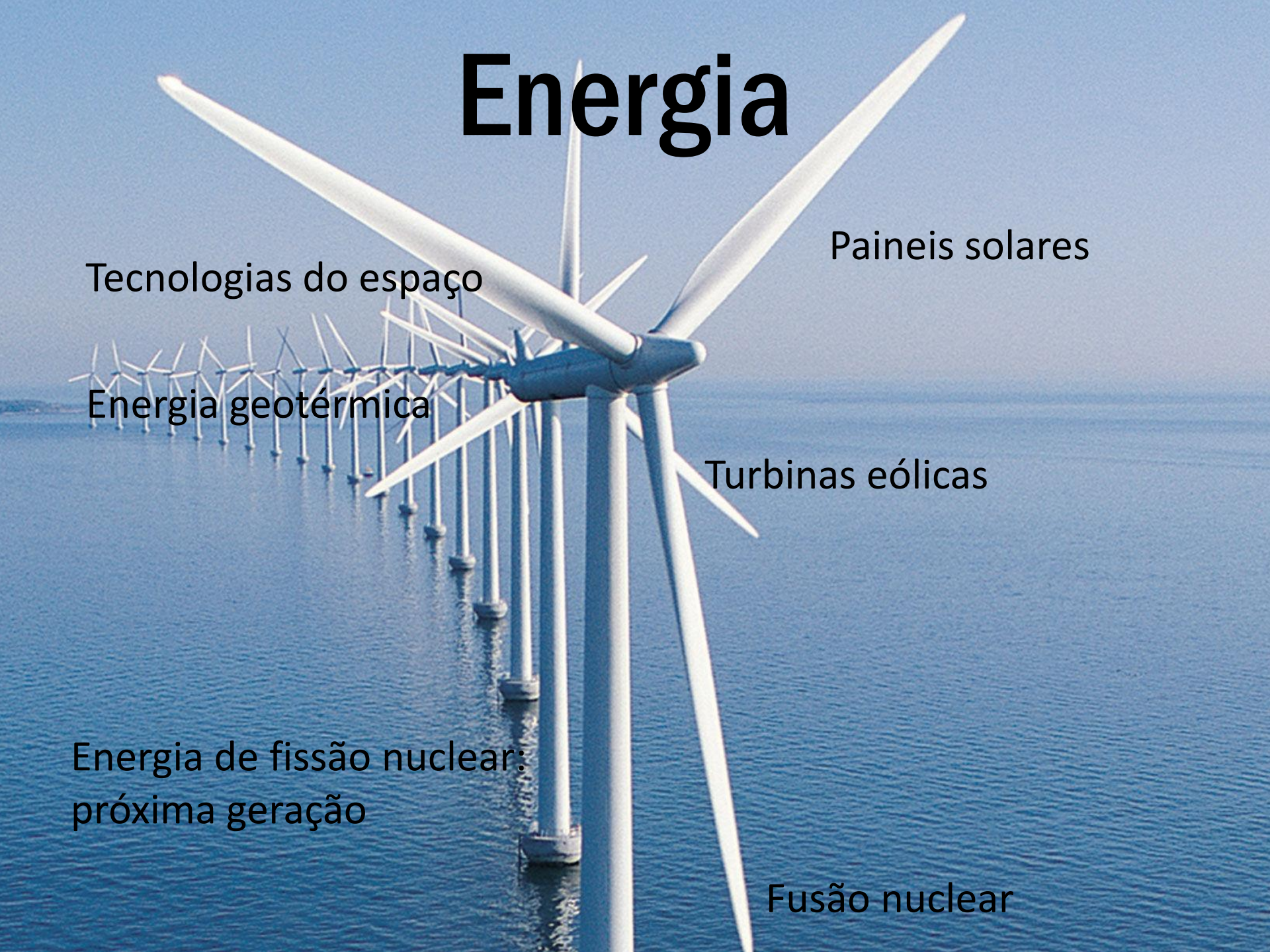


www.futuretimeline.net

Transição energética



Energia



Tecnologias do espaço

Paineis solares

Energia geotérmica

Turbinas eólicas

Energia de fissão nuclear:
próxima geração

Fusão nuclear

Metais críticos para as energias verdes

- Metais de alta tecnologia: Lítio, Cobalto, Gálio, Ítrio, Índio, Telúrio
- Terras Raras: Lantânio, Cério, Praseodímio, Neodímio, Samário, Európio, Térbio e Disprósio

US Department of Energy, 2010. Critical Materials Strategy, 165p



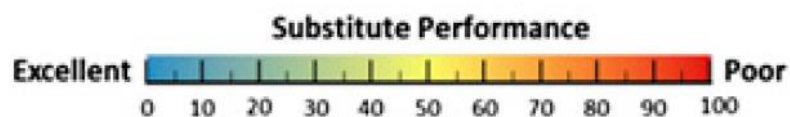
Reutilizar, Reduzir, Reciclar, Substituir



Substitute performance

H																	He
Li 41	Be 63											B 41	C	N	O	F	Ne
Na	Mg 94											Al 44	Si	P	S	Cl	Ar
K	Ca	Sc 65	Ti 63	V 63	Cr 76	Mn 96	Fe 57	Co 54	Ni 62	Cu 70	Zn 38	Ga 38	Ge 44	As 38	Se 47	Br	Kr
Rb	Sr	Y 95	Zr 66	Nb 42	Mo 70	Tc	Ru 63	Rh 96	Pd 39	Ag 44	Cd 38	In 60	Sn 36	Sb 57	Te 38	I	Xe
Cs	Ba 63	*	Hf 38	Ta 41	W 53	Re 90	Os 38	Ir 69	Pt 66	Au 40	Hg 45	Tl 100	Pb 100	Bi 46	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

* Lanthanides	La 75	Ce 60	Pr 41	Nd 41	Pm	Sm 38	Eu 100	Gd 63	Tb 63	Dy 100	Ho 63	Er 63	Tm 88	Yb 88	Lu 63
** Actinides	Ac	Th 35	Pa	U 63	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



Um problema global de primeira grandeza

Crescimento demográfico e aumento do consumo
pressionam procura de mais matérias-primas



Podem os oceanos profundos suprir proporções significativas de matérias-primas às novas gerações?

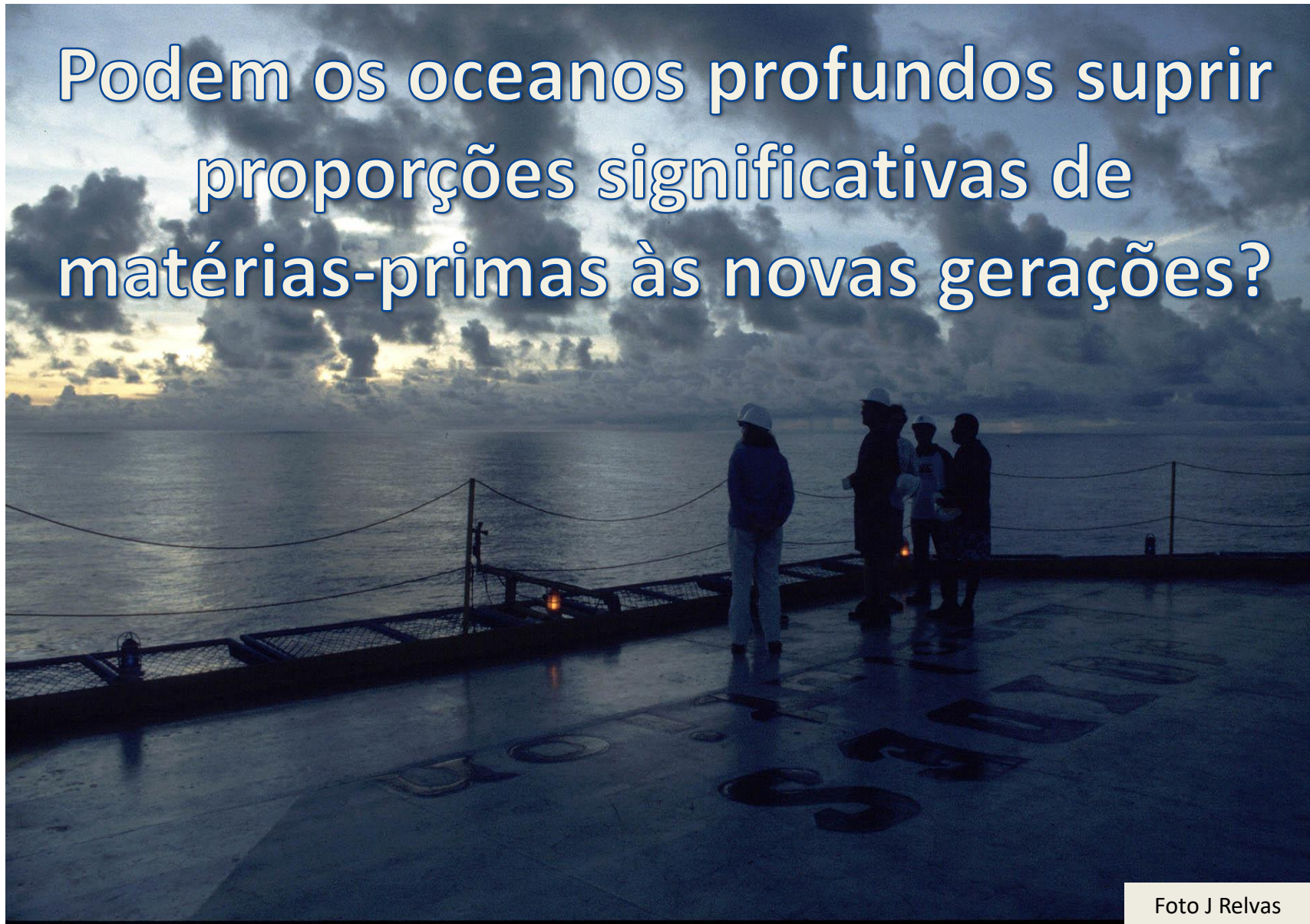


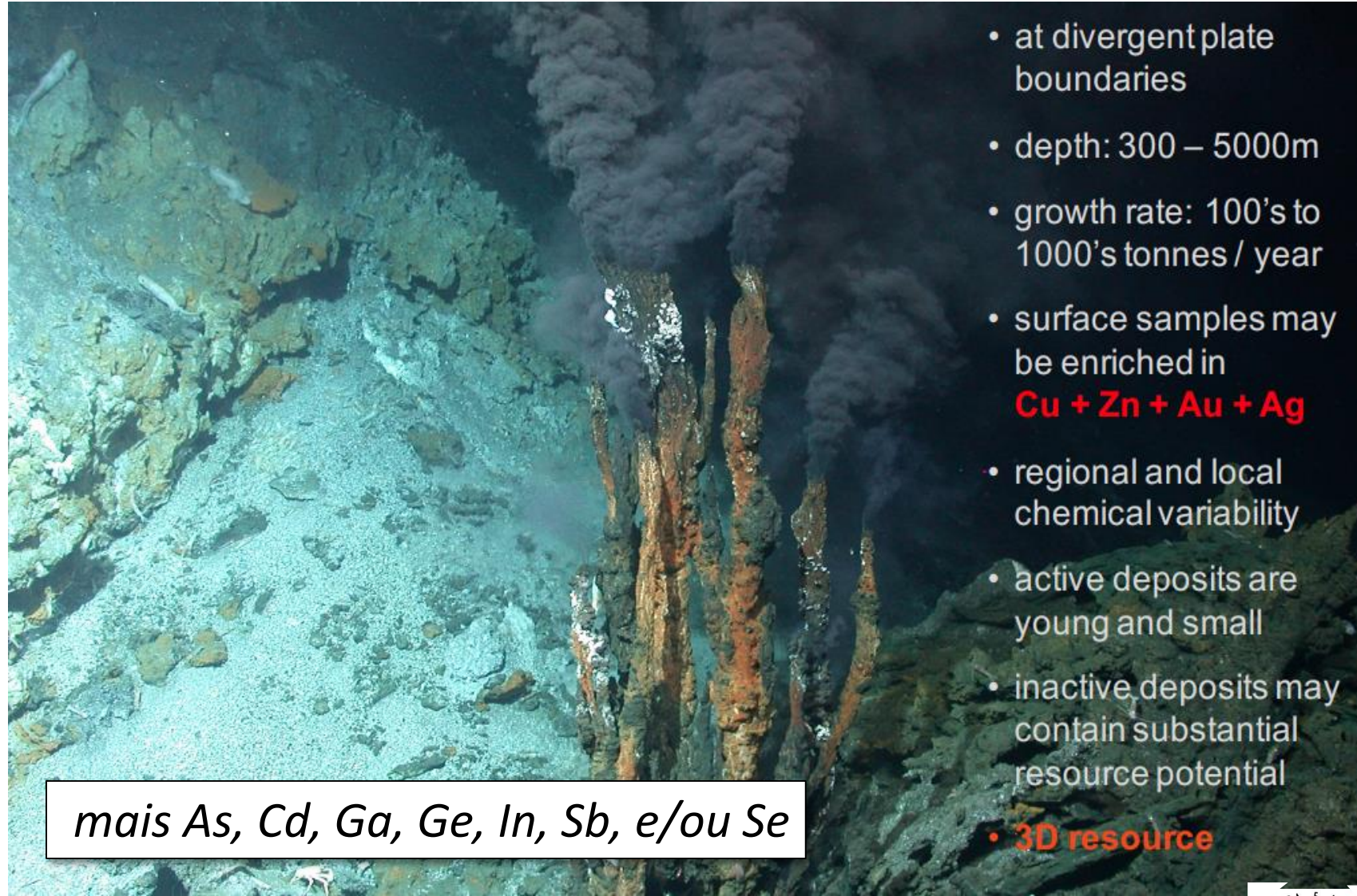
Foto J Relvas

Erosão dos continentes

- < 200m profundidade
- Cassiterite (Tailândia, Indonésia)
- Areias auríferas (Alasca, N Zelândia, Filipinas)
- Diamantes (Namíbia, África do Sul)
- Areia e Gravilha
 - Construção
 - Preservação/recuperação das linhas de costa/litoral

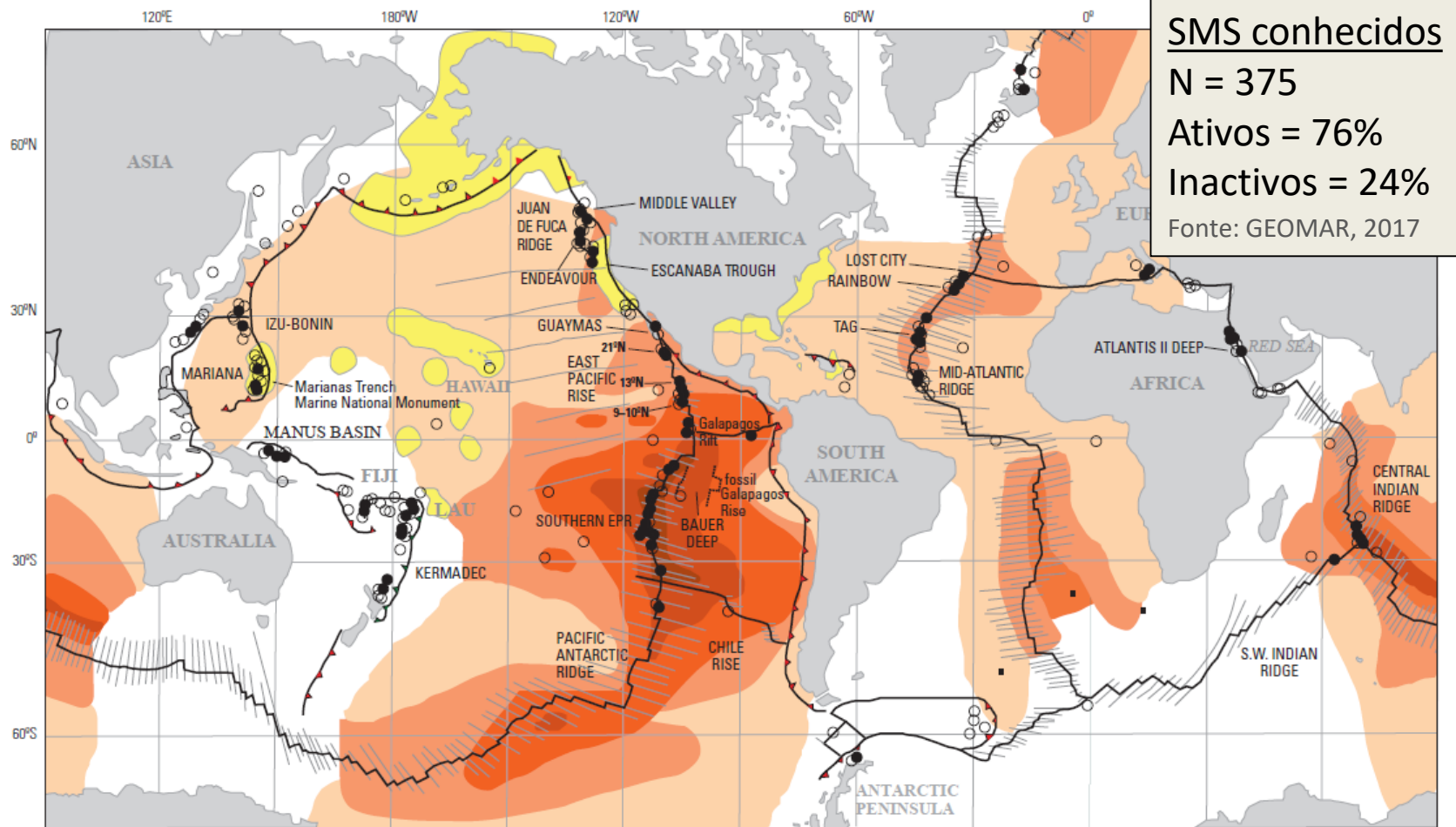
Sulfuretos Maciços Submarinos

Petersen (2018; Royal Society / ISA workshop)

