Università di Trieste
LAUREA MAGISTRALE IN GEOSCIENZE
Curriculum Geofisico
Curriculum Geologico Ambientale

Anno accademico 2017 – 2018

Geologia Marina

Modulo 6.1 Offshore Research and Economic Activities

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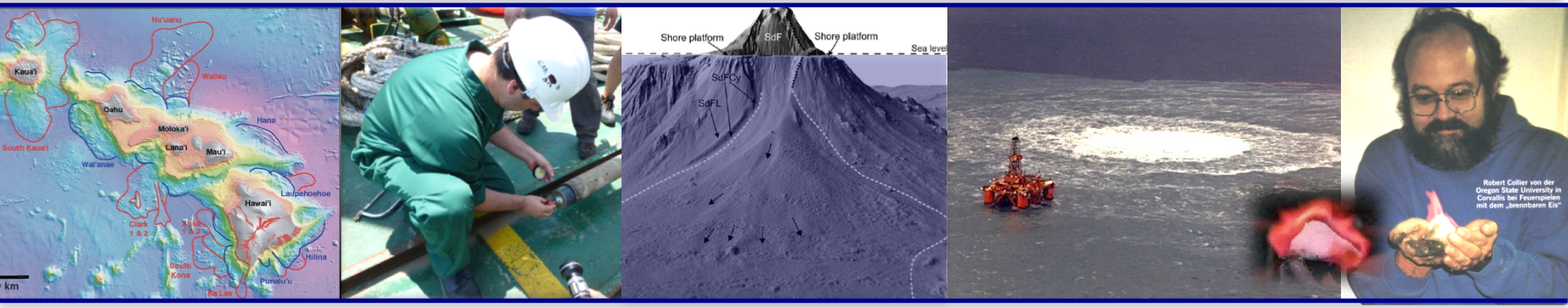
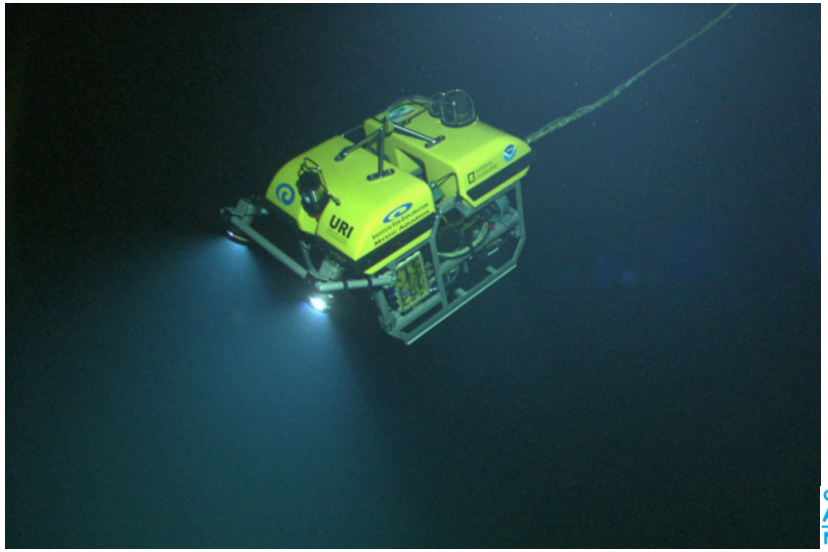


THE USE OF SEABED: RISKS AND OPPORTUNITIES

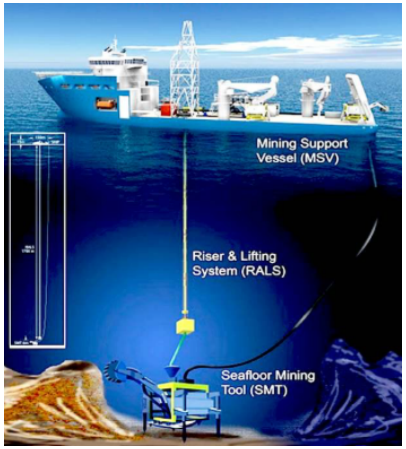
- **Average ocean water depth: 3,682.2 m**
- **Equivalent to a pressure of 36,121.3 kP, 361.21 bar o 356.49 atmospheres**
- **Light is rapidly absorbed in water. From about 100 m down there is absolute darkness**



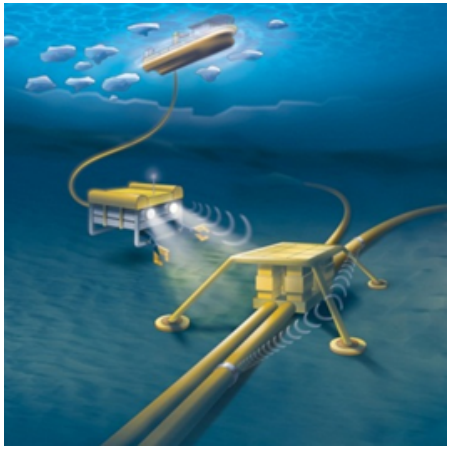
Less than 50% of the oceans have been explored

DESPITE THE HOSTILE ENVIRONMENT, THE USE OF THE SEABED IS GROWING, AS THE BLUE ECONOMY IS GROWING

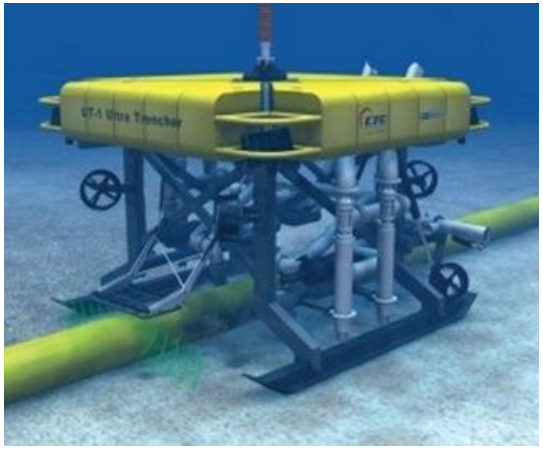
DEEP SEA MINING



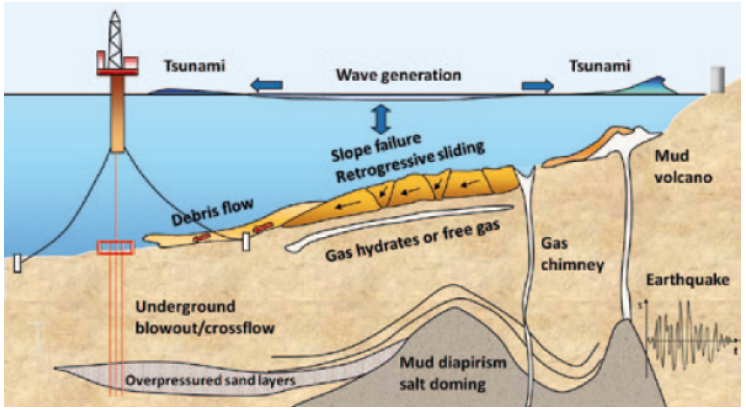
SUBSEA OIL & GAS TECHNOLOGY



COMMUNICATION CABLES



KNOWLEDGE GAP:



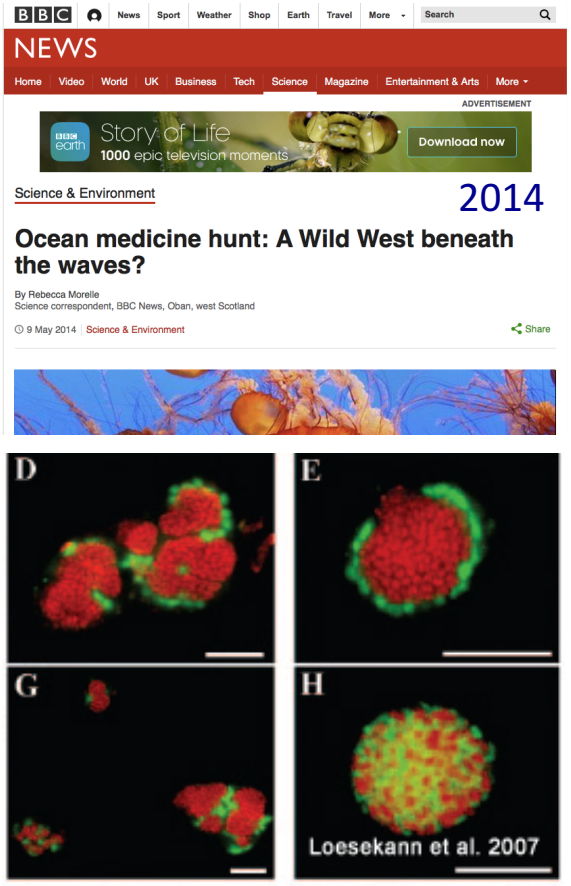
- **IN THE WATER COLUMN**
- **ON THE SEABED**
- **BELOW THE SEABED**

NOT ONLY:

Oceans represent a resource to e discovered for new chemical and biological products with a potential use in pharmaceutic industry

Monsoons to Microbes: Understanding the Ocean's Role in Human Health.
National Research Council (US) Committee on the Ocean's Role in Human Health. Washington (DC): National Academies Press (US); 1999.

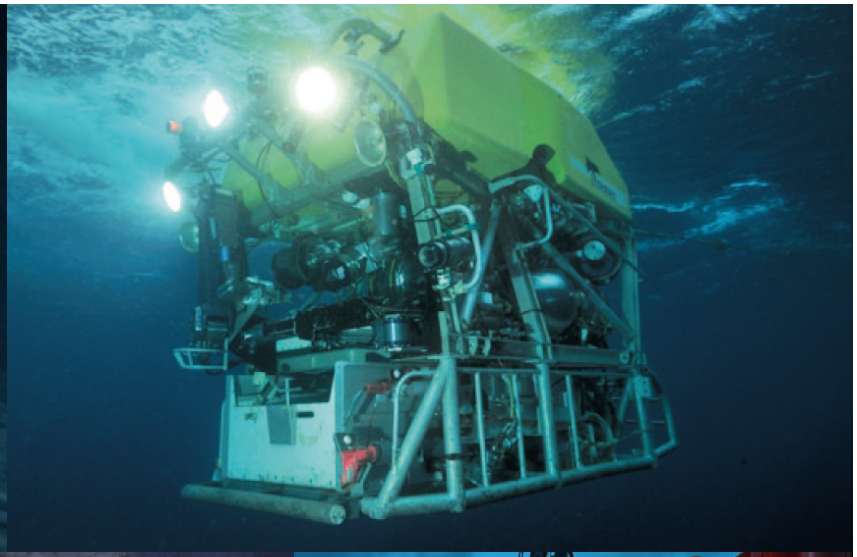
- **The Marine Environment as a Source of Chemical Diversity**
- **The Discovery and Development of Marine Pharmaceuticals: Current Status**
- **Marine Microorganisms as a Novel Resource for New Drugs**
- **The Marine Environment as a Source of Molecular Probes**
- **The Ocean as a Source of New Nutritional Supplements**



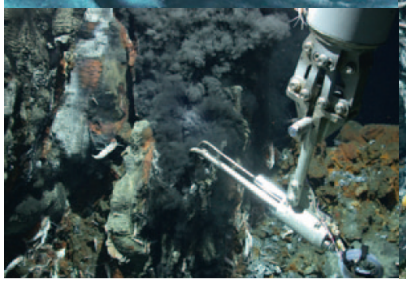
DS³F
www.deep-sea-frontier.eu

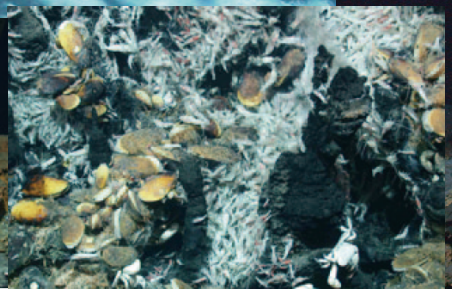
OCEANS ARE A FRONTEER OF OUR KNOWLEDGE

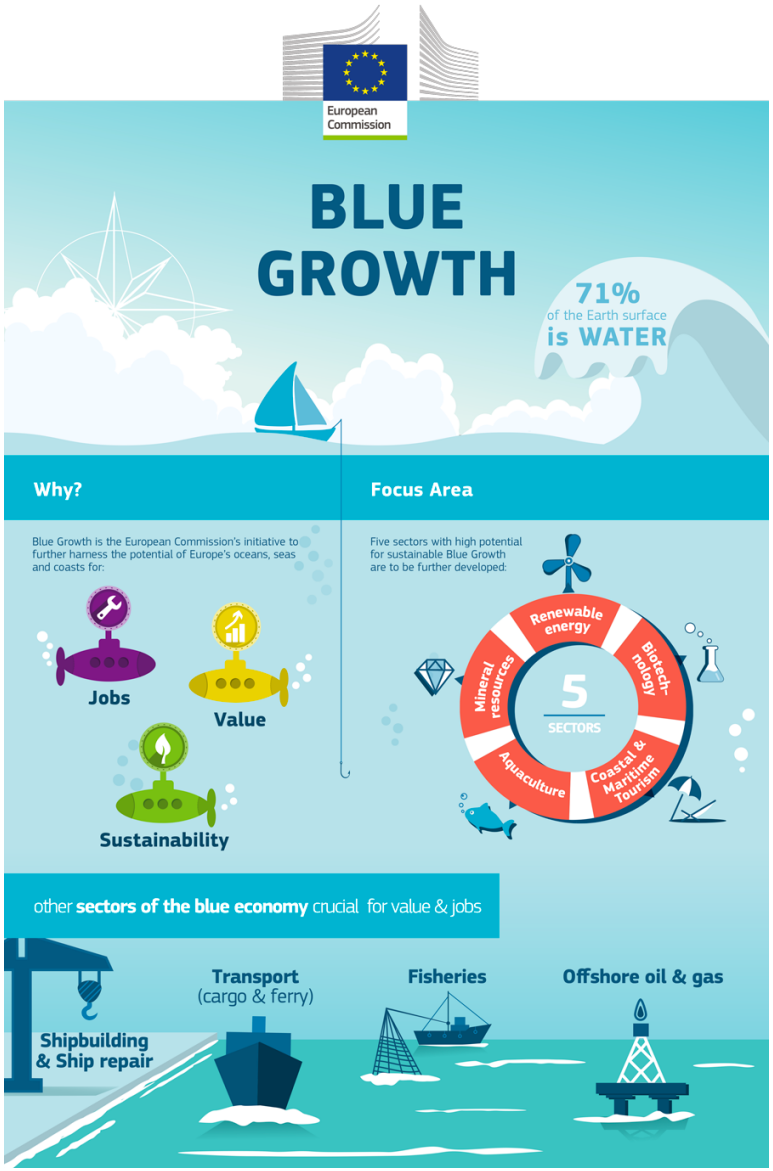
The Deep Sea and Sub-Seafloor Frontier



Responsible use of deep sea
Resources







Blue Growth is the long term strategy to support sustainable growth in the marine and maritime sectors as a whole.

Organisation for Economic Co-operation and Development (OECD)

Ocean industries bear a potential of an **important contribution to employment growth**, which could result in the creation of approximately 40 million full-time equivalent jobs globally in 2030

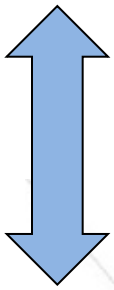
Two ways to see the world :

Pure Research (Natural SCIENCE)

- Exploring the 'blue planet' - 71% oceans
- Onshore geology dominated by submarine deposits
- 'No geology without marine geology' (Kuenen 1958)
- To understand *how the Earth works* (in the past, present and future), we need to study what goes on in and beneath the oceans over time

Applied Research (Natural R€$OURC€$)

- Using the seabed (for cables, pipelines, platforms…)
- Exploring for opportunities (solid, liquid & gas)
- All offshore activities require some understanding of how the Earth works, for exploration/exploitation
- In turn, an important driver for pure research activity (both technologically and financially)



Sources: Wikimedia commons

➢ Working at sea is expensive - vessels cost 10,000-100,000€/day

OGS Explora: a publicly-funded research vessel

- acquired by OGS in 1989, only ocean-going ship owned by a research institute
- scientific campaigns worldwide (from Antarctica to the Arctic)
    - € 10^6/year from Italian government for use & maintenance

OGS Explora *in Galway harbour, Ireland, 2009 (International Polar Year campaign)*

Operating costs offshore :€15-25,000/day In port :€6-10,000/day)

Secondary activity: commercial service work

- contracted to offshore companies (e.g. Fugro)
- geophysical/geological surveys (e.g. cables, exploration…)
- return to origins: originally a Geco-Prakla seismic boat (1973-1989)

Offshore (geo-) economic activities

- Submarine cables & pipelines
- Renewable energies (wind farms)
- Seabed mapping (a service industry)
- Nearshore sand and gravel mining
- Deep sea mineral mining
- Bio-prospecting (sub-seabed)
- **Hydrocarbon exploration**
- Methane hydrates?

