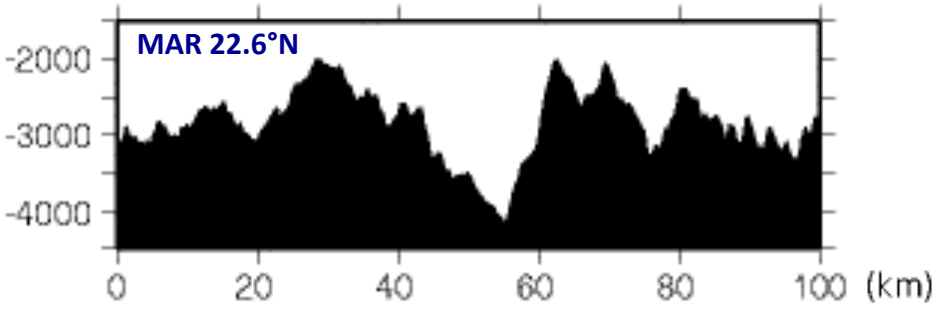
Submarine Cables

1875: Challenger Expedition (1st oceanographic campaign) finds evidence of the Mid-Atlantic Ridge…

Source: Buck & Poliakov (1998, Nature)

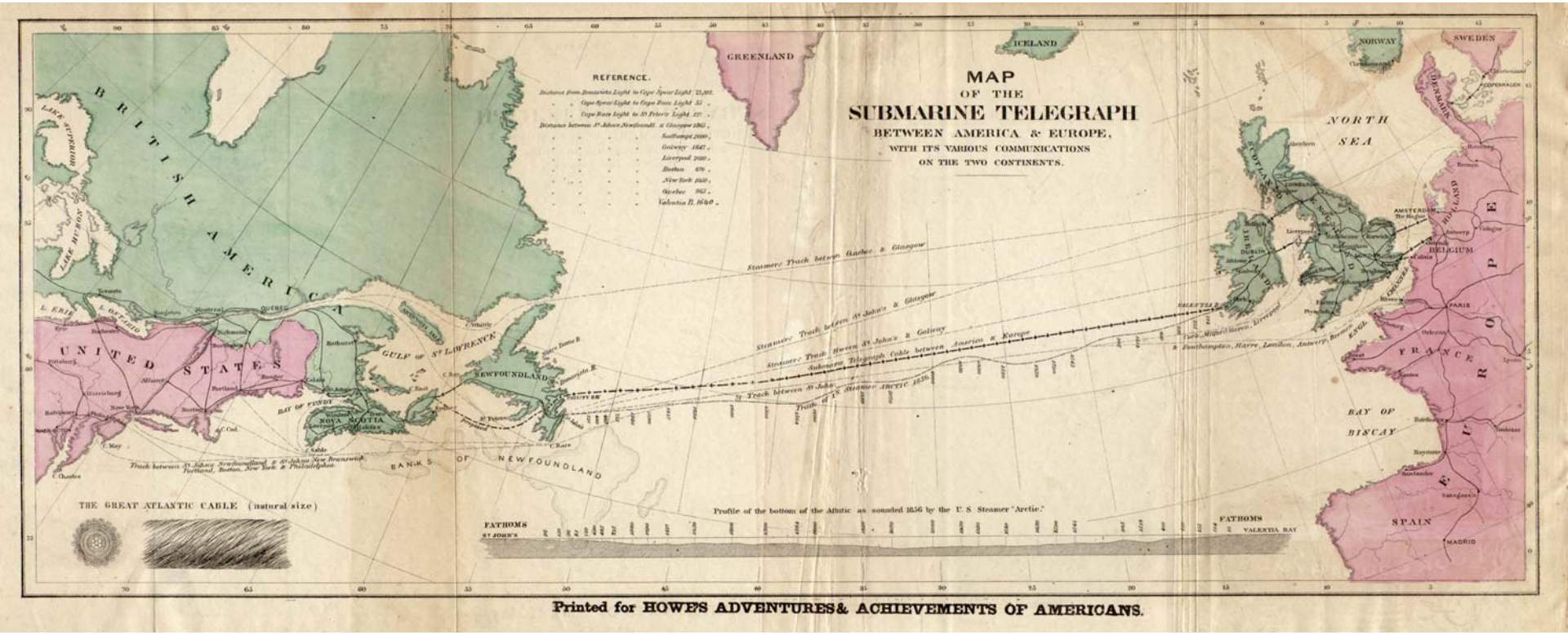


Source: Berann (1968) from Doel et al. (2006, J Hist Geog)

1901: global network of telegraph cables (that often failed)

http://industrialhistoryhk.org/submarine-cables-maps-1901-1991-worldwide-hong-kong-networks/

SUBMARINE CABLES

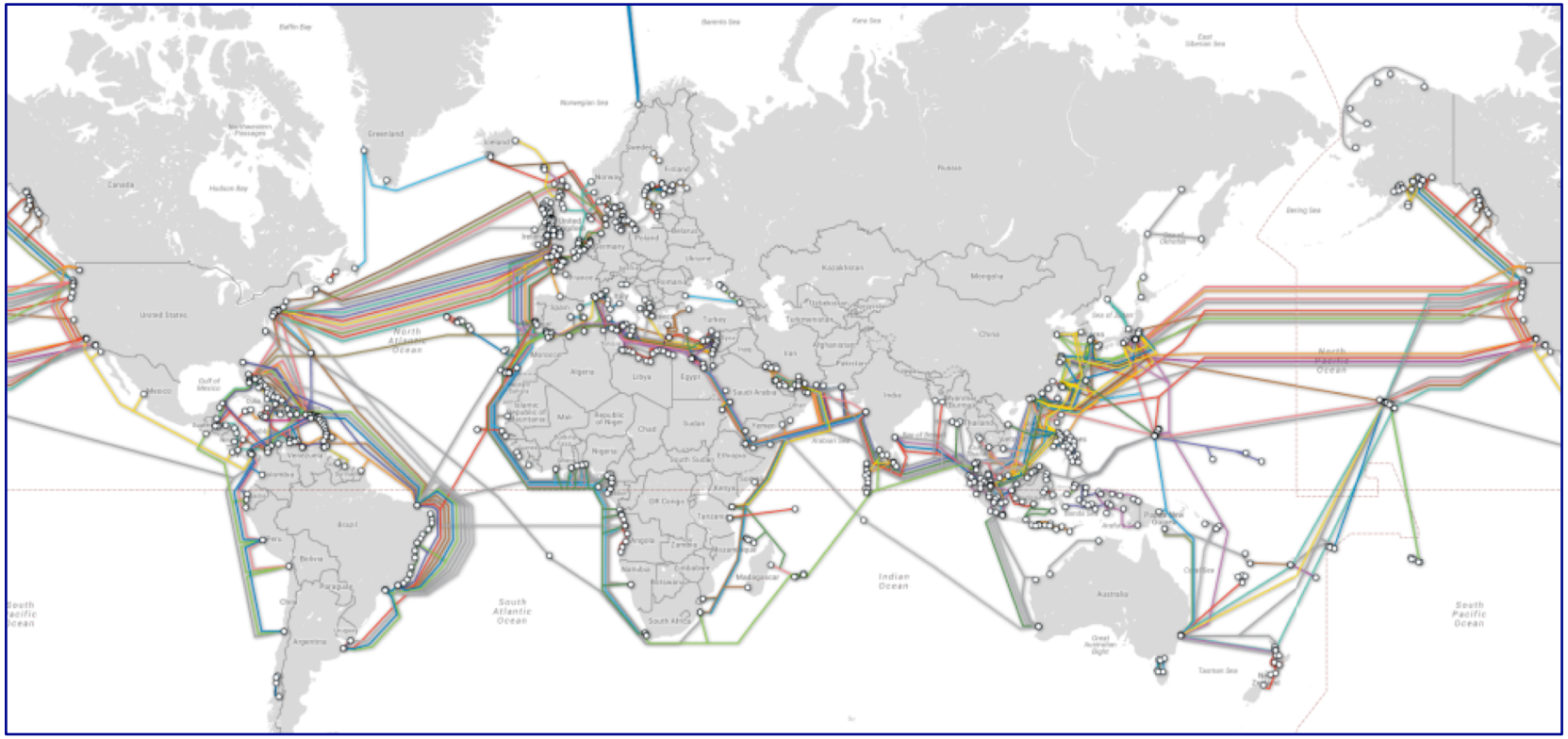


Data Transmission

- Satellites orbits 36.000 km
- Transmission time 0,250 sec
- 1000 megabits per second

- Transatlantic cable (Rome-NY about 7.000 km)
- Transmission time 0,065 sec
- Terabits per second

SUBMARINE CABLES



Data Transmission

- 1975/1980 - 45 Mb/s, repeaters every 10 km
- 1987 - 1.7 Gb/s, repeaters every 50 km
- 1990 - 2.5 GB/s, repeaters every 100 km
- 1992/2001 10 Tb/s, repeaters every 160 km
- Recent times 14 Tb/s

Reel-lay vessel

Plough system

Late 20th century – developments in cable (& pipeline) technology

1940s: cable technology adapted to oil pipelines ('Operation Pluto', France-UK)

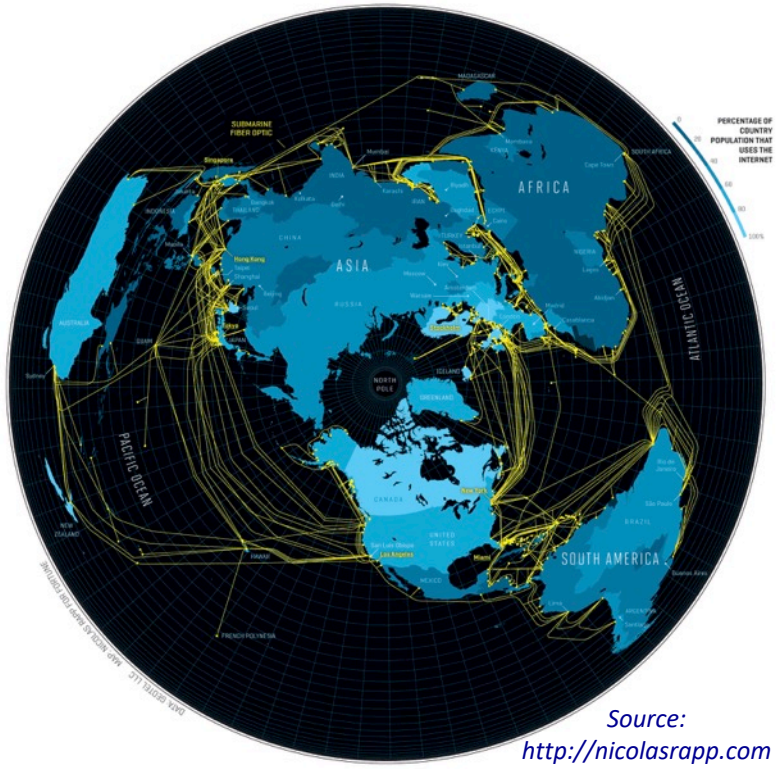
1956: 1st trans-Atlantic telephone cable (TAT-1)

1961: 1st undersea power cable (France-UK)

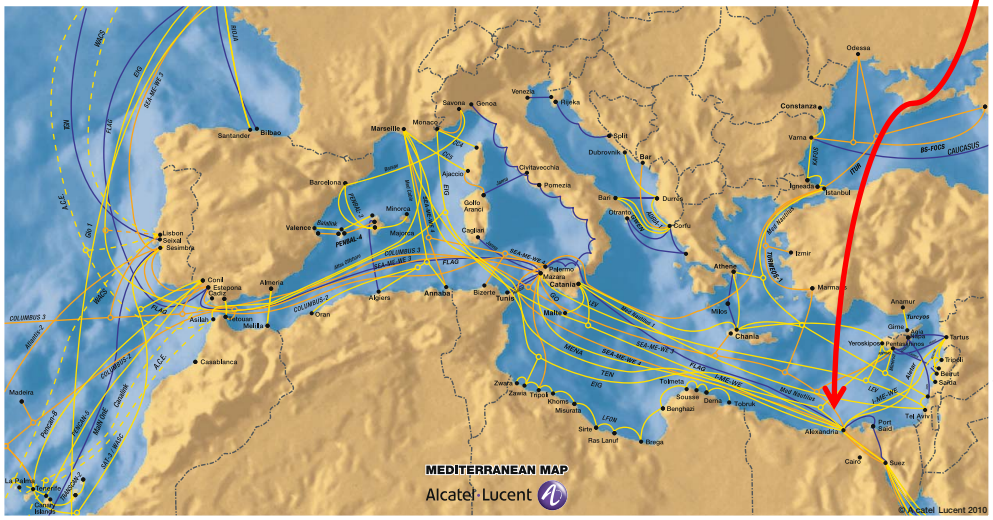
1988: 1st trans-Atlantic fibre optic cable (TAT-8)

21st century global network of optic cables

- Undersea fibre optic cables carry 99% of world telecommunications (= internet)
- Sources of damage: fishing and anchors (Egypt 2008)
- To protect them, cables (& some pipelines) are now buried - in water depths up to 2500 m!



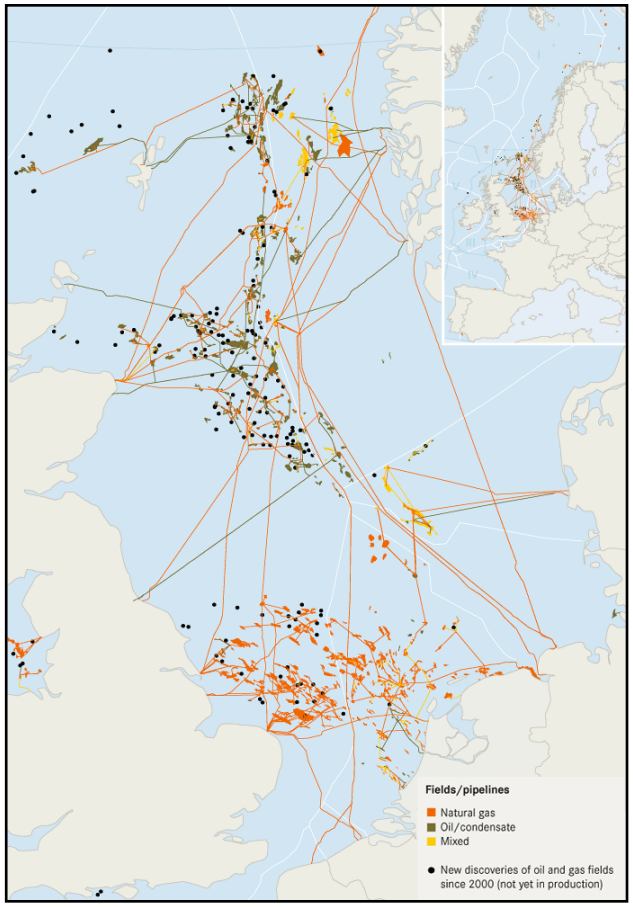
Source: http://nicolasrapp.com



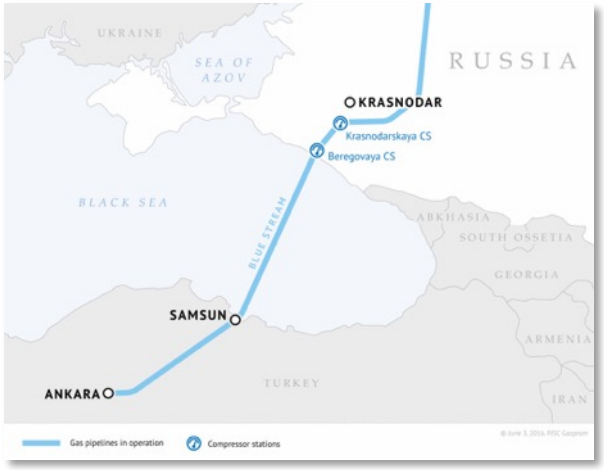
Cable (& pipeline) routes guided by **seabed mapping** (geomorphology + geology)

PIPELINES

- Connect offshore oil and gas field to land
- Connect islands to land
- Shorten the pipe route



(GALSI maximum WD 2824m)



(Blue Stream Maximum WD 2200m)

Trans Adriatic Pipeline (TAP)

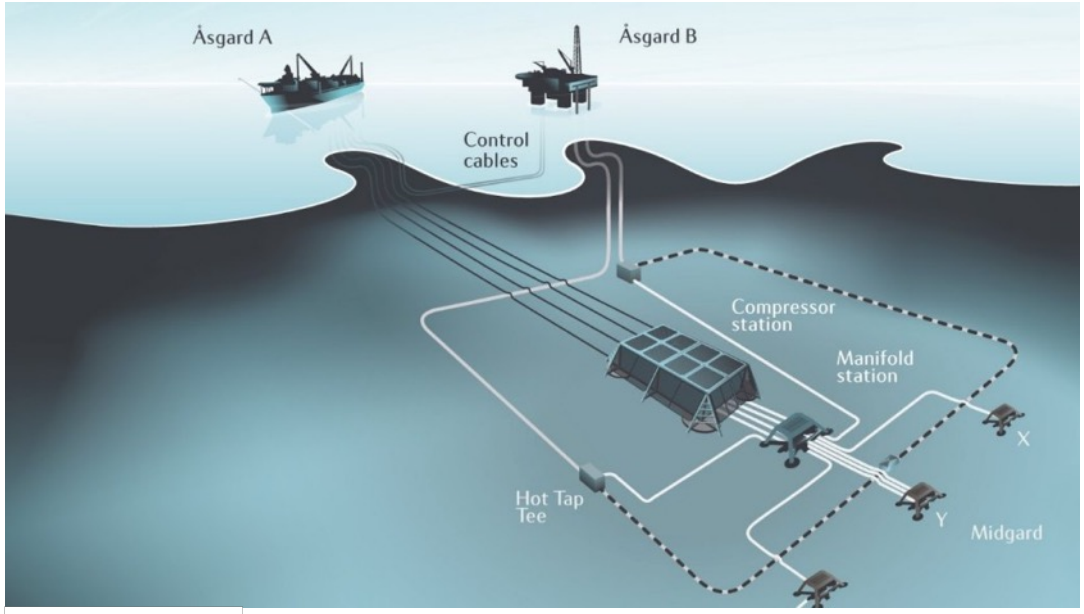
TAL
transalpine pipeline

https://www.youtube.com/watch?v=OFUERqu8tpQ

https://myzikk.com/2018/08/19/saipems-robots-set-to-cap-undersea-oil-blowouts/

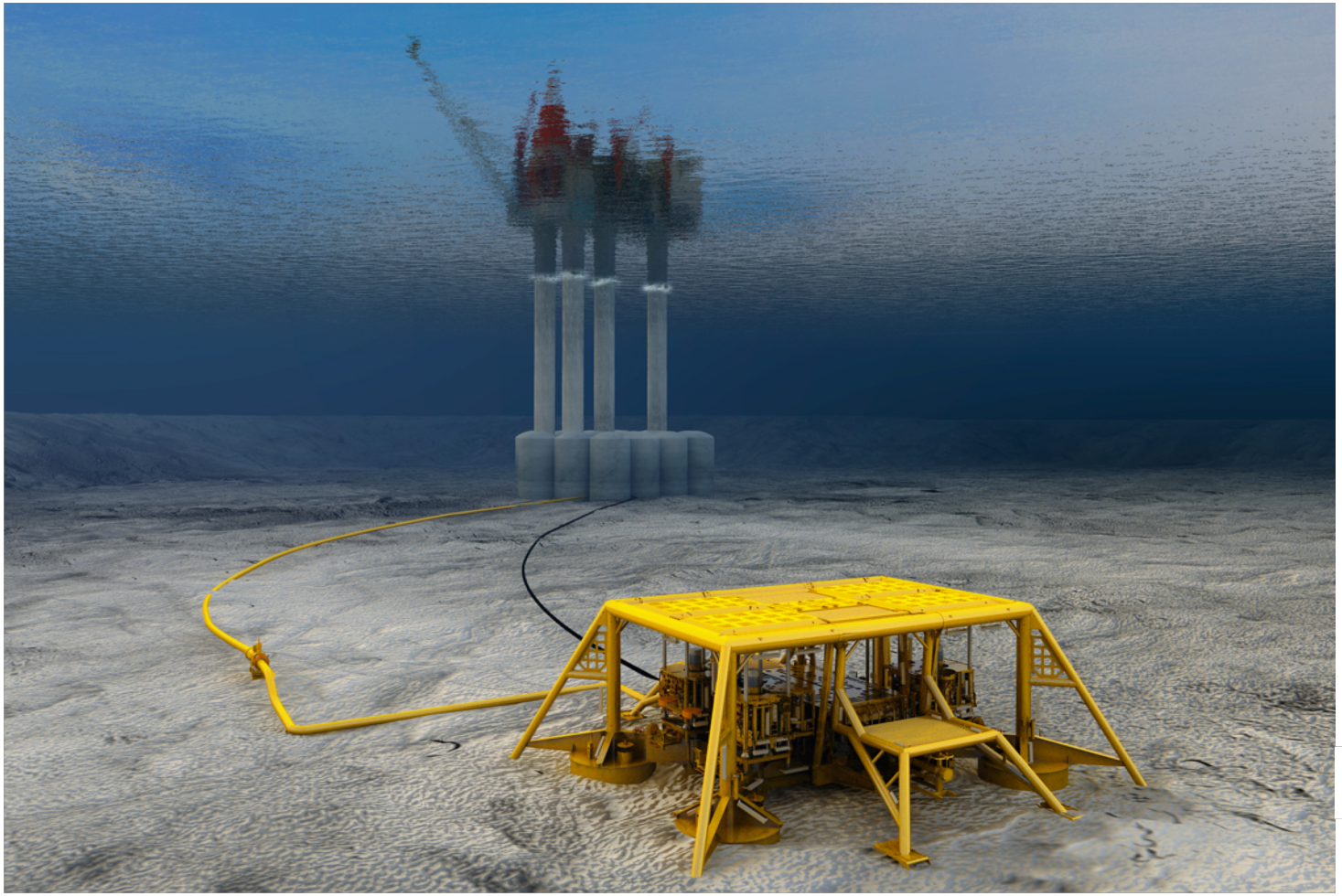
PLATFORMS FOUNDATIONS and SUBSEA INSTALLATION