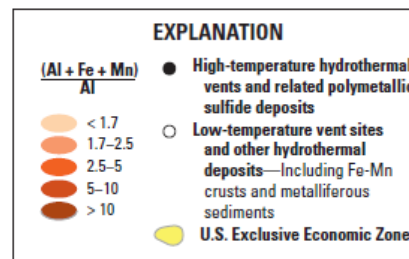


mais As, Cd, Ga, Ge, In, Sb, e/ou Se

- at divergent plate boundaries
- depth: 300 – 5000m
- growth rate: 100's to 1000's tonnes / year
- surface samples may be enriched in **Cu + Zn + Au + Ag**
- regional and local chemical variability
- active deposits are young and small
- inactive deposits may contain substantial resource potential
- **3D resource**



Distribuição dos sedimentos
 metalíferos submarinos,
 sulfuretos maciços e campos
 hidrotermais ativos
 conhecidos

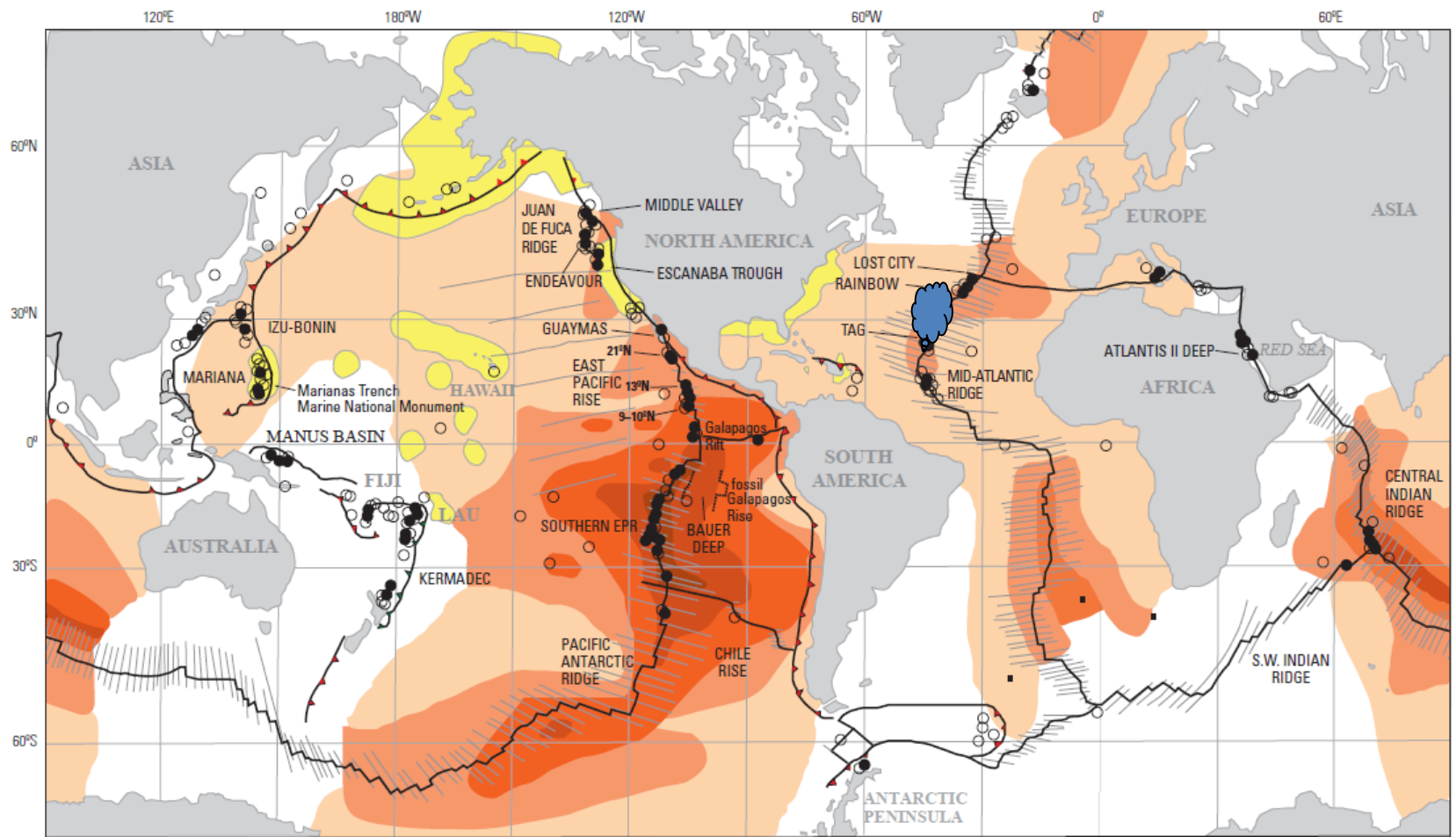


Modified by Shanks III (2012) after
 Hannington et al. (2007) and Bostrom
 et al. (1969)

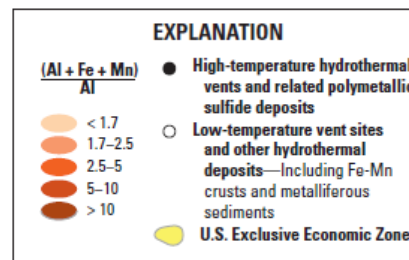
Sulfuretos Maciços Submarinos

Petersen (2018; Royal Society / ISA workshop)



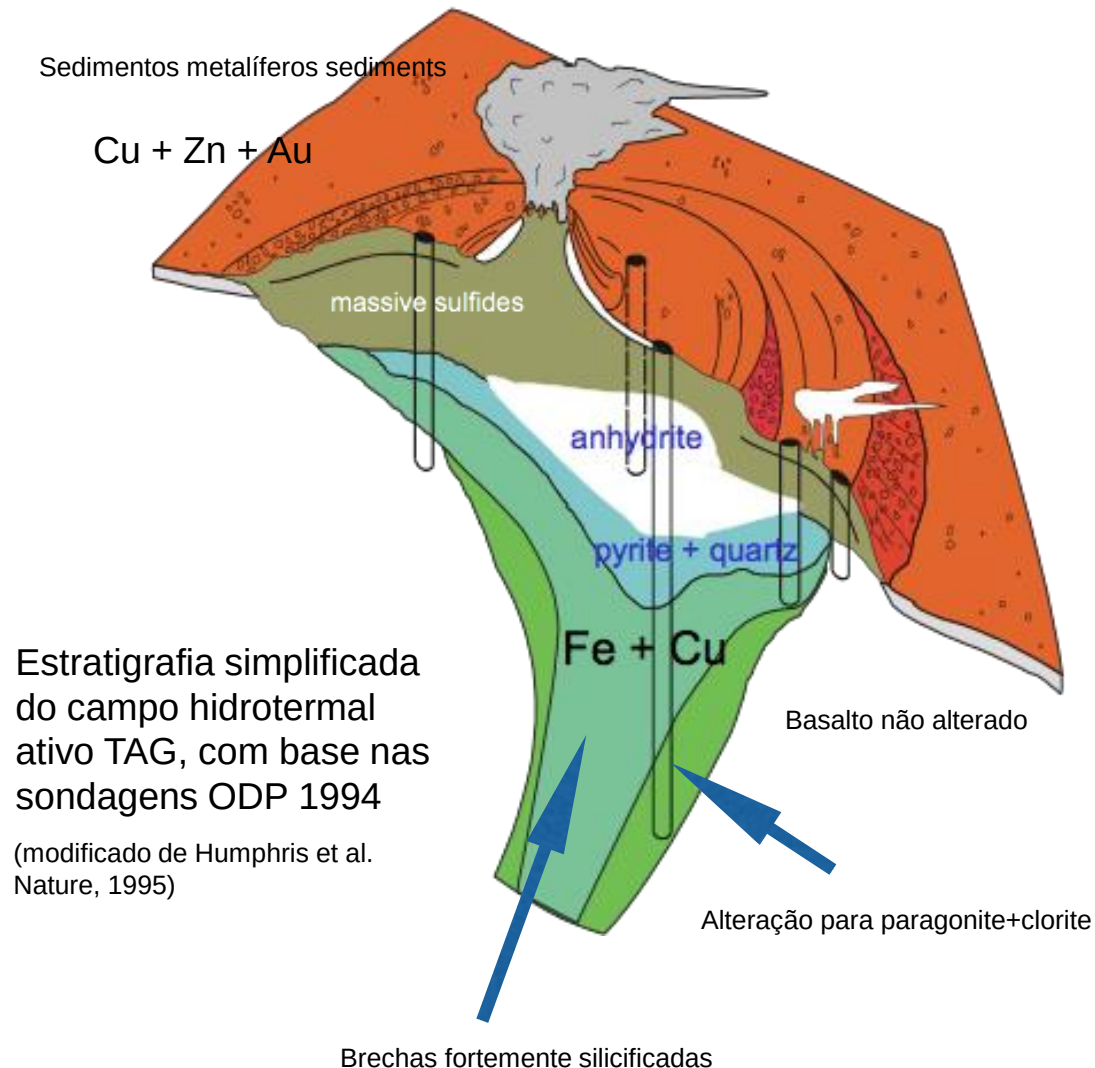


Distribuição dos sedimentos metalíferos submarinos, sulfuretos maciços e campos hidrotermais ativos conhecidos



Modified by Shanks III (2012) after Hannington et al. (2007) and Bostrom et al. (1969)

TAG



Estratigrafia simplificada
do campo hidrotermal
ativo TAG, com base nas
sondagens ODP 1994

(modificado de Humphris et al.
Nature, 1995)

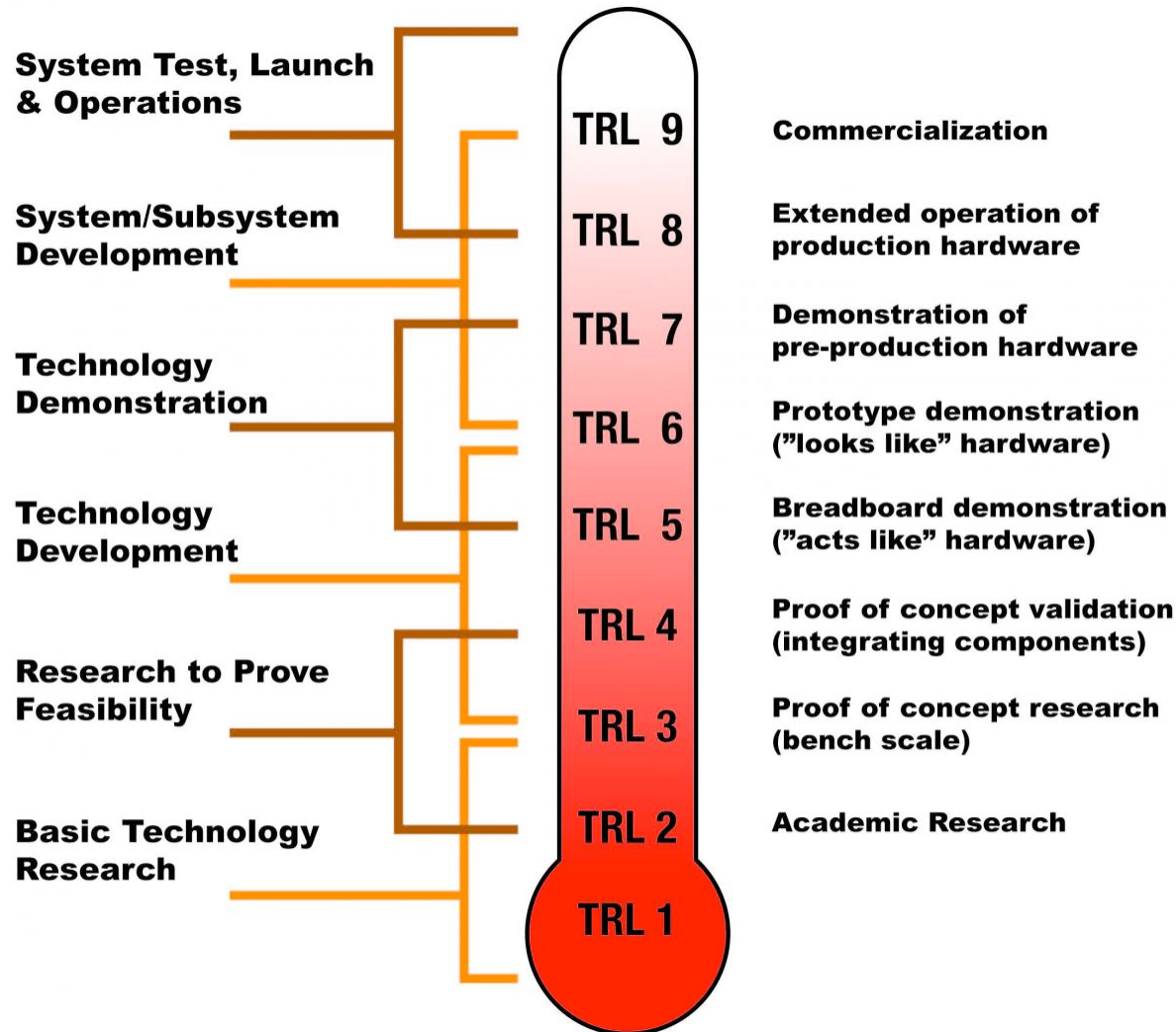
	Sup. ODP (n=120)	(n=95)
Cu (wt.%)	7.4	2.1
Zn	12.1	0.6
Au (ppm)	3.1	0.5
Ag	173	8
Pb	316	72

profundidade 3670m
diâmetro 200m
altura 50m
4Mt @ 2.1% Cu, 0.6% Zn

Hannington et al, 1998

Aumentar os níveis de prontidão tecnológica

(TRL - Tech Readiness Levels)

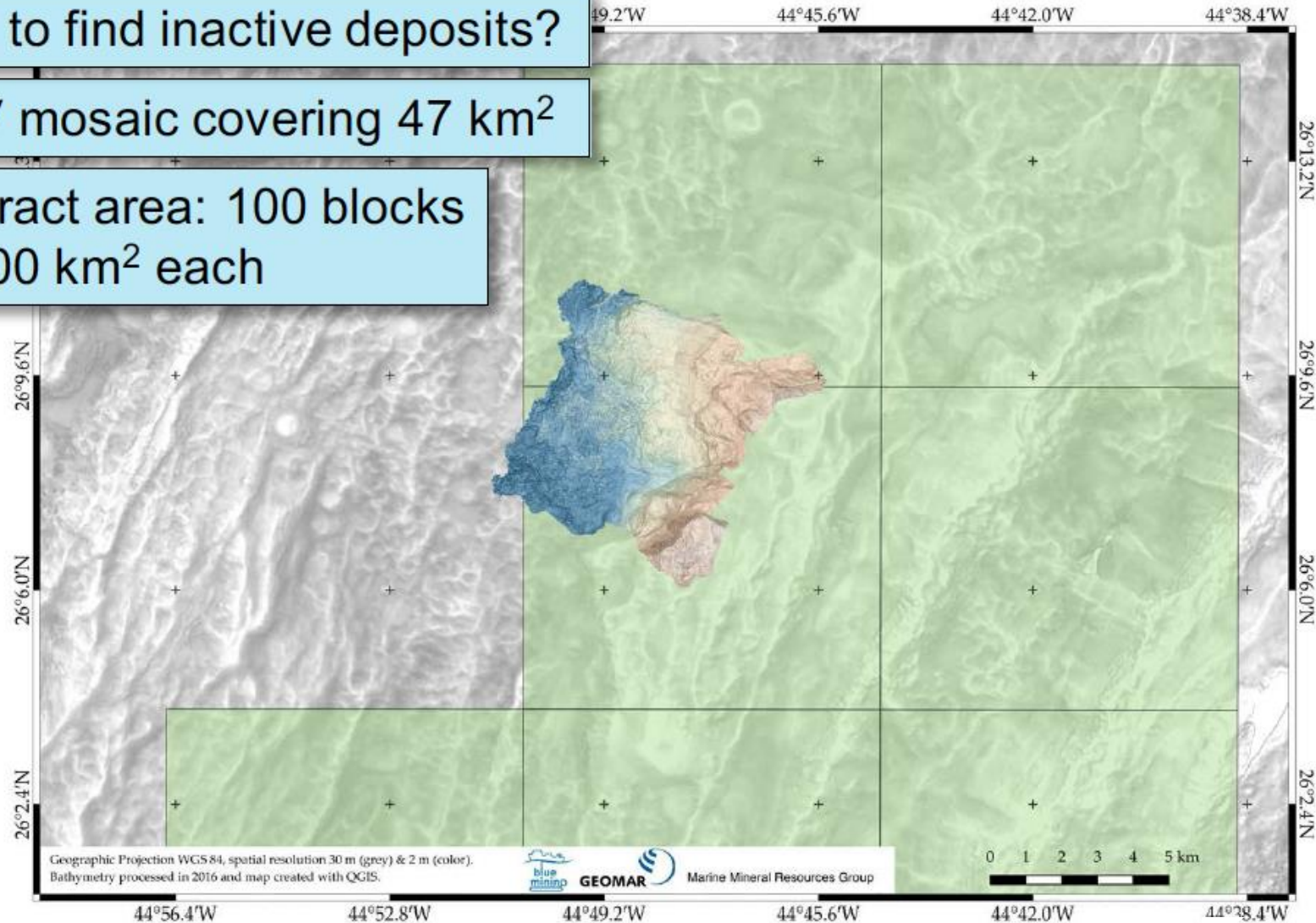


how to find inactive deposits?