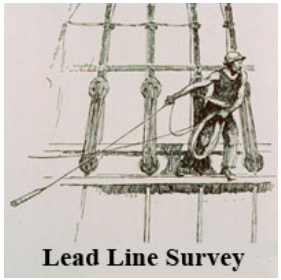
Seabed installations, old & new

Natural resources, nearshore to deep-sea

nearshore

deep sea

Submarine Cables (and the need of scientific research)


Lead Line Survey

Oldest (?) offshore economic activity requiring knowledge of geology :

seabed depth, form, composition?

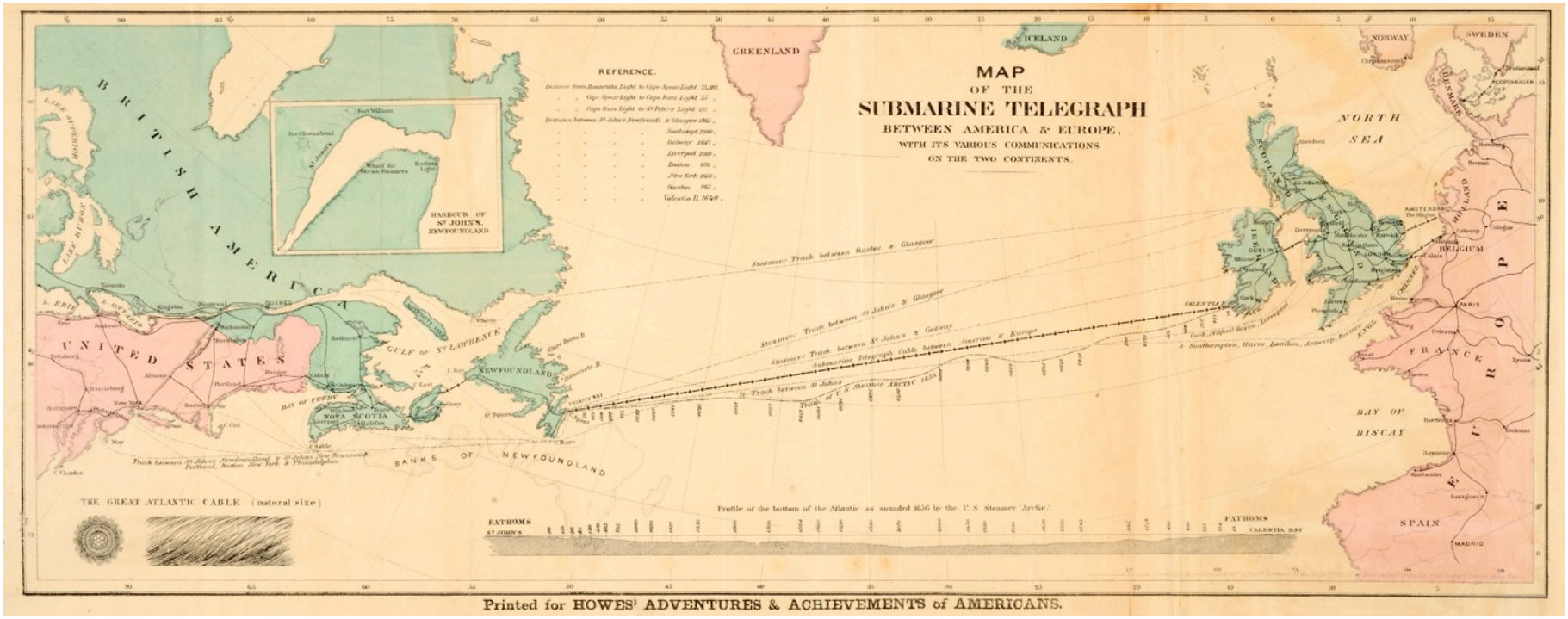
1850-1853 : 1st undersea telegraph cables

UK to France, Ireland, the Netherlands – water depths <50 m

1857-1858 : 1st trans-Atlantic telegraph cable

Ireland to Newfoundland - 3000 km, 4600 km of cable

"...the bottom of the sea between the two places is a plateau, which seems to have been placed there especially for the purpose of holding the wires of a submarine telegraph." (US Navy report 1854)

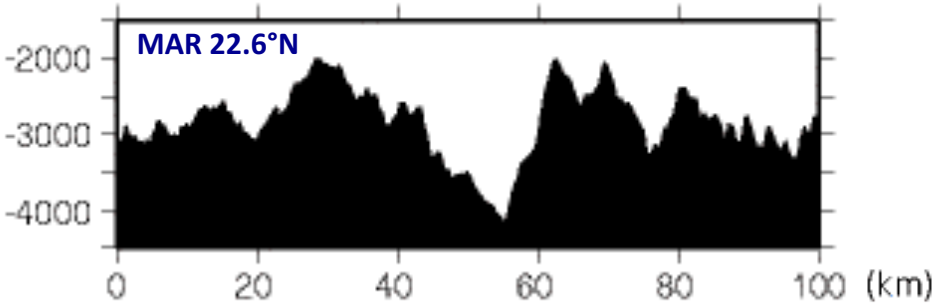


http://libweb5.princeton.edu/visual_materials/maps/websites/thematic-maps/qualitative/telegraph.html

Submarine Cables

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

Source: Buck & Poliakov (1998, Nature)

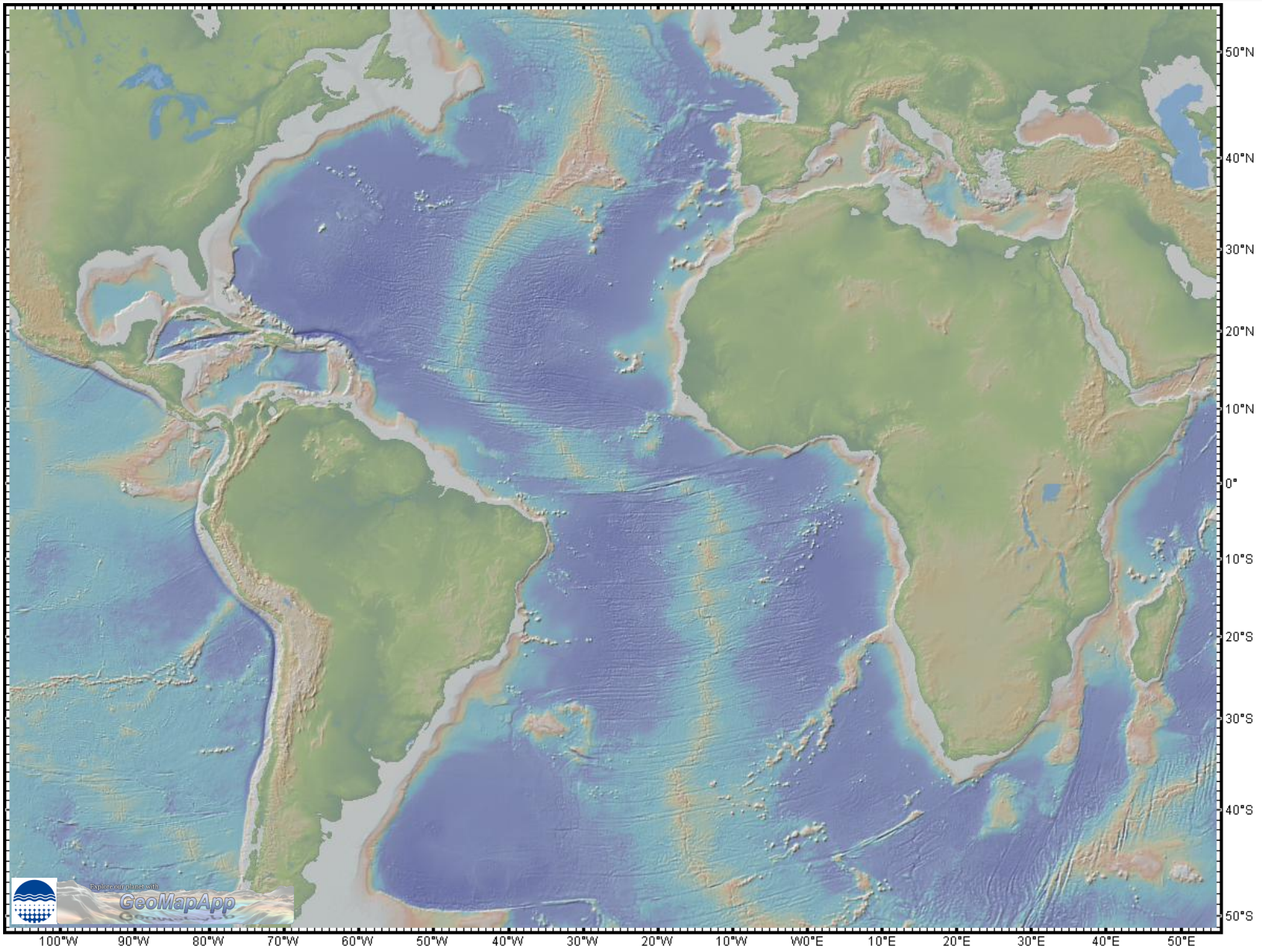


Source: Berann (1968) from Doel et al. (2006, J Hist Geog)

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

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

GEOLOGICAL COMPLEXITY OF CONTINENTAL MARGINS


50°N
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10°N
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20°S
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40°S
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90°W
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60°W
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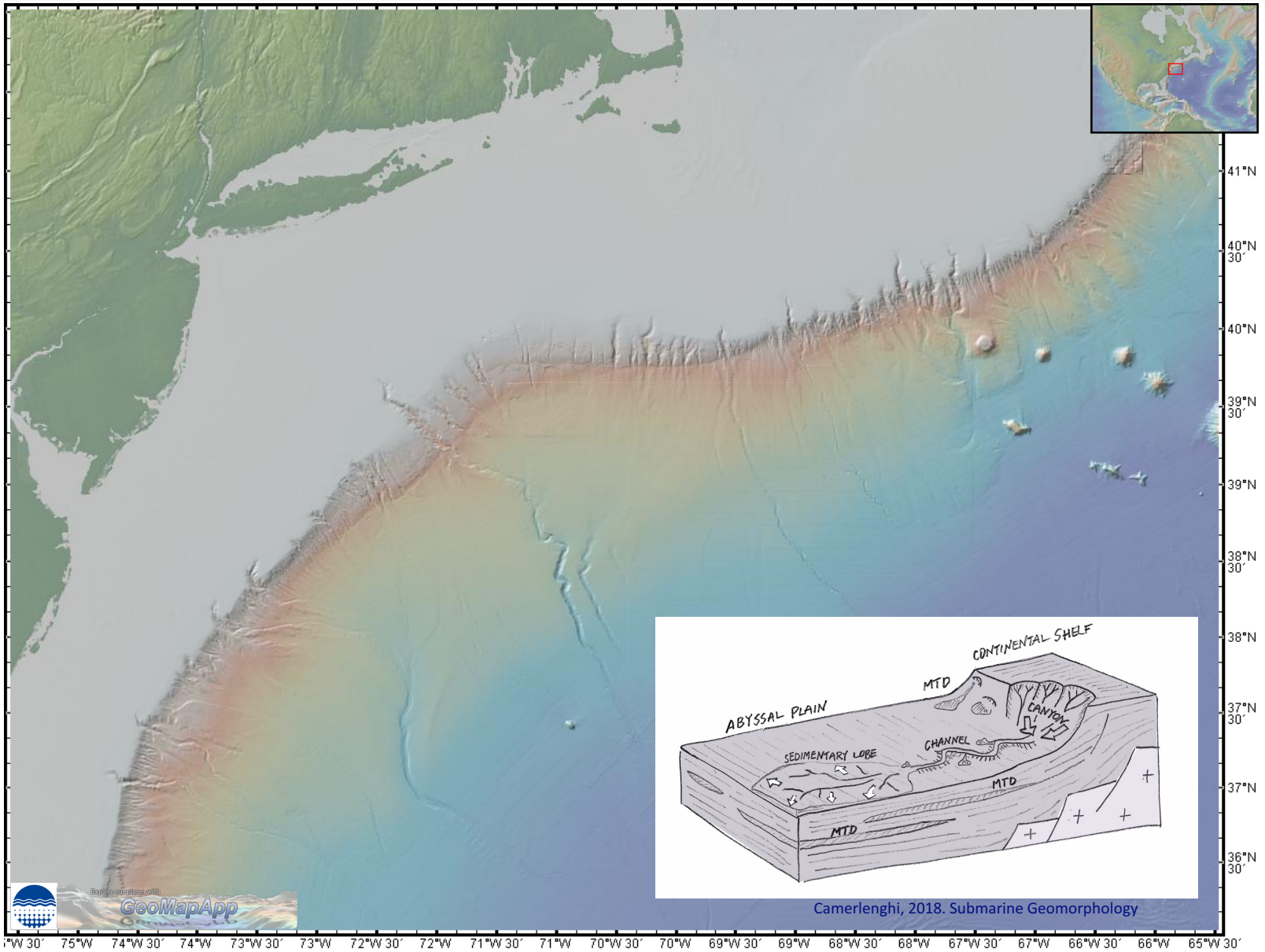
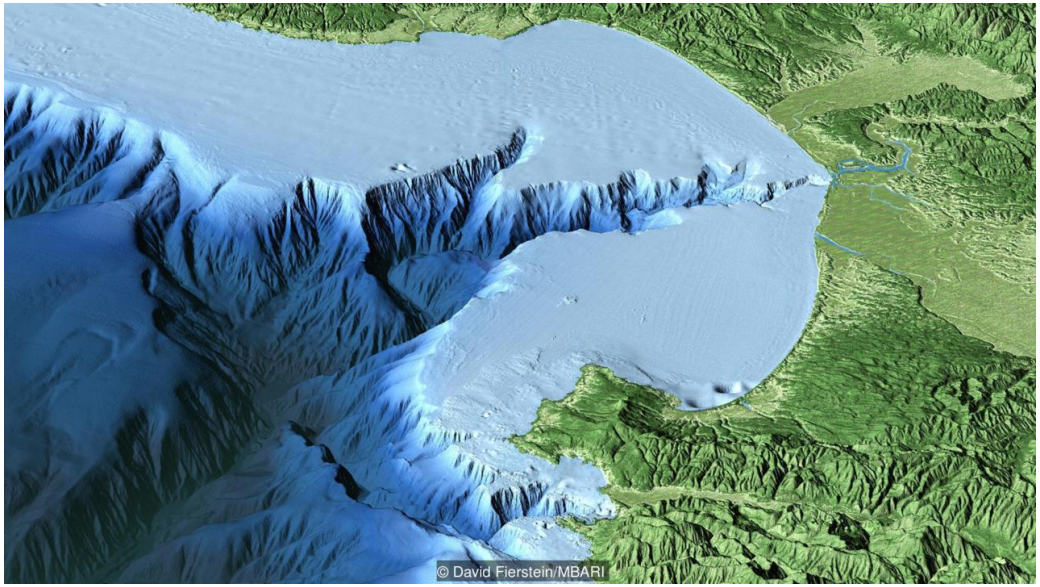
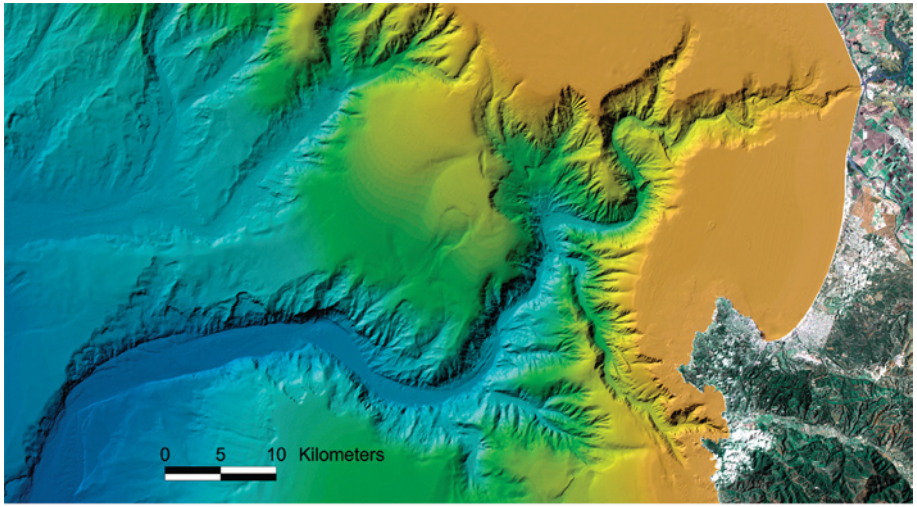
GeoMapApp