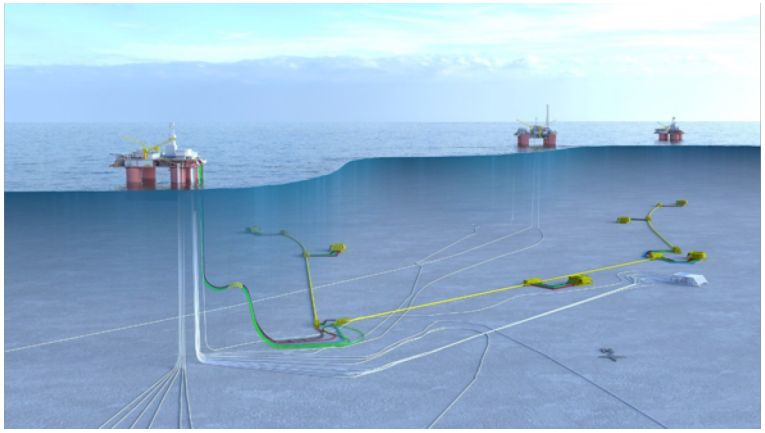
Mikkel (Norway)

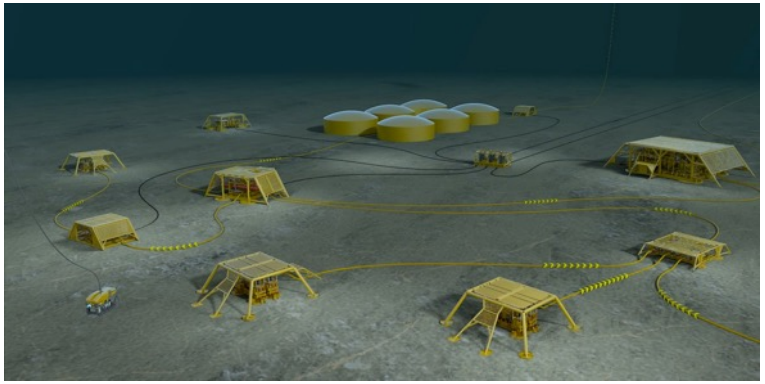


Statoil

DrillingFormulas.Com







Subsea installations

Åsgard Statoil subsea installation (Norway)
https://www.youtube.com/watch?v=GIu8U3XHXpE

Seabed Mapping – an offshore service industry

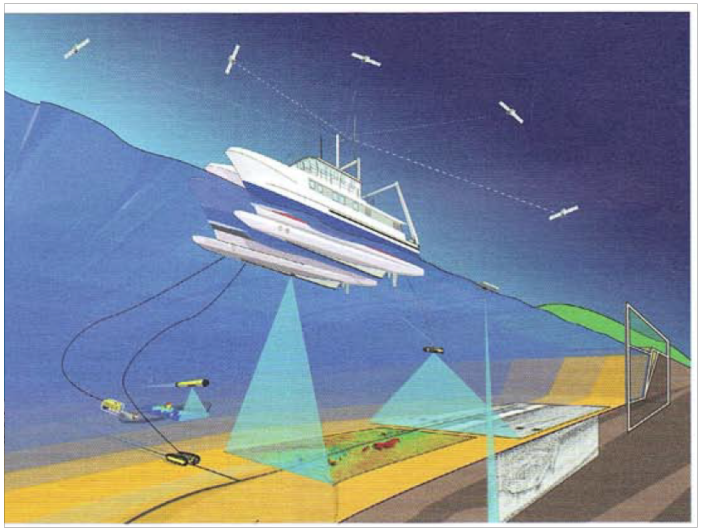
Supports the siting and maintenance of seabed installations (cables, pipelines, wind farms, platforms…)

- Multibeam & sidescan sonar bathymetry
- Subottom profiling (seismic)
- Magnetic measurements

remote methods

- Sediment sampling (coring and grabs)
- Remotely Operated Vehicles (ROVs)

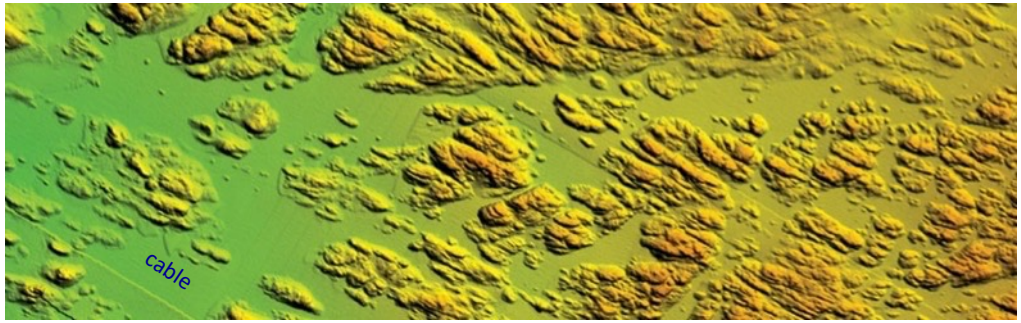
direct methods



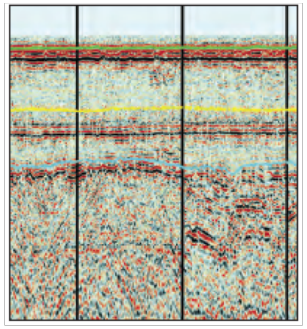
Source: downloads.n-o-s.eu/partners/mmt-ab/

Source: www1.gardline.com

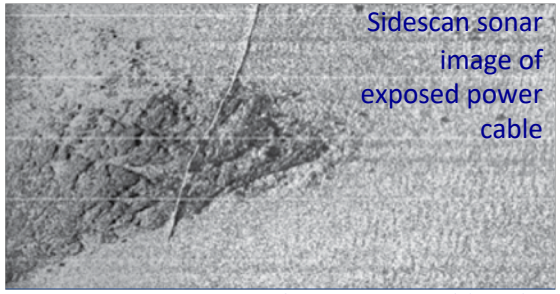
multibeam sonar image

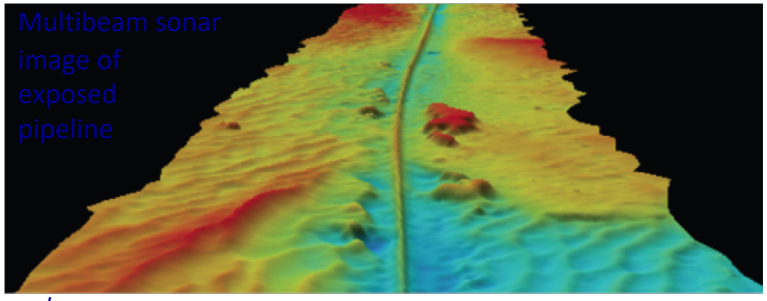


seismic profile



Cable plough





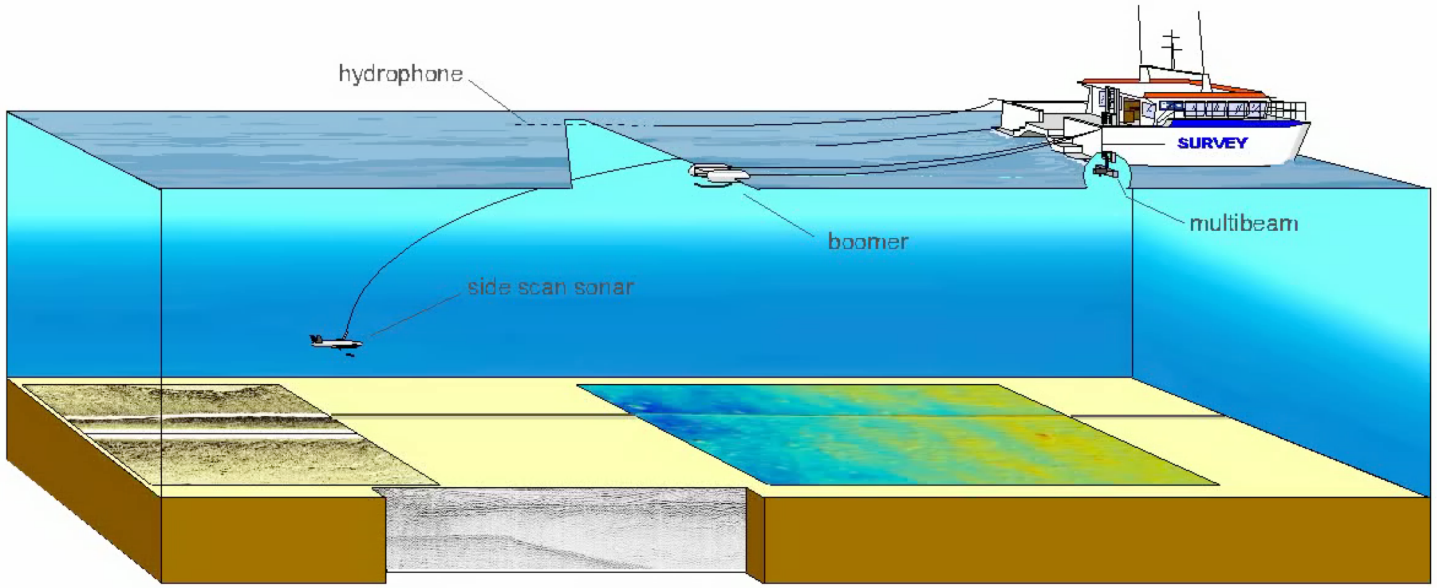
Source: www.osirisprojects.co.uk

Trenching ROV

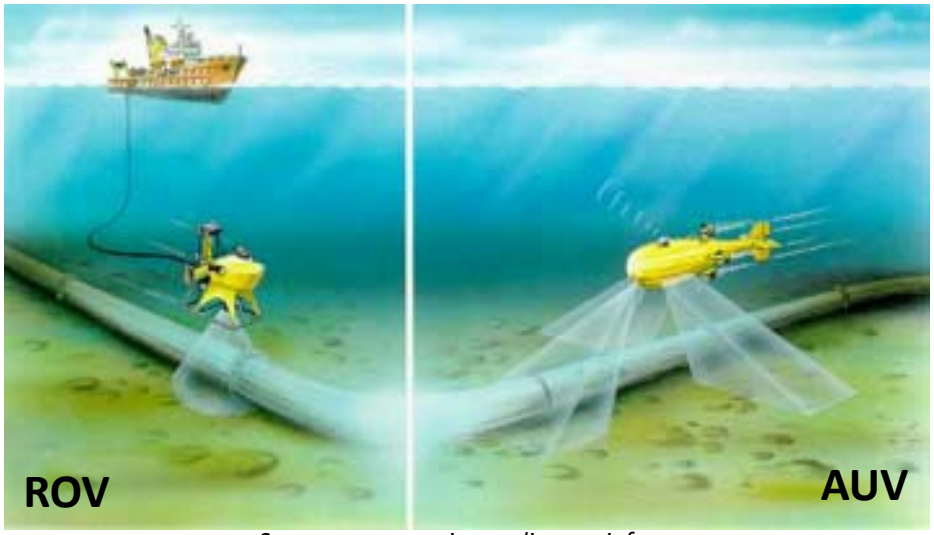
Sources: www.pharos offshoregroup.com

> OGS Explora has undertaken several commercial cable surveys

Seabed mapping - geophysical methods (swath & profile data)



Source: www.osirisprojects.co.uk

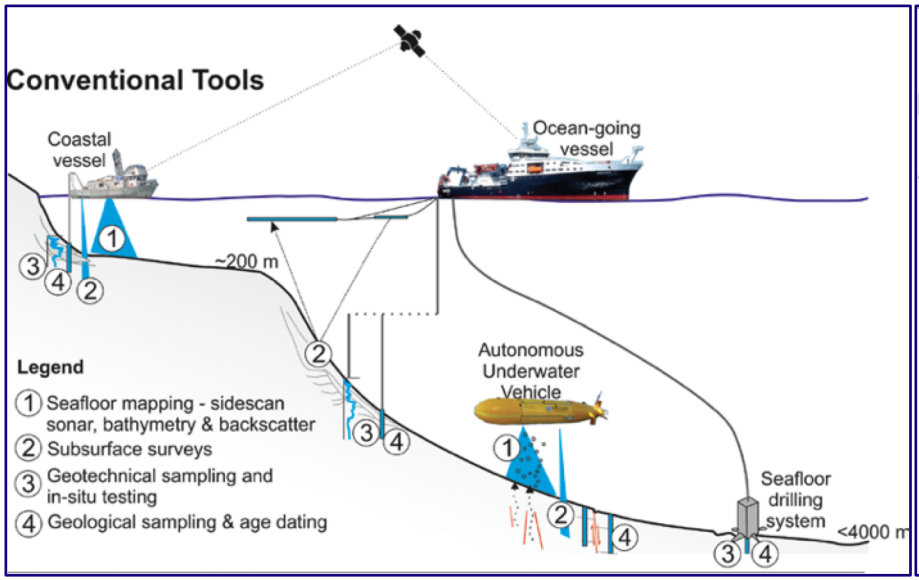


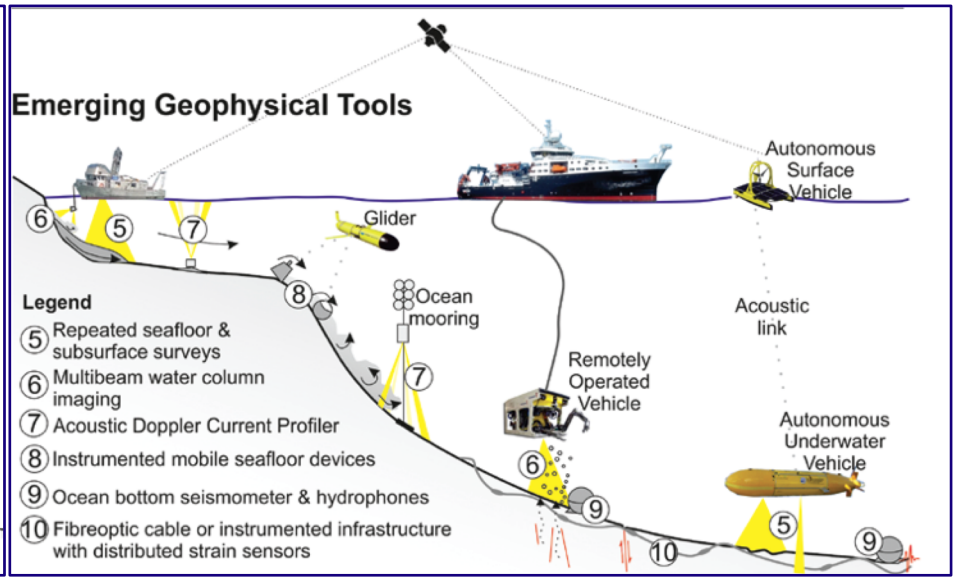
Source: www.ogniwa-paliwowe.info

Deployment to seabed of :

- Remotely Operated Vehicles (ROVs)
- Autonomous Underwater Vehicles (AUVs)