AUV mosaic covering 47 km²

contract area: 100 blocks
of 100 km² each

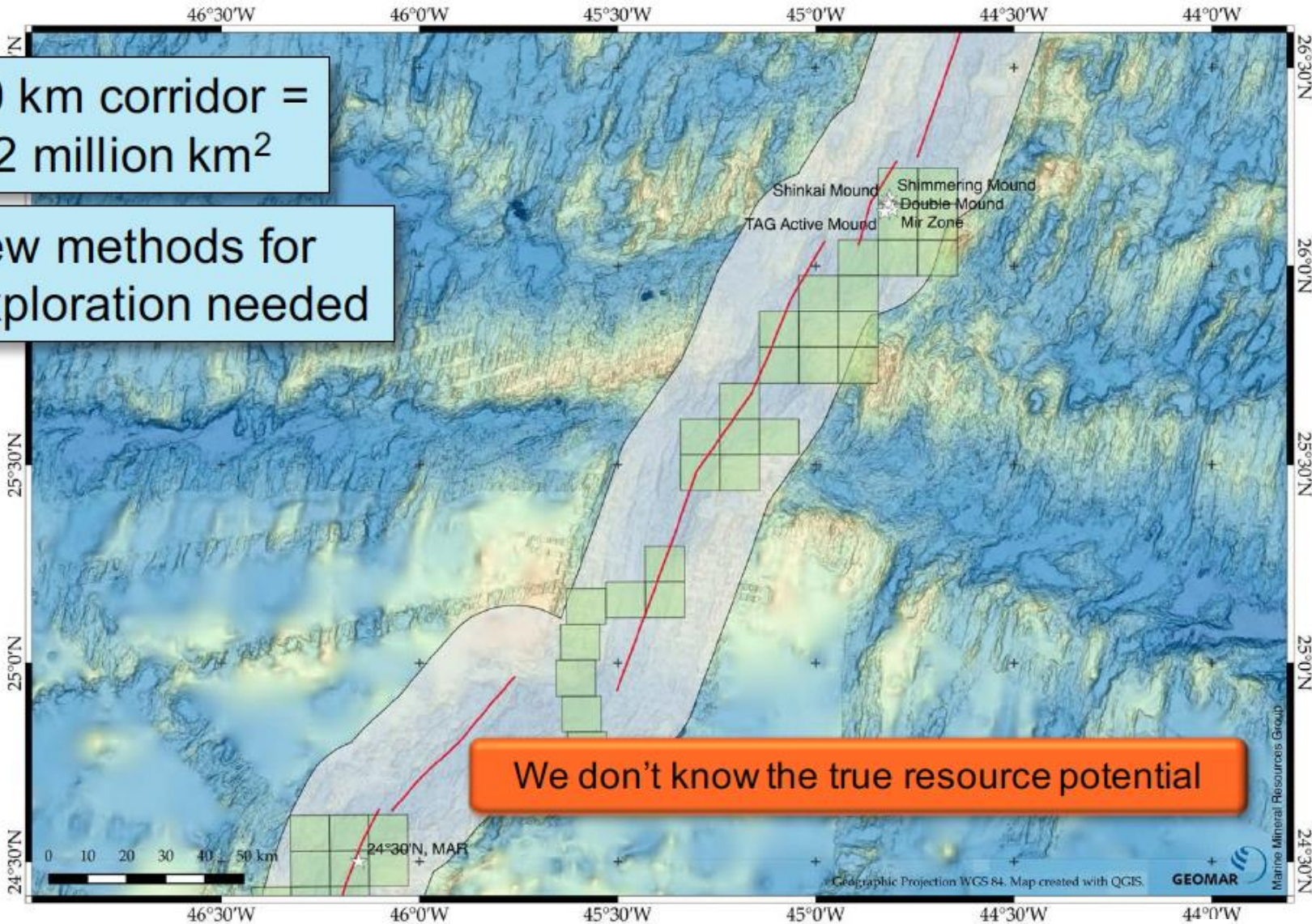
Petersen (2018; Royal Society / ISA workshop)



20 km corridor =
3.2 million km²

new methods for
exploration needed

Petersen (2018; Royal Society / ISA workshop)



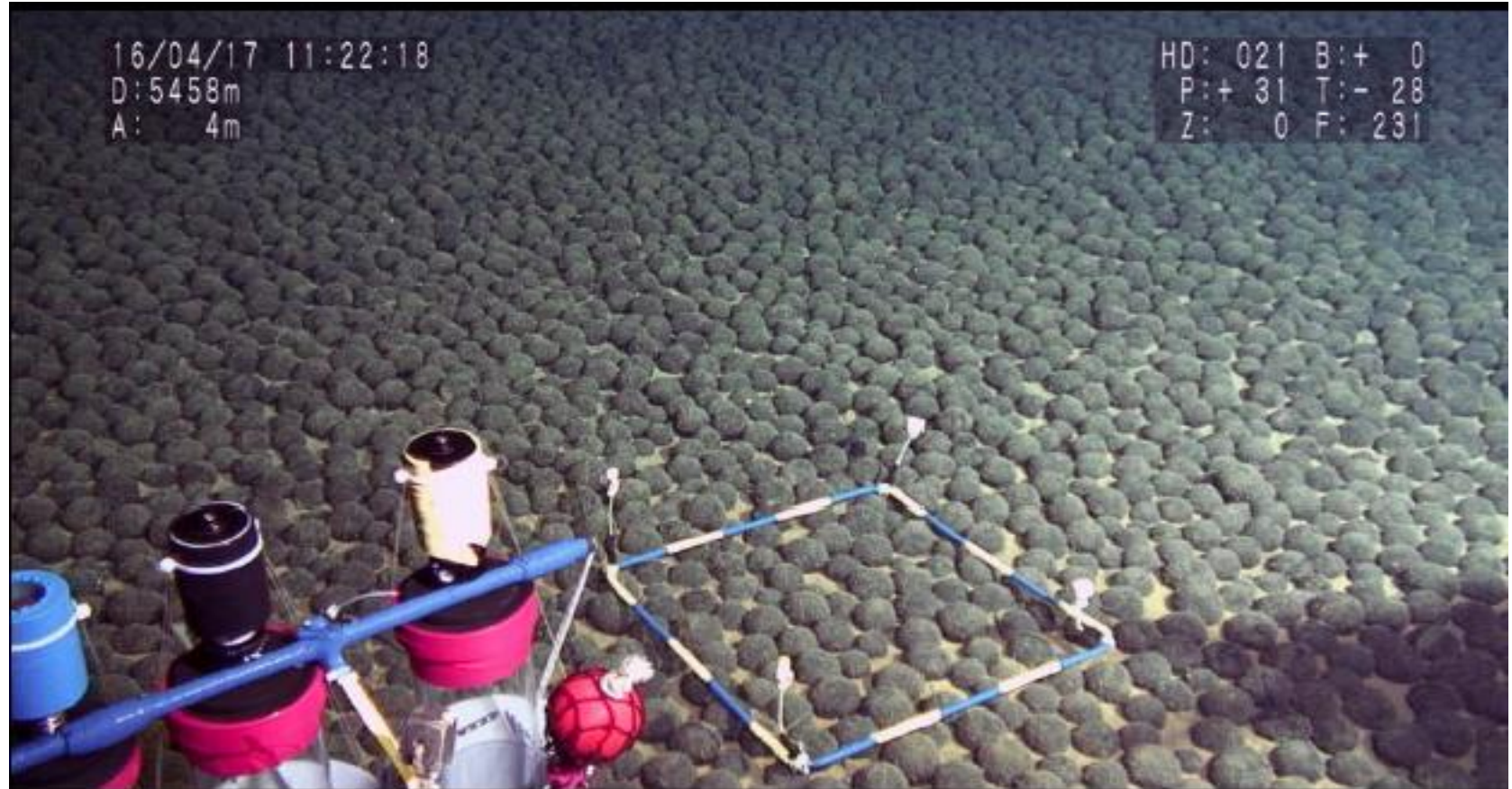
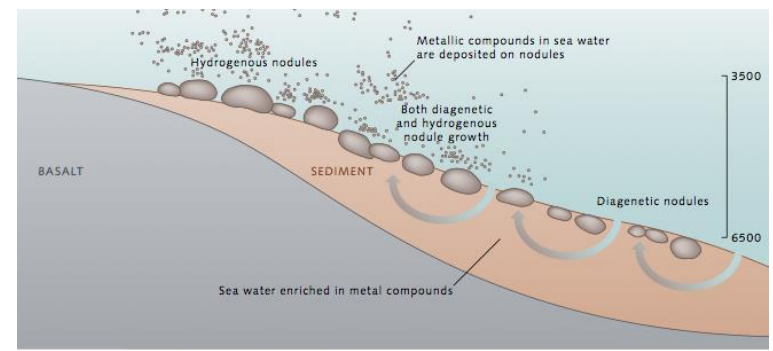
Nódulos manganesíferos

- form on sedimented deep sea plains (3000 – 6500m)
- nodules grow on the sediment and get metals from sediment pore water and seawater
- growth rate: <5 – 20 mm / mio years
- concentric growth around a nucleus
- contain Mn and Fe; plus **Cu + Ni + Co**
- 2D resource



Petersen (2018; Royal Society / ISA workshop)

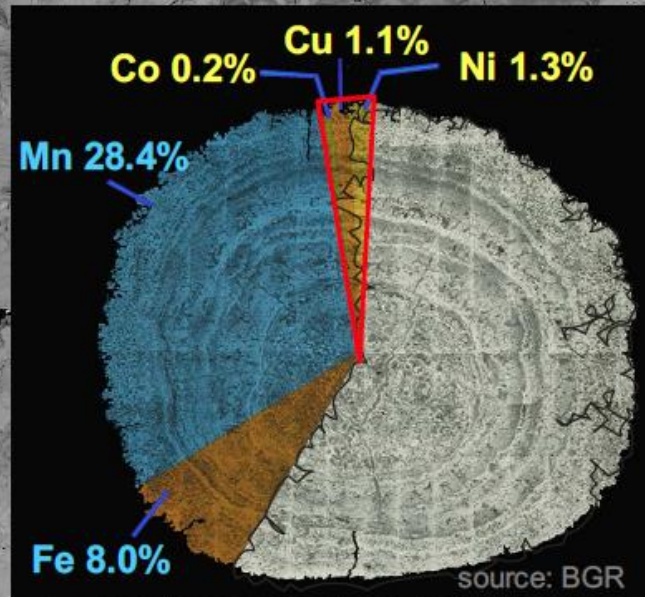
Nódulos Mn



World Ocean Review 3, 2014
(Eds. Lange, Petersen, Rupke, Soding and Wallmann)

Coimbra | 27 de abril, 2019

Nódulos Mn

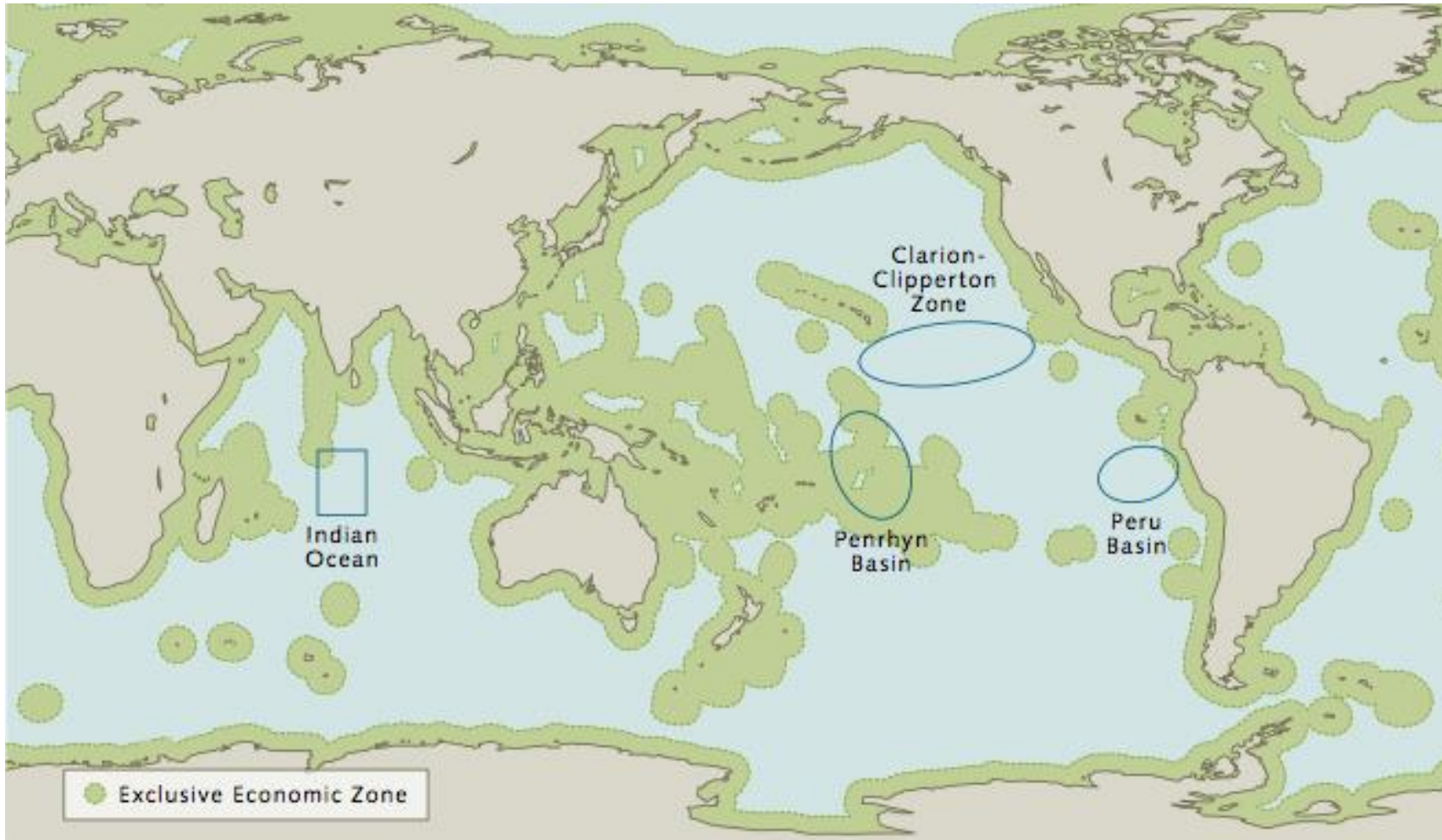


typical composition of manganese nodules (CCZ)

plus Li, Mo, REEs, Y, and Zr

from Hein et al., 2013	Atlantic	Indic	Pacific
Mn (wt.%)	15.5	20.2	21.0
Fe (wt.%)	23.0	10.3	8.5
Ni (wt.%)	0.31	0.81	1.06
Cu (wt.%)	0.14	0.69	0.90
Co (wt.%)	0.23	0.18	0.22
Ni+Cu+Co	0.68	1.68	2.18