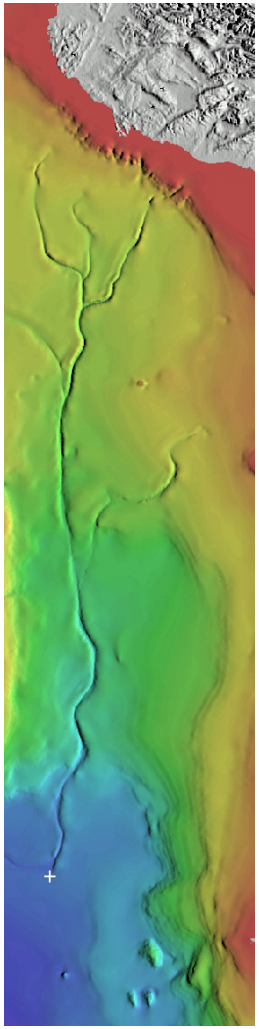


Camerlenghi, 2018. Submarine Geomorphology

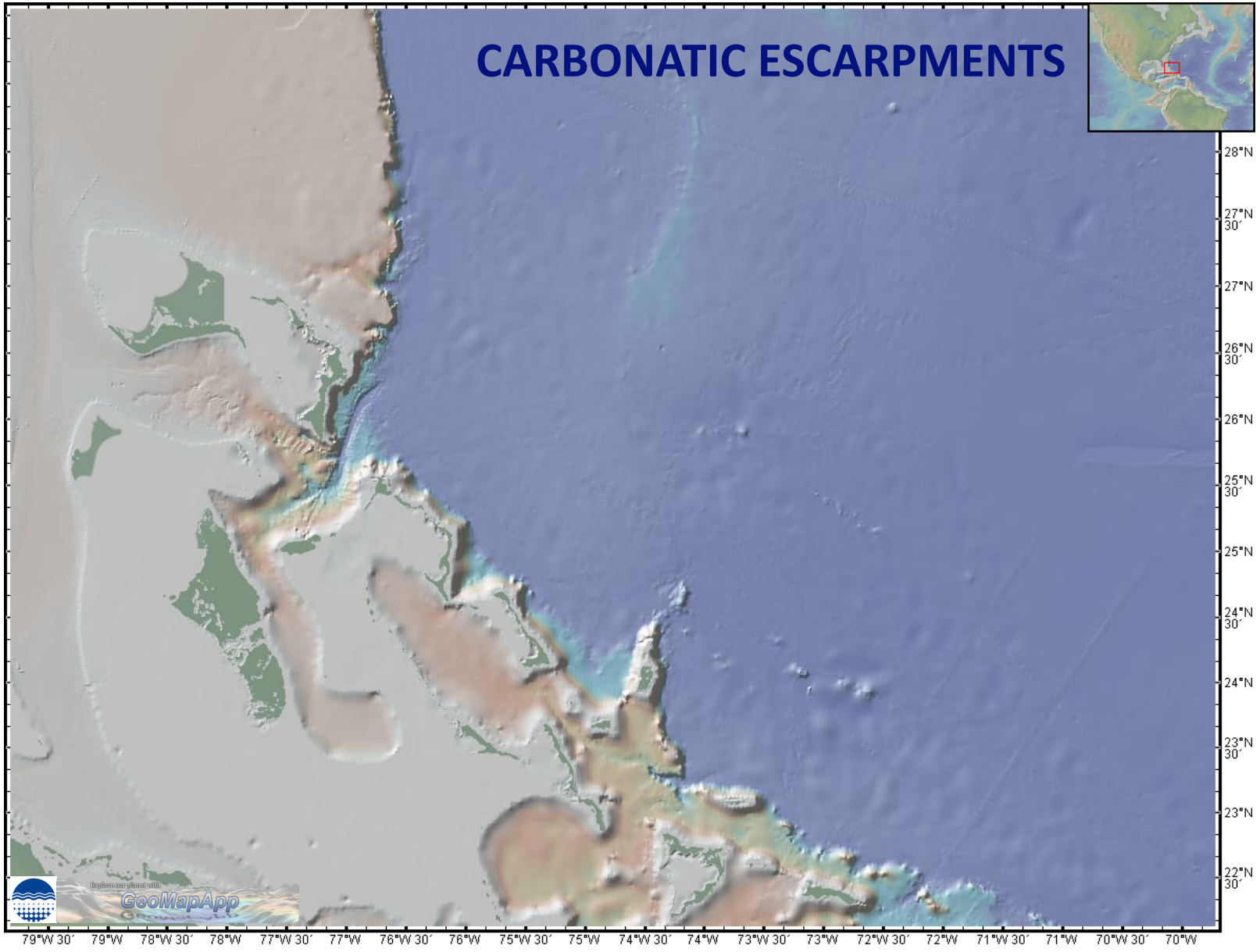
Submarine canyons and deep sea channels



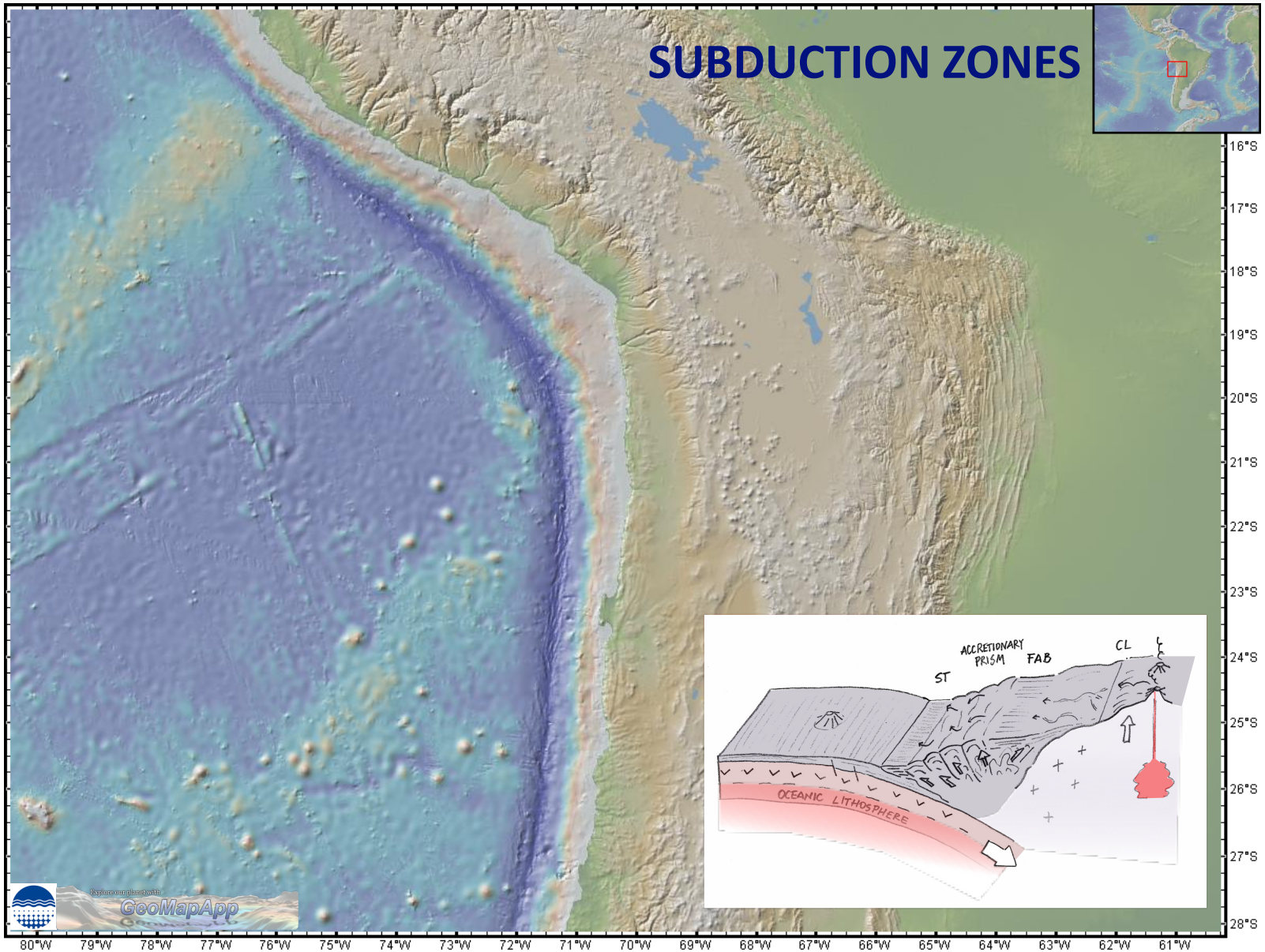




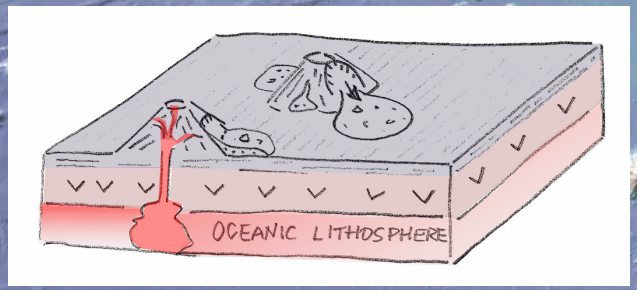
CARBONATIC ESCARPMENTS



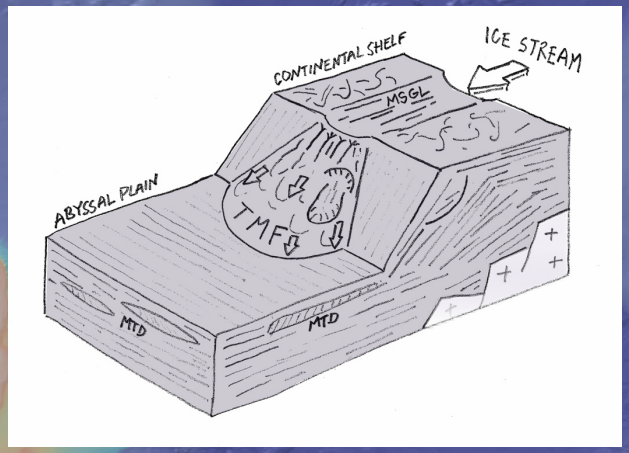
SUBDUCTION ZONES



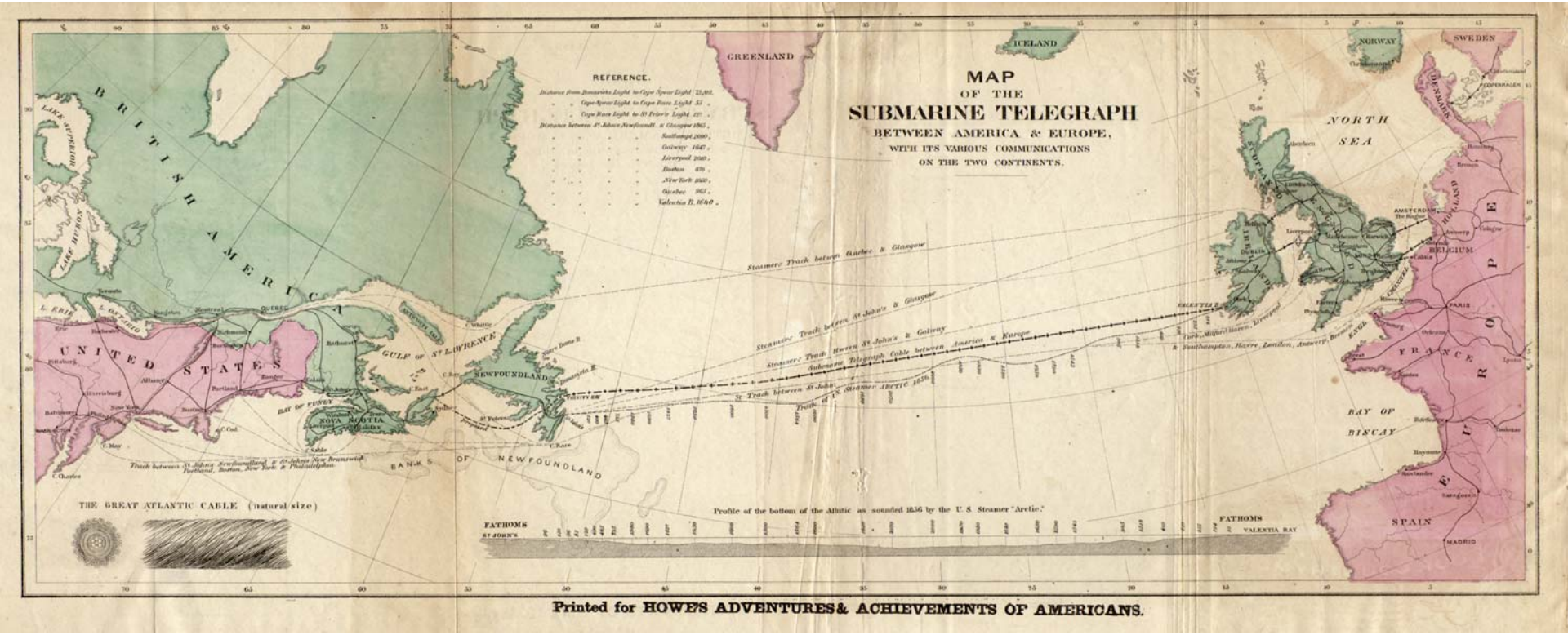
VOLCANIC ISLANDS



GLACIAL MARGINS



SUBMARINE CABLES

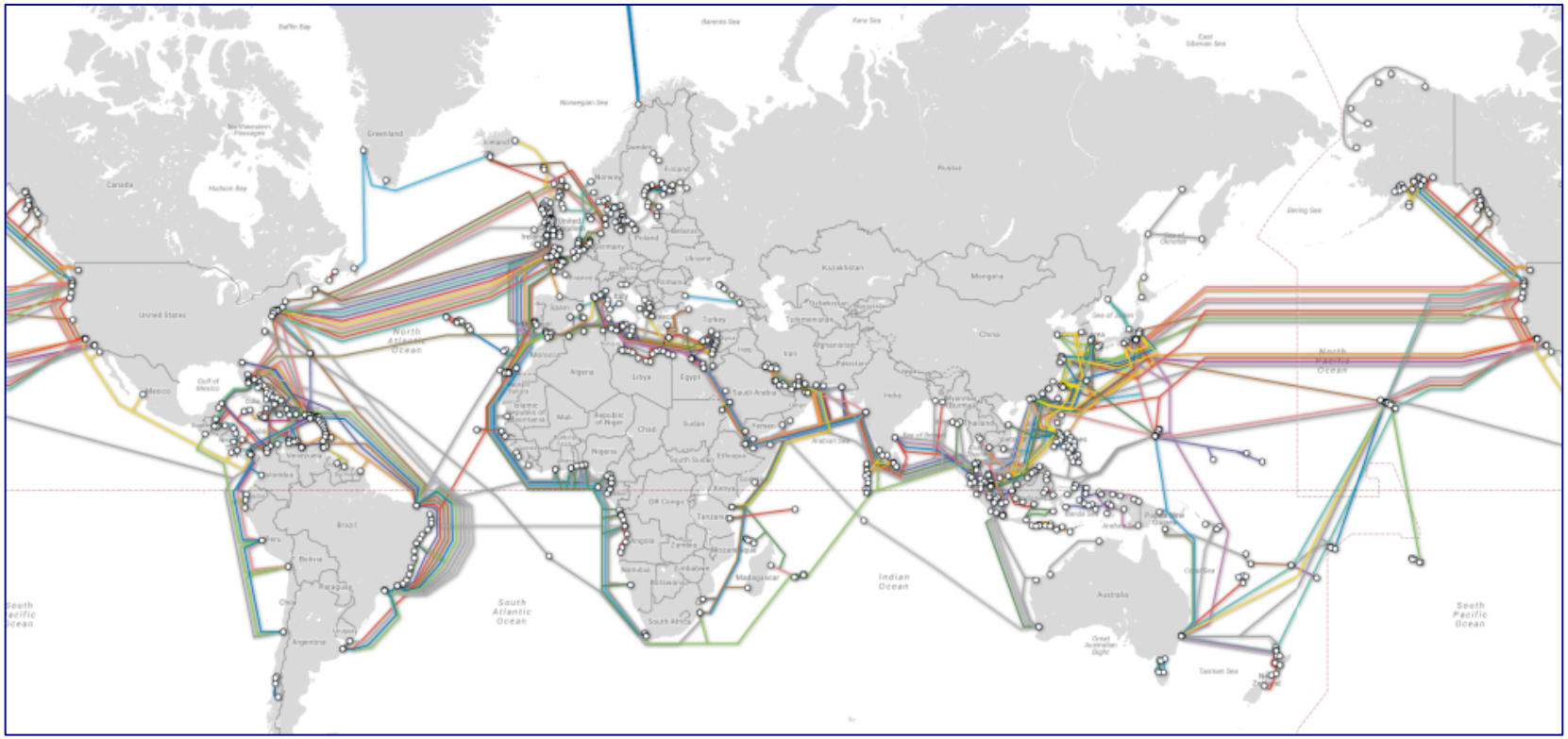


Data Transmission

- 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

The $300m cable that will save traders milliseconds

In the high-speed world of automated financial trading, milliseconds matter. So much so, in fact, that a saving of just six milliseconds in transmission time is all that is required to justify the laying of the first transatlantic communications cable for 10 years at a cost of more than $300m.

By Christopher Williams, Technology Correspondent, 8:00AM BST 11 Sep 2011

Seabed survey work for the Hibernian Express, as the **6,021km (3,741 mile)** fibre-optic link will be known, is already under way off the east coast of America. The last cables laid under the Atlantic were funded by the dotcom boom in the 1990s when telecoms infrastructure firms rushed to criss-cross the ocean.

The laying of the new transatlantic communications cable is a viable proposition because Hibernia Atlantic, the company behind it, is planning to sell a special superfast bandwidth that will have hyper-competitive trading firms and banks in the City of London and New York queuing to use it. In fact it is predicted they will pay about 50 times as much to link up via the Hibernian Express than they do via existing transatlantic cables. **The current leader**, Global Crossing's AC-1 cable, **offers transatlantic connection in 65 milliseconds**. **The Hibernian Express will shave six milliseconds off that time**. Of course, verifiable figures are elusive and estimates vary wildly, but **it is claimed that a one millisecond advantage could be worth up to $100m (£63m) a year to the bottom line of a large hedge fund.**