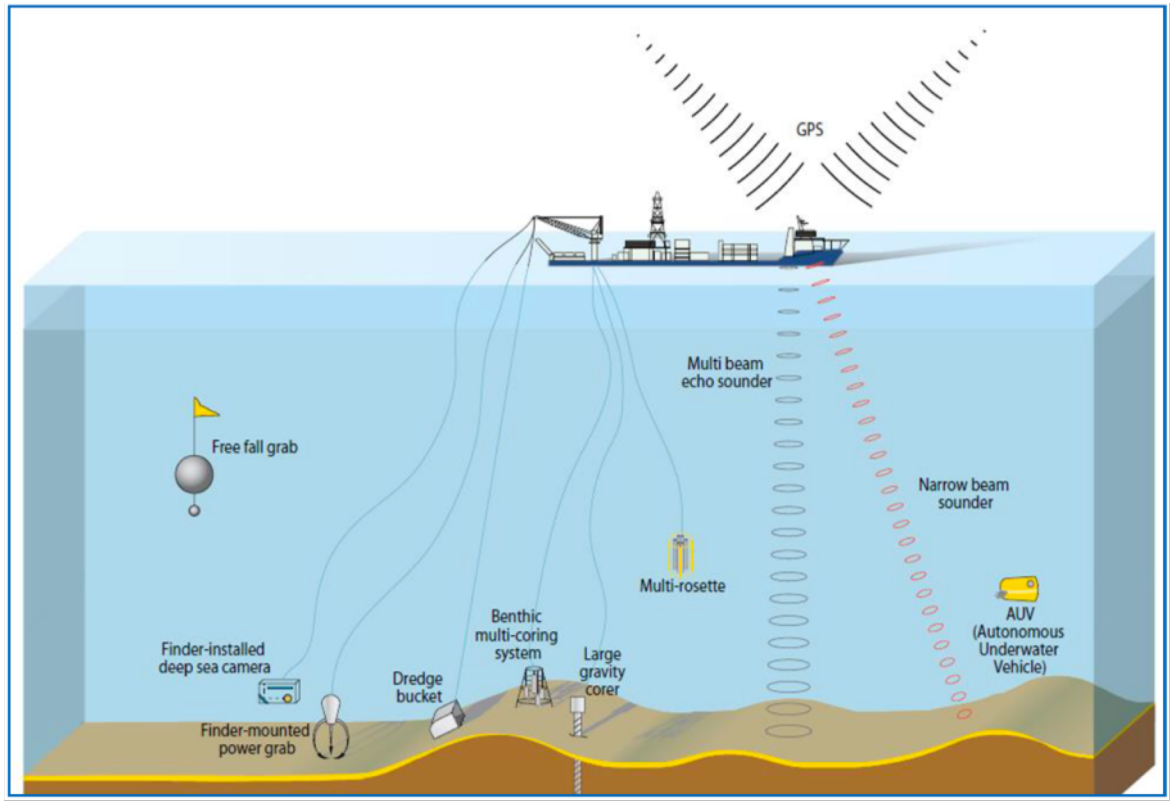
Multi-national offshore industries





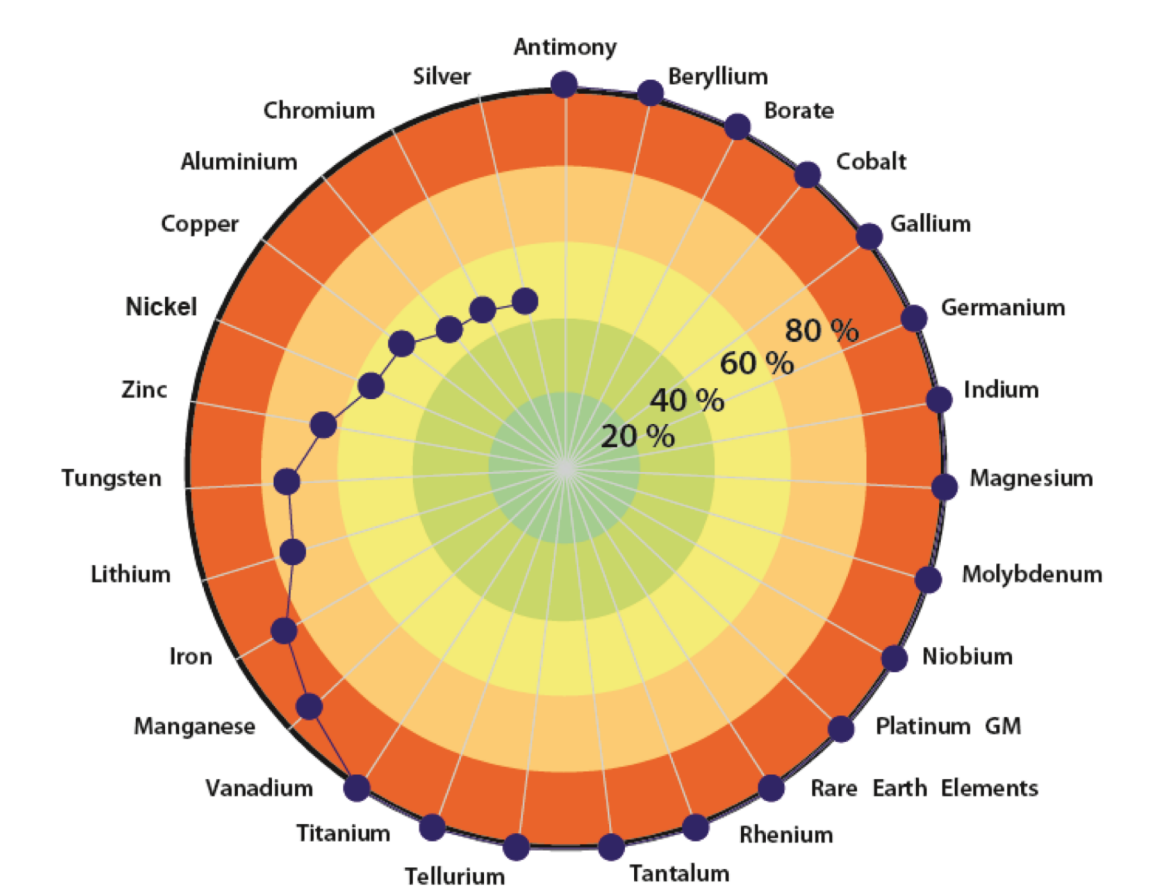
Clare et al., 2017, Near Surface Geophysics

DEEP SEA MINING



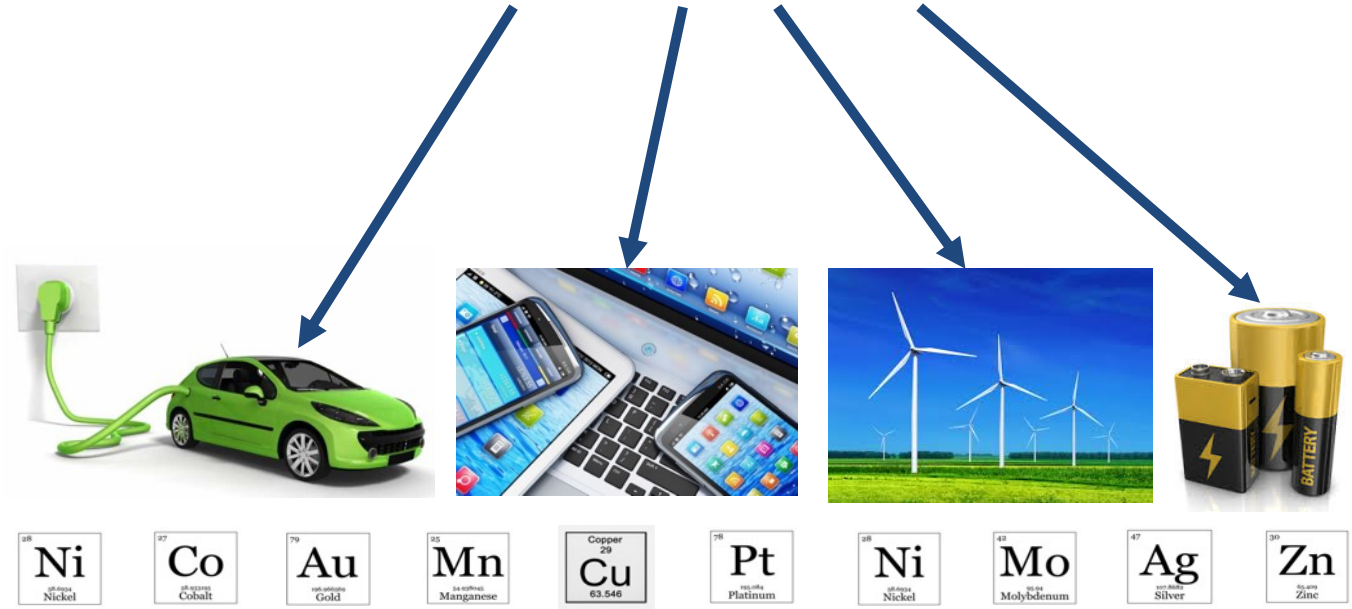
- Securing sustainable access to raw materials and strategic material reducing country's dependency from import.
- Developing advanced technology that could keep Italy as one of the leading exporters of advanced offshore exploration technologies, creating specialized jobs
- Identify possible industry alternative for companies operating in the oil & gas sector.

Source: Study to investigate the state of knowledge of deep-sea mining
Final Report under FWC MARE/2012/06 - SC E1/2013/04

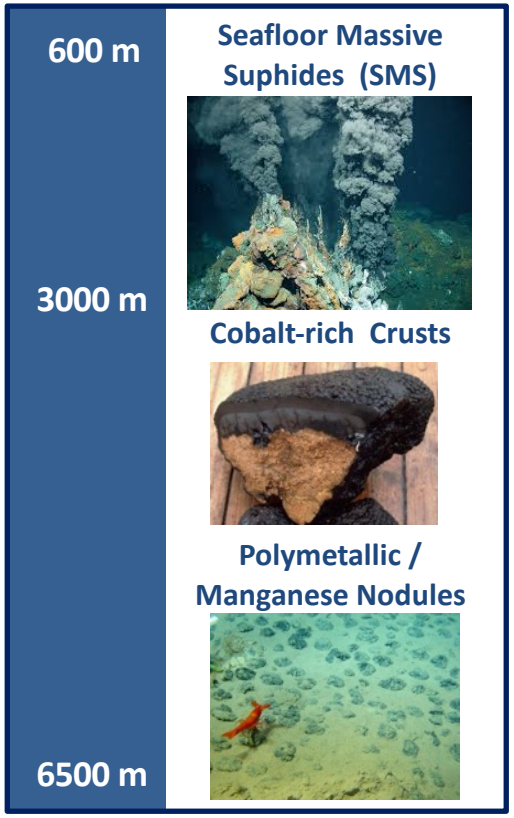


Import dependence of Europe in 2006, for selected critical raw materials, as published in a Report by the European Commission. Note that the value for Gallium is not reliable, due to significant changes for different years.

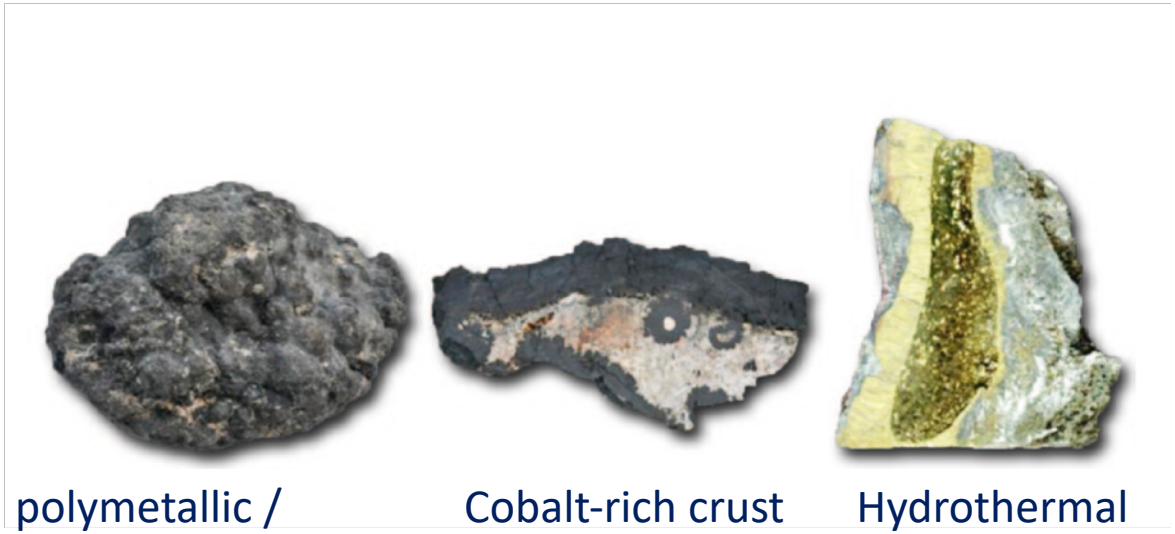
Sustainable and strategic sourcing of minerals for energy production and consumption.



- Risorse minerarie i progressiva riduzione in tutte le miniere terrestri (Australia, Africa, Sud America)
- Incremento demografico mondiale porterà ad ulteriore aumento richieste
- Fondali oceanici (>4000 m) estremamente ricchi di risorse minerarie (noduli manganese, cobalto, indio) oltre a molti metalli rari e preziosi.
- Queste risorse sono in aree oceaniche aperte al di fuori delle giurisdizioni nazionali
- L'autorità internazionale che eroga le concessioni è la International Seabed Authority
- Molti paesi sono già in fase esplorativa: USA, Germania (in modo molto attivo), Francia, Giappone, Russia e Belgio.
- Le concessioni esplorative dovrebbero essere riaperte nel 2018



Three types of mineral resources of the deep sea



polymetallic / Manganese nodule

Cobalt-rich crust

Hydrothermal sulfides

Minerals in the Deep Sea (Polymetallic Nodules, Crusts, Sulphides)

1. 'Manganese' nodules

- 97% Mn-Fe hydroxides, 3% cobalt, copper, nickel, traces of platinum & tellurium
- up to 20 cm in diameter (size of potatoes to cabbages)
- concretions precipitated from seawater or pore waters *very very slowly* (1-3 mm/Myr)
- lie at seabed over vast areas (Pacific & Indian oceans), in depths > 4000 m

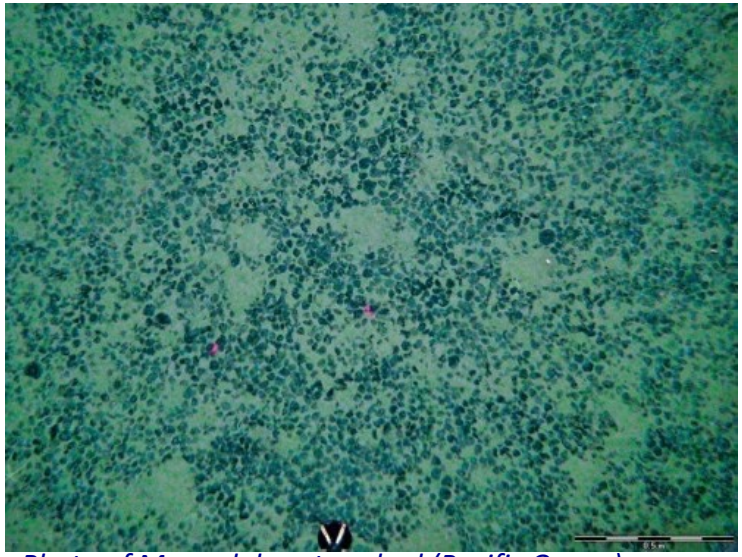
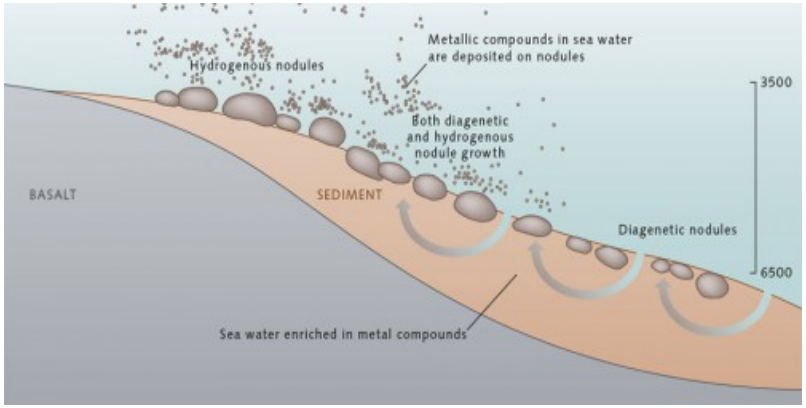
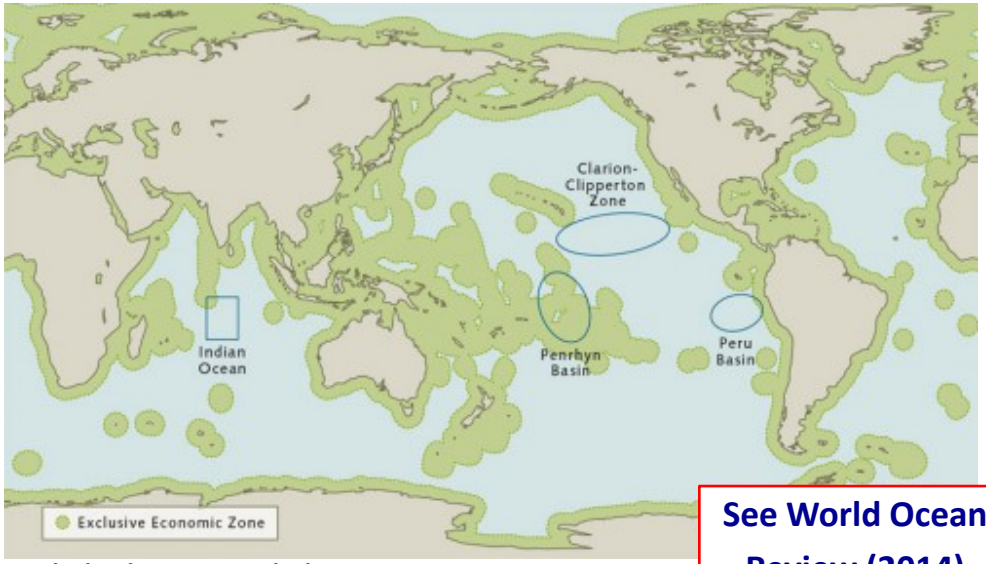


Photo of Mn nodules at seabed (Pacific Ocean)



Schematic of Mn nodules formation processes



Global Mn nodule concentrations

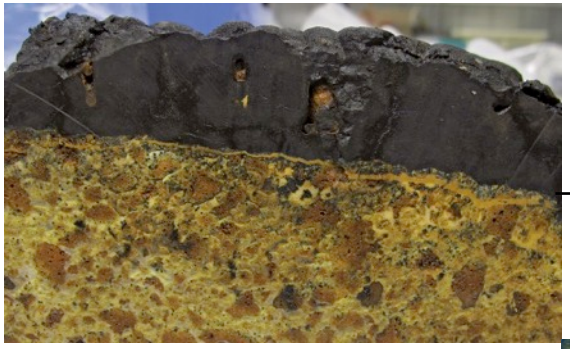
See World Ocean Review (2014)

Source for all: World Ocean Review (http://worldoceanreview.com)

Minerals in the Deep Sea

2. Cobalt crusts

- composition similar to Mn-Fe nodules, more cobalt and platinum
- also precipitates, formed very very slowly (millions of years)
- found on flanks of seamounts (currents), in water depths 1000-3000 m
- differing distribution than nodules, but overlap; mainly in Prime Crust Zone

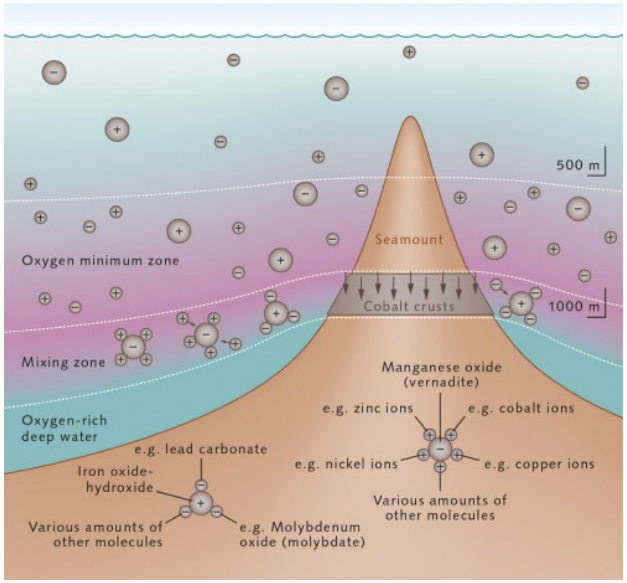


crust (cms thick)

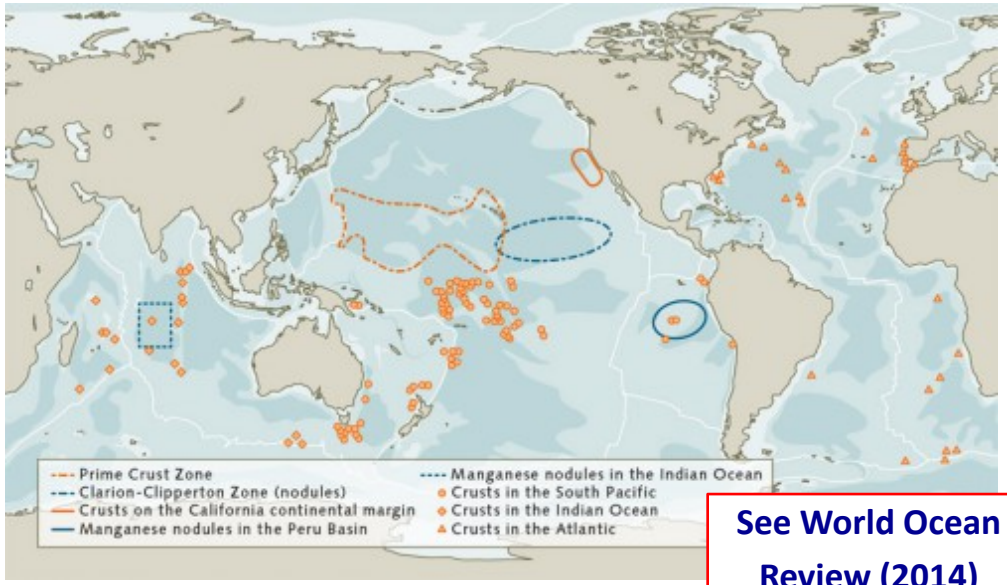
rocky substrate

Cross-section of cobalt crust (SW Pacific)