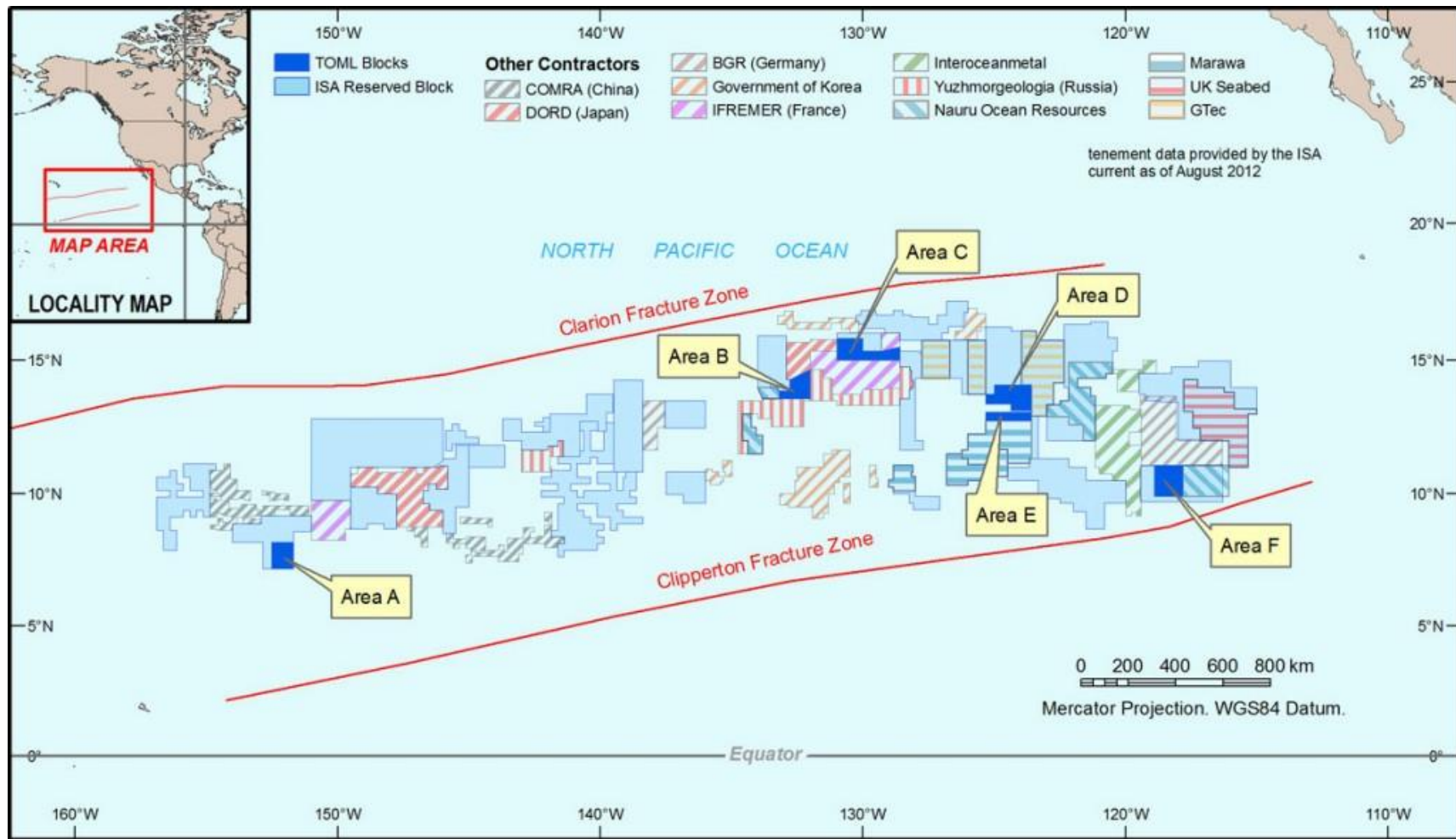
Nódulos Mn



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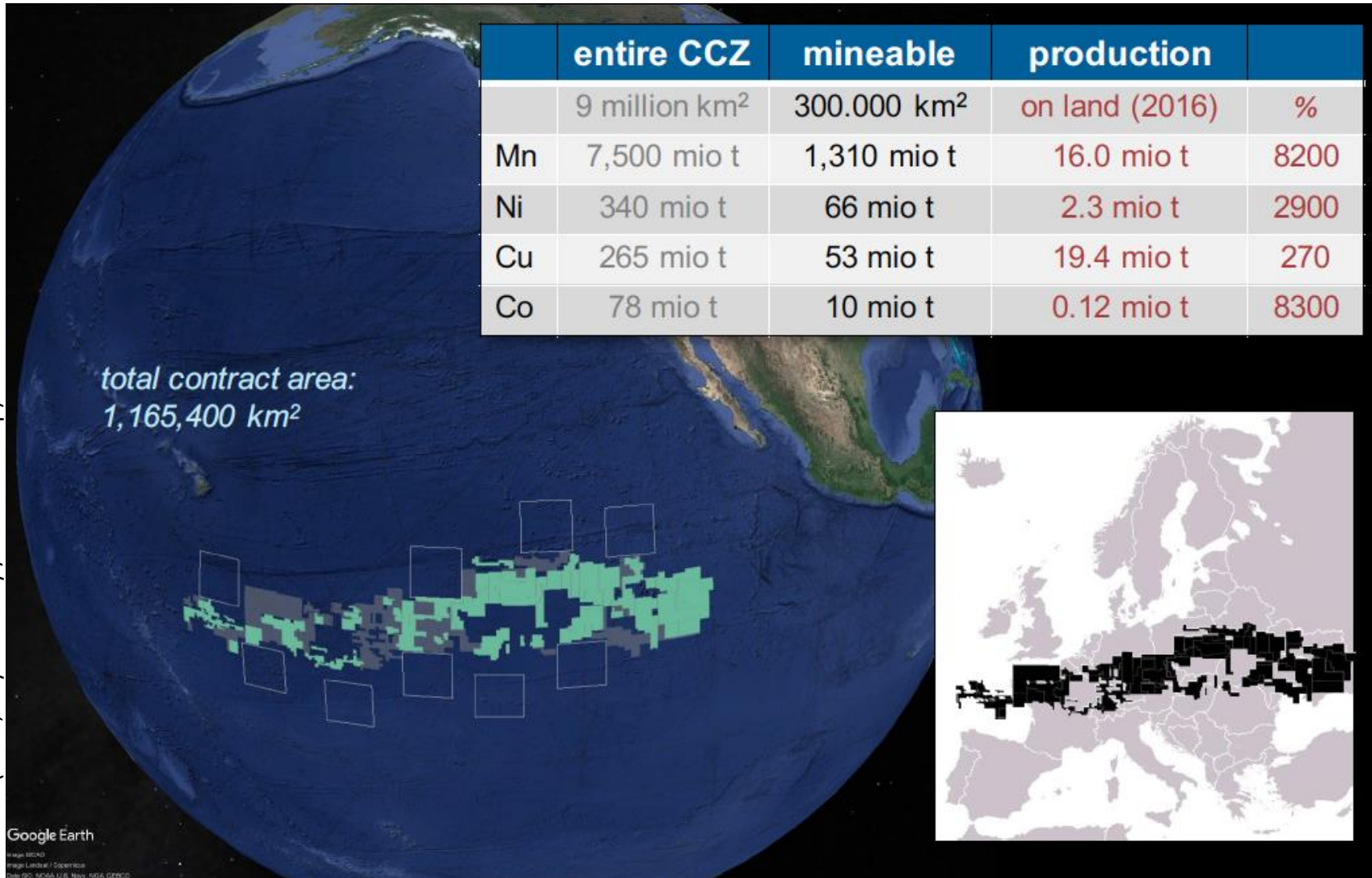
Nódulos Mn

Petersen et al. (2016; Marine Policy)

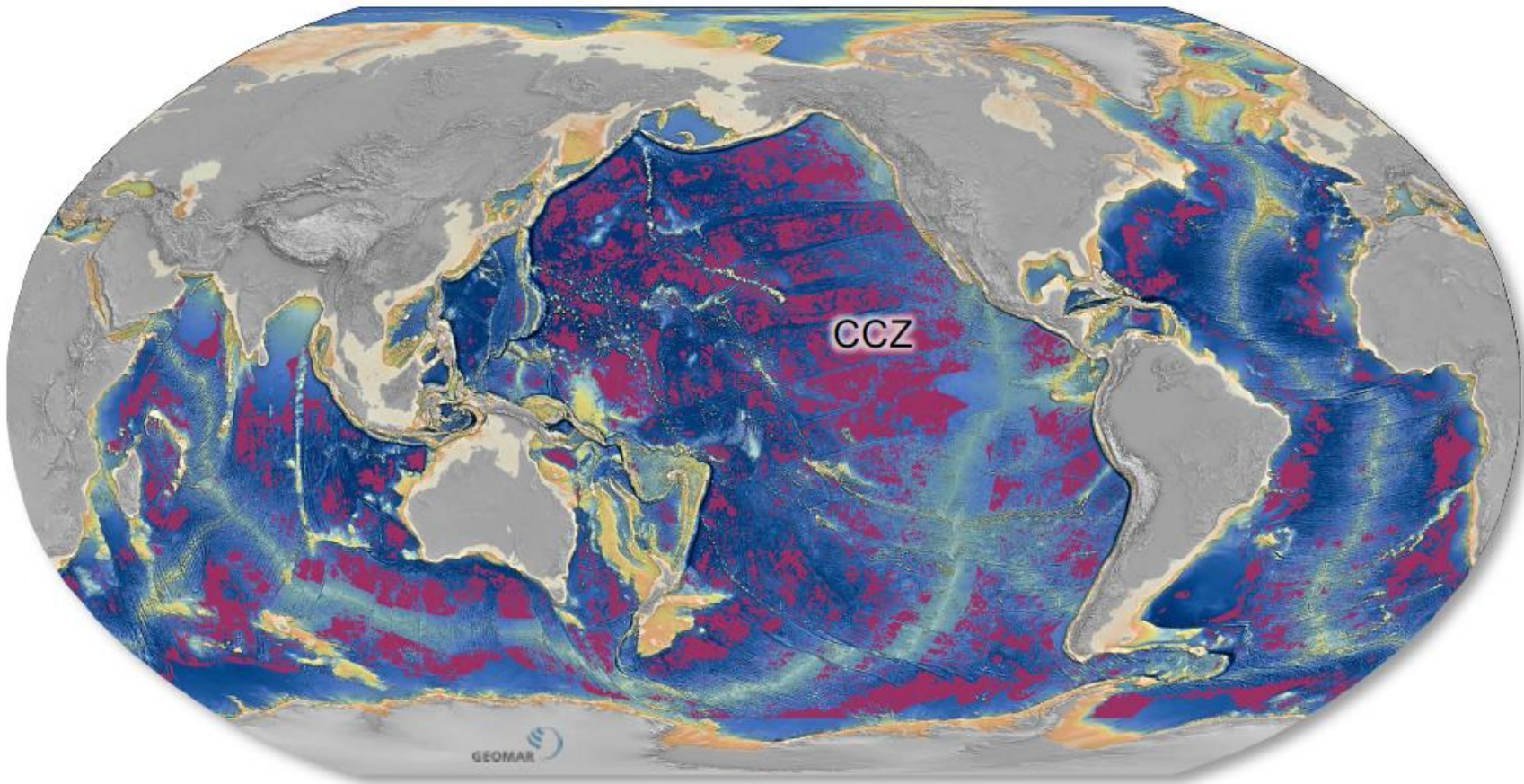


Potential mineiro da CCZ

Petersen (2018; Royal Society / ISA workshop)



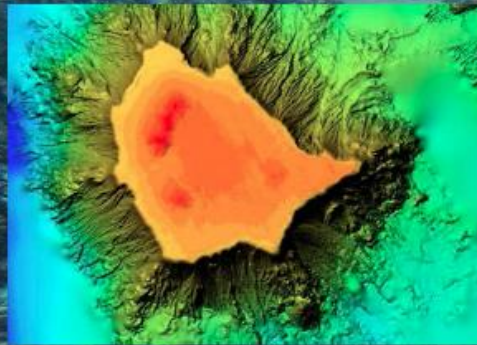
Áreas potenciais para nódulos Mn



deep-sea basins where manganese nodule could form
(based on morphology, age of the crust, sedimentation rate)

Petersen (2018; Royal Society / ISA workshop)

Crostras ferro-manganesíferas ricas em cobalto



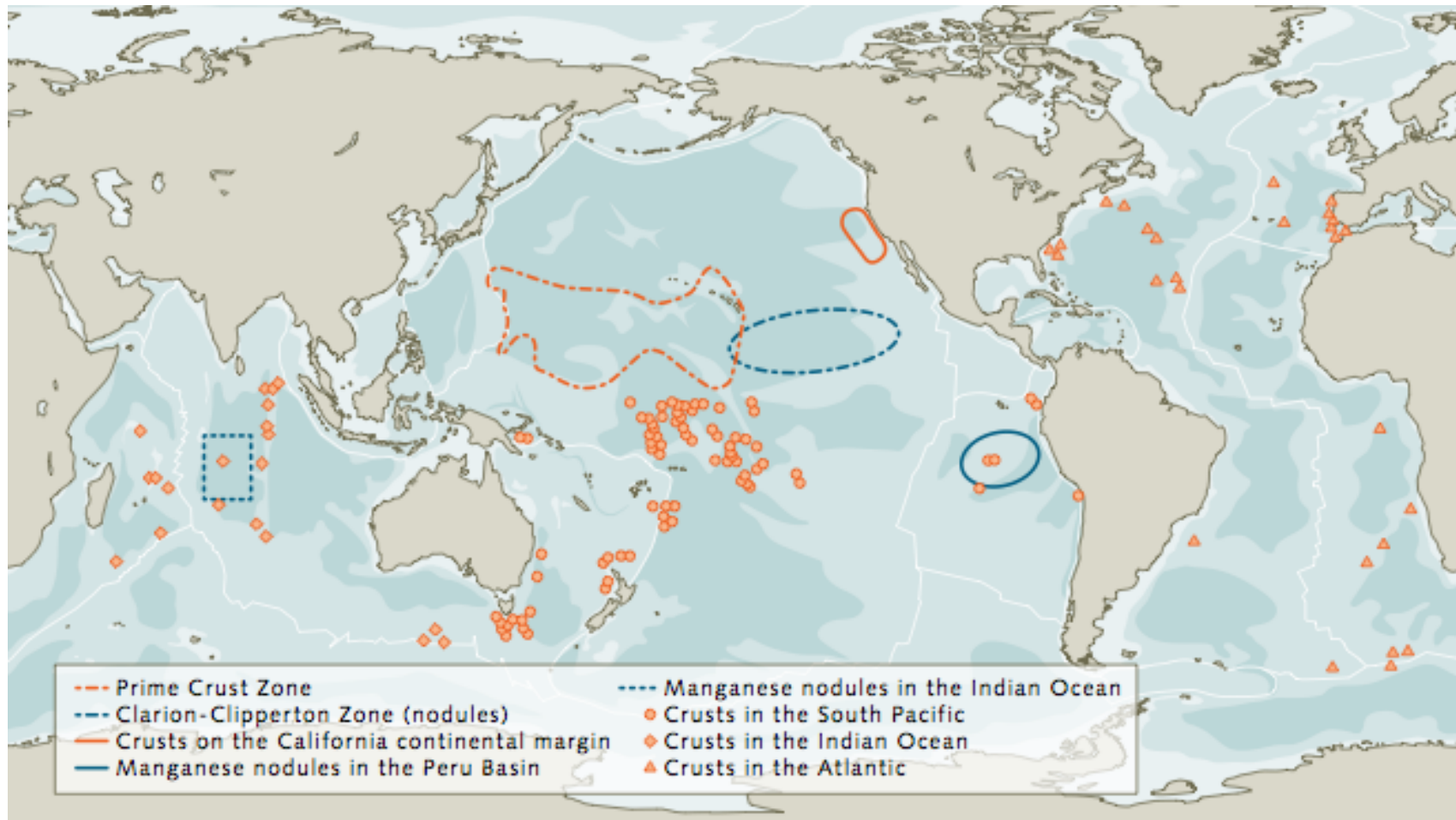
- grow on flanks of old seamounts
- growth rate: 1-5 mm / mio years from dissolved seawater
- highest metal contents of **Co + Ni** between 800 – 2500 m
- 2D occurrences



ROV KIEL 0000 2015-05-24 19:25:54

Petersen (2018; Royal Society / ISA workshop)