Some City experts have criticised the growth in vast volumes of electronic trading, where computers automatically buy and sell stocks with no human input. The British firm laying the cable, Global Marine Systems, is plotting a new route that is shorter than any previously taken by a transatlantic cable. As closely as possible, it will follow "the great circle" flight path followed by London-to-New York flights.

"We spent 18 months planning the route," says Mike Saunders, Hibernia Atlantic's vice-president of business development. "If it ever gets beaten for speed we end up giving our customers their money back, basically, so my boss would kill me if we got it wrong."

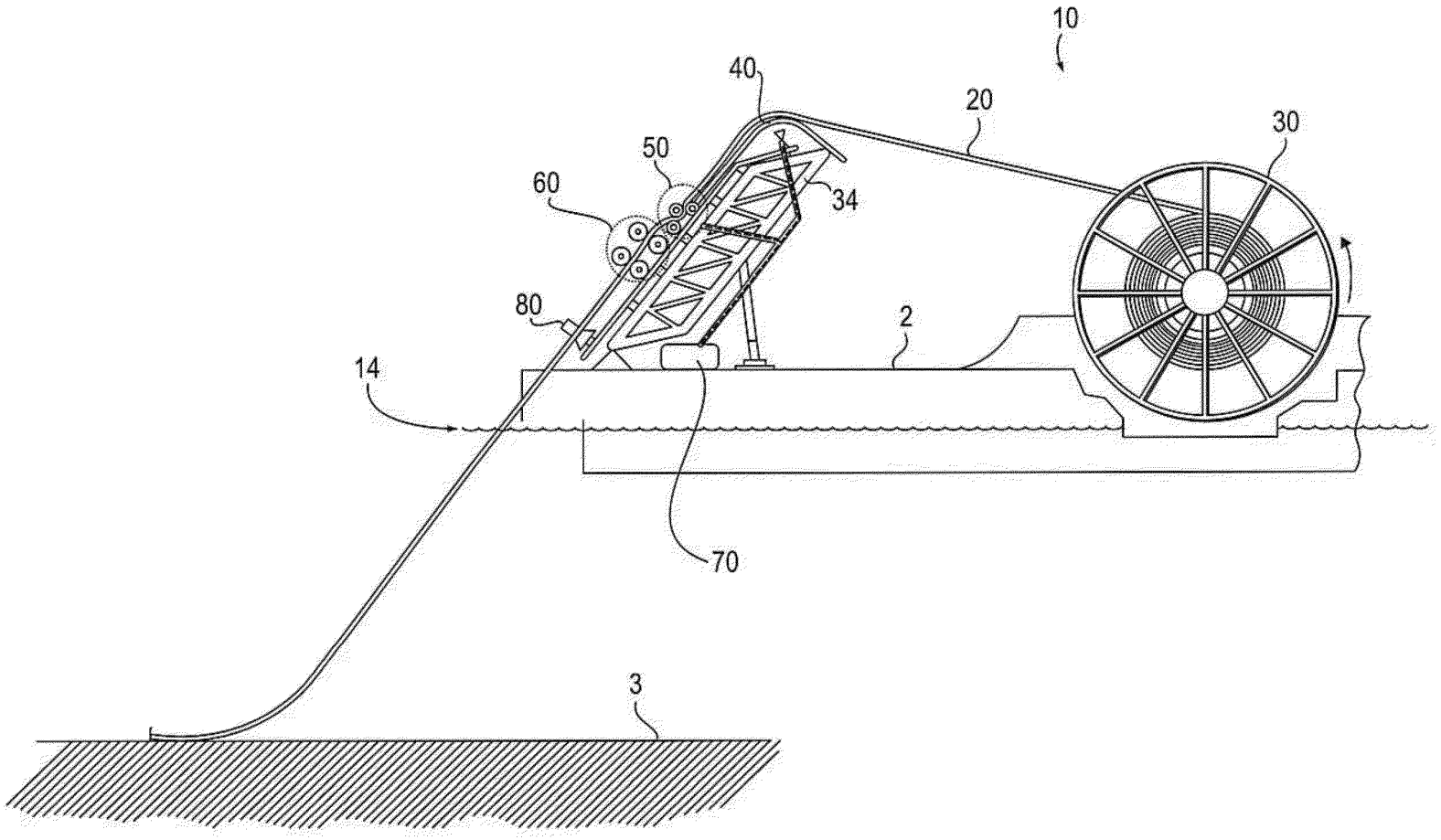
And, he says, customers from hedge funds, currency dealers and exotic proprietary trading firms are queuing up for the switch-on in 2013.

"That's the way these guys think," Mr Saunders says. "If one of them is on a faster route, they all have to get on it."

http://www.telegraph.co.uk/technology/news/8753784/The-300m-cable-that-will-save-traders-milliseconds.html

Reel-lay vessel

Reel-lay



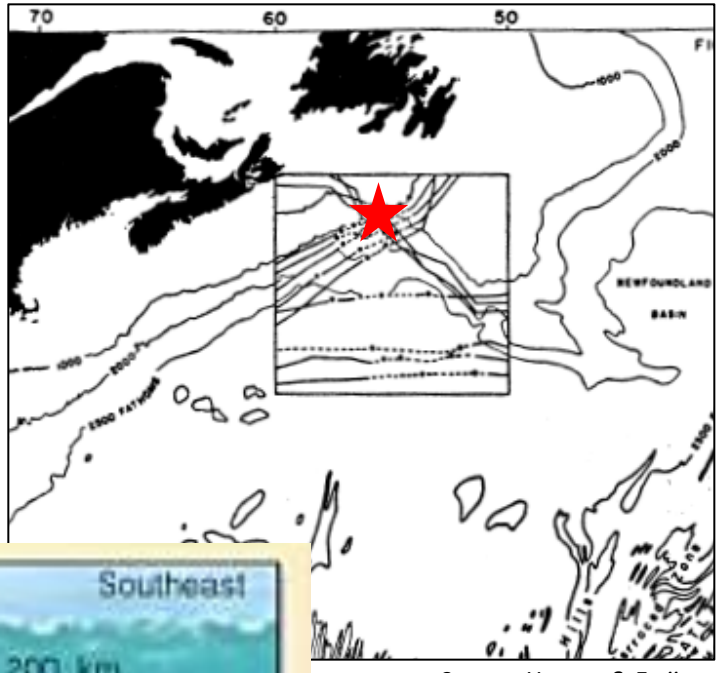
Plough system

Submarine cable breaks and the advancement of science

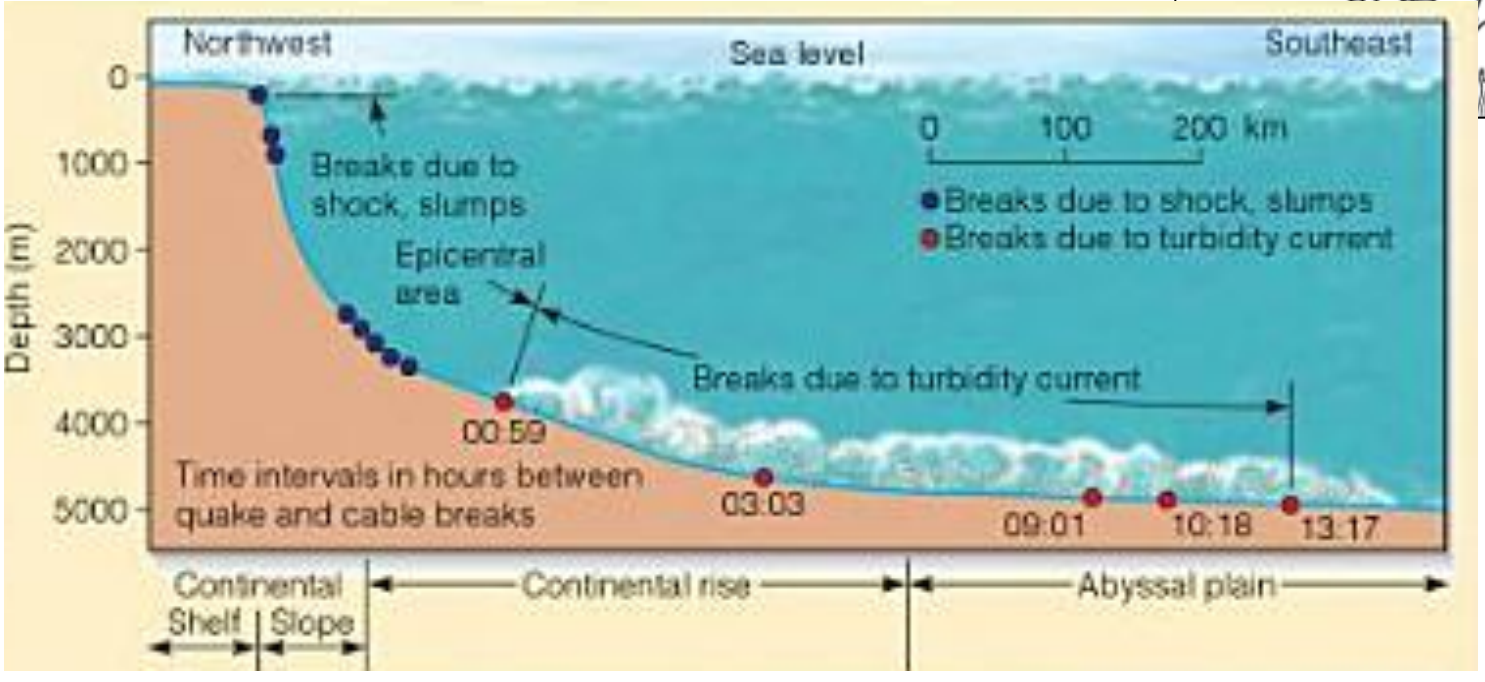
Eastern Canada & the Grand Banks earthquake

- 18 Nov 1929, *earthquake* off NS/Nfld (magnitude 7.2)
- Followed by submarine *cable breaks* (12 cables)
- Breaks younger downslope (over 13 hours, 600 km)
- *Landslide* evolved downslope into a *density current*

  (1st direct evidence) - speeds up to 100 km/hr



Source: Heezen & Ewiing (1952, Am J Sci)



Source: Heezen & Hollister (1972) The Face of the Deep

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

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

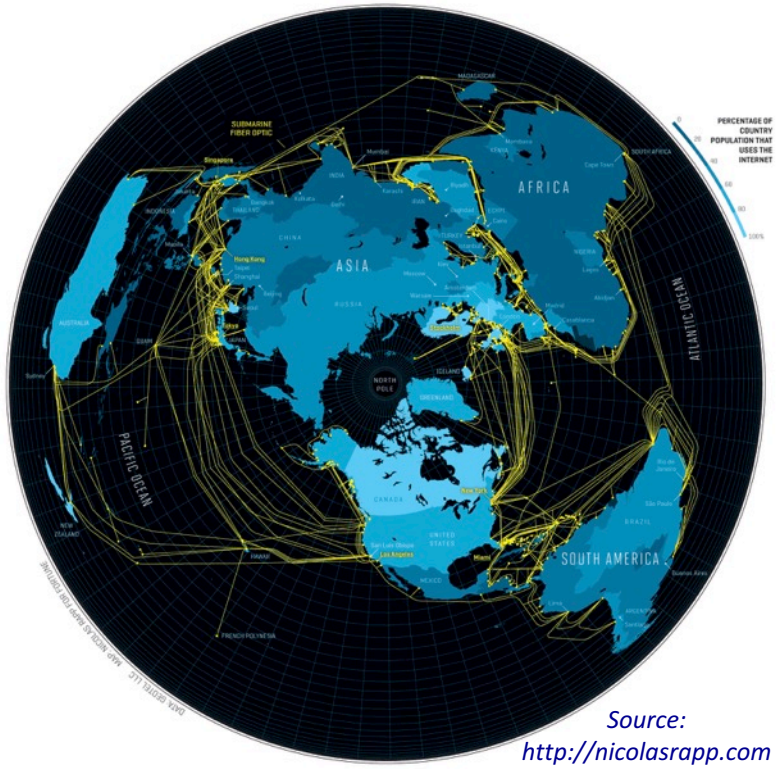
1956: 1st trans-Atlantic telephone cable (TAT-1)