Single-celled organism at seabed on cobalt crusts



Schematic of cobalt crust formation on seamount flanks



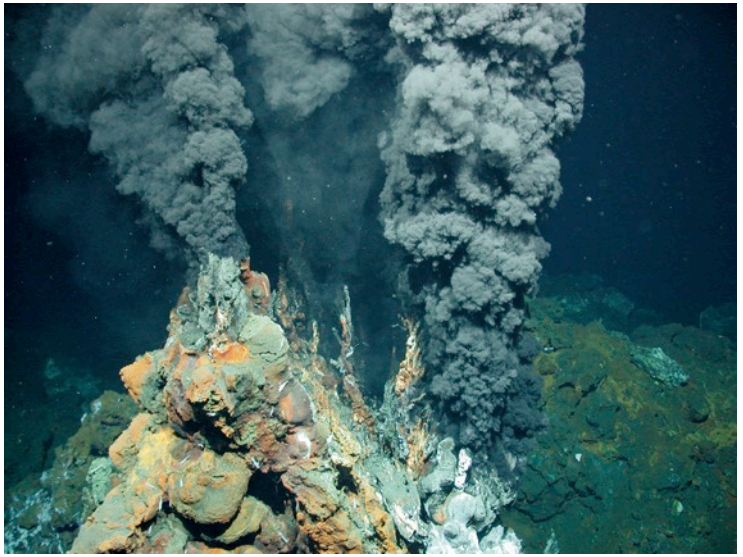
Source for all: World Ocean Review (http://worldoceanreview.com)

See World Ocean Review (2014)

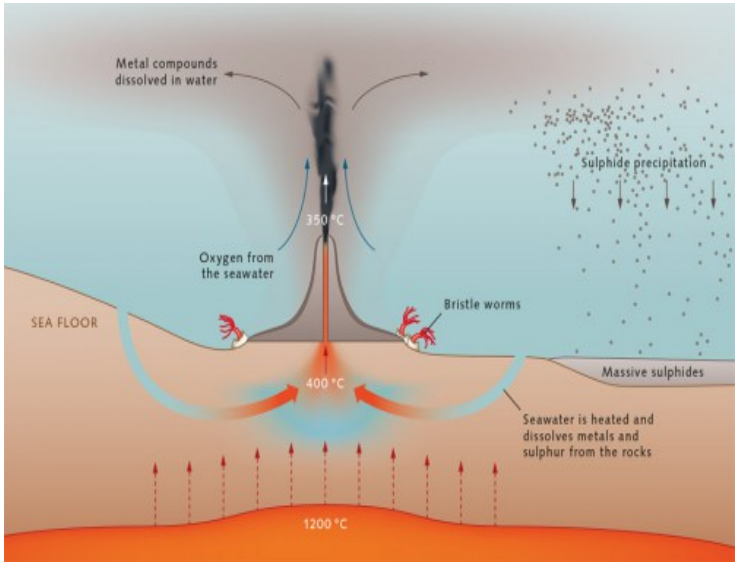
Minerals in the Deep Sea

3. Massive sulphides

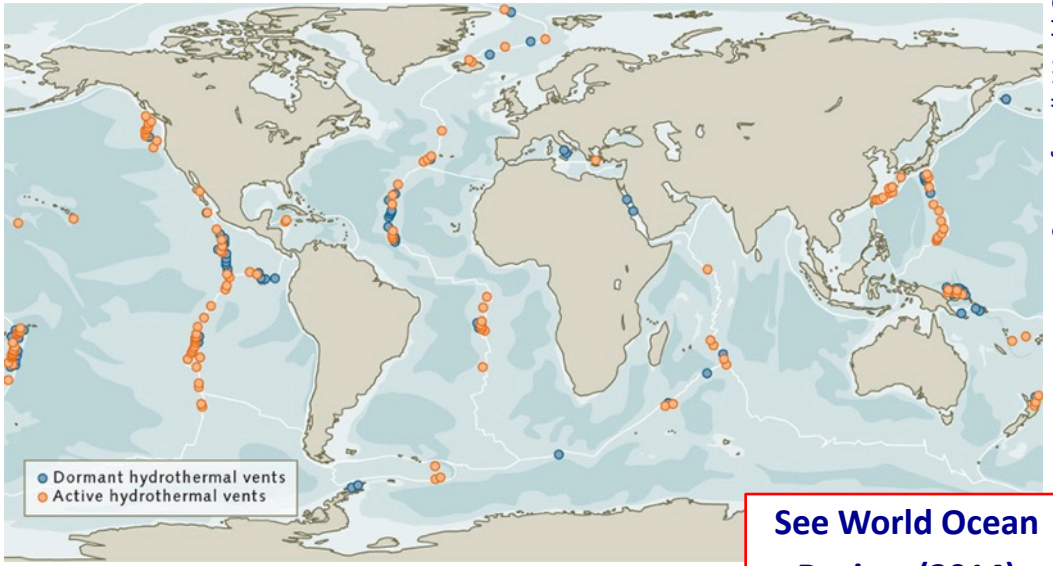
- Iron sulphides with copper, gold, zinc & silver
- Sulphides and other metals precipitate from seawater near volcanoes
- 'Black smokers' discovered in 1978 – hydro-thermal vents (metal-rich fluids up to 400°C)
- Found in areas of recent and present volcanism, in water depths 500-4000 m (including offshore Italy)



Black smoker hydrothermal vent



Schematic of massive sulphide precipitation next to volcano



See World Ocean Review (2014)

Source for all: World Ocean Review (http://worldoceanreview.com)

Mining Deep Sea Minerals

Still in exploration phase

- 1960-70s: 'boom' - huge interest, 10^8 spent
- 1980-90s: 'bust' (prices fell)
- Today - prices are high again… and ability to map the seabed has significantly improved

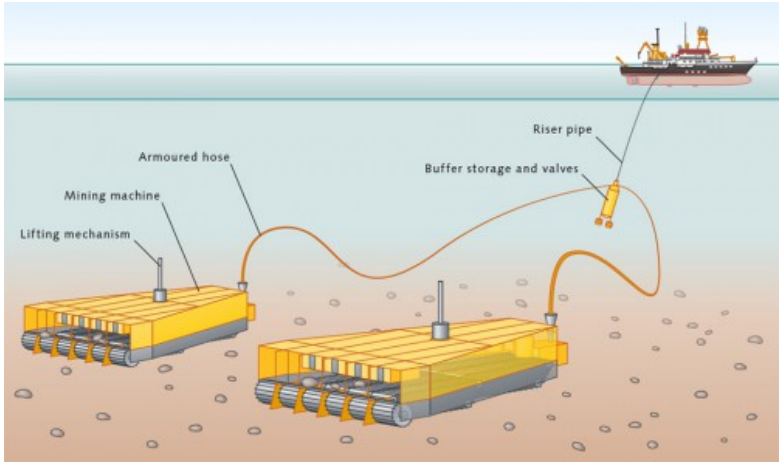
→ drove the signing of UNCLOS (1982) and the creation of the International Seabed Authority (ISA 1994) to regulate the 'boom'

- ISA issued 6 licences from 1984-2011; issued 21 licences in the last 5 years (all beyond EEZs, none being developed)

Precious metals (Mn, Co, Cu, Ni, Pt, Te, Au, Zn, Ar) just lying at seabed…

How do you pick them up?

- Nodules – various concepts proposed
- Impact on ecosystems?
- Crusts, how to detach from seabed?
- Main current interest is in sulphides…
  (relatively small volumes globally, but concentrated precipitates)

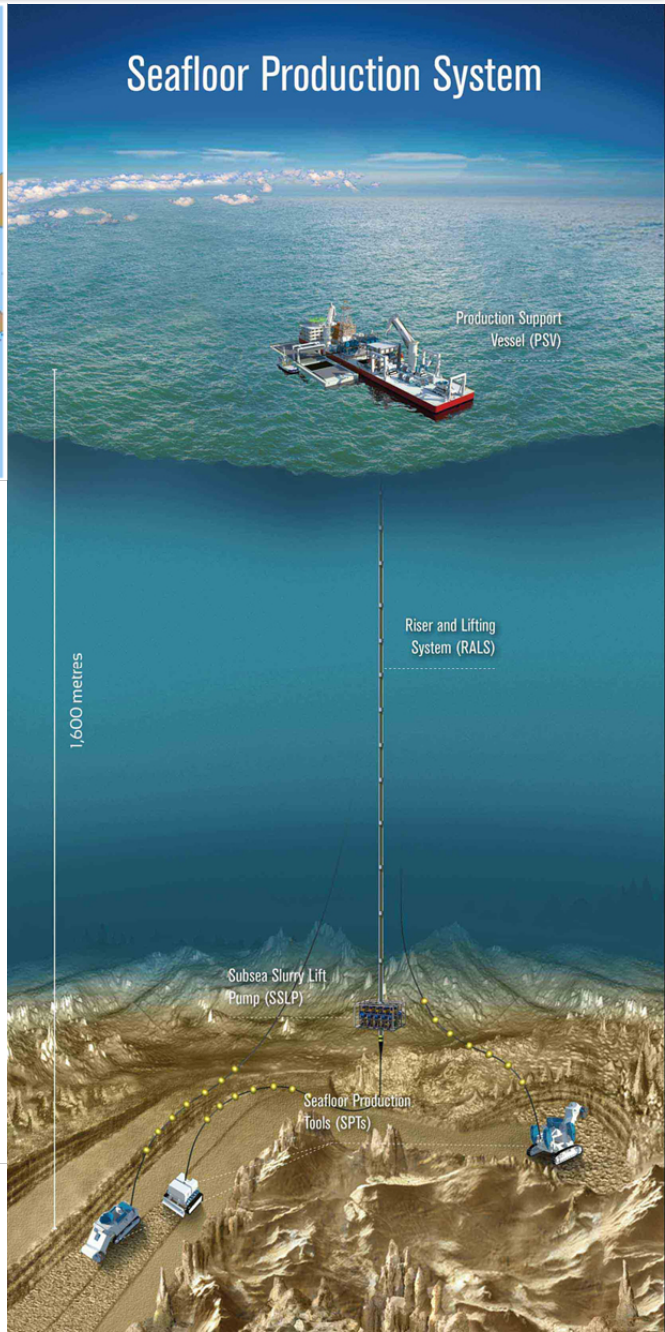


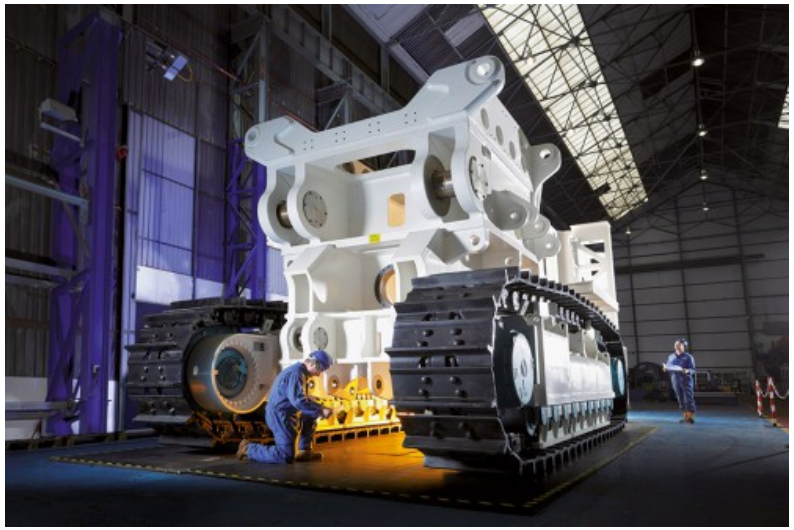
These machines have not been built !

Mining Deep Sea Minerals

Solwara 1 Project, Papua New Guinea

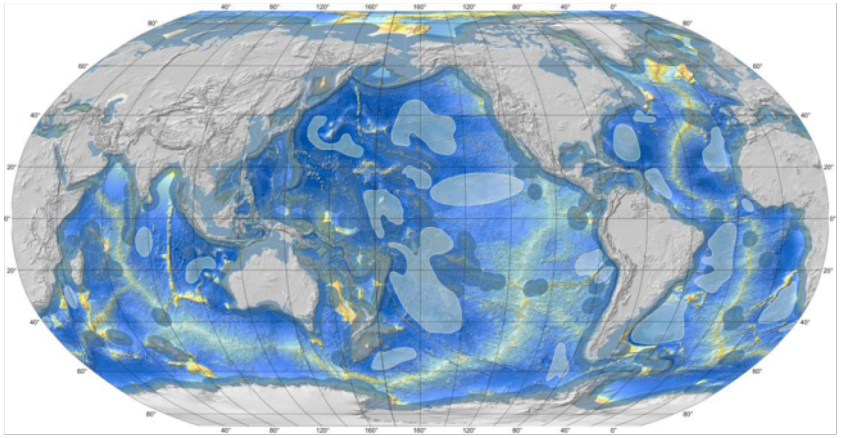
- 'world's first commercial seafloor copper-gold project from Seafloor Massive Sulphides (SMS)'
- Within EEZ of Papua New Guinea
- Launched in 2008, still on paper…
- now (re)scheduled for 2016



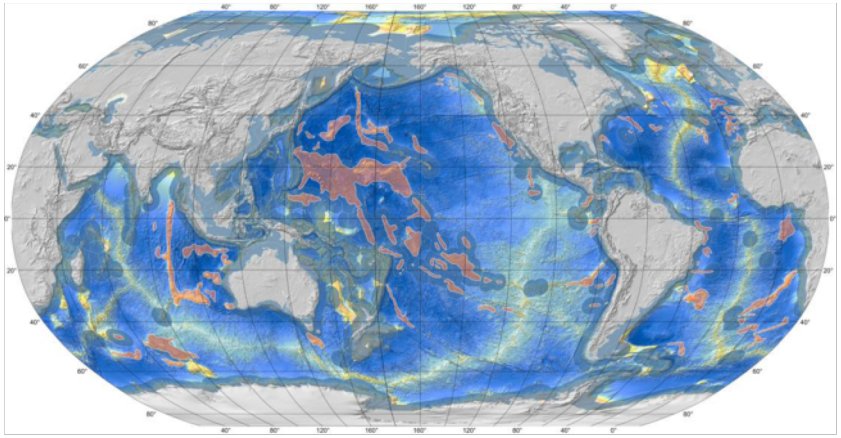


Chassis of seabed rock cutter (adapted cable trencher)

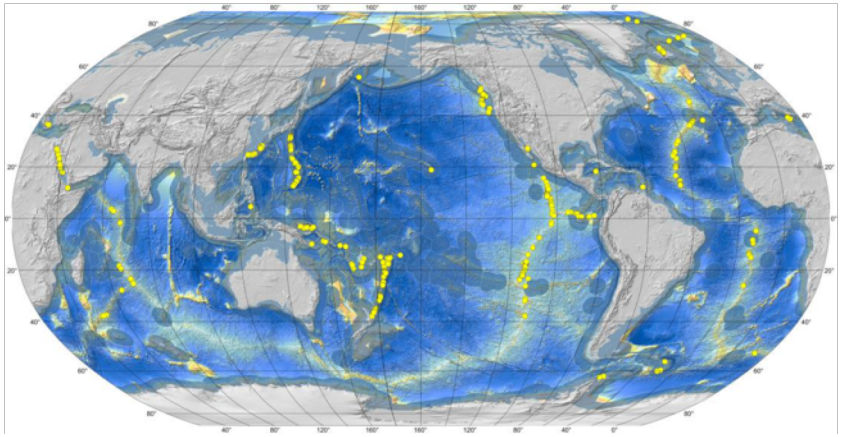
Sources: www.nautilusminerals.com



Area with highest manganese nodule potential

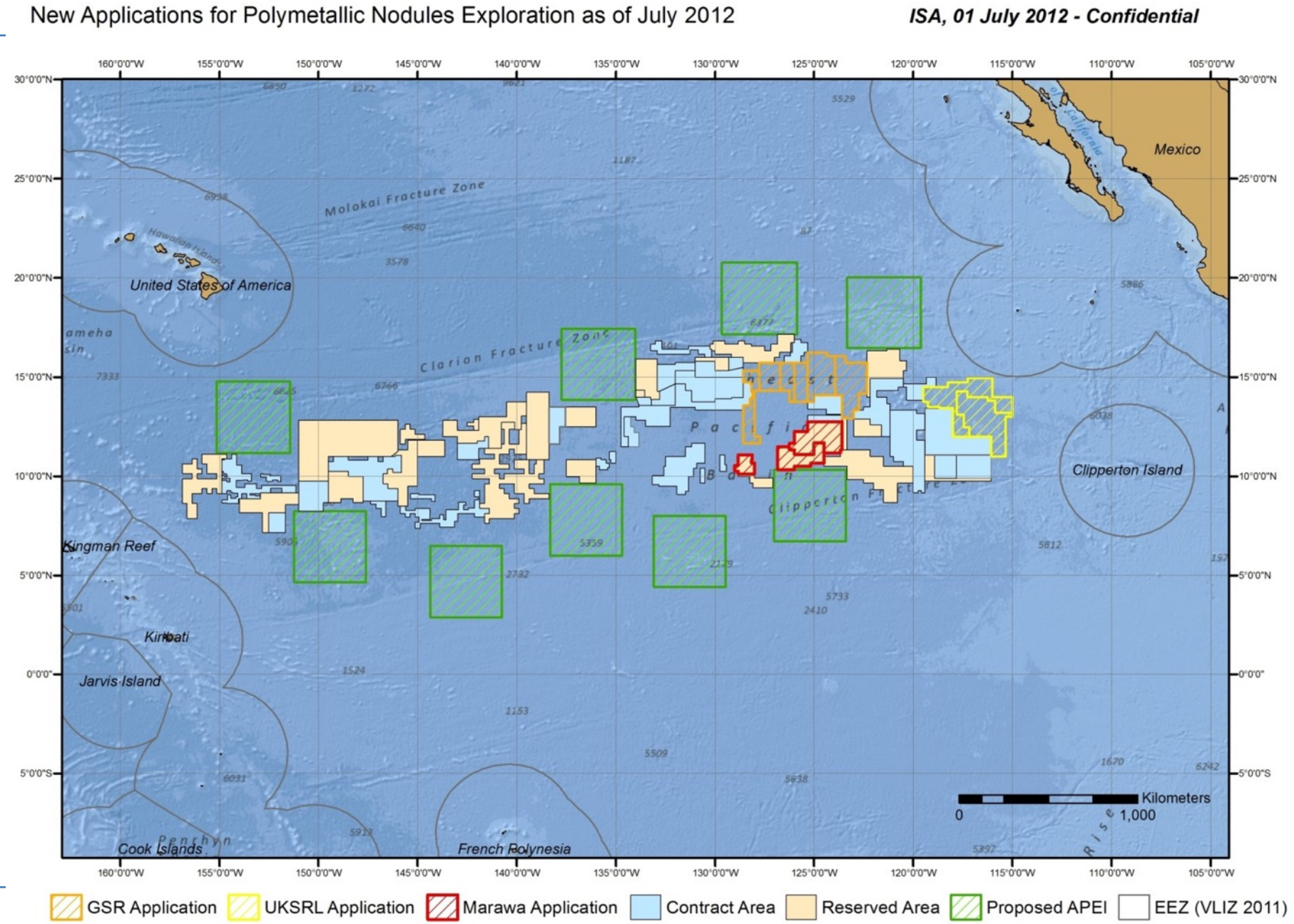


Area with highest ferromanganese crust potential

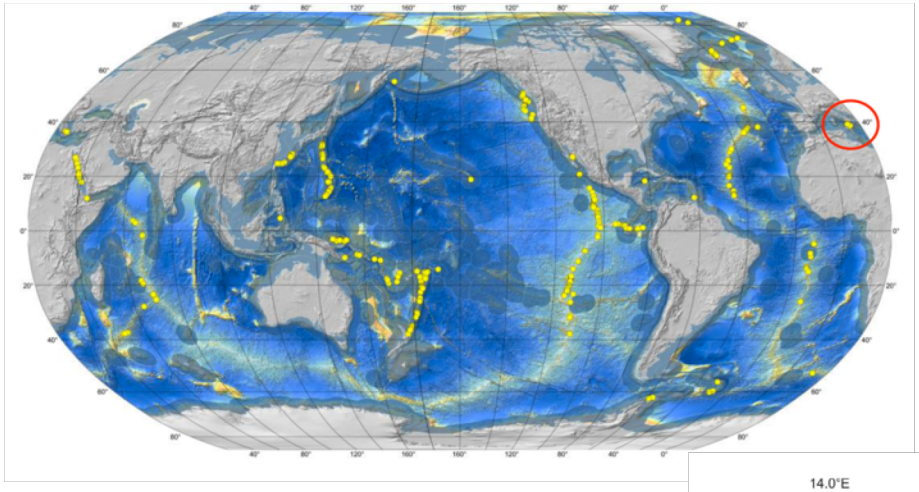


seafloor massive sulphide occurrences

Study to investigate state of knowledge of deep sea mining
Final report Annex 1 Geological Analysis
FWC MARE/2012/06 – SC E1/2013/0