Crostras polimetálicas



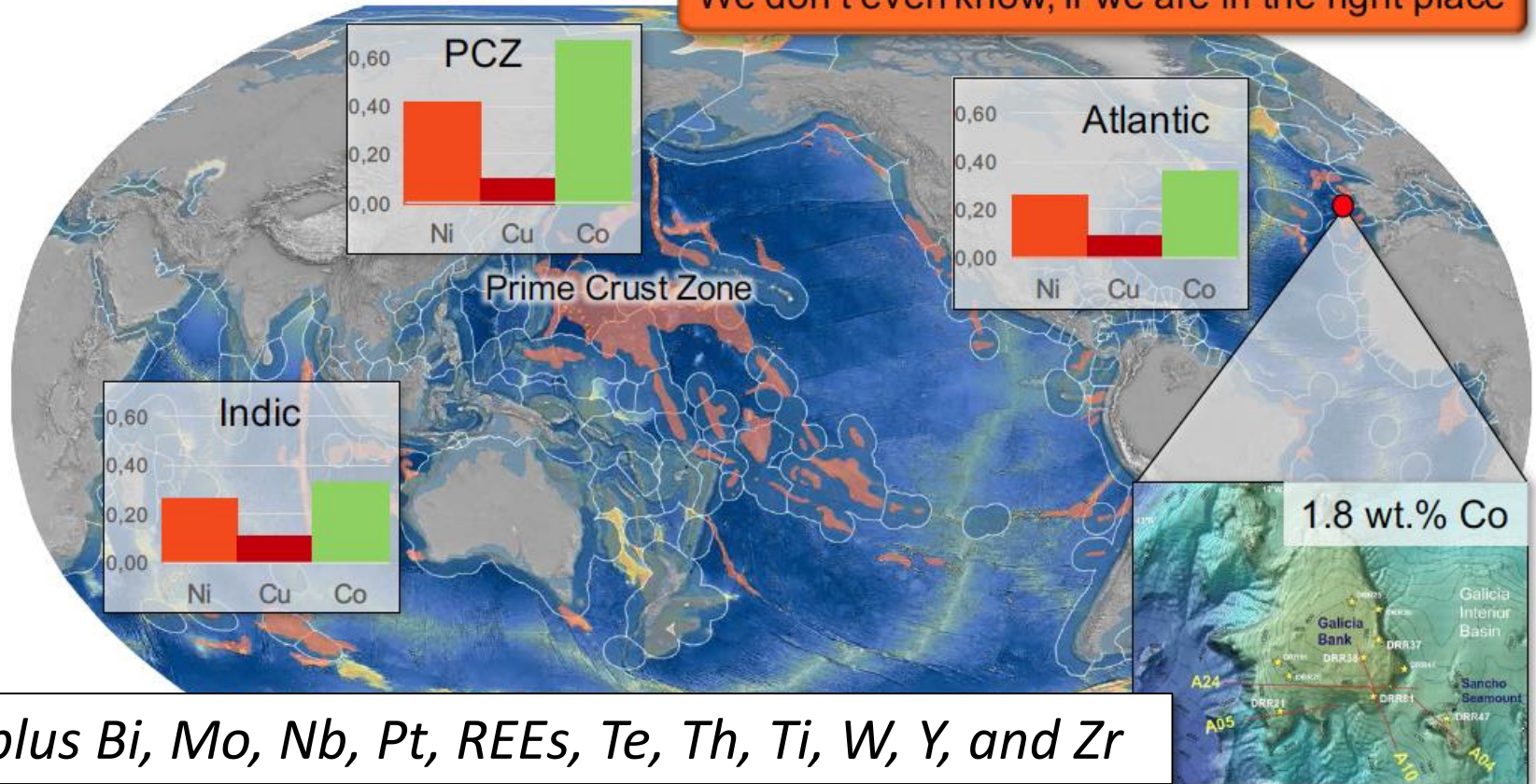
World Ocean Review 3, 2014

(Eds. Lange, Petersen, Rupke, Soding and Wallmann)

Croostas polimetálicas

We don't even know, if we are in the right place

Petersen (2018; Royal Society / ISA workshop)



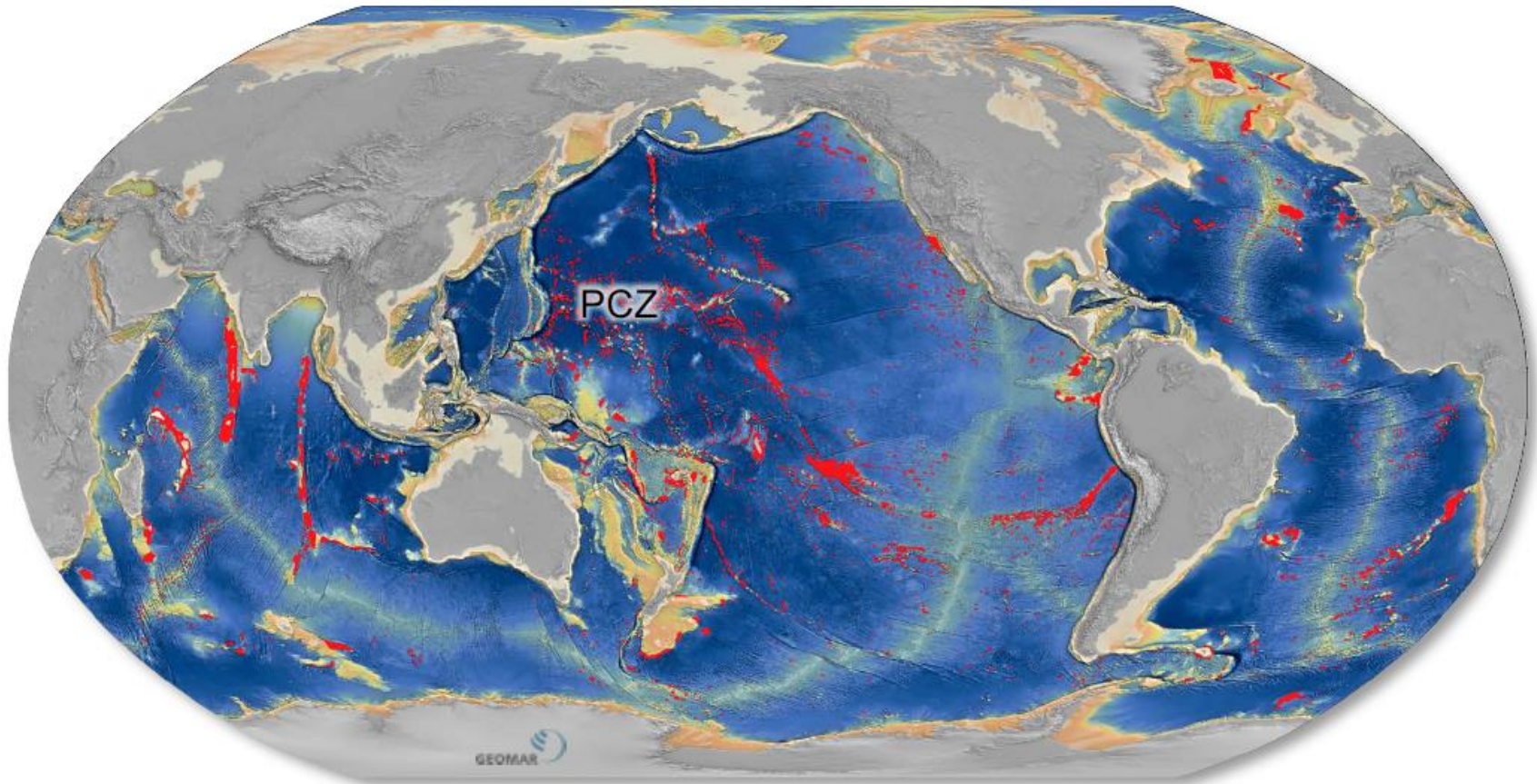
Gonzalez et al., 2016

plus Bi, Mo, Nb, Pt, REEs, Te, Th, Ti, W, Y, and Zr

areas with highest ferromanganese crust potential
(based on morphology, age of the crust, metal input; source Hein et al., 2013)

Áreas potenciais para crostas polimetálicas

7.5 billion tons of crusts in the PCZ



seamounts important for manganese crust formation
(based on morphology, age of the crust, sedimentation rate)

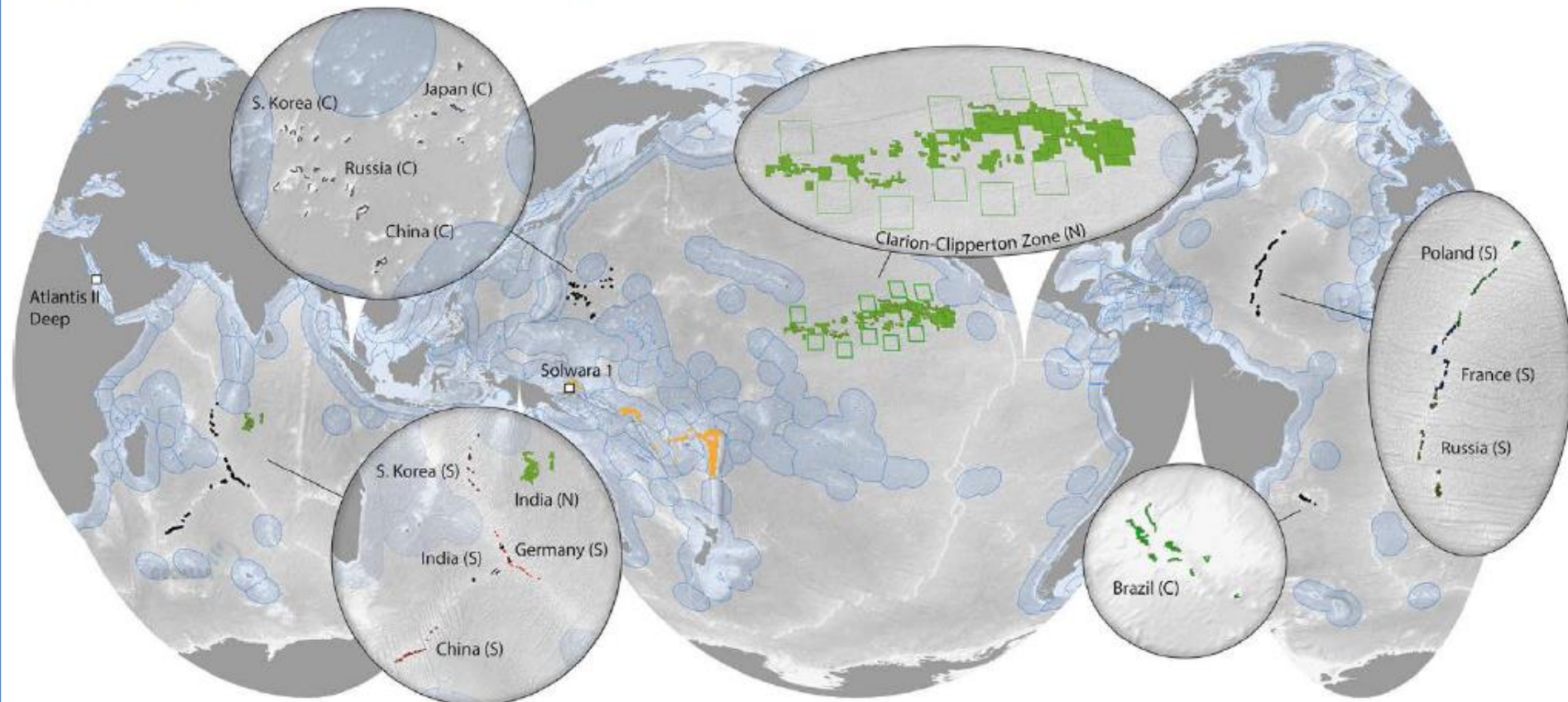
Petersen (2018; Royal Society / ISA workshop)

Coimbra | 27 de abril, 2019

Necessidade urgente de regulação

Marine Mineral Resources from the Deep Sea

The regulatory requirements: There are very different regulatory needs for different resources. There is no “one size fits all” solution.



modified from Petersen et al., 2016, Marine Policy

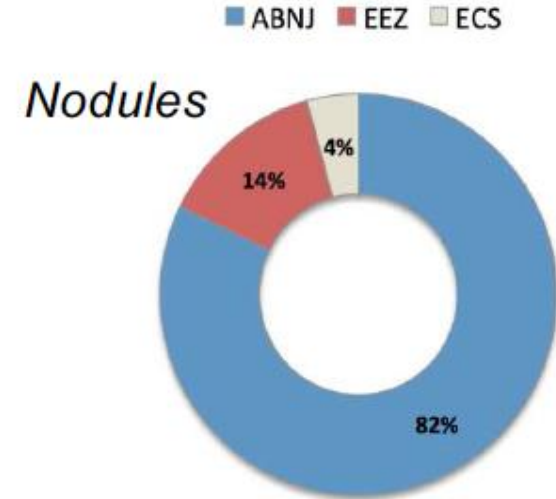
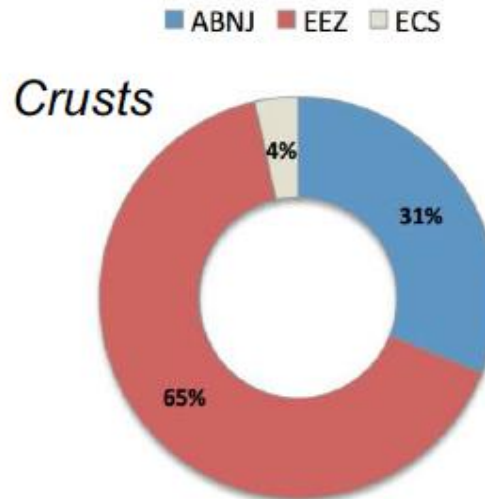
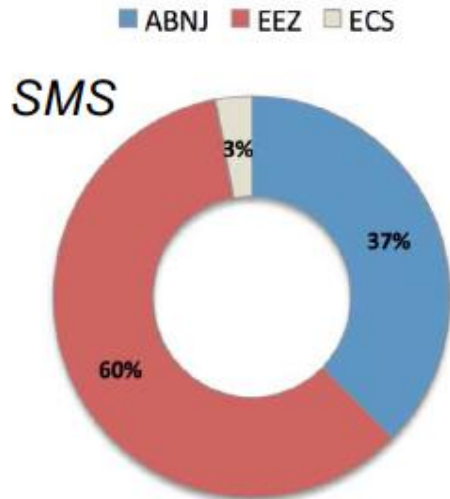
location of global deep-sea mining and exploration license areas

Exploration largely in areas where we already have information !

Marine Mineral Resources from the Deep Sea

The regulatory requirements: There are very different regulatory needs for different resources. There is no “one size fits all” solution.

- More than 80% of the known Mn nodule fields are located in the “Area”
- Only 30% of the high-grade crusts are in the “Area”; most are in EEZs.
- Only 37% of the known seafloor massive sulfide deposits are in the “Area”.
- Less than 5% of the resources are in applications for extensions of the shelf.