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

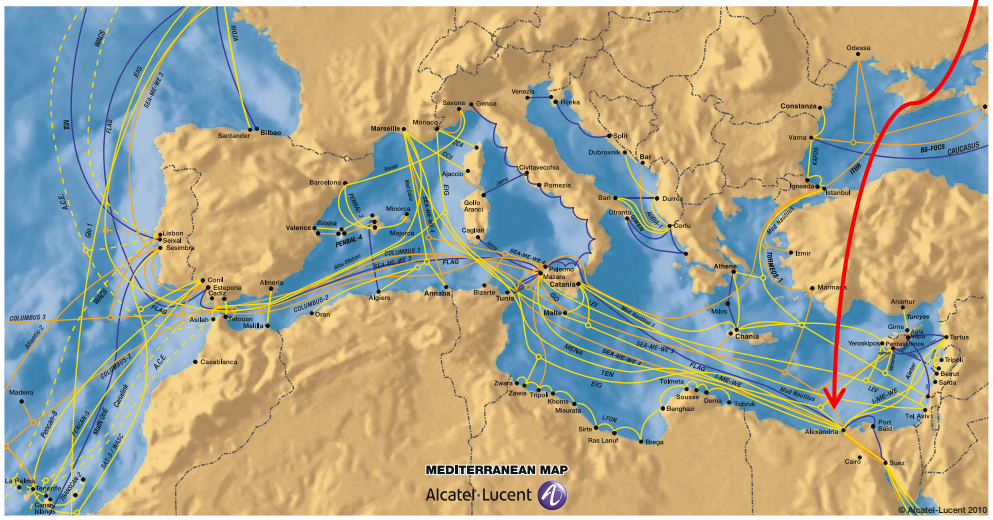
1988: 1st trans-Atlantic fibre optic cable (TAT-8)

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)

Seabed Mapping – an offshore service industry

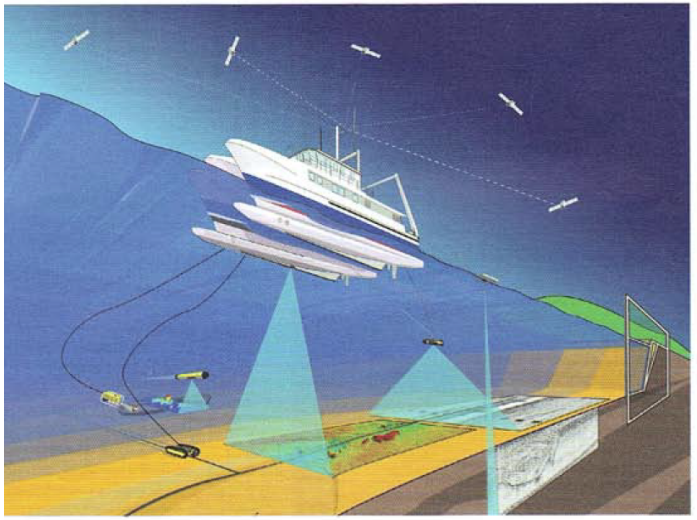
Supports the siting and maintenance of seabed installations (cables, pipelines, wind farms, platforms…)

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

remote methods

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

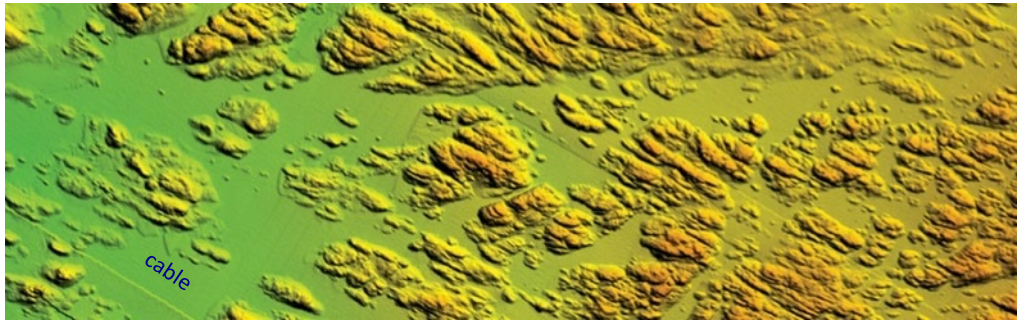
direct methods



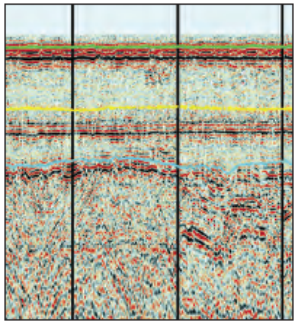
Source: downloads.n-o-s.eu/partners/mmt-ab/

Source: www1.gardline.com

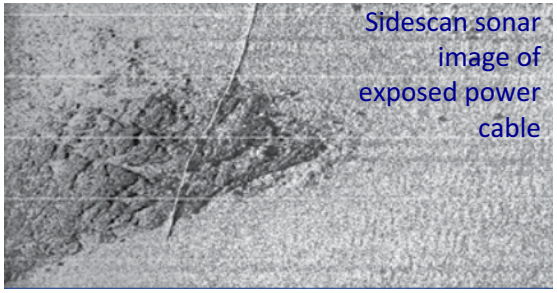
multibeam sonar image

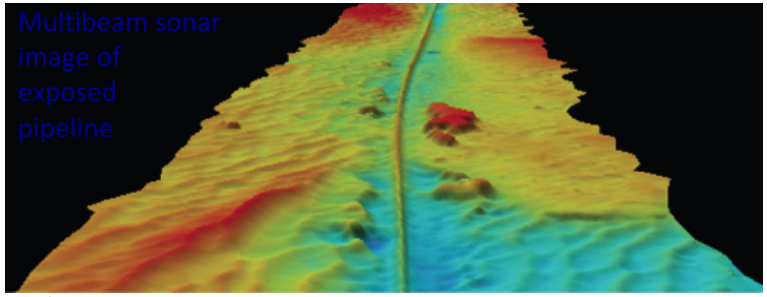


seismic profile



Cable plough





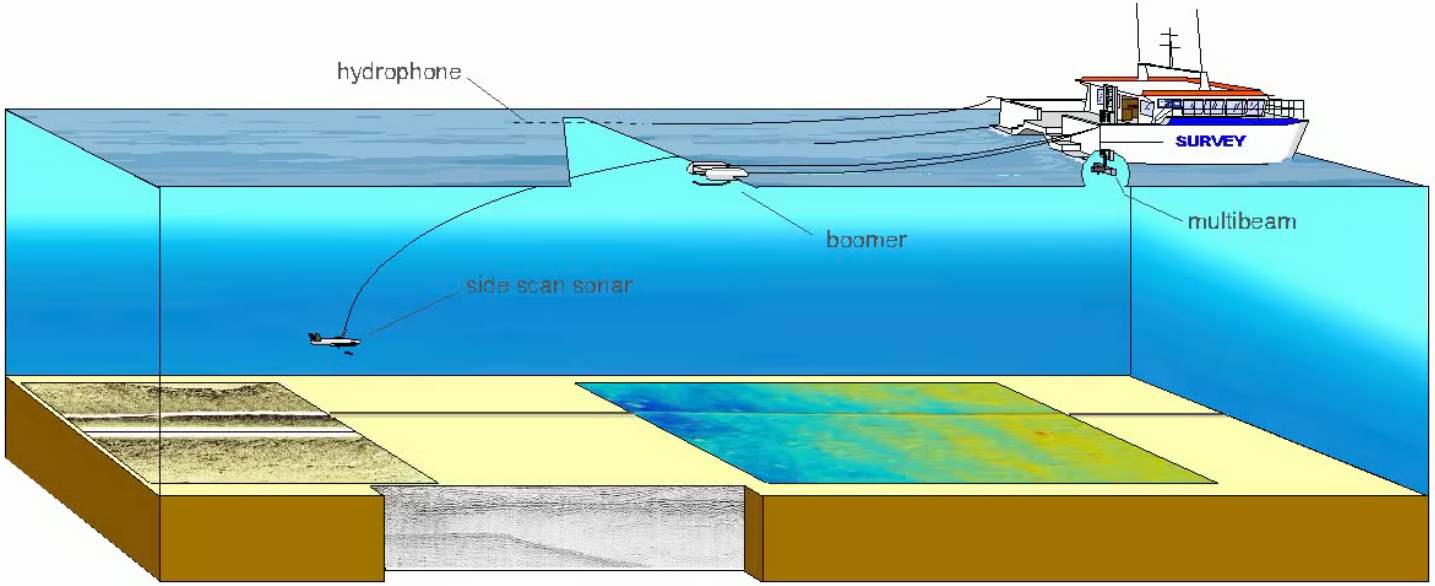
Source: www.osirisprojects.co.uk

Trenching ROV

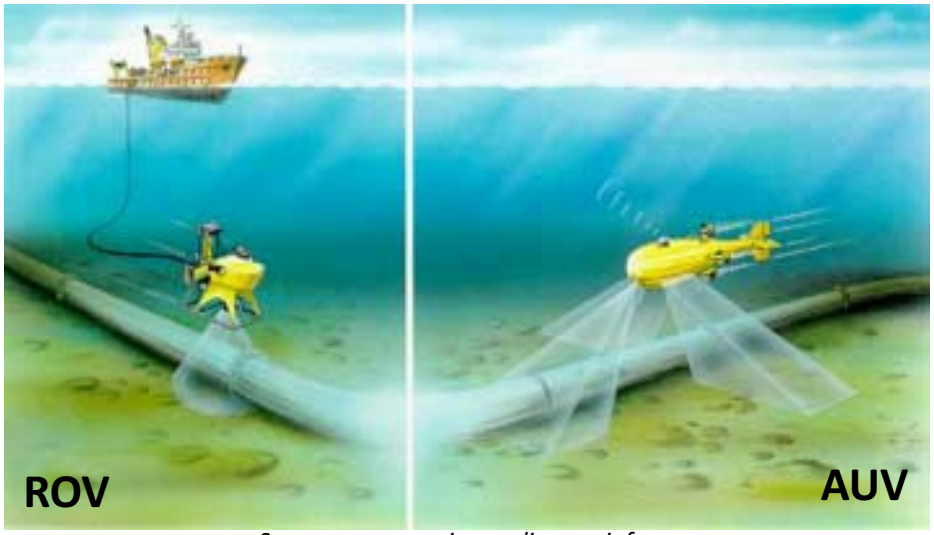
Sources: www.pharos offshoregroup.com

> 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 :

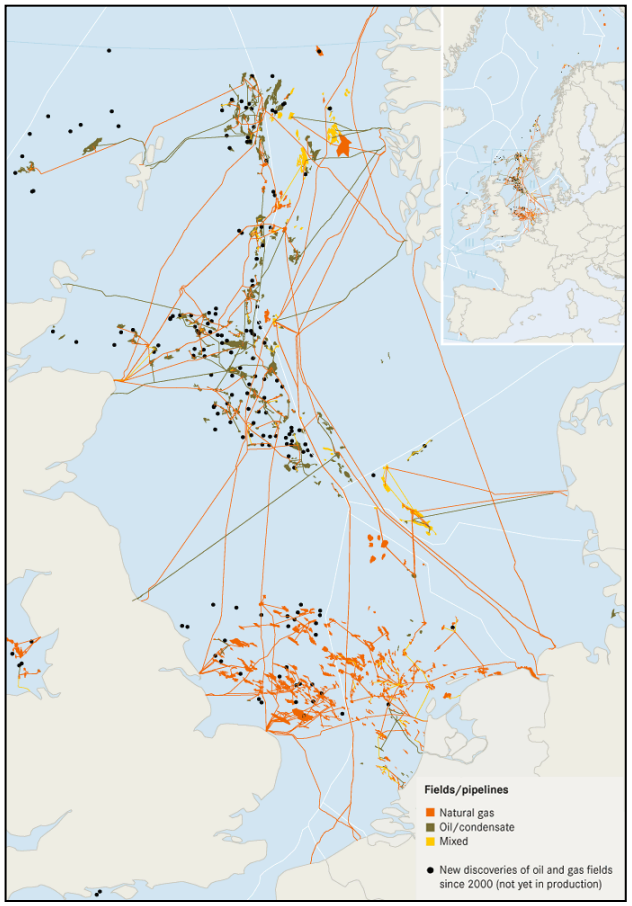
- Remotely Operated Vehicles (ROVs)
- Autonomous Underwater Vehicles (AUVs)

Multi-national offshore industries

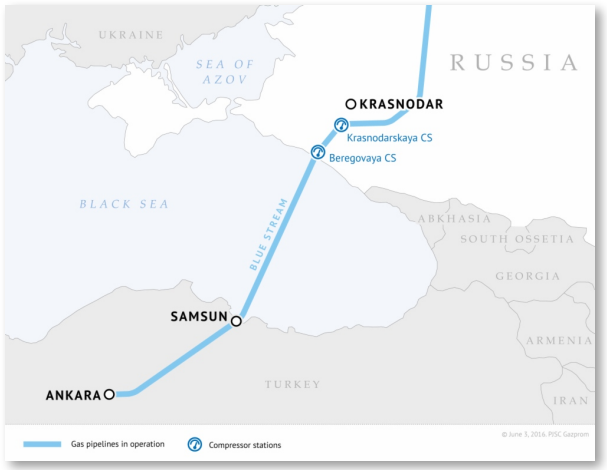
INCREASING USE OF THE SEABED FOR ECONOMIC ACTIVITIES

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

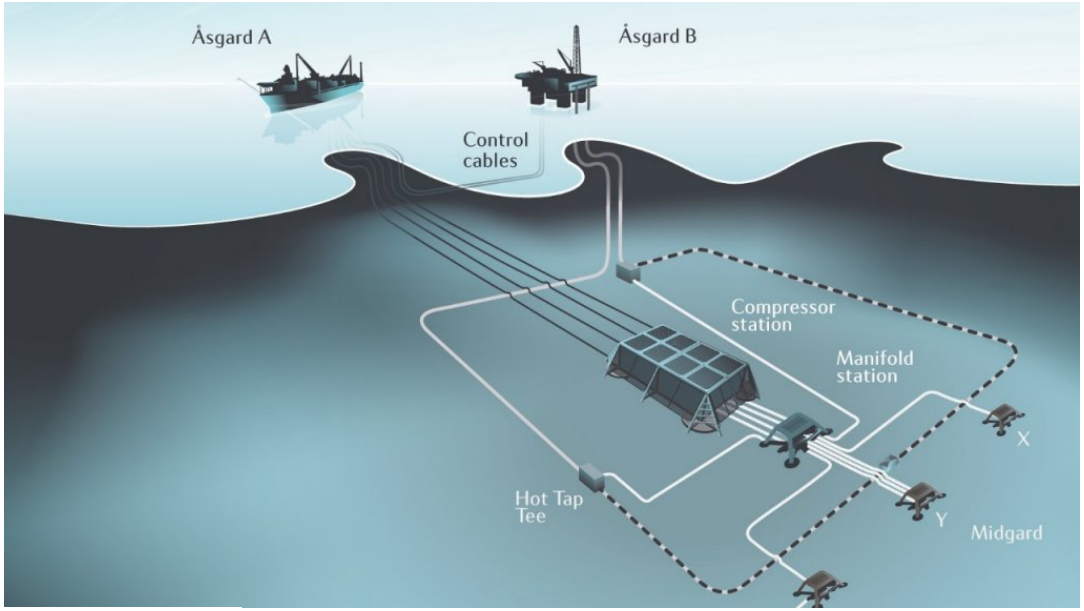
Trans Adriatic Pipeline (TAP)