New Applications for Polymetallic Nodules Exploration as of July 2012
ISA, 01 July 2012 - Confidential
Molokai Fracture Zone
Clarion Fracture Zone
Clipperton Fracture Zone
Hawaiian Islands
United States of America
Mexico
Clipperton Island
Kingman Reef
Kiribati
Jarvis Island
Cook Islands
French Polynesia
Penrhyn
Kilometers
0
1,000
GSR Application
UKSRL Application
Marawa Application
Contract Area
Reserved Area
Proposed APEI
EEZ (VLIZ 2011)

Tyrrhenian Sea



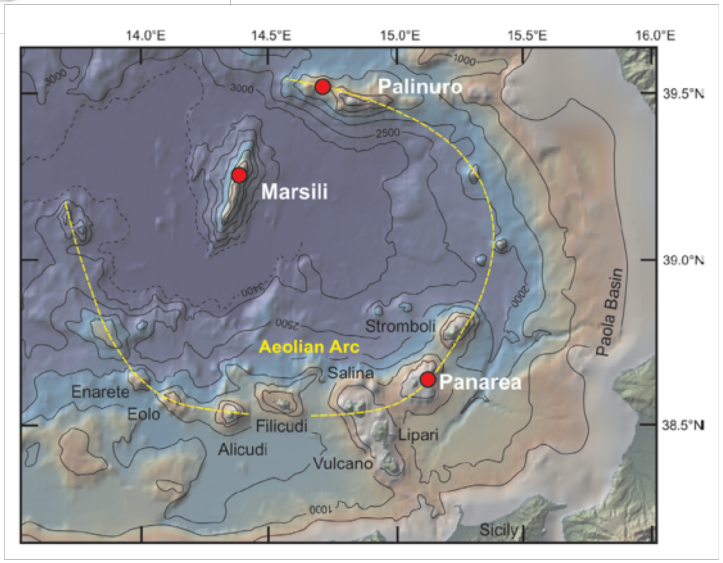
Seafloor massive sulphide occurrences (306 sites) cpnsidered in the Study to investigate state of knowledge of deep sea mining

Final report Annex 1 Geological Analysis
FWC MARE/2012/06 – SC E1/2013/04

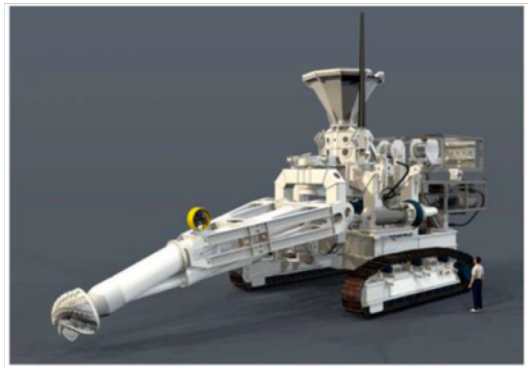
AN OPPORTUNITY FOR RESEARCH AND TECHNOLOGICAL DEVELOPMENT IN OUT BACKYARD

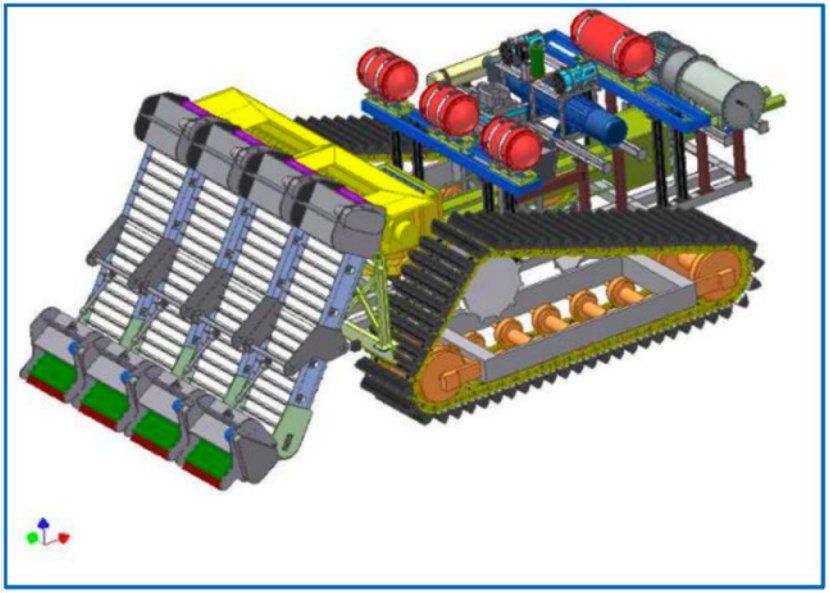
Submarine Shallow-water Hydrothermal Systems in Volcanic Arcs of the Tyrrhenian Sea.

Petersen et al., 2008. InterRidge News

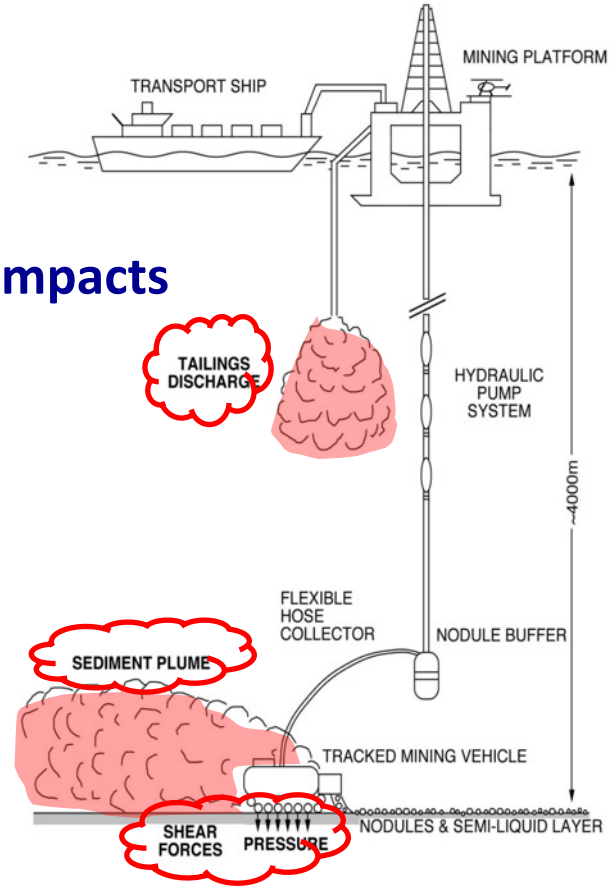


DEEP SEA MINING





Impacts



Source: Study to investigate the state of knowledge of deep-sea mining
Final Report under FWC MARE/2012/06 - SC E1/2013/04

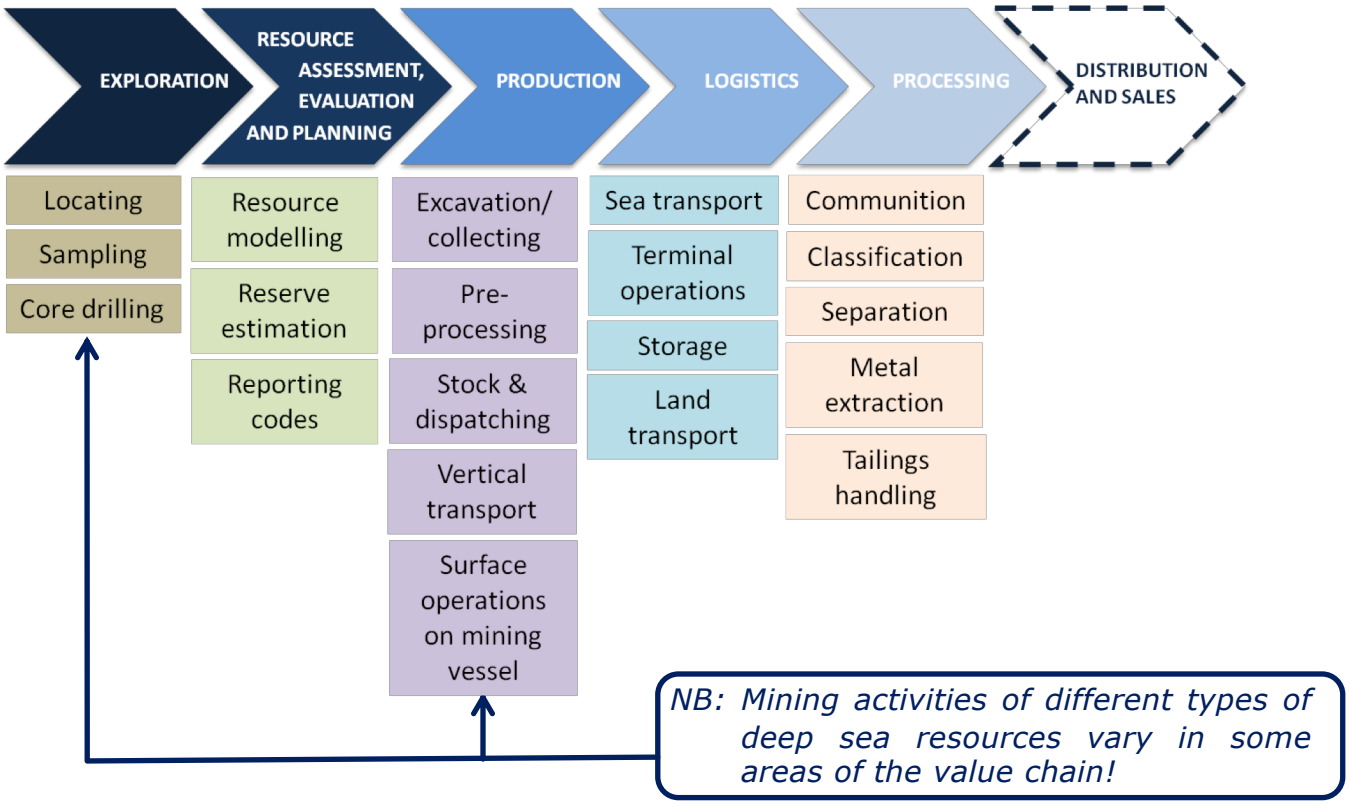
DEEP SEA MINING:
AN OPPORTUNITY FOR THE ITALIAN OFFSHORE INDUSTRY?

Marko Keber, Luca Ambrosio
Fincantieri Oil & Gas S.p.A., Trieste, Italy

Angelo Camerlenghi, Federica Donda, Umberta Tinivella, Valentina Volpi
OGS – Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Borgo Grotta Gigante, Italy

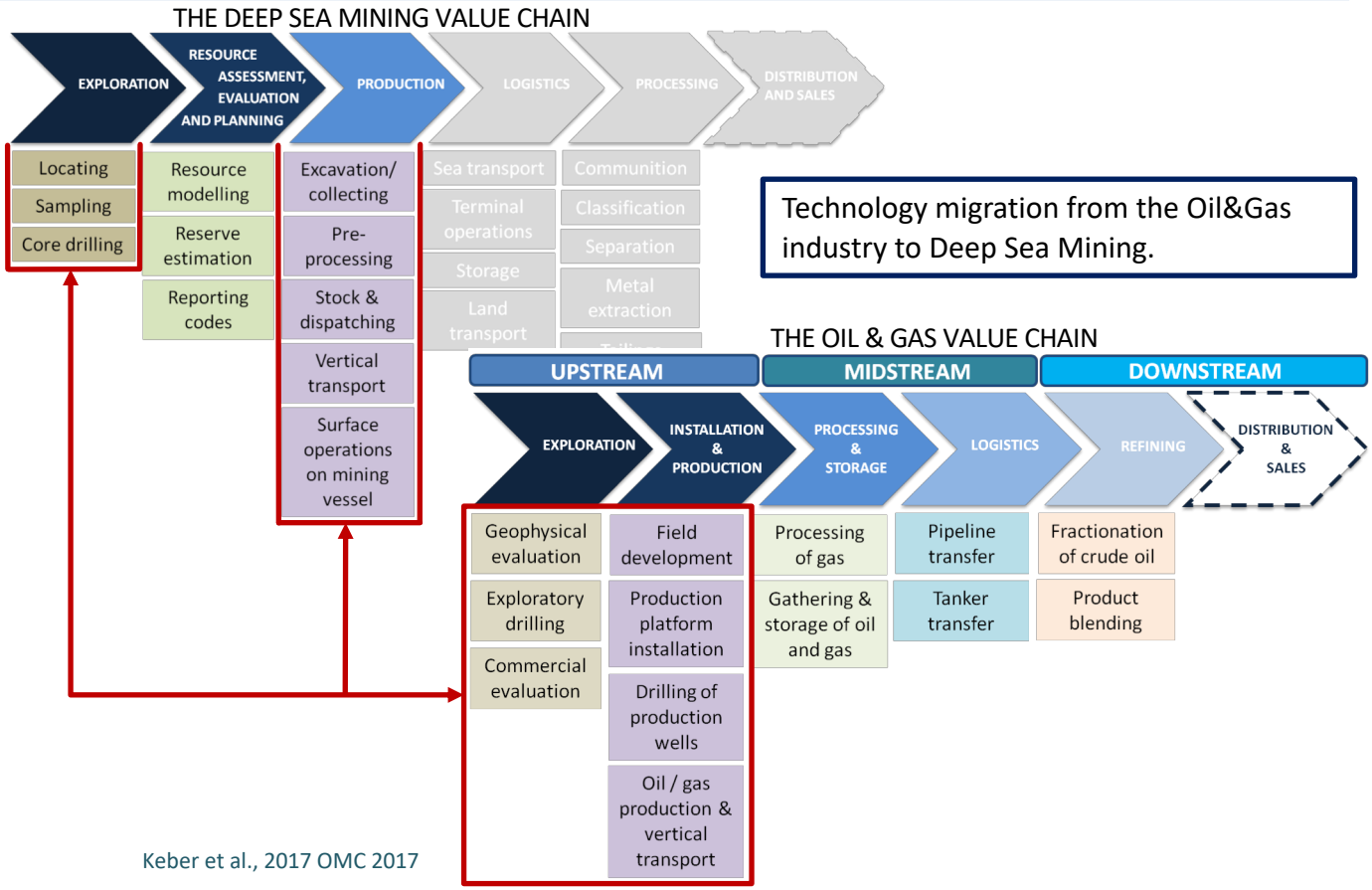
OMC Ravenna 2017

The Deep Sea Mining Value Chain



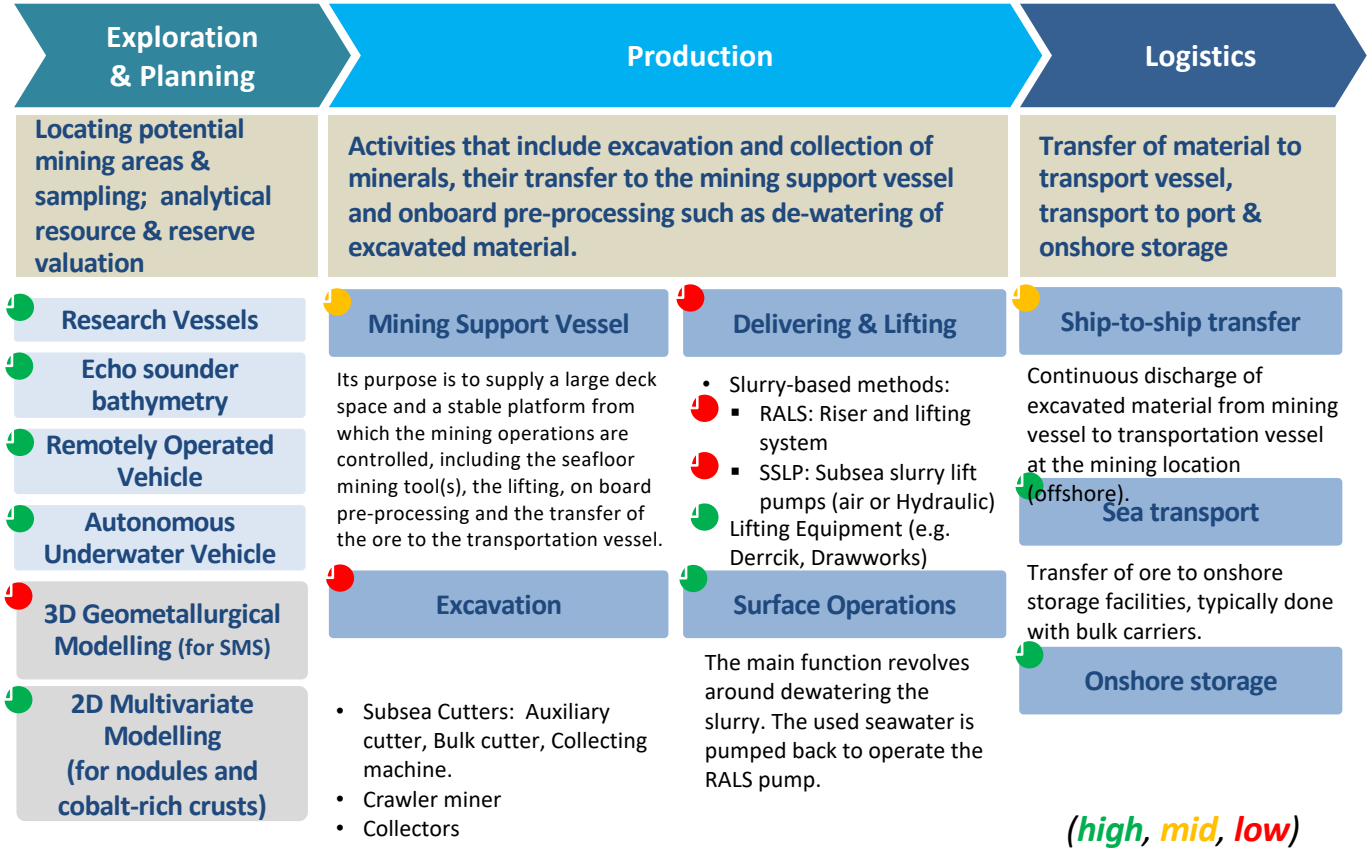
Keber et al., 2017 OMC 2017

From Offshore Oil & Gas to Deep Sea Mining



Keber et al., 2017 OMC 2017

Readiness Level of Deep Sea Mining Technology

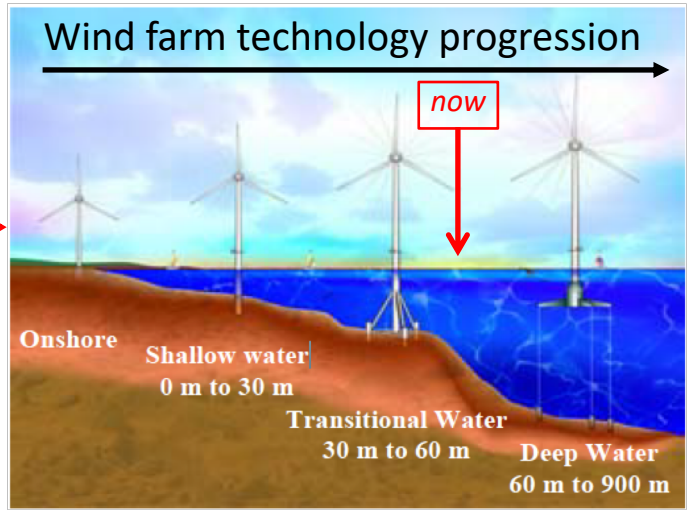


Keber et al., 2017 OMC 2017

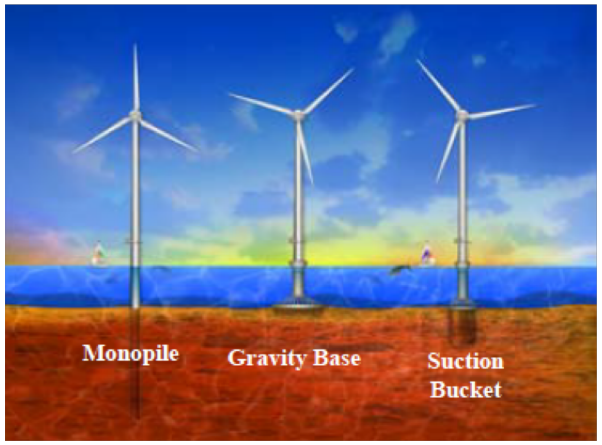
Seabed Installations - for Renewable Energies