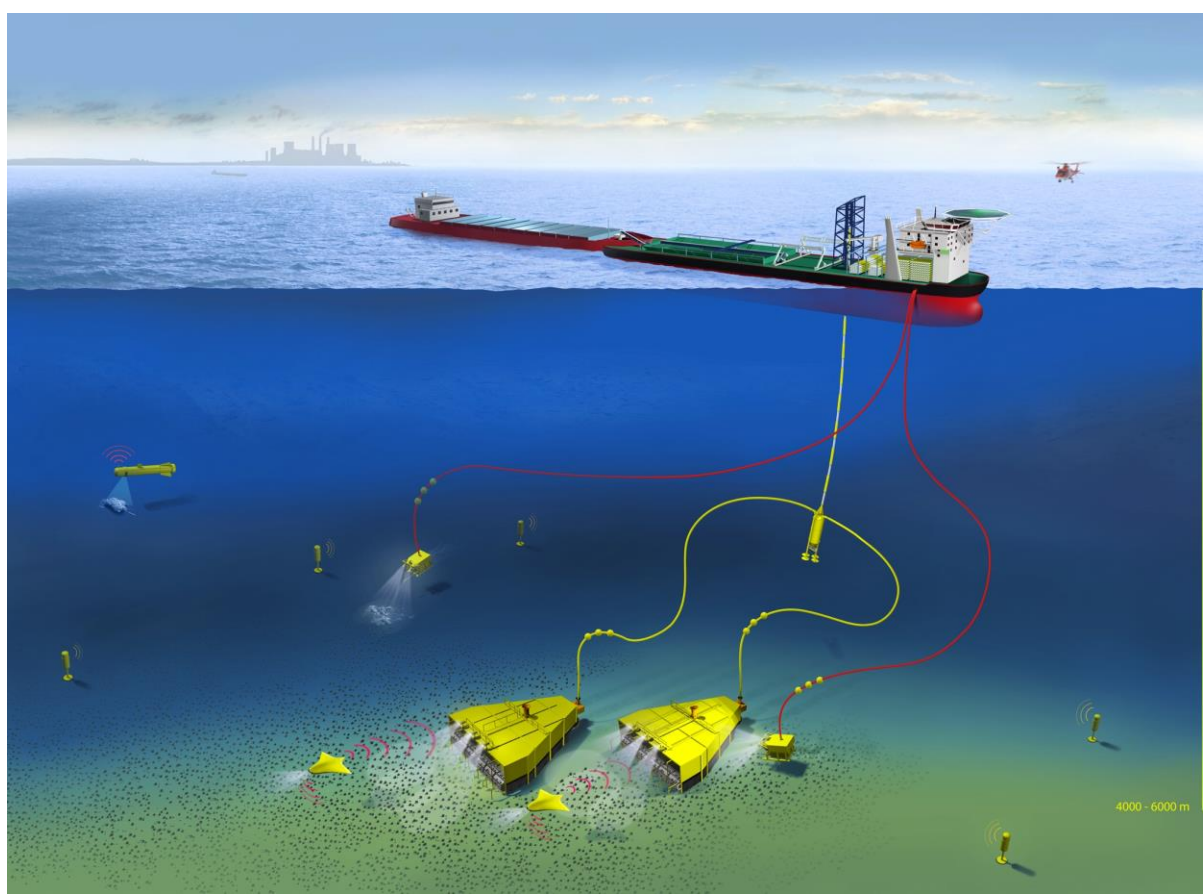


Uma indústria mineira global offshore espera pelo momento certo para emergir

Seafloor Production System

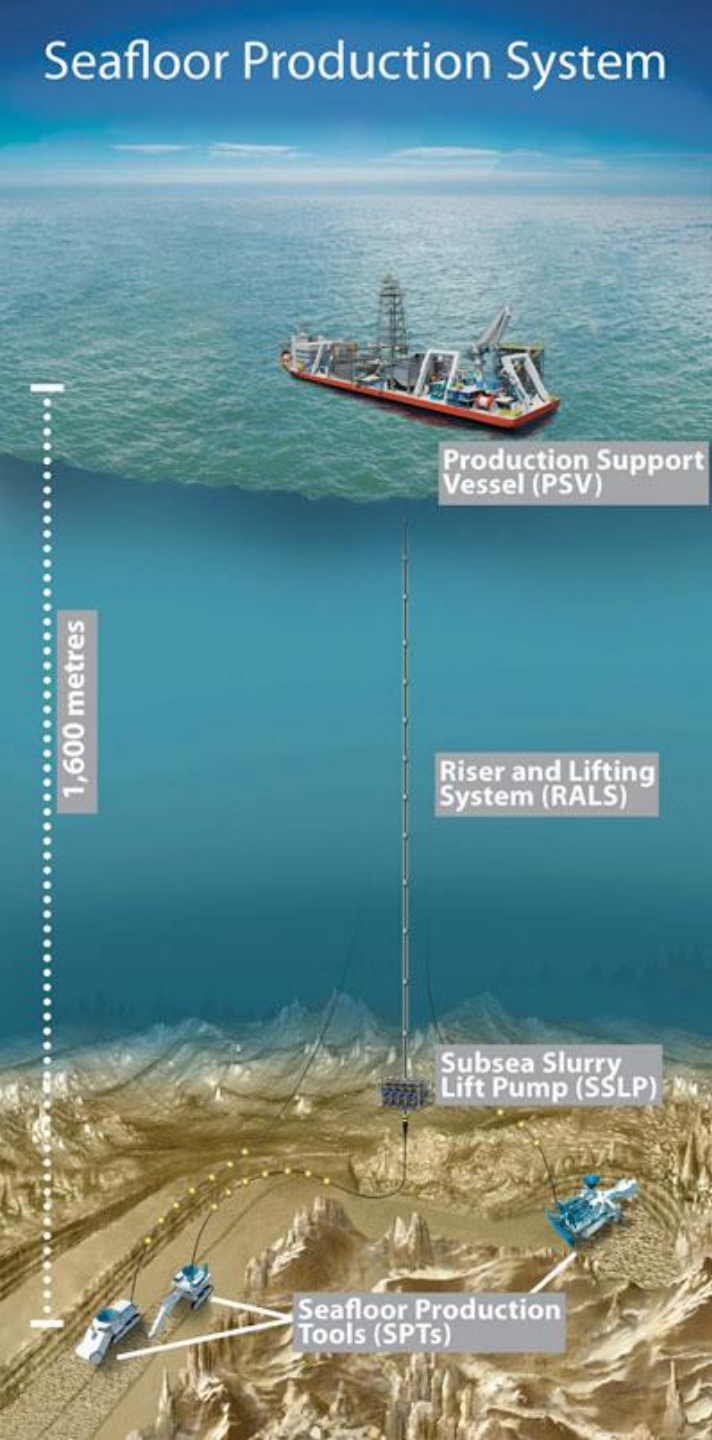
The diagram illustrates a seafloor production system. At the surface, a **Production Support Vessel (PSV)** is shown. A vertical **Riser and Lifting System (RALS)** extends from the vessel down to a **Subsea Slurry Lift Pump (SSLP)** located on the seafloor. The depth is indicated as **1,600 metres**. The SSLP is connected to **Seafloor Production Tools (SPTs)** on the seafloor. The seafloor is depicted with a complex, rocky terrain.

A tecnologia é só um custo; não um real obstáculo

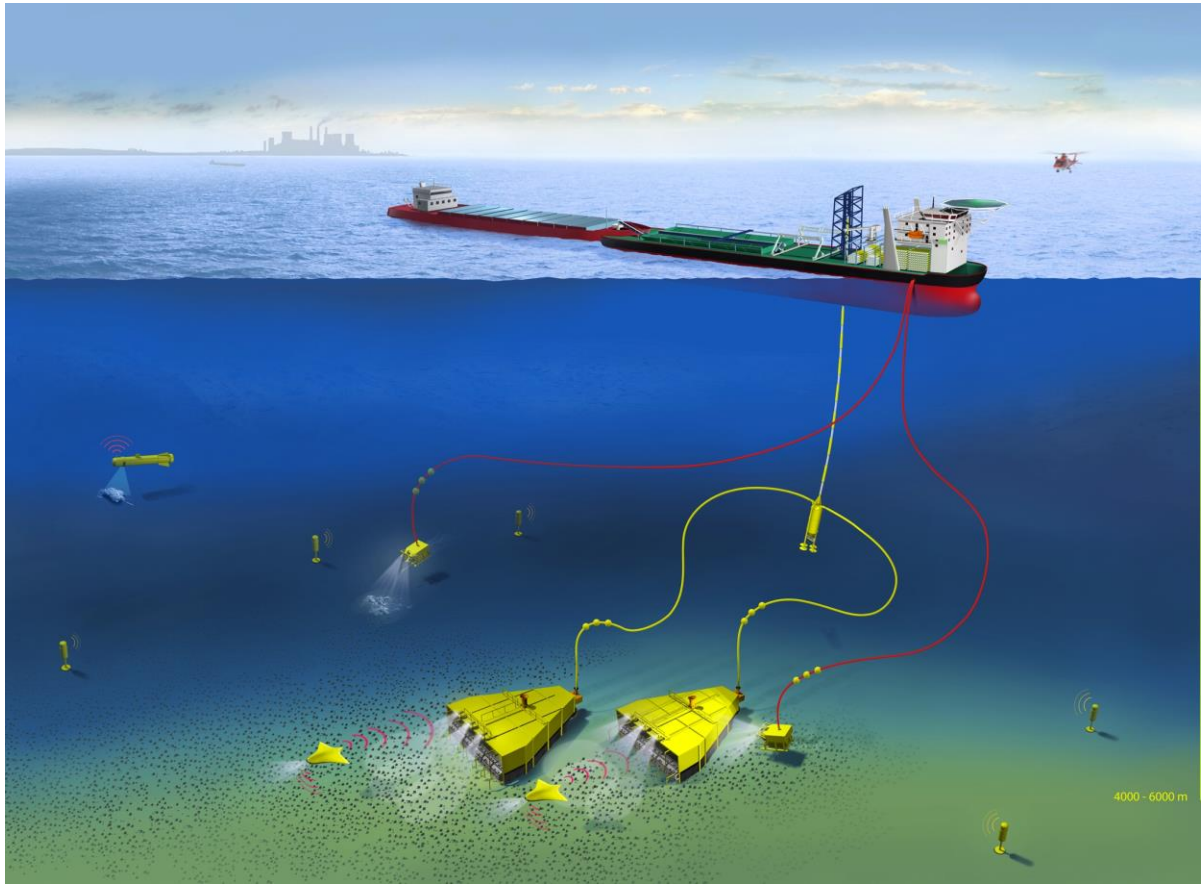


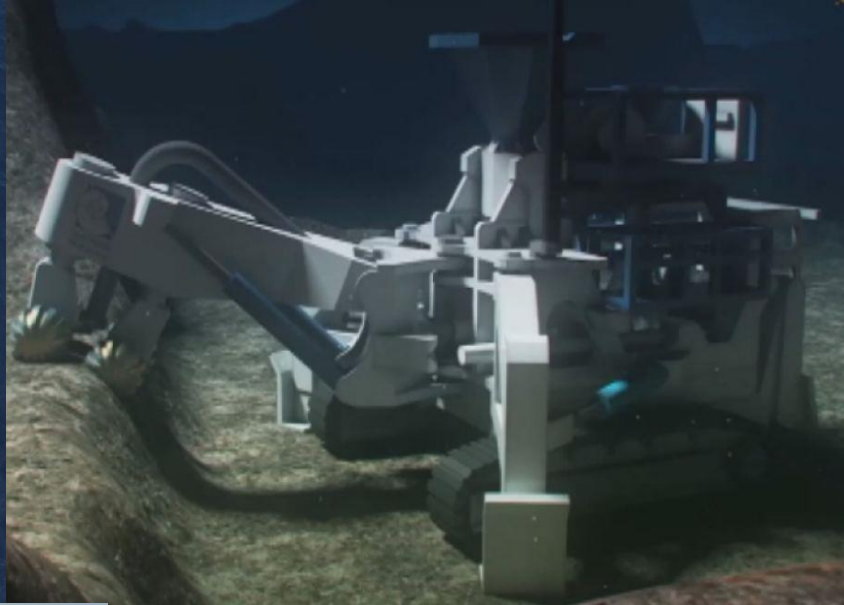
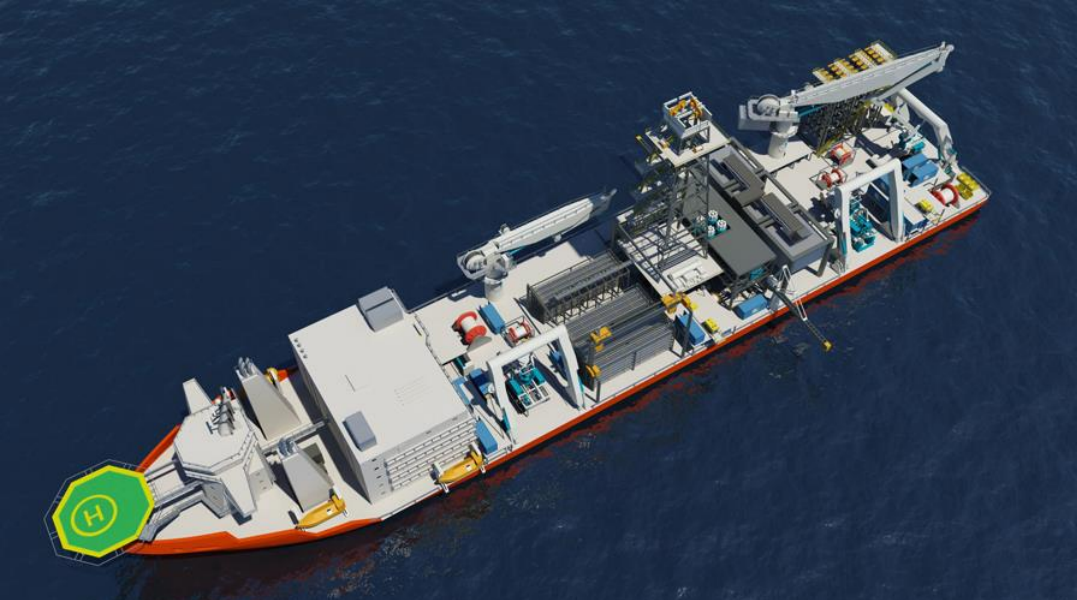
4000 - 6000 m

Seafloor Production System



Sim, isto são só desenhos



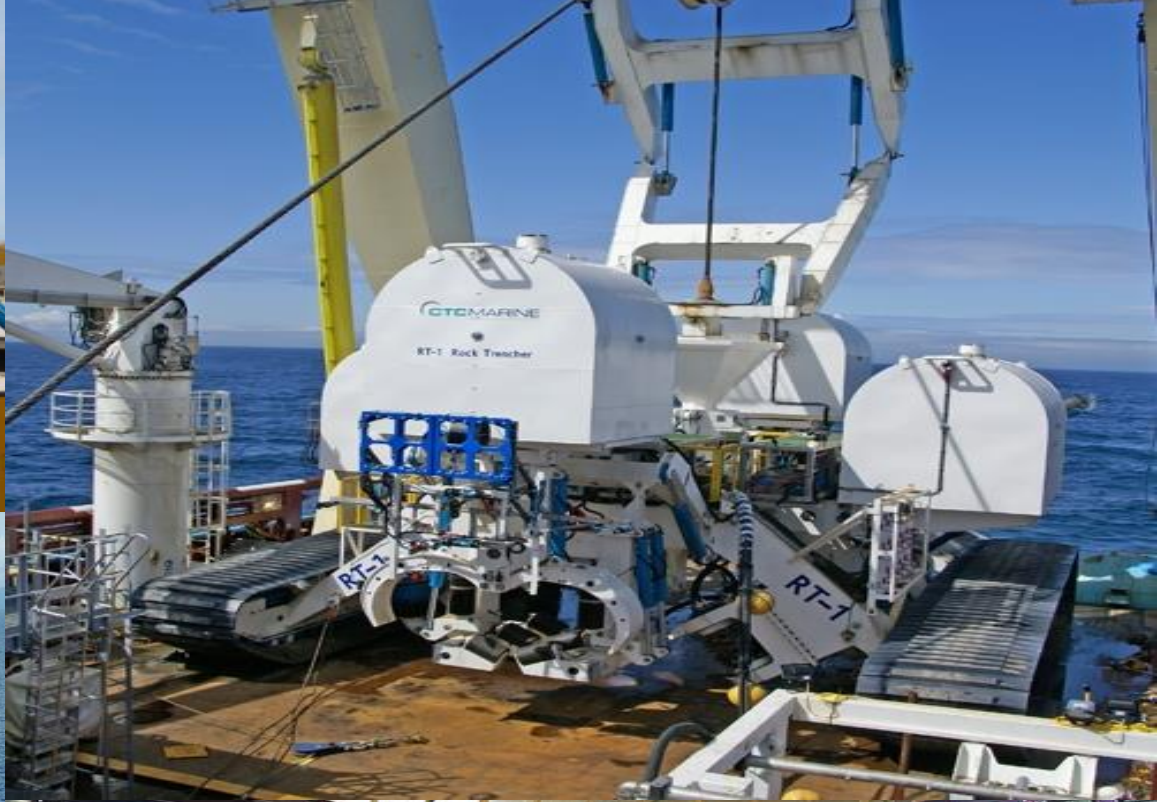




Não, isto não são desenhos

Coimbra | 27 de abril, 2019





Eastern Manus Basin, PNG – Concessões Nautilus

Location	size/tonnage	N	Cu	Zn	Au	Ag	depth (m)
			wt. %		ppm		
Western Manus Basin							
Solwara 11	-	26	1.6	16.9	1.2	180	1390 - 1450
Solwara 18	-	2	0.3	19.6	0.2	110	1310
Central Manus Basin							
Vienna Woods, Solwara 2	-	215	1.2	21.0	10.0	355	2470 - 2500
Solwara 03	-	31	1.1	21.3	15.2	642	2560 - 2590
Solwara 10	-	12	7.7	15.2	2.5	165	2240
Solwara 14	-	14	1.4	19.2	3.3	97	2240
Solwara 16	-	6	2.1	18.6	2.8	105	2160
Eastern Manus Basin							
Suzette (Solwara 01)	90 000 m ²	250	9.7	5.4	15.0	174	1460
Suzette (Solwara 01)*	1 030 000 t	indicated	7.2	0.4	5.0	23	1460
Suzette (Solwara 01)*	1 540 000 t	inferred	8.1	0.9	6.4	34	1460
North Su	-	4	7.1	1.6	4.8	39	1183
South Su	-	4	7.4	9.2	6.8	191	1309
Solwara 05 (N of North Su)	30 000 m ²	12	6.0	8.3	14.6	282	1635 - 1680
Solwara 09 (west of North Su)	15 000 m ²	17	6.3	10.6	19.9	296	1680
PACMANUS	45 000 m ²	336	7.4	22.5	13.7	267	1650 - 1815
Solwara 12 (near Desmos)	-	10	7.0	22.6	13.7	425	1870
Solwara 12 (near Desmos)*	230 000 t	inferred	7.3	3.6	3.6	56	1870
Solwara 13 (Yuam Ridge)	30 000 m ²	7	9.1	30.7	4.7	546	2000