INCREASING USE OF THE SEABED FOR ECONOMIC ACTIVITIES

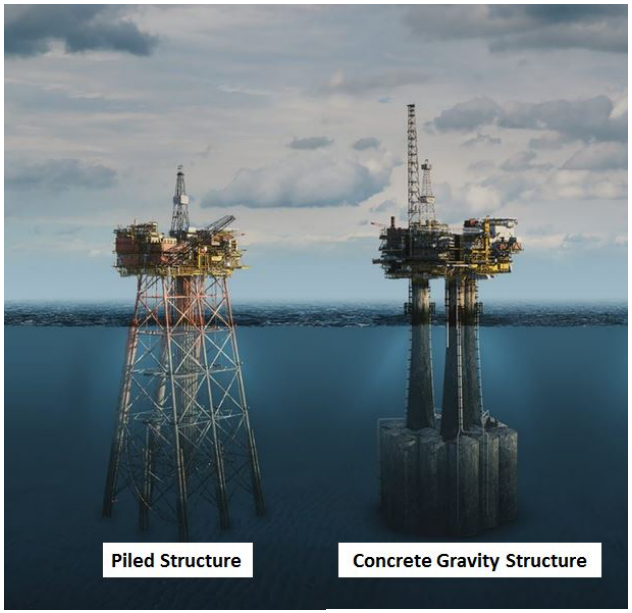
TAL
transalpine pipeline

PLATFORMS FOUNDATIONS and SUBSEA INSTALLATION

Mikkel (Norway)



Statoil



DrillingFormulas.Com

Subsea installations

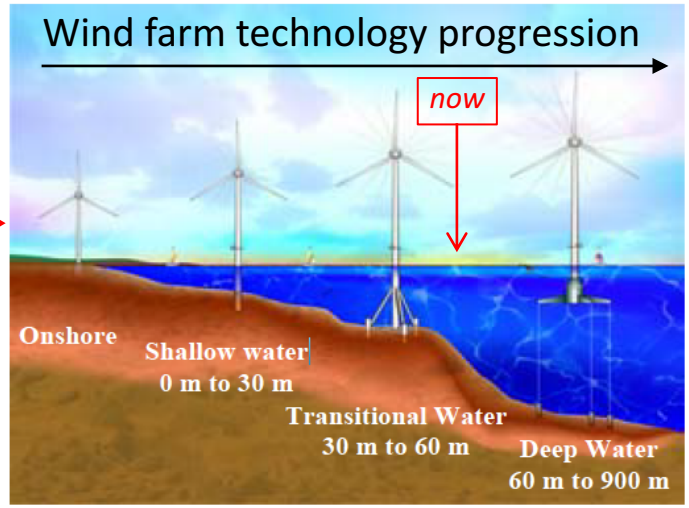
Åsgard Statoil subsea installation (Norway)

https://www.youtube.com/watch?v=GIu8U3XHXpE

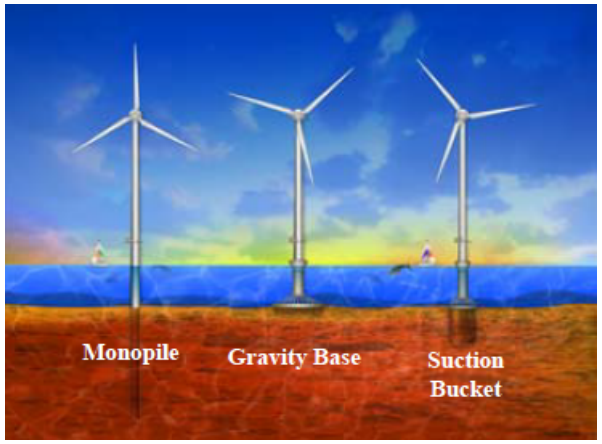
Seabed Installations - for Renewable Energies

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

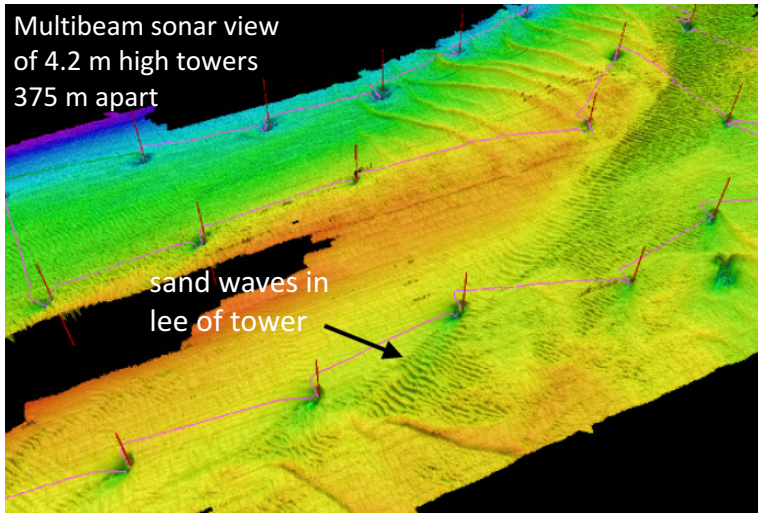
Wind farm seabed installations >40 projects world-wide

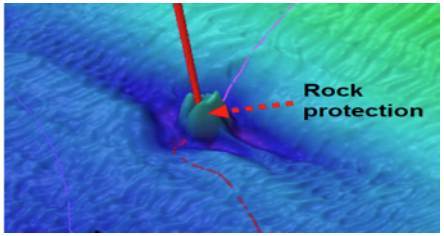


Sources: Musial et al. (2006, OTC 18355)



Different foundations…
all require knowledge of seabed





Seabed mapping

+ monitoring surveys:

- sand wave migration
- scour of foundations

Same companies as cables

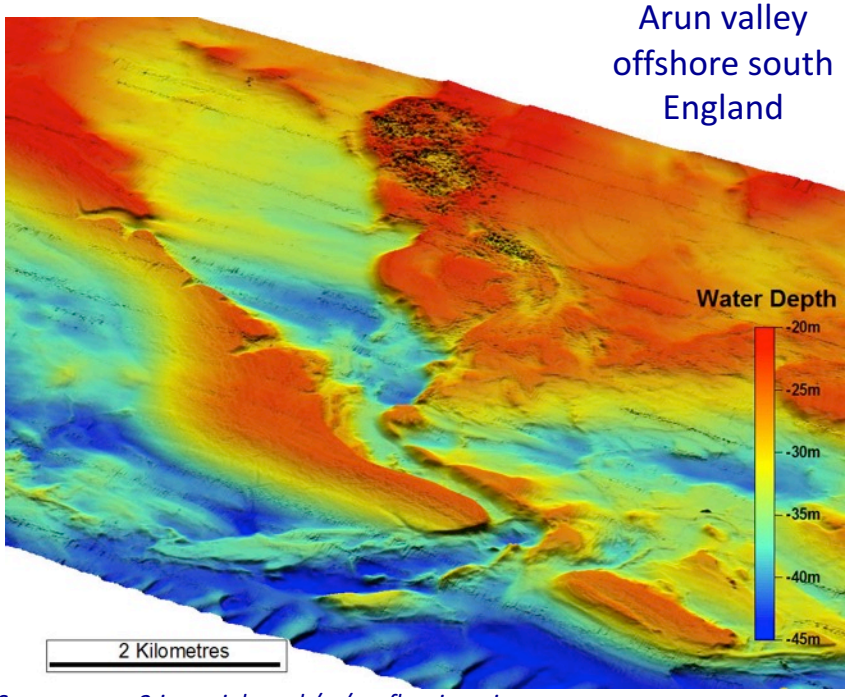
Source: Scroby Sands Offshore Wind Farm – Coastal Processes Monitoring. Cefas, UK, 2006

Seabed Sand and Gravel Mining

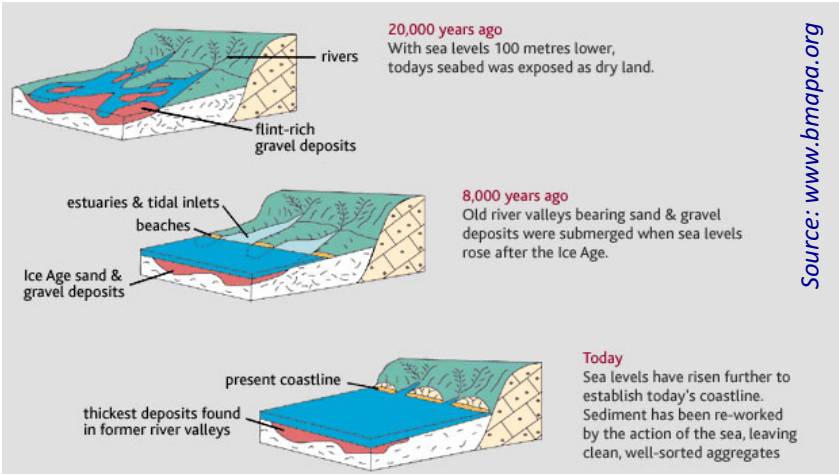
Not very 'glamorous' minerals… but a big business

- 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



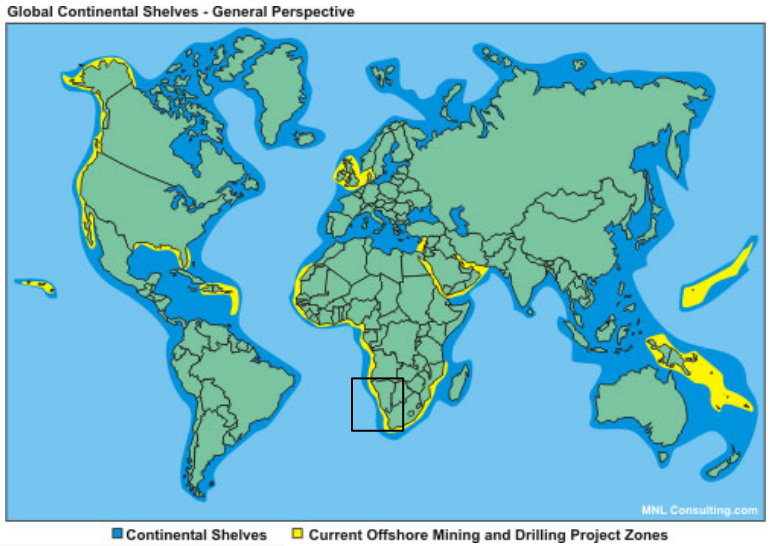
- An industry 2nd to oil & gas in the US (in Europe, mainly North Sea countries*)
- Globally, we use >40 x 10^9 tonnes/yr = twice the sediment carried by all the rivers of the world

*(*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)

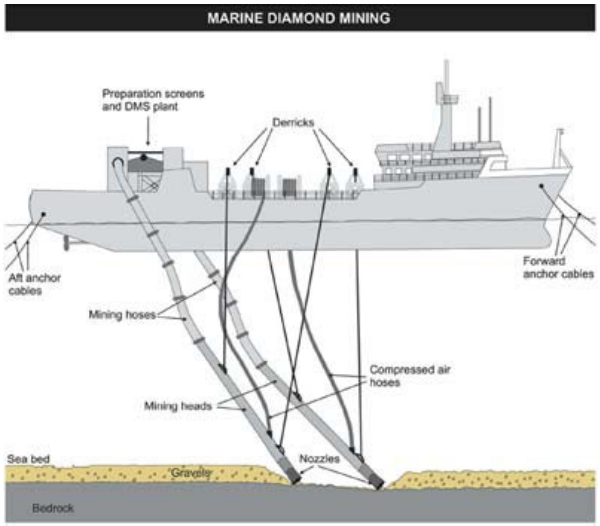


Source: www.mnlconsulting.com

Various mining techniques

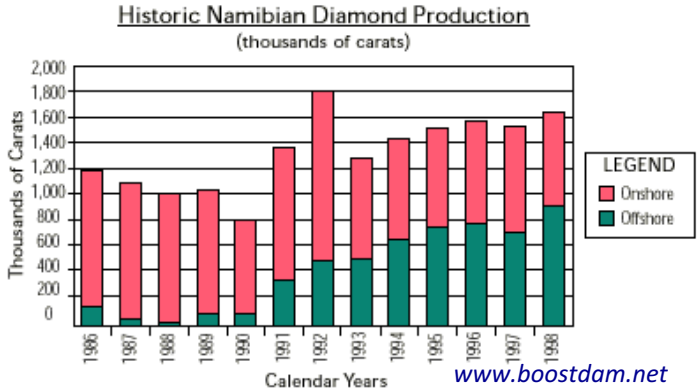
- Horizontal – seabed crawlers →
- Vertical – suction drilling (water jets)
- Airlift – compressed air jets

www.marinelog.com



Source: 2011.polarhusky.com

Diamonds from offshore Namibia (www.imdhgroup.com)