- **Wind**, wave, tide, ocean currents, temperature & salinity differences…

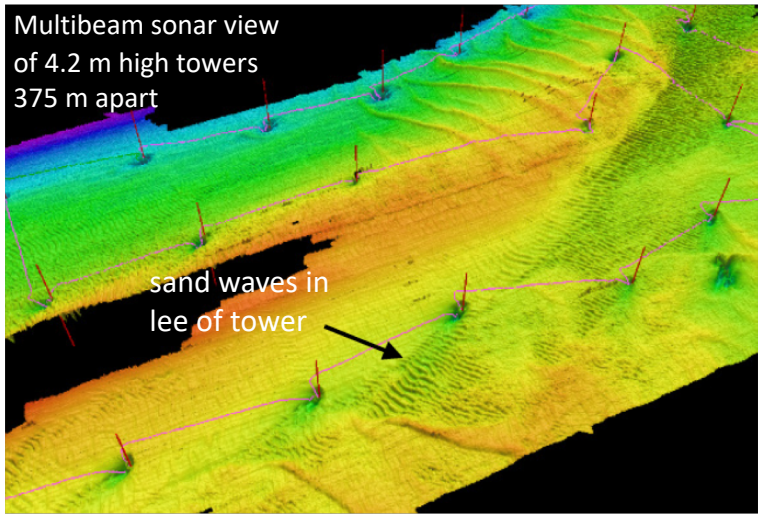
Wind farm seabed installations >40 projects world-wide

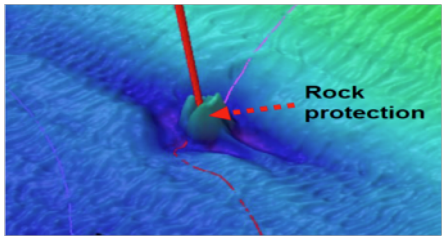


Sources: Musial et al. (2006, OTC 18355)



Different foundations…
all require knowledge of seabed





Seabed mapping

+ monitoring surveys:

- sand wave migration
- scour of foundations

Same companies as cables

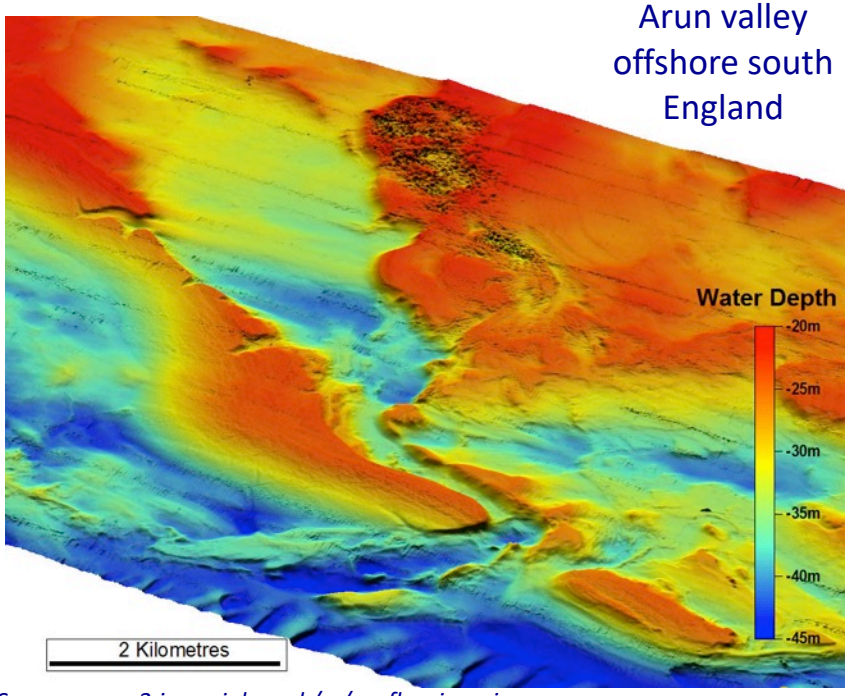
Source: Scroby Sands Offshore Wind Farm – Coastal Processes Monitoring. Cefas, UK, 2006

Seabed Sand and Gravel Mining

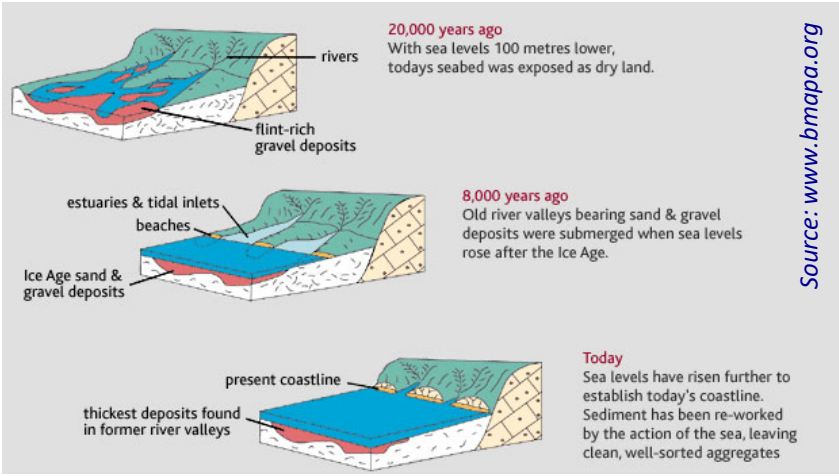
Not very 'glamorous' minerals… but a big business

- Used worldwide in construction, coastal engineering…
- Suction dredging from surface vessels
- Minimal science until recently – low value, large volumes…
- Science overlap - post-glacial sea level rise, early human civilisations (submarine archaeology)…

Arun valley offshore south England



Source: www3.imperial.ac.uk/.../seafloorimaging



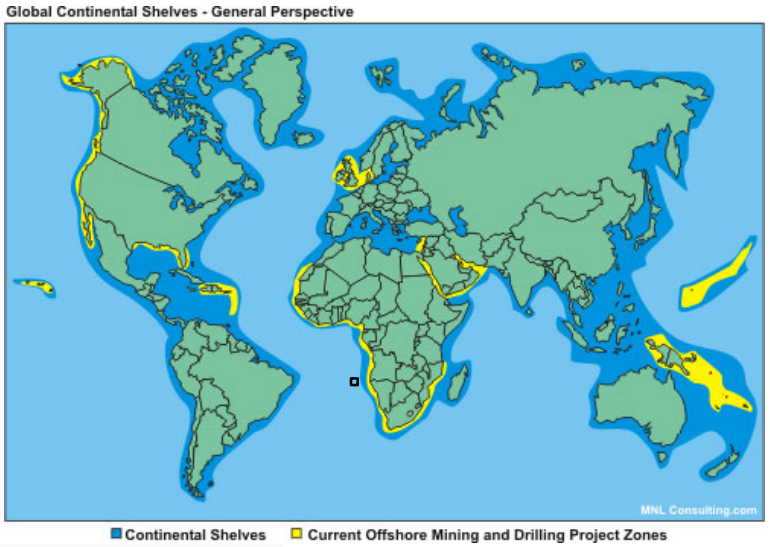
- An industry 2nd to oil & gas in the US (in Europe, mainly North Sea countries*)
- Globally, we use >40 x 10^9 tonnes/yr = twice the sediment carried by all the rivers of the world

*(*Velegrakis et al.2010, Journal of Coastal Research 51, 1-14)*

Seabed Diamond/Gold Mining

- More glamorous - but similar dredging techniques, in depths up to 150 m
- Exploration activity off South Africa, Australia & Asia, Alaska… →

Diamond mining off Namibia (De Beers)

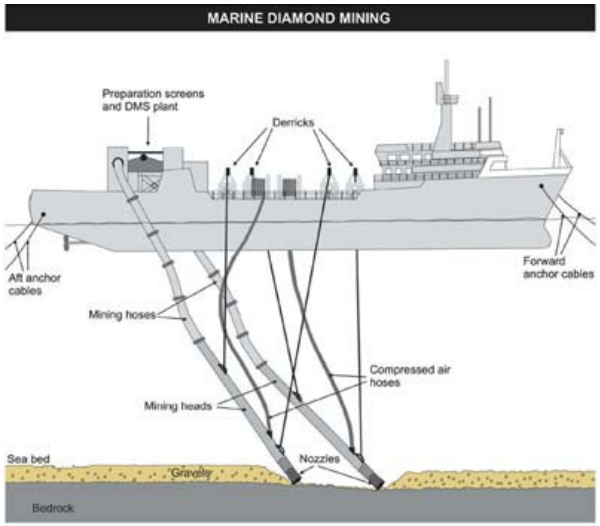


Source: www.mnlconsulting.com

Various mining techniques

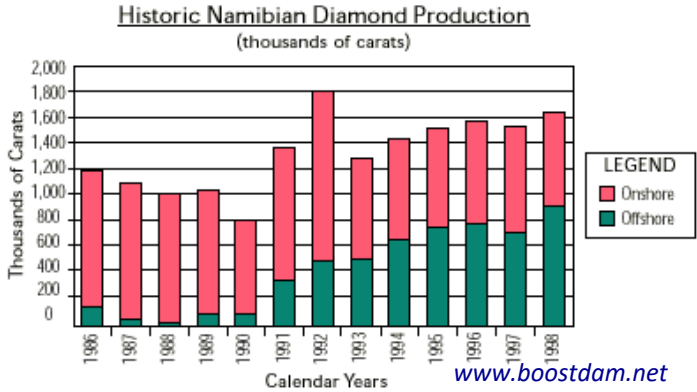
- Horizontal – seabed crawlers →
- Vertical – suction drilling (water jets)
- Airlift – compressed air jets

www.marinelog.com



Source: 2011.polarhusky.com

Diamonds from offshore Namibia (www.imdhgroup.com)



www.boostdam.net

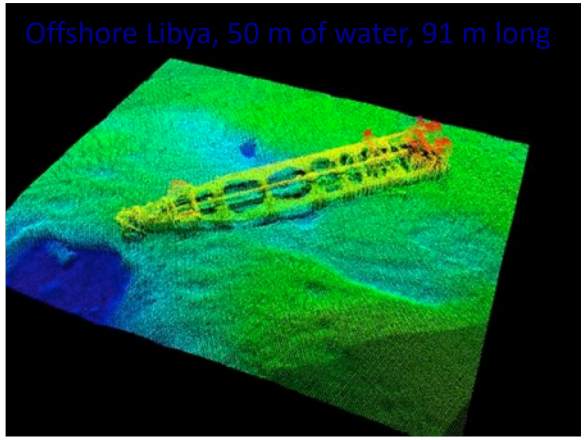
Seabed Treasure Hunting

Glamorous! Salvage companies involved in raising wrecks (e.g. Costa Concordia) or in looking for 'sunken treasure' – using the remote and direct techniques of seabed mapping

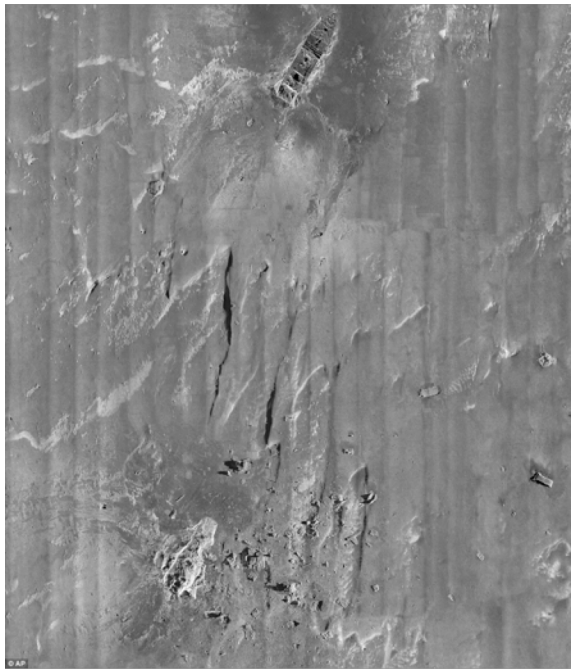
http://shipwreck.net/

ODYSSEY MARINE EXPLORATION

Source: www.osirisprojects.co.uk



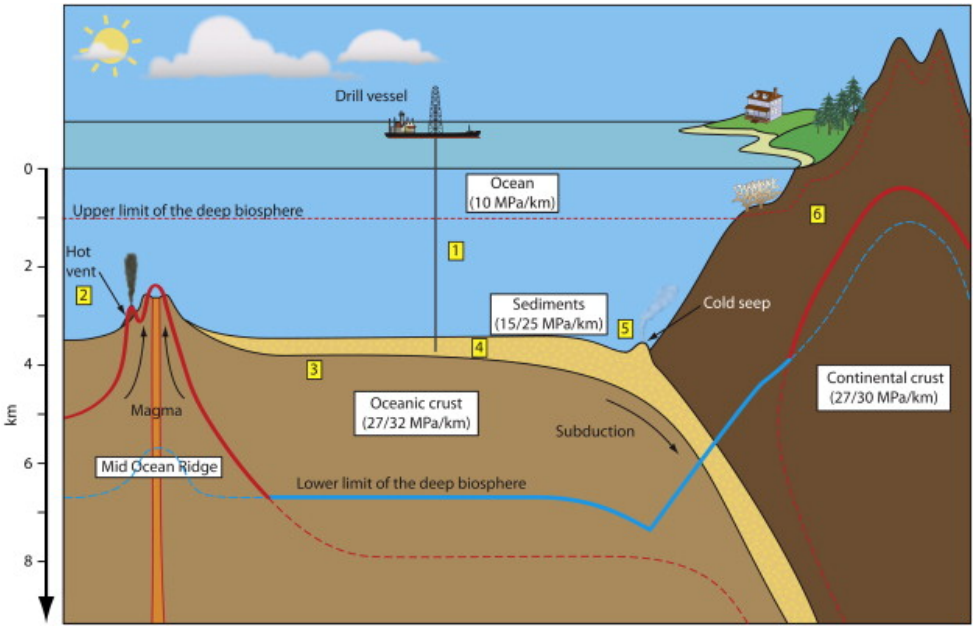
http://subseaworldnews.com/2013/07/25/hms-echo-finds-18-wrecks-in-mission-offshore-libya/



RMS Titantic debris field on sonar imagery (3800 m)
(www.dailymail.co.uk 09.03/2012)

Earth's deep biosphere

- Postulated by Thomas Gold (1992, 1999) - *The Deep, Hot Biosphere* (Springer)
- Earth's crust to depths of kilometers – sustained by thermally-driven fluid circulation : geosphere-biosphere coupling
- Microbial life, ½ to 2/3 of all biomass
- Largely chemosynthetic (primitive) life forms, living in 'extreme environments'



Source: Oger & Jebbar 2010, Research in Microbiology

(Geo-) Bio-prospecting

- "The development of drugs [pharmaceuticals] from marine organisms" - UN Atlas of the Oceans
- There already exist (highly profitable) 'bioactive compounds' from sponges and corals (primitive organisms, metabolic pathways in many ways similar to ours)
- Modern genetic methods simplify the search → growing commercial interest
- Japan spends a billion dollars a year (80% private sector)… big business
- Opposing views on whether genetic resources beyond the 'shelf' are covered by UNCLOS/IAS ("the common heritage of mankind") or are private? *See World Ocean Review*