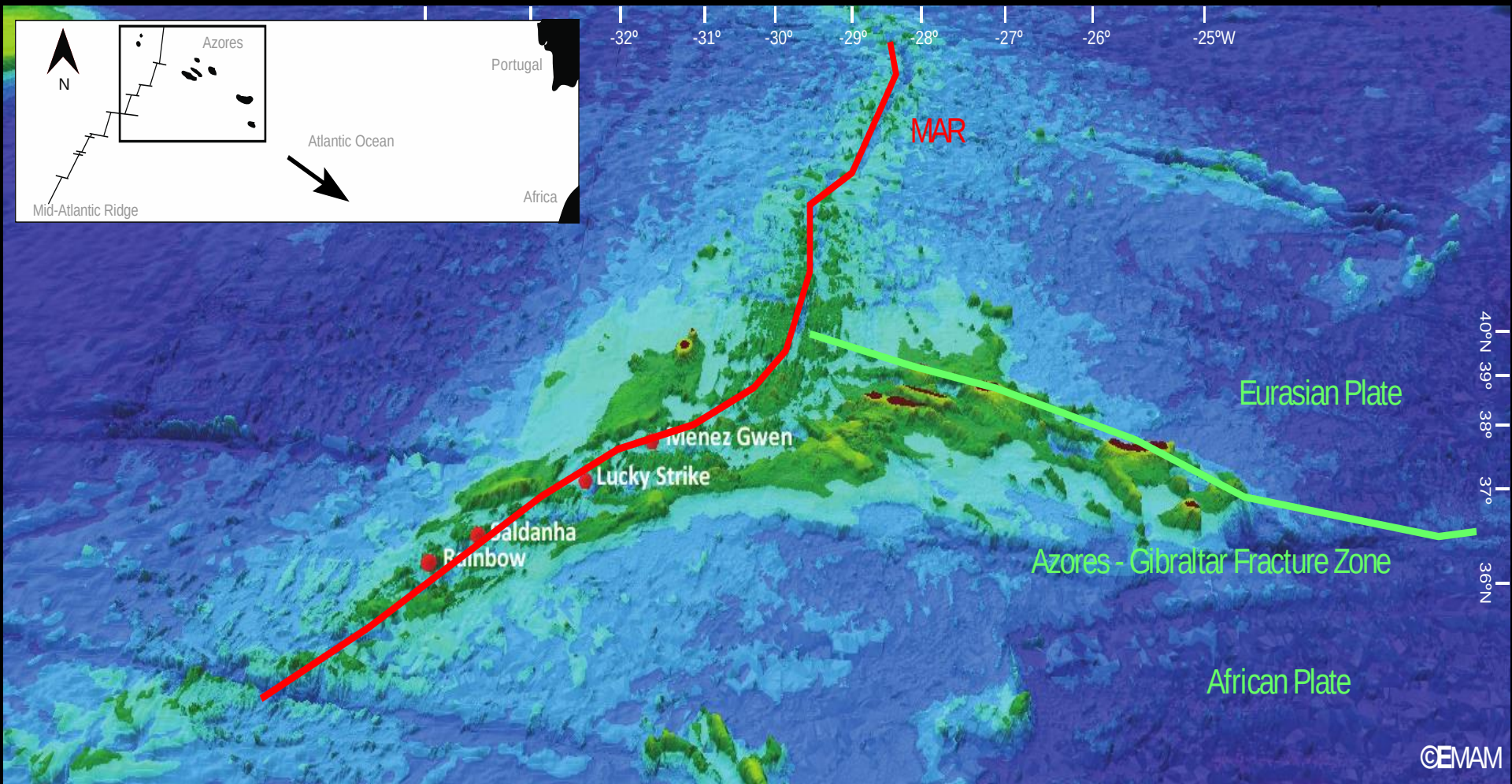
(Petersen and Hein, 2013, after Hannington et al., 2010; 2011; Lipton, 2012)

Projeto Nautilus

A Nautilus espera que os seus lucros provenientes da mina de Solwara 1 excedam 1 bilião de dólares/ano. A Nautilus afirma que planeia produzir cerca de 80,000 toneladas de cobre metálico e 150,000-200,000 onças de ouro por ano (US\$275 milhões para o ouro e US\$783 milhões para o cobre – US\$1.058 biliões no total).

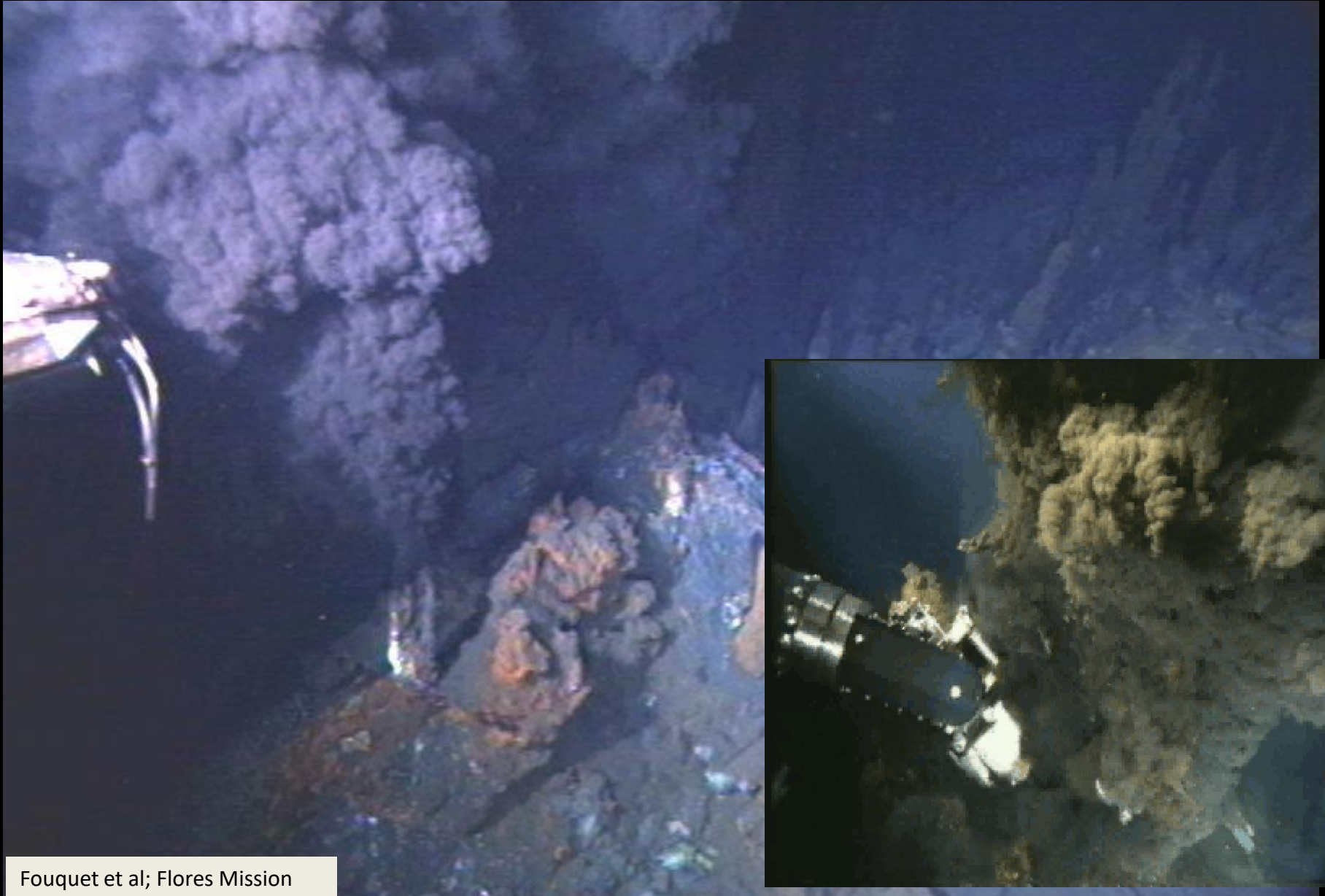


Crista Média Atlântica





Rainbow

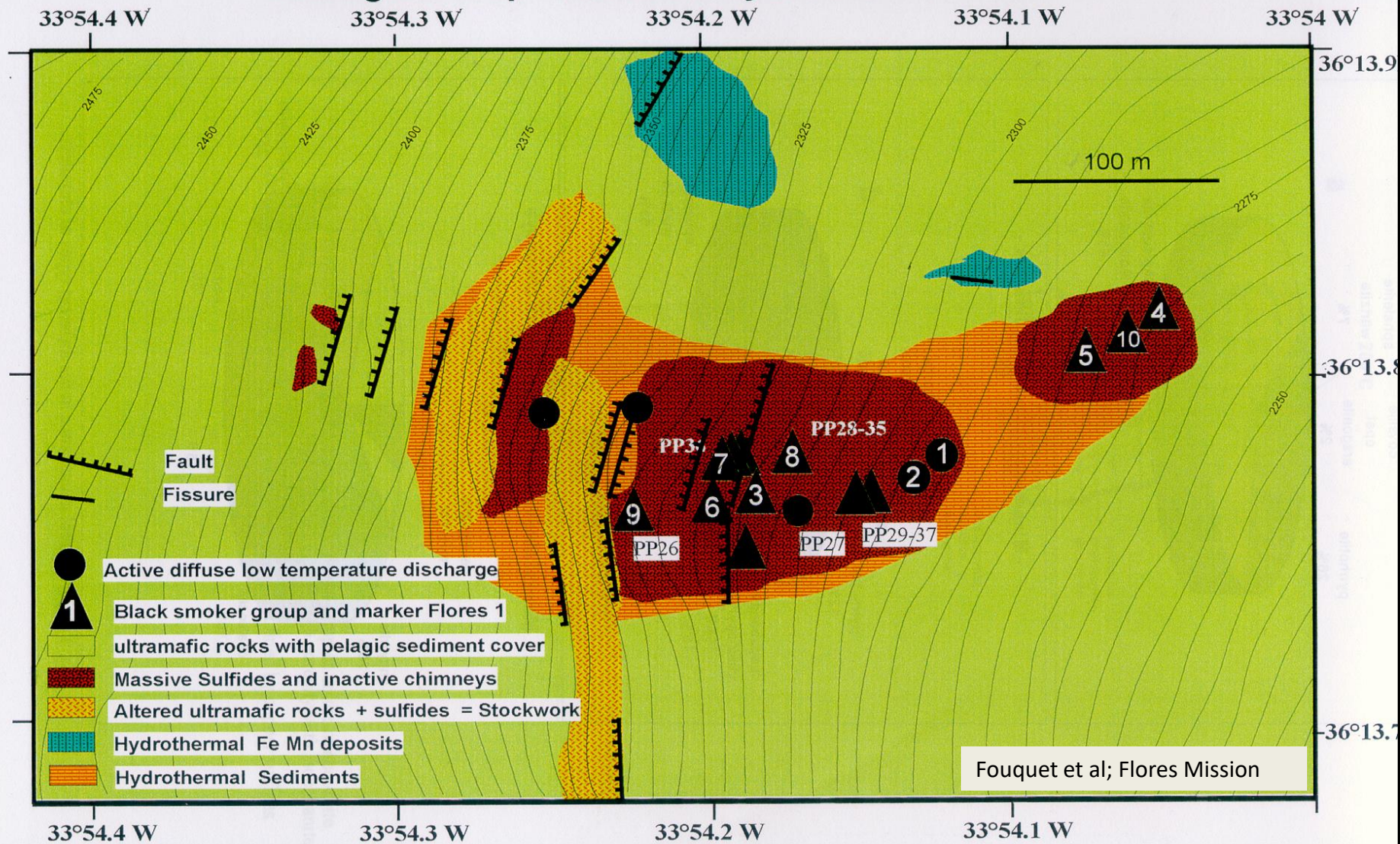


Fouquet et al; Flores Mission



Rainbow

Geological Map - Rainbow hydrothermal field





Rainbow



Massive Sulfide
Chimney Fragment

Metalliferous Sediments

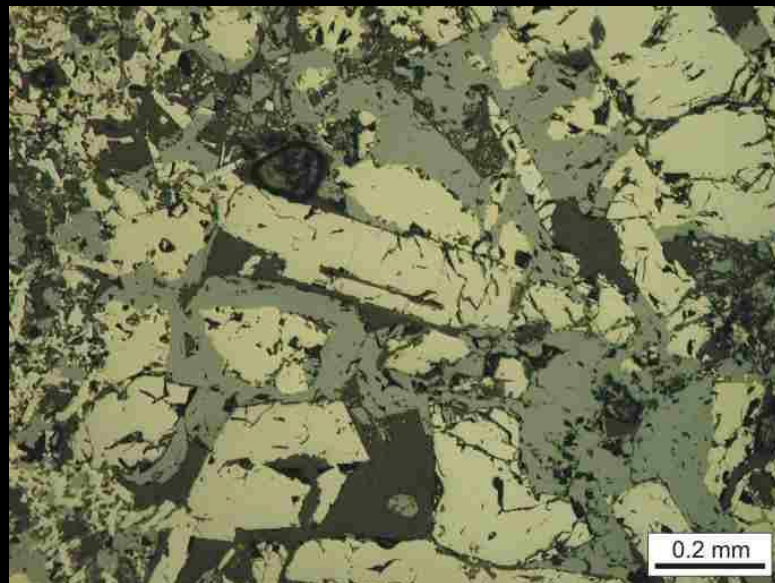
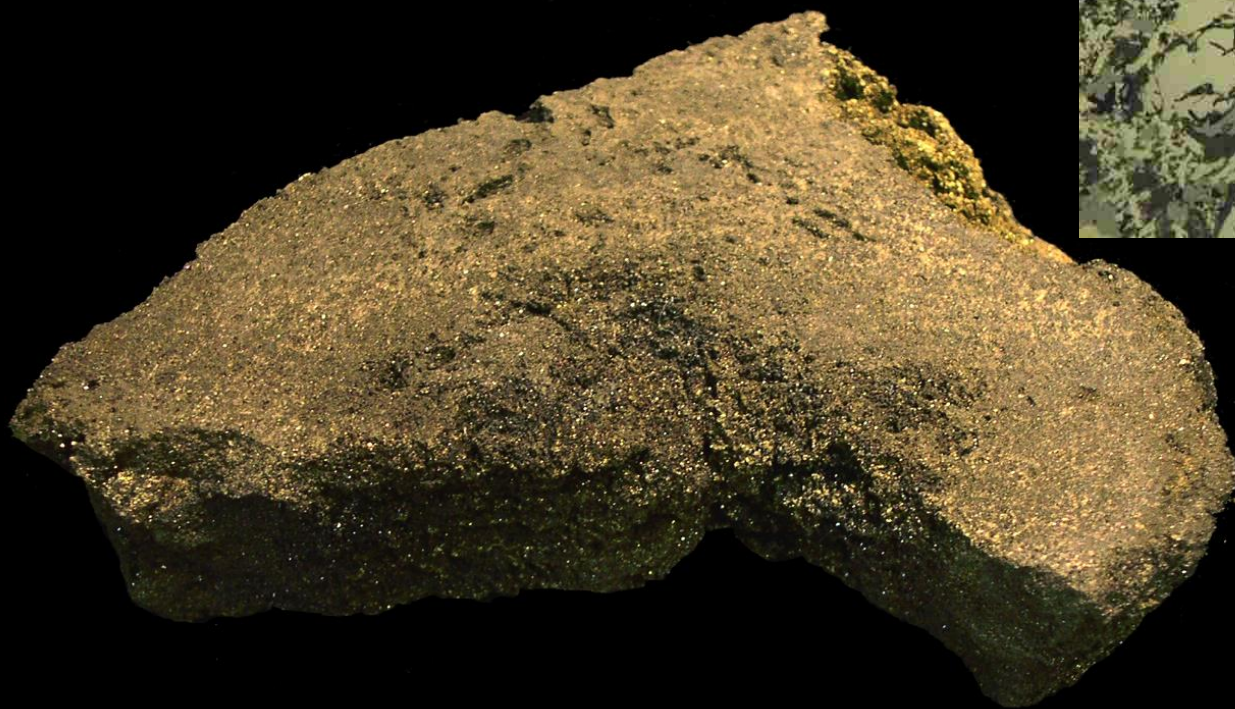