www.boostdam.net

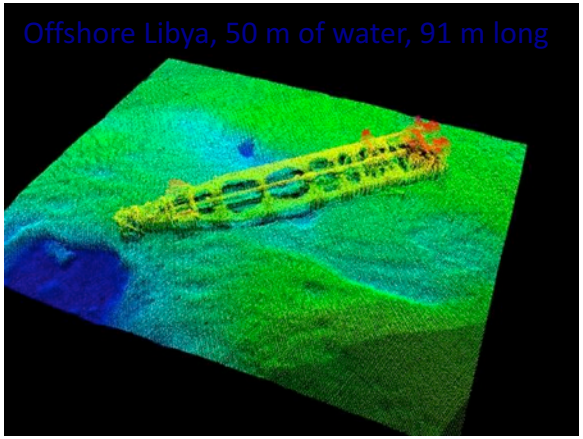
Seabed Treasure Hunting

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

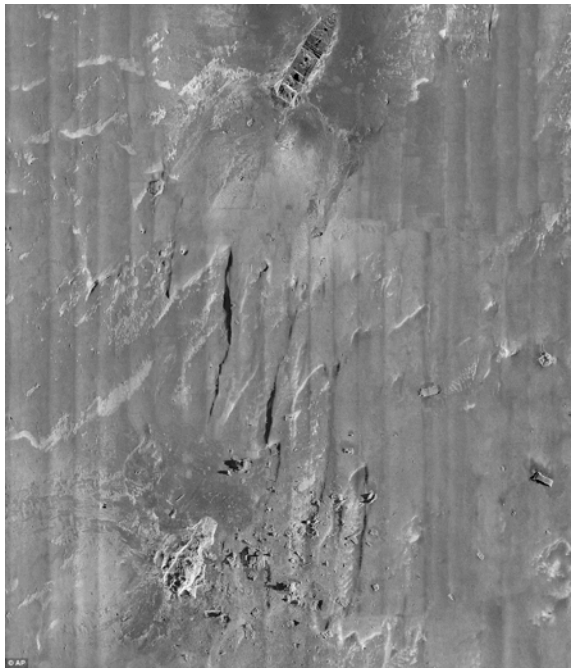
http://shipwreck.net/

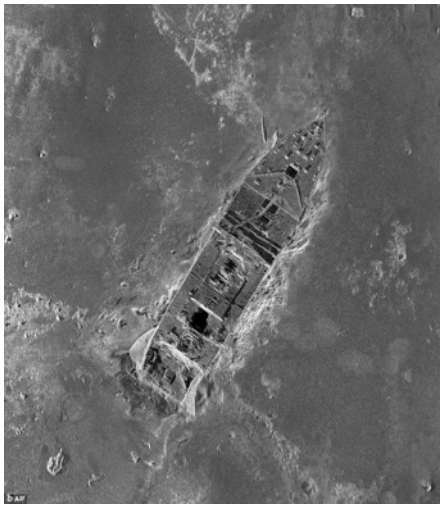
ODYSSEY MARINE EXPLORATION

Source: www.osirisprojects.co.uk



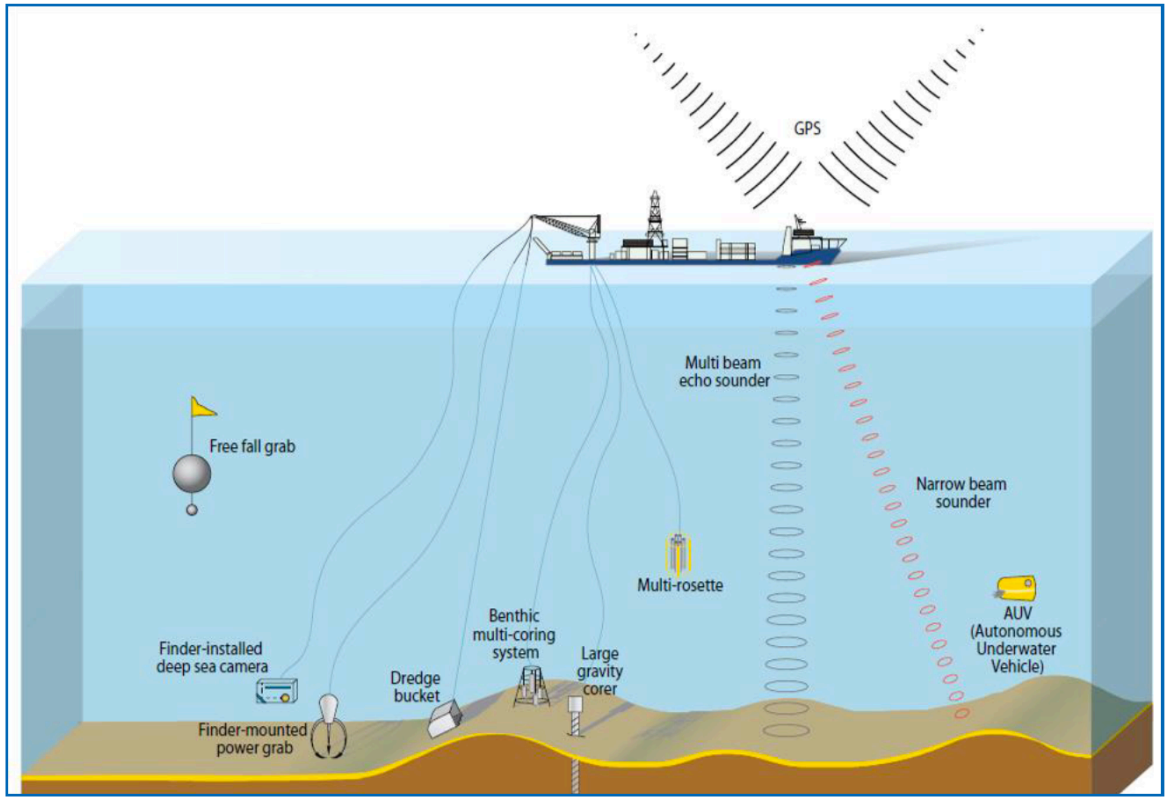
http://subseaworldnews.com/2013/07/25/hms-echo-finds-18-wrecks-in-mission-offshore-libya/





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

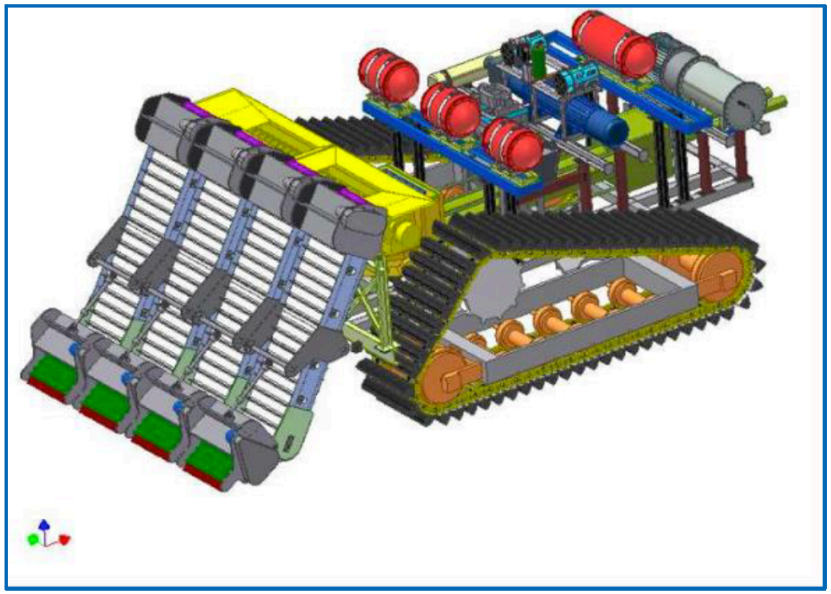
DEEP SEA MINING

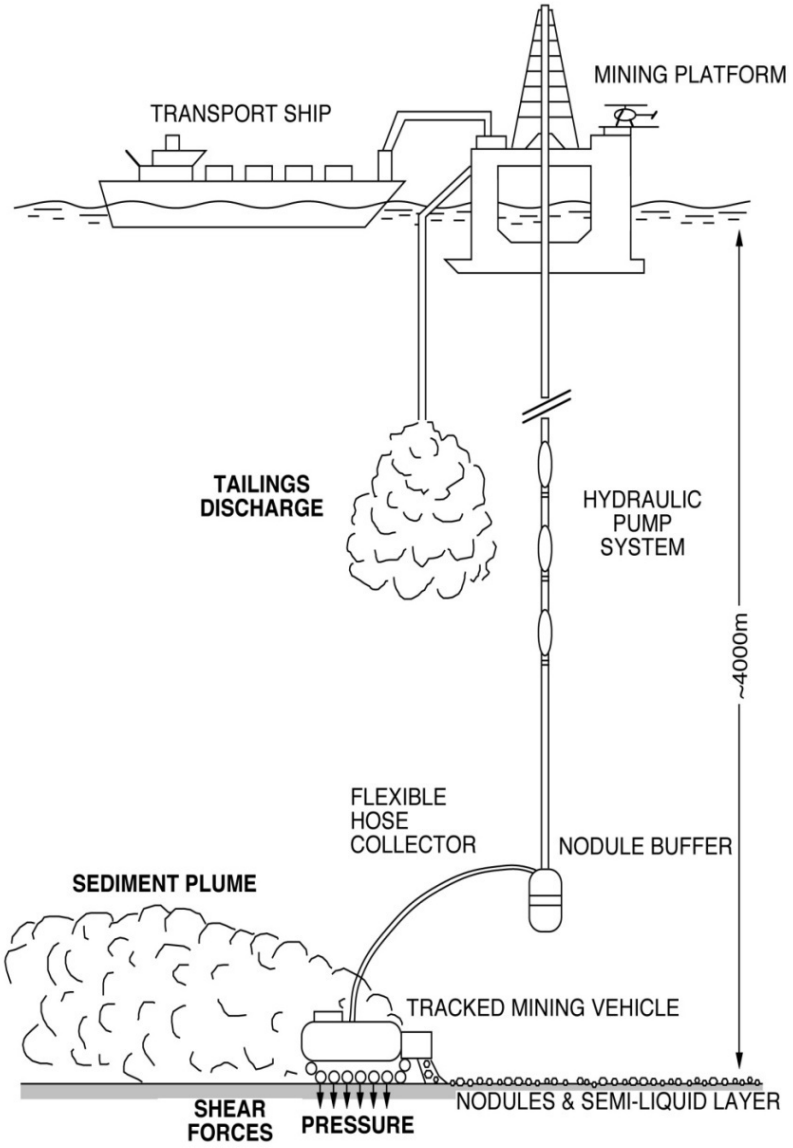


- Securing sustainable access to raw materials and strategic material reducing country's dependency from import.
- Developing advanced technology that could keep Italy as one of the leading exporters of advanced offshore exploration technologies, creating specialized jobs
- Identify possible industry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

DEEP SEA MINING





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

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

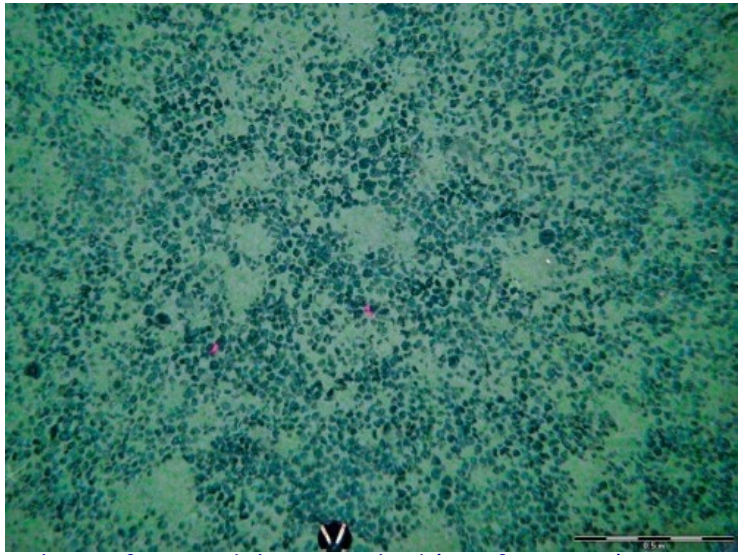
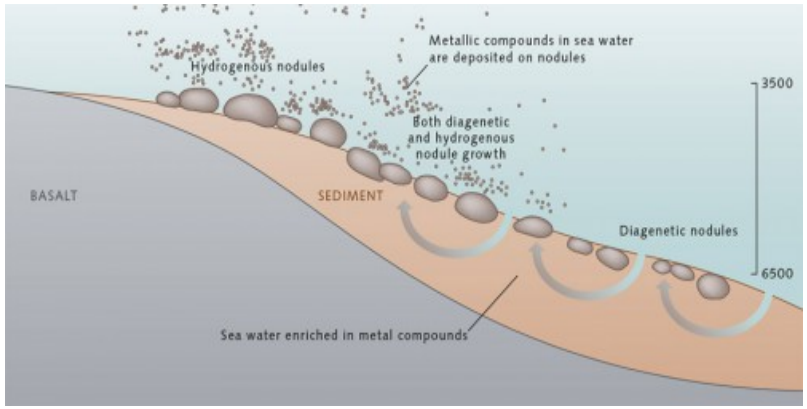
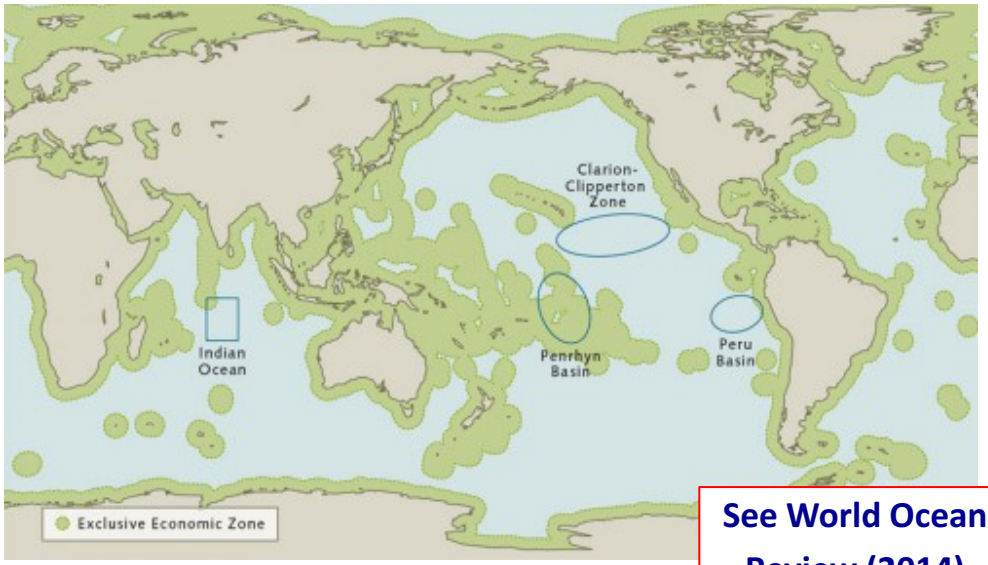


Photo of Mn nodules at seabed (Pacific Ocean)



Schematic of Mn nodules formation processes



Global Mn nodule concentrations

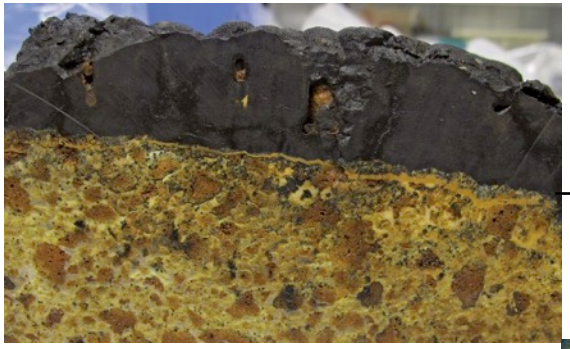
See World Ocean Review (2014)

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

Minerals in the Deep Sea

2. Cobalt crusts

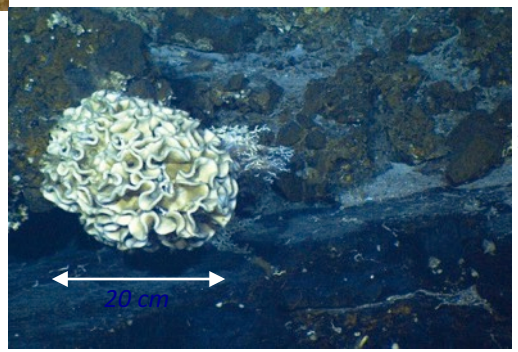
- composition similar to Mn-Fe nodules, more cobalt and platinum
- also precipitates, formed very very slowly (millions of years)
- found on flanks of seamounts (currents), in water depths 1000-3000 m
- differing distribution than nodules, but overlap; mainly in Prime Crust Zone



crust (cms thick)

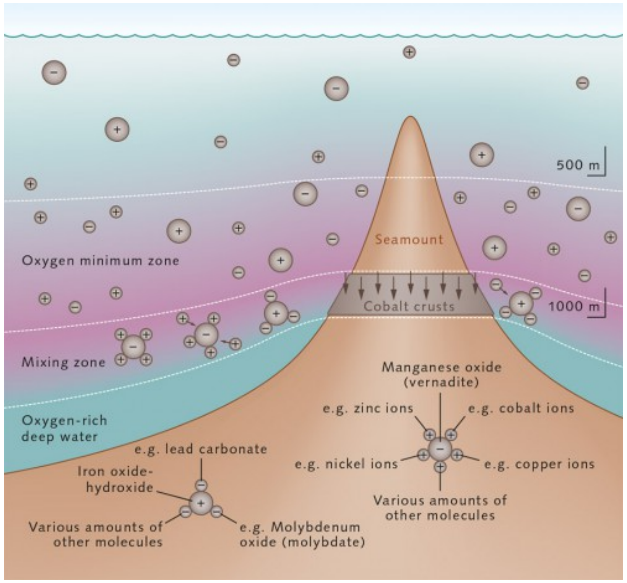
rocky substrate

Cross-section of cobalt crust (SW Pacific)