Sedimentary Basin Analysis vs Petroleum System Analysis

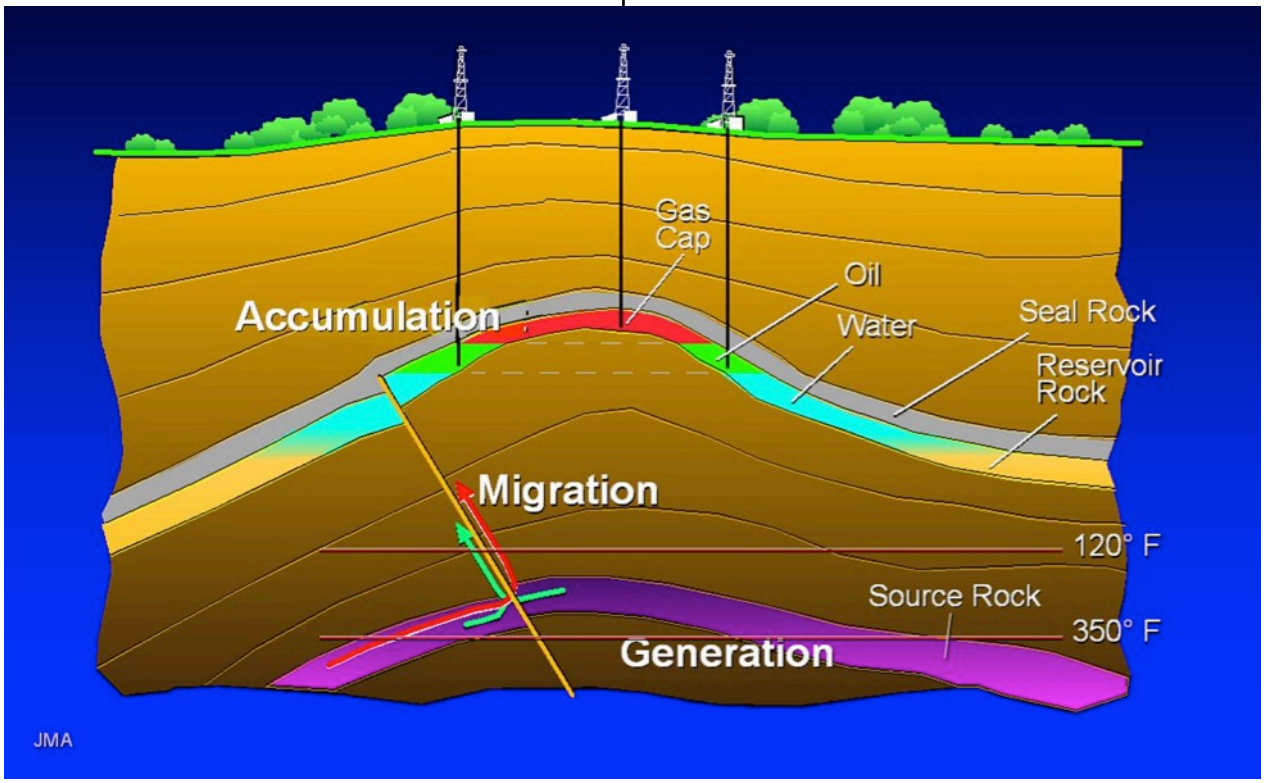
The academic geologist sees…

- deposition of strata
- folding
- faulting
- uplift & erosion

The petroleum geologist looks for…

- source rocks (organic rich)
- migration pathways
- reservoirs
- traps & seals

Understand-ing Earth systems



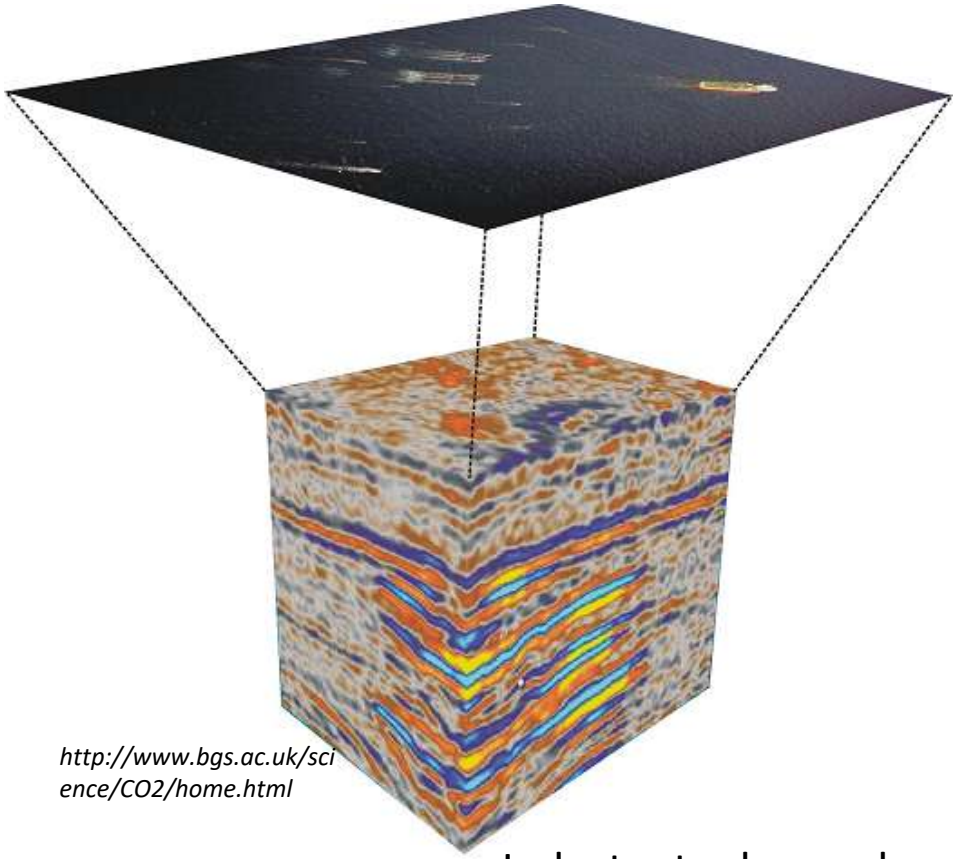
Finding oil & gas

Source: petroleumsupport.com/reservoir-system-to-accumulate-hydrocarbon.html/petroleum-system/

Academic and petroleum geologists use basically the same tools…

Geophysics (remote)

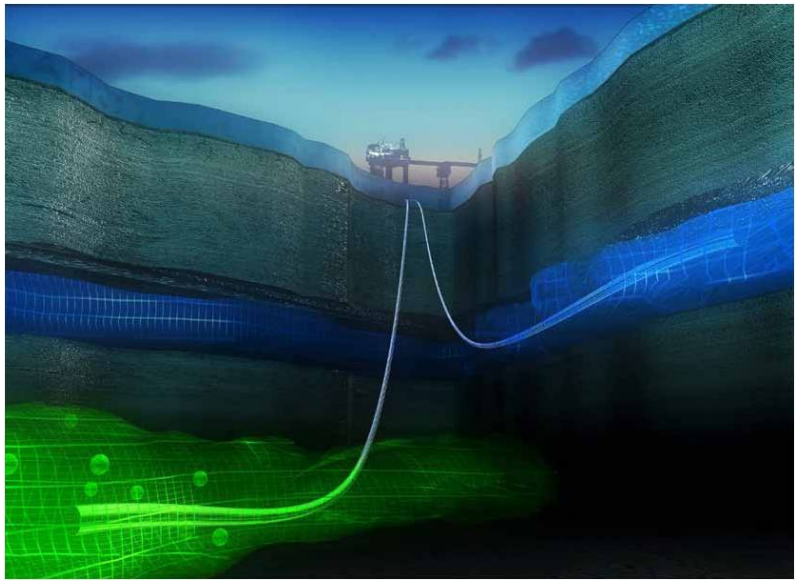
- Gravity & magnetic fields
- Seismic data (2D & 3D)



http://www.bgs.ac.uk/science/CO2/home.html

Geology/geochemistry (samples)

- Sediment cores
- Drillsites/wells



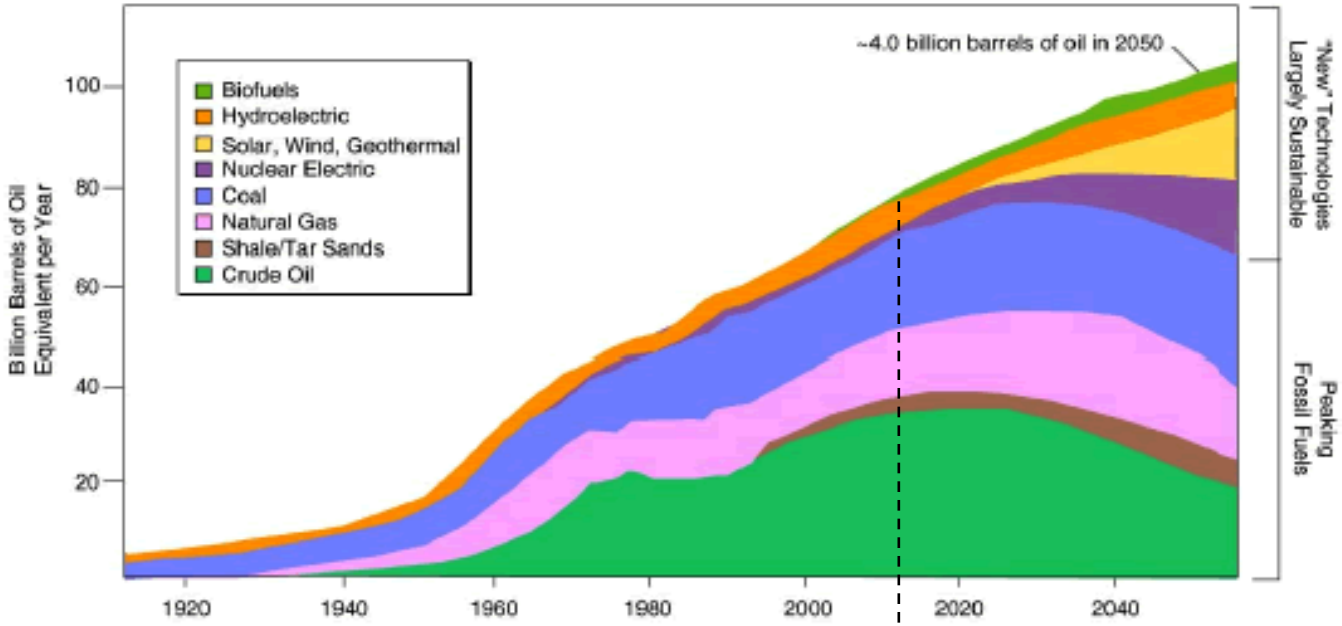
Source: seriousgamesmarket.blogspot.it/2010/09/serious-games-as-oil-drilling-3d.html

Industry tools are almost always bigger & better
(with eventual benefits to science)

Hydrocarbons = by far the biggest offshore industry

because industrial society runs mainly on petroleum…

World Energy Demand – Long-Term Energy Sources



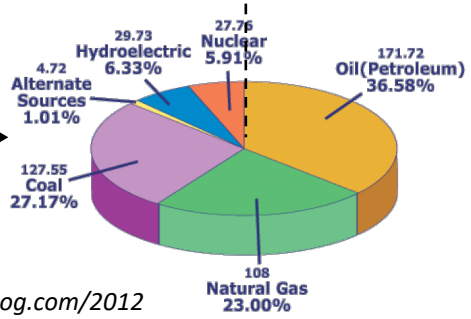
Sources: Lynn Orr, *Changing the World's Energy Systems*, Stanford University Global Climate & Energy Project (after John Edwards, American Association of Petroleum Geologists); SRI Consulting.

Fossil fuels:
majority of energy use today and for the foreseeable future (forecast to decrease as percentage)

World Energy Use 2012:

87% fossil fuels

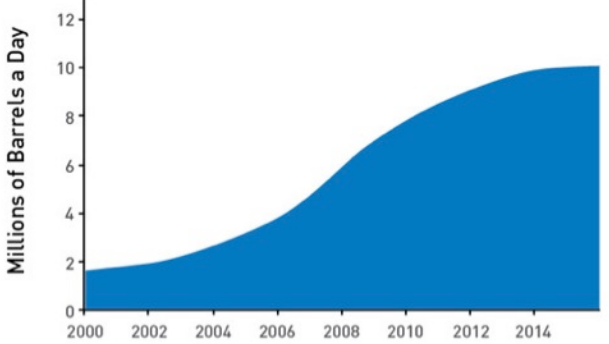
60% oil & gas



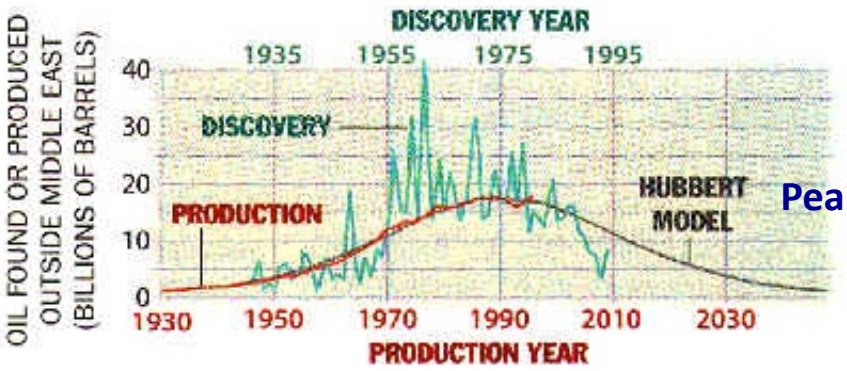
Source: triplehelixblog.com/2012

DEEPWATER PRODUCTION

Source: www.total.com

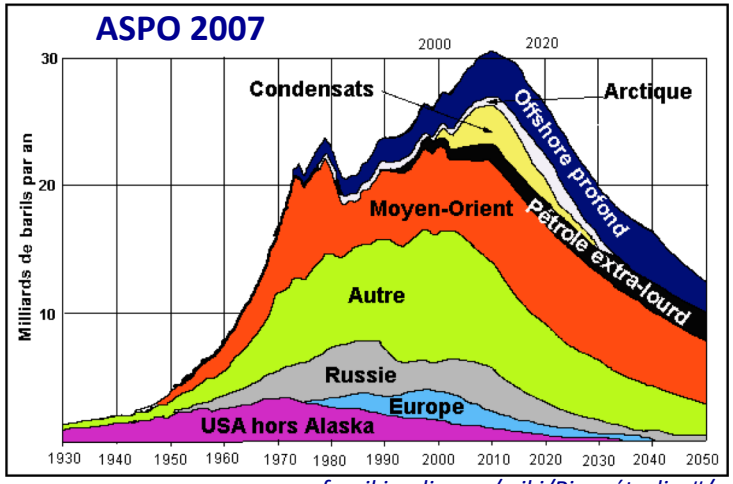


Hydrocarbons – are we at peak production?

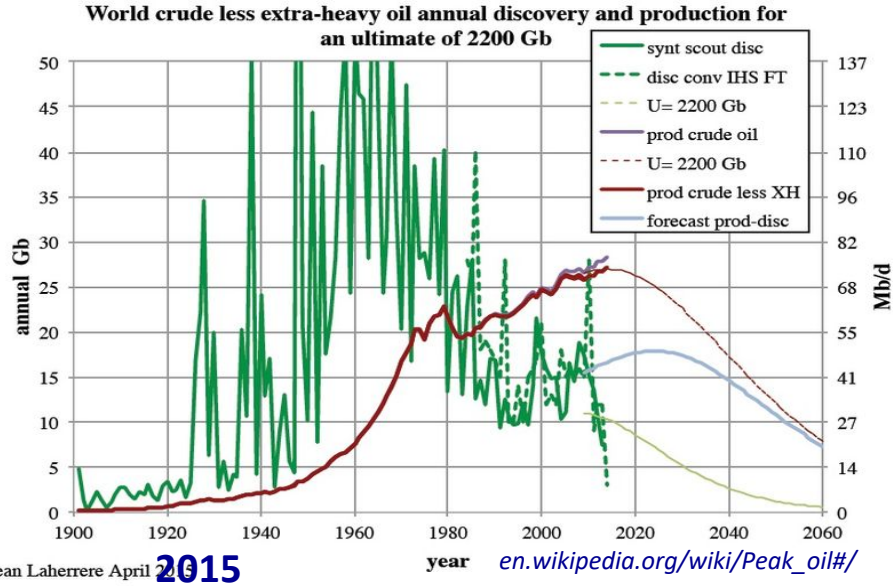


Peak Oil

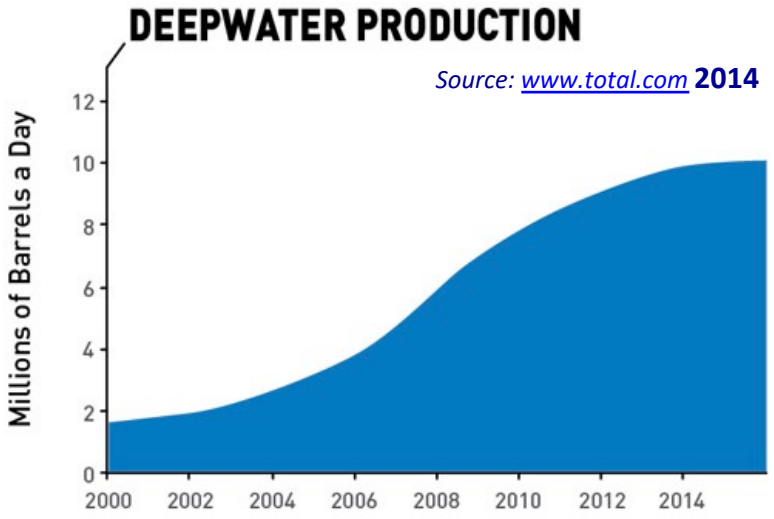
*Campbell & Laherrre **1996**, Scientific American – The End of Cheap Oil*



fr.wikipedia.org/wiki/Pic_pétrolier#/



en.wikipedia.org/wiki/Peak_oil#/



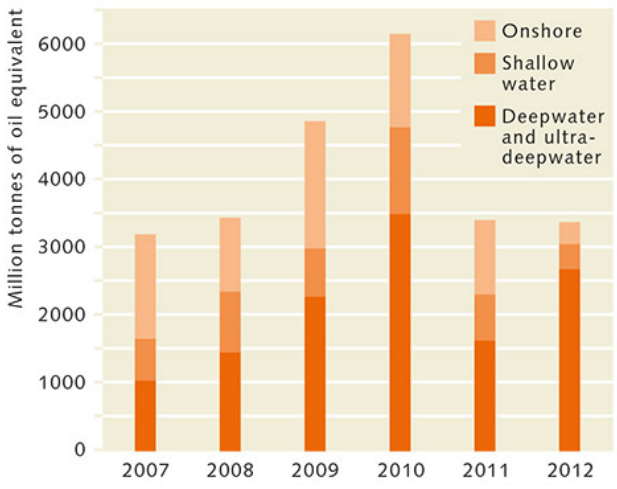
2015

Green: discoveries peaked in the 1960s

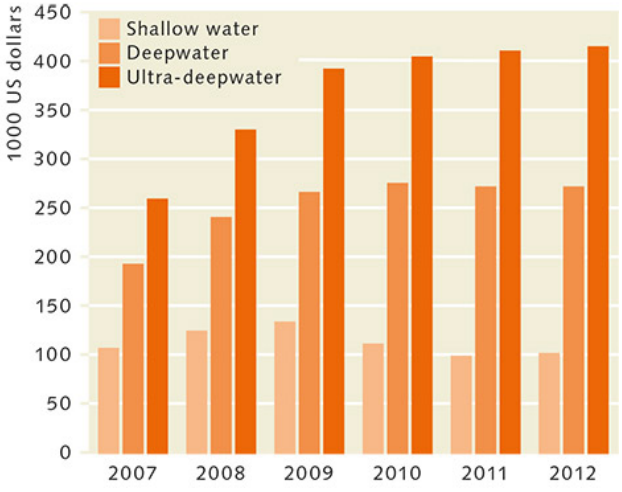
Red: production peaking now?

Deep water production is peaking?