Rainbow





Rainbow



8.35 wt Cu
5.1 wt% Zn
0.57 wt % Co
5.7 ppm Au
n.d. Ni



Rainbow

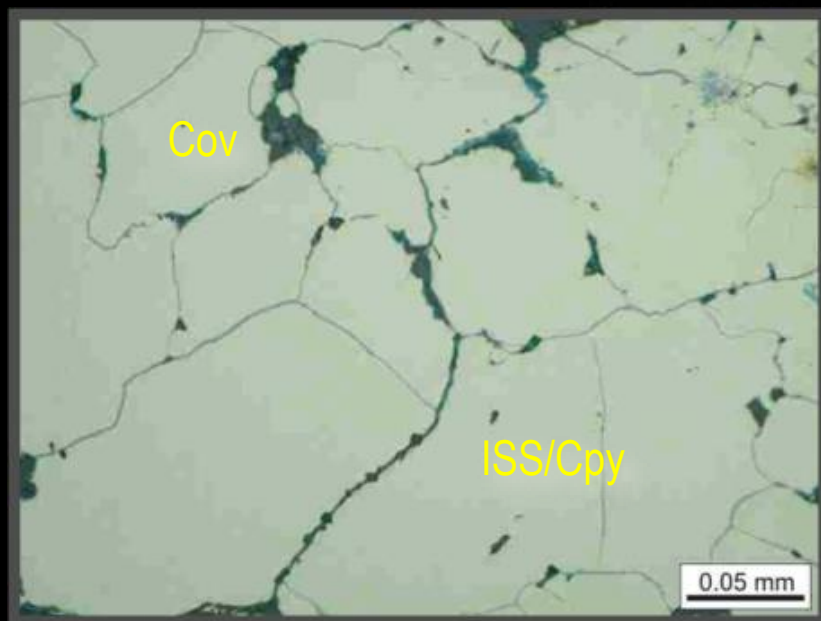
27.98 wt% Cu

0.63 wt % Co

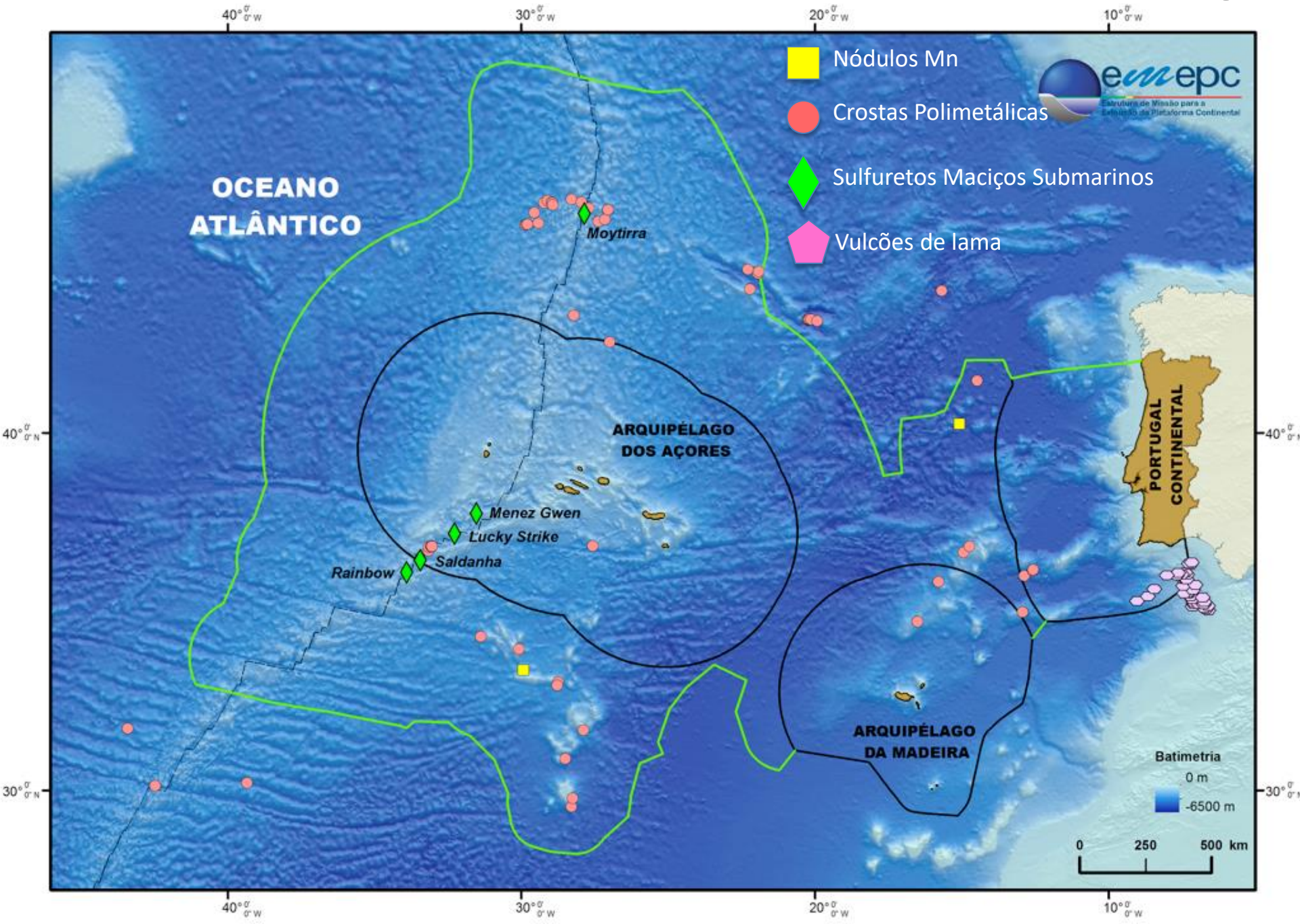
672 ppm Zn

6.3 ppm Au

n.d. Ni



Recursos Minerais Marinhos na Plataforma Continental Expandida de Portugal



Mineração Zero Não é Opção

- Se não é plantado, tem de ser minerado.
- A mineração é tão necessária como a agricultura ou as pescas – sim, é problemática, mas não mais problemática!
- Indústria e ambiente: queremos (e precisamos) ambos
- Mais de 7 biliões de pessoas para servir; muitos mais no futuro
- Mineração moderna já não merece má reputação

'Dirty Mining' é passado



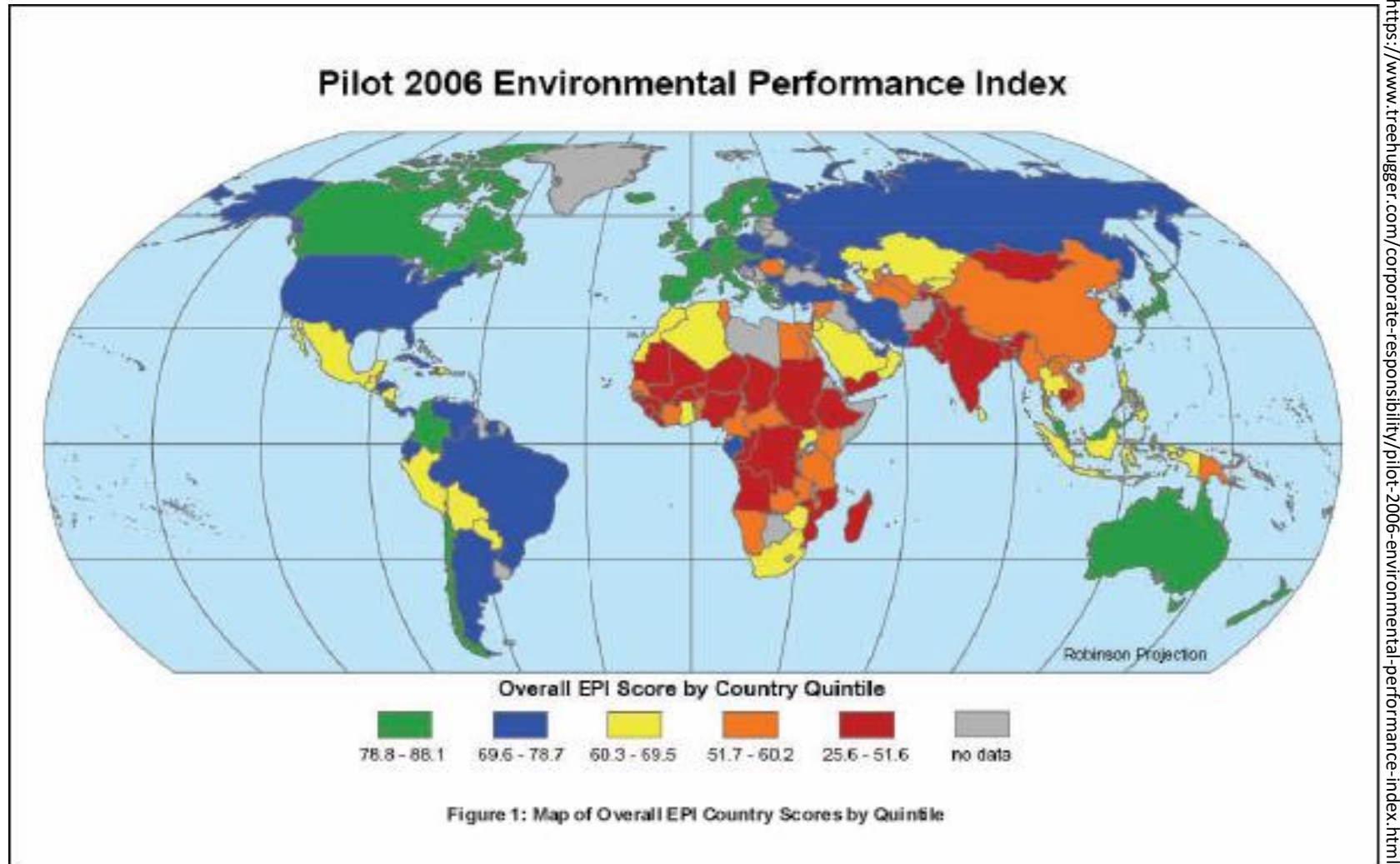
'Green Mining' é o presente



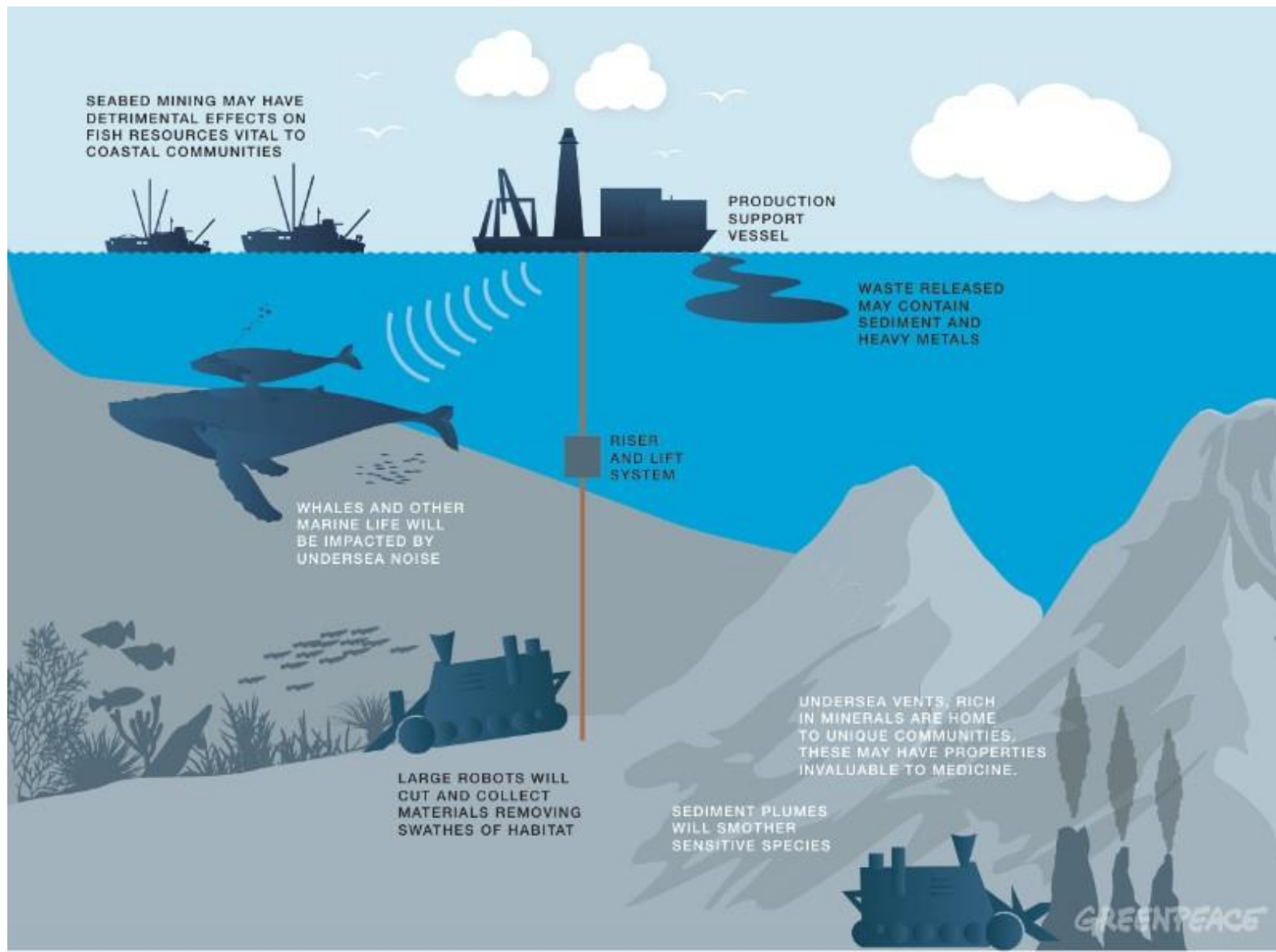
Fotos J Relvas



'Green Mining' é o presente



Ecosistemas marinhos e questões ambientais



Greenpeace



Deep Seabed Mining

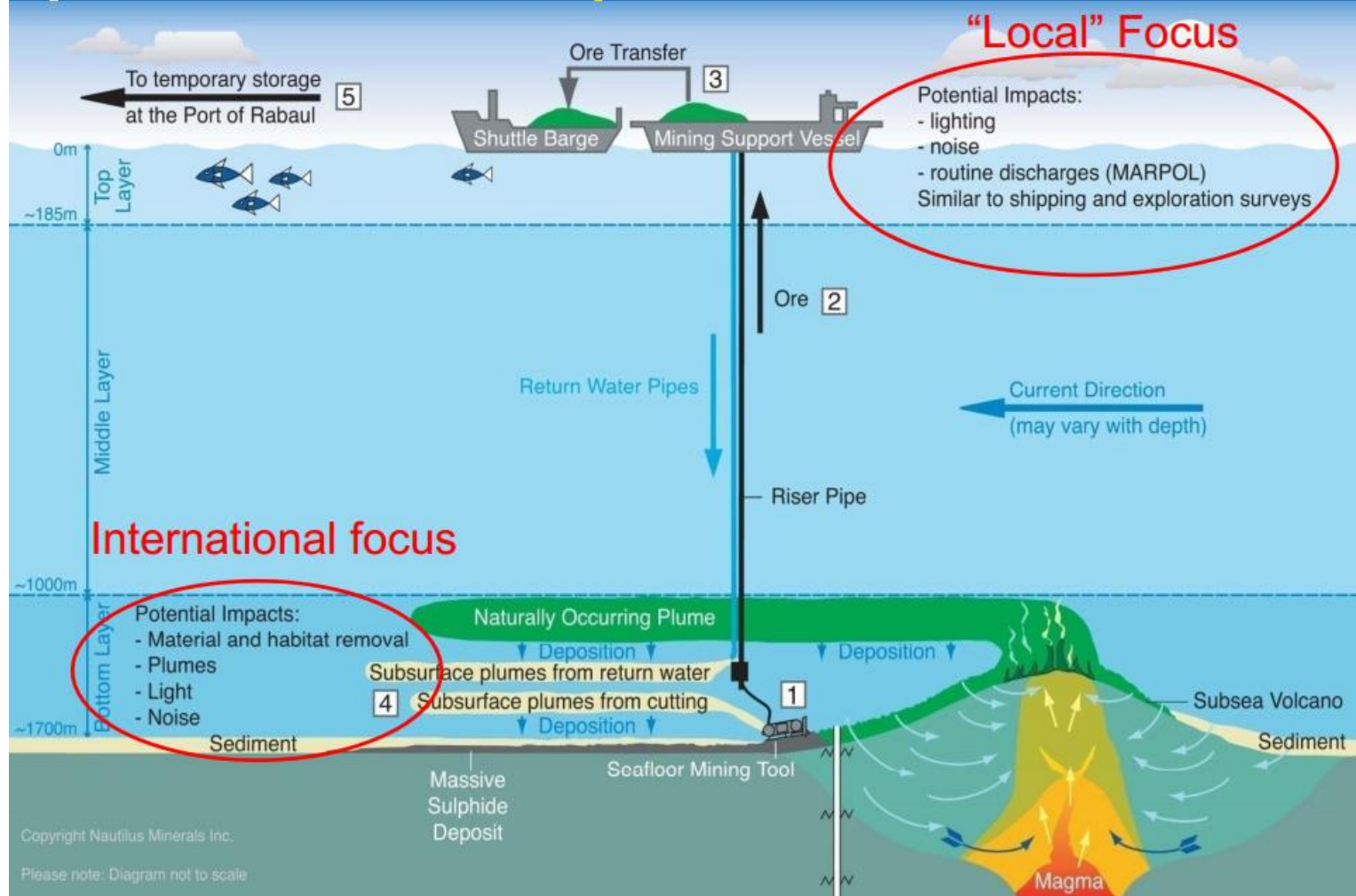
An urgent wake-up call to protect our oceans

July 2013

GREENPEACE

Nautilus Minerals Inc.

Potential Impacts (note: cartoon only)



Queremos oceanos limpos: temos de fazer bem!

- * A definição da regulação mineira pela International Seabed Authority é ainda um processo em curso.
- * Esta janela de tempo constitui uma oportunidade para que as ONGs e os cientistas contribuam para modelar uma boa regulamentação antes que a mineração efetivamente comece.
- * Avaliação detalhada de impacto ambiental, estratégias de mitigação, definição de *baselines*, monitorização de longo-termo.

Queremos oceanos limpos: temos de fazer bem!

Estudar (quais os impactos? Necessidade crítica de instalações-piloto submarinas)

Exequibilidade (custos e benefícios?)

Avaliação de risco (valerá a pena o risco?)

Pensar “ecofriendly” (não há planeta B; em caso de dúvida assumir pior cenário)

Se existir um benefício real para a sociedade, não houver impactos negativos irreversíveis e nenhuma melhor alternativa, vamos começar com muita precaução.



Obrigado pela vossa atenção