Global oil & gas discoveries



Costs of drilling



Source: World Ocean Review (http://worldoceanreview.com)

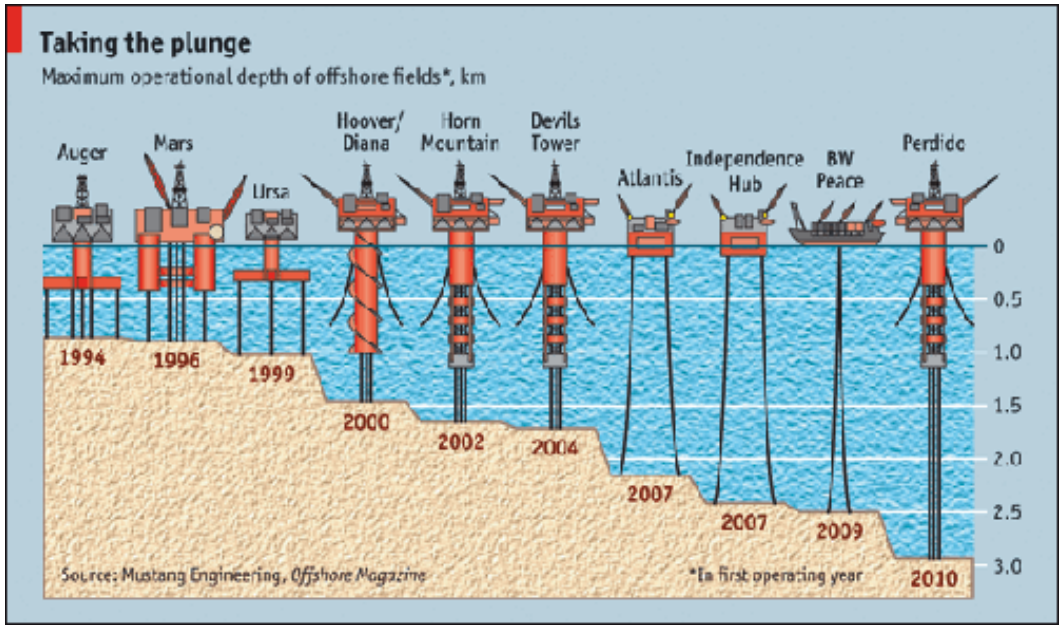
Shallow : 0-400 m

Deep : 400-1500 m

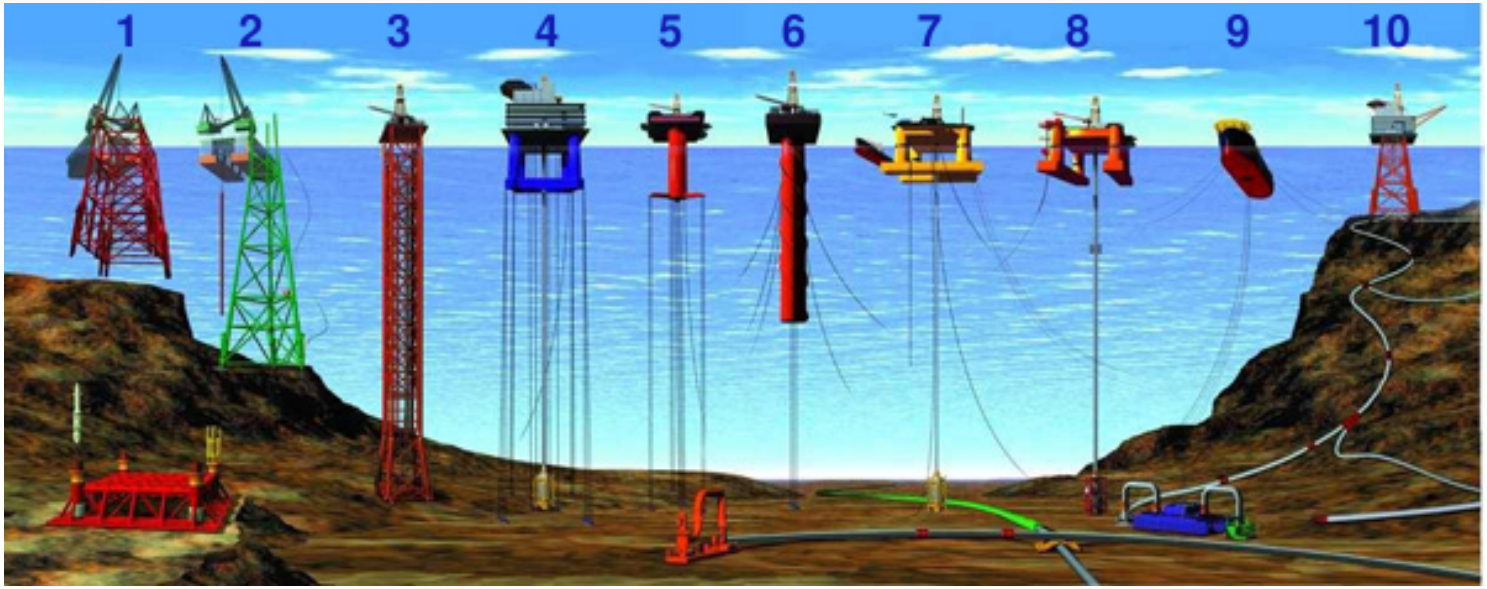
Ultradeep : >1500 m

Most global discoveries are offshore in deep and ultra-deep water (and cost a lot more)

- Petroleum industry is progressively moving into ultra-deep water, 3174 m in 2013 (offshore eastern India)
- Still within national jurisdictions – EEZ/'Continental Shelf'



Source: www.energyandcapital.com/articles/oil-rigs-drilling-ever-deeper/



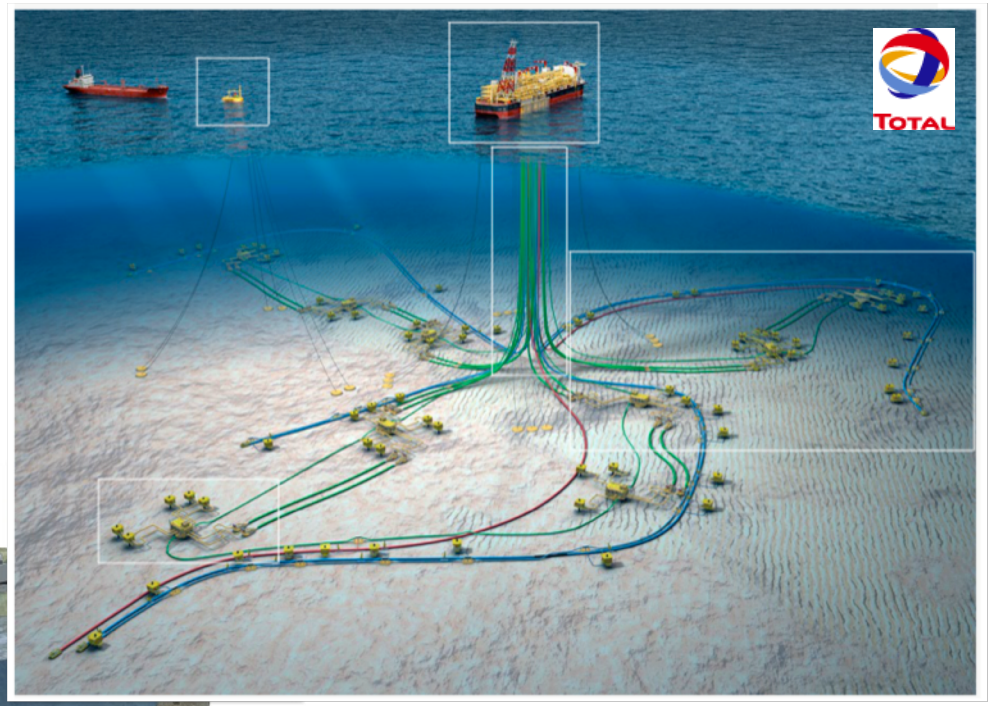
Types of Offshore Oil and Gas Structures (in 2005)

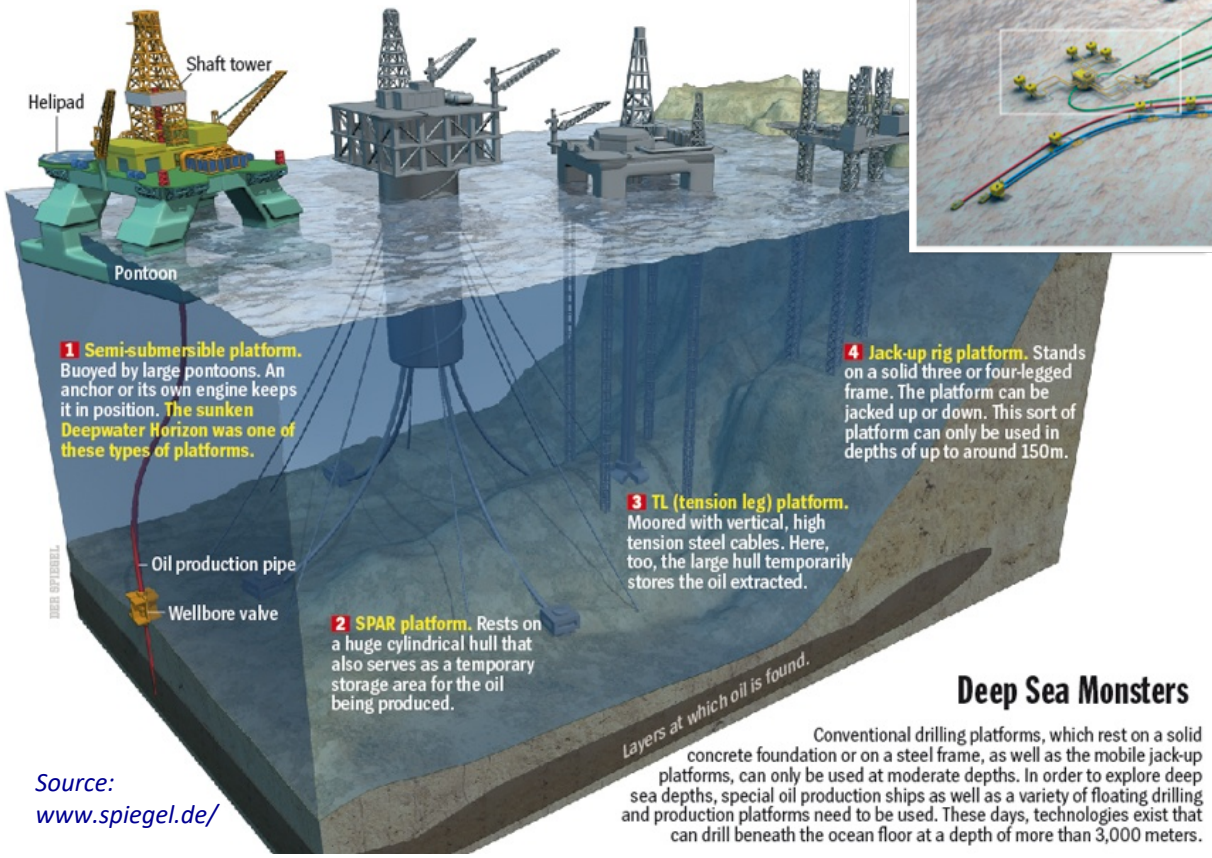
1 & 2) Conventional fixed platforms (deepest: 412 m GOM, 1991)
3) Compliant tower (deepest: 534 m GOM, 1998)
4 & 5) Vertically moored tension leg platforms (deepest: 1,425 m GOM, 2004)
6) Spar (deepest: 1,710 m GOM, 2004)
7 & 8) Semi-submersibles (deepest: 1920 m GOM 2003)
9) Floating production, storage, and offloading facility (deepest: 1,345 m Brazil, 2005)
10) Sub-sea completion and tie-back to host facility (deepest: 2,307 m GOM, 2004)

Source: http://commons.wikimedia.org/wiki/File:Types_of_offshore_oil_and_gas_structures.jpg

Source: www.shell.com

Enormous investments, technical challenges, and achievements by offshore industry in exploration, drilling and (only in some cases) production…





Source: www.spiegel.de/

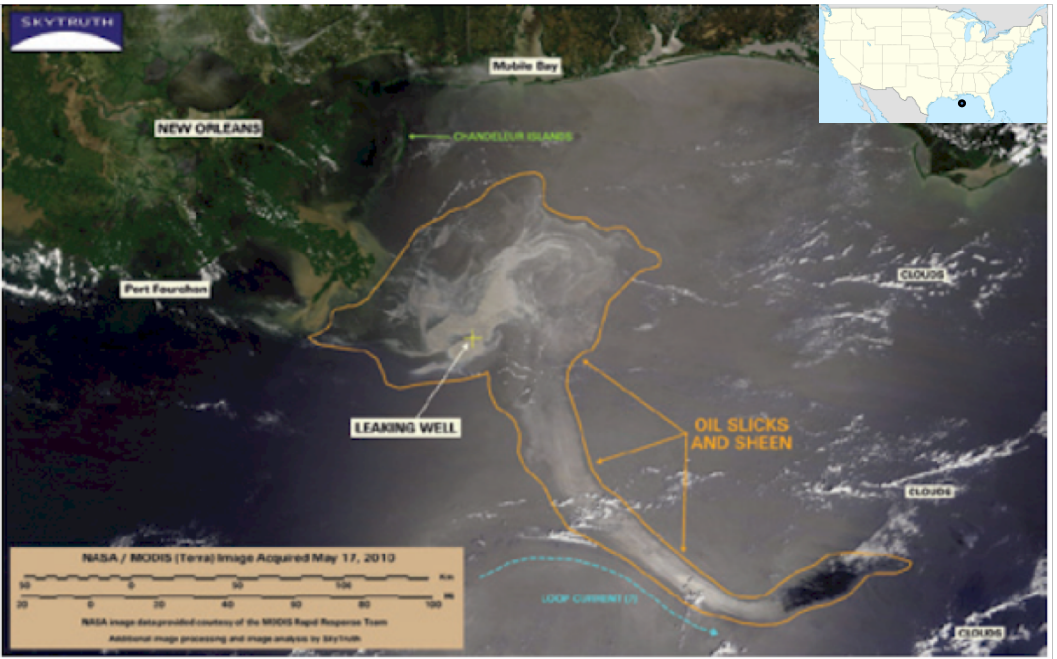
"The conquest of the deep offshore, the oil industry's latest and perhaps most extra-ordinary adventure…" (www.total.com)

And corresponding risks…

Blowout = uncontrolled release of hydrocarbons after pressure control systems fail

Deepwater Horizon drilling rig (semi-submersible), Gulf of Mexico, April 20 2010 : blowout

Sources: eijournal.com/2011/deepwater-horizon-revisited

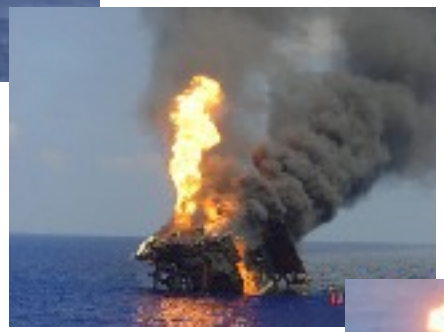


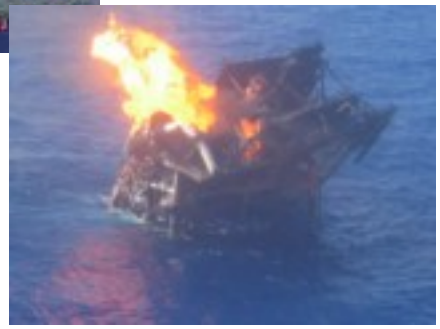
Explosion, fire, 11 deaths, massive oil spill…

Source: www.greenpeace.org - Shrimp boat

Rig: GSF Adriatic IV Jack-Up
Date: 10 August 2004
Location: Temsah, Mediterranean Sea, Egypt
Operator: Platform run by Petrobel

GSF Adriatic IV at Temsa before the blowout



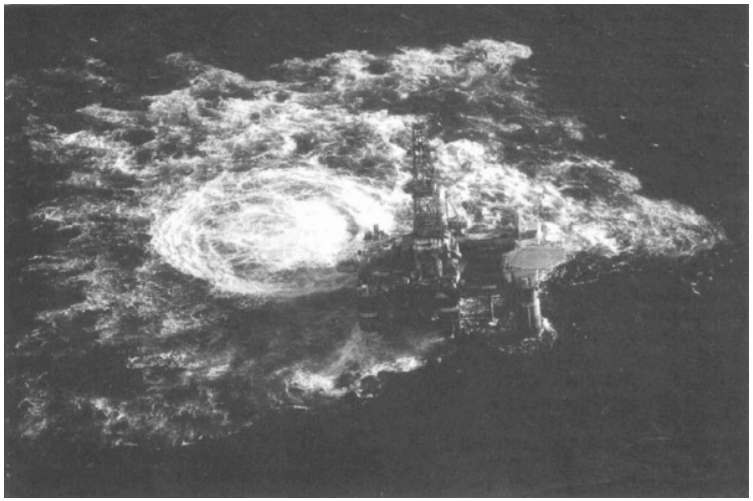


Blowout → explosion, fire, rig sank (no loss of life)

Source: home.versatel.nl/the_sims/rig/index.htm

Rig: Smedvig West Vanguard Semi-Sub
Date: 06 October 1985
Location: Haltenbanken, Norwegian Shelf
Operator: Statoil

Blowout, explosion, fire, 1 death (missing);
rig eventually restored



Source: home.versatel.nl/the_sims/rig/index.htm

Rig: Petromar V Drillship
Date: 27 Aug 1981
Location: Off Natuna Island, South China Sea
Operator: Mobil

Several dozen incidents (mainly blowouts) since 1964 – every year or so

Source: home.versatel.nl/the_sims/rig/index.htm

EU REGULATORY FRAMEWORK

ENVIRONMENT

Marine Strategy Framework Directive adopted on 17 June 2008.

SCOPE: to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. the Directive sets out eleven qualitative descriptors which describe what the environment will look like when GES has been achieved.

Descriptor 1. Biodiversity is maintained
Descriptor 2. Non-indigenous species do not adversely alter the ecosystem
Descriptor 3. The population of commercial fish species is healthy
Descriptor 4. Elements of food webs ensure long-term abundance and reproduction
Descriptor 5. Eutrophication is minimised
Descriptor 6. The sea floor integrity ensures functioning of the ecosystem
Descriptor 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
Descriptor 8. Concentrations of contaminants give no effects
Descriptor 9. Contaminants in seafood are below safe levels
Descriptor 10. Marine litter does not cause harm
Descriptor 11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Descriptor 6. The sea floor integrity ensures functioning of the ecosystem

Main pressures on the sea-floor?

Human activities induce different kinds of pressures that can affect the sea-floor. The main pressures that directly impact the state of the sea bottom are:

1. **Coastal infrastructures (ports, defenses against erosion, etc.) and offshore installations (oil and gas platforms, wind farms, etc.);**
2. **Offshore mining and sand extraction;**
3. Release of dredged sludge;
4. Moorings;
5. Some fishing practices (trawling, dredging, etc.);
6. Aquaculture (unused fish feed, fish faeces, etc.);
7. Introduction of non-indigenous species (trough ballast water for instance);
8. Pollution (chemical pollution, litter);
9. Changes in riverine inputs (organic enrichment of particulate matter, etc.);
10. Sediment remobilization by fishing equipment (trawls, dredges);
11. Changes in freshwater riverine inputs as a consequence of damming and irrigation;
12. Changes in solid matter riverine inputs; and
13. Release of large quantities of warm (power plant cooling) or salty water (from desalination facilities)

DIRECTIVE 2013/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 June 2013 on safety of offshore oil and gas operations

PREVENTION OF MAJOR ACCIDENTS RELATING TO OFFSHORE OIL AND GAS OPERATIONS

- General principles of risk management in offshore oil and gas operations
- Safety and environmental considerations relating to licences
- Public participation relating to the effects of planned offshore oil and gas exploration operations on the environment
- Offshore oil and gas operations within licensed areas
- Liability for environmental damage

Among the documents submitted for carrying out offshore oil and gas operations:

Report on major hazards for a production installation
Report on major hazards for a non-production installation

In the entire document the term 'geo' is used only for geographical meaning

National implementation of the EU Directive:

Italian Ministry of Economic Development
Increased safety of offshore installations

Among other activities….

- Evaluation of the seismic hazard (including induced-seismicity) of current platforms based on their position with respect to tectonic structures and induced pressures (load)
- Feasibility studies for seismic monitoring and soil deformation
- Studies of geological and stratigraphic conditions of new marine areas open to research and cultivation of hydrocarbons

Increased royalties on Oil and Gas to fund research projects on (among other):

- **Submarine geo-hazards (slope stability, enhanced erosion, gas emissions)**
- **Seismicity including induced seismicity**

Recommended Reading

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Law of the Sea

- *http://www.un.org/depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm*
- *http://en.wikipedia.org/wiki/United_Nations_Convention_on_the_Law_of_the_Sea*
- *http://en.wikipedia.org/wiki/Maritime_boundary*

Marine Resources

- World Ocean Review (*worldoceanreview.com)*