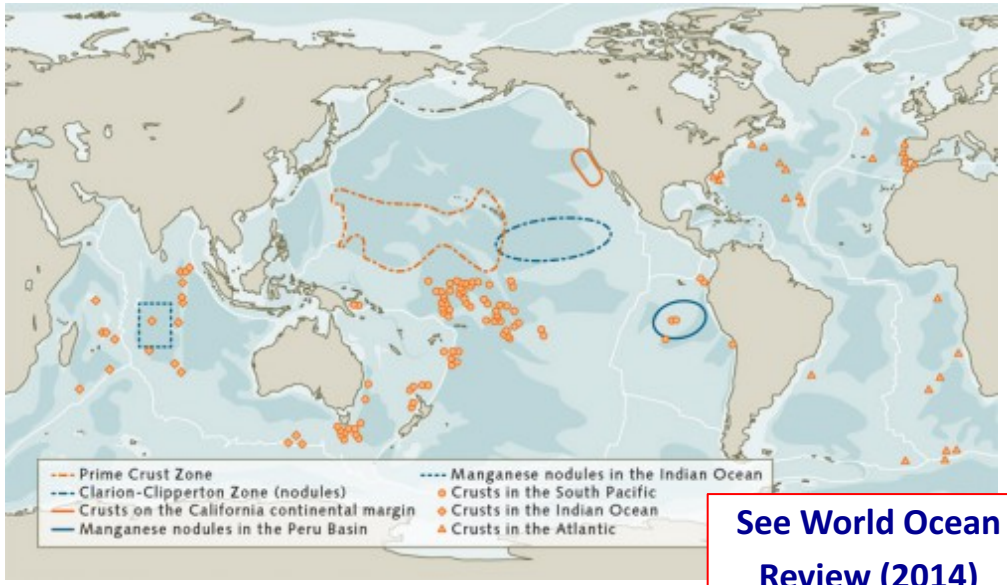


Single-celled organism at seabed on cobalt crusts

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



Schematic of cobalt crust formation on seamount flanks

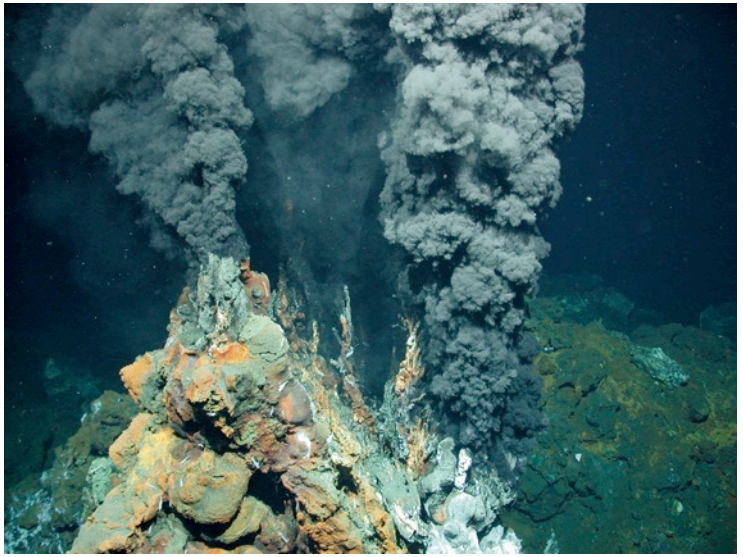


See World Ocean Review (2014)

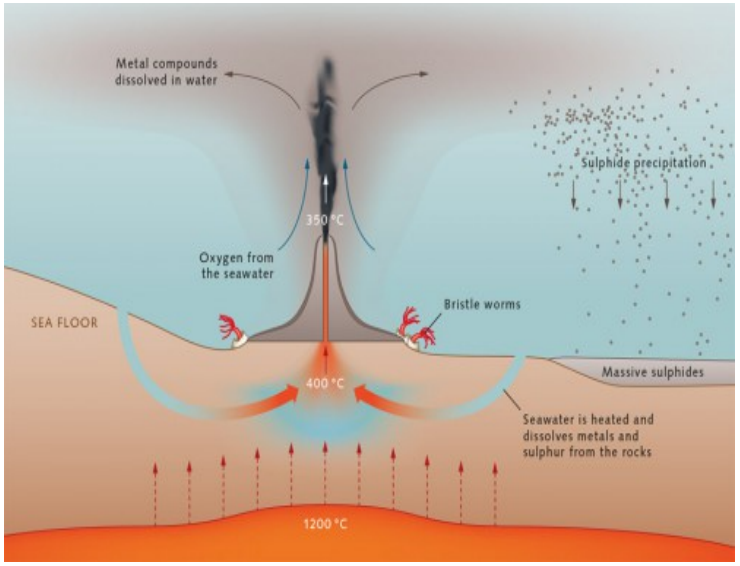
Minerals in the Deep Sea

3. Massive sulphides

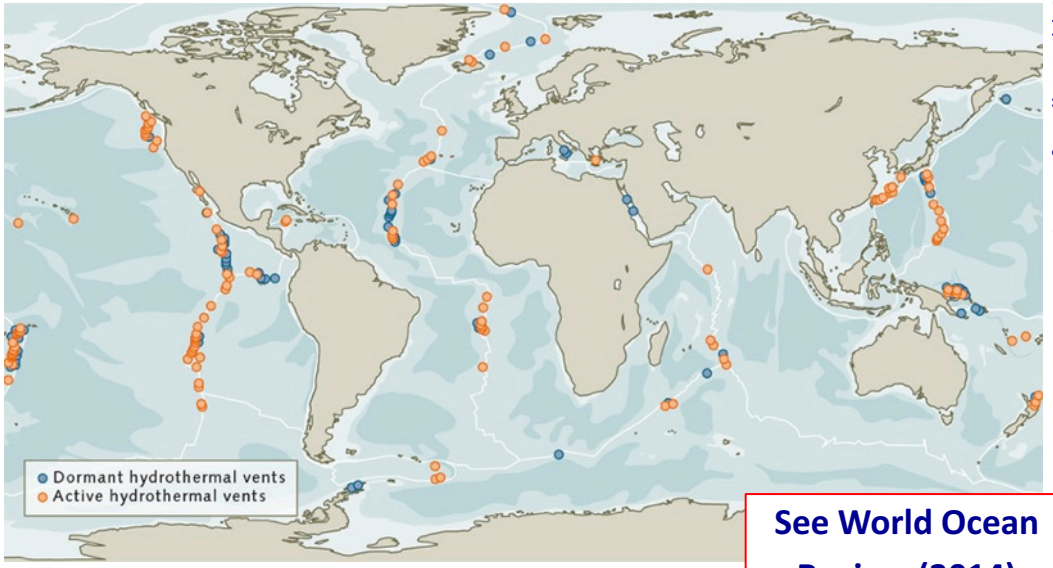
- Iron sulphides with copper, gold, zinc & silver
- Sulphides and other metals precipitate from seawater near volcanoes
- 'Black smokers' discovered in 1978 – hydro-thermal vents (metal-rich fluids up to 400°C)
- Found in areas of recent and present volcanism, in water depths 500-4000 m (including offshore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

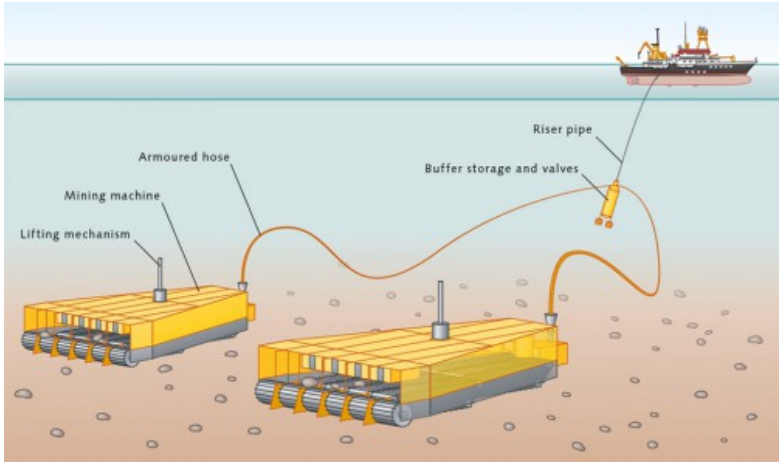
→ drove the signing of UNCLOS (1982) and the creation of the International Seabed Authority (ISA 1994) to regulate the 'boom'

- 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)

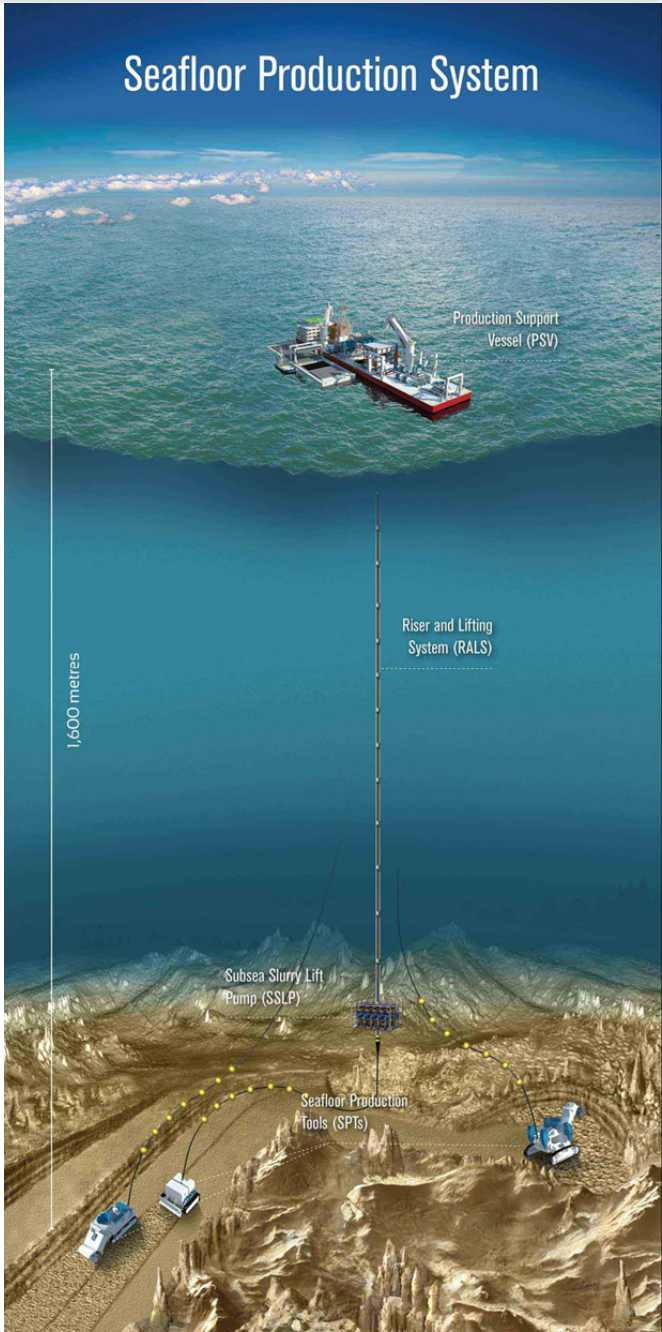


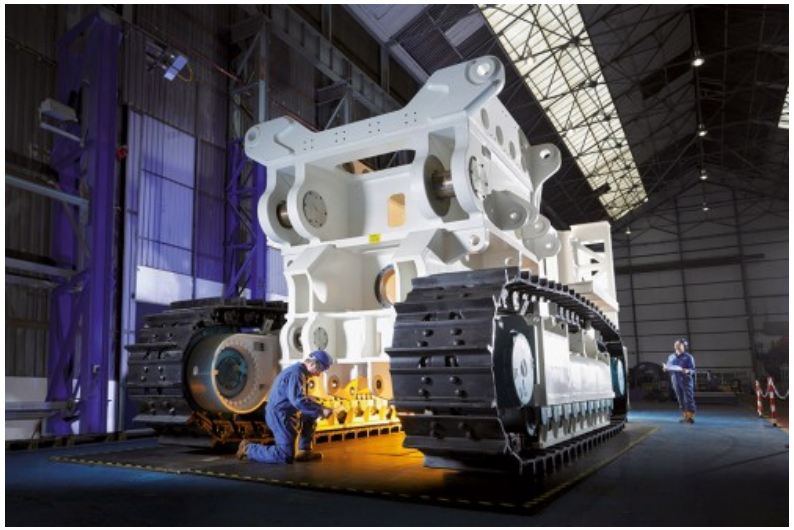
These machines have not been built !

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





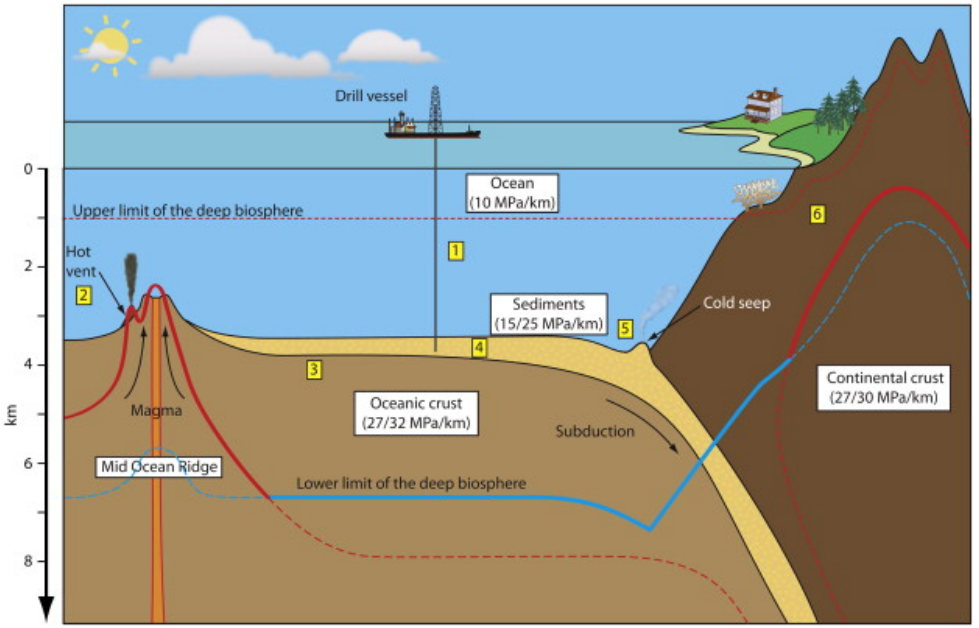
Chassis of seabed rock cutter (adapted cable trencher)

Sources: www.nautilusminerals.com

NAUTILUS Minerals Niugini

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

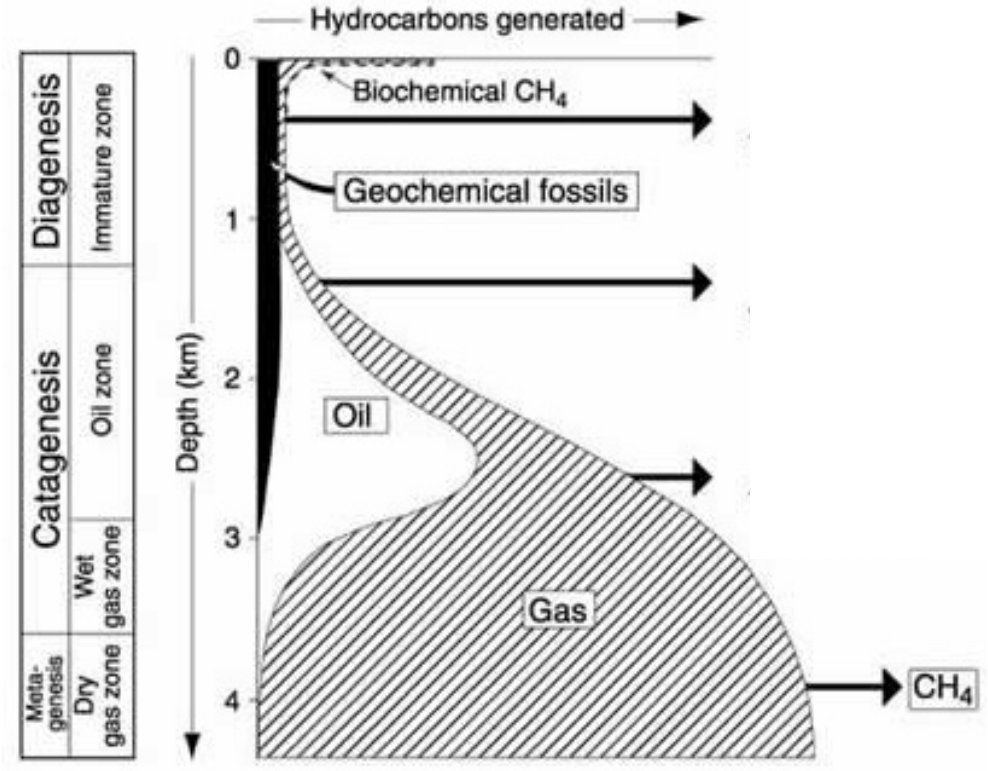
(Geo-) Bio-prospecting

- "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*

HYDROCARBONS = Oil & Gas = Petroleum = Fossil Fuels

> a very short course in petroleum geology (in 4 slides)

- Formed from organic carbon (dead plants/animals) buried in (mainly marine) sedimentary successions → burial = increasing Temperaure & Pressure (cooking)
- Shallow diagenesis → kerogens → deeper thermogenesis



shallow (biogenic) methane

oil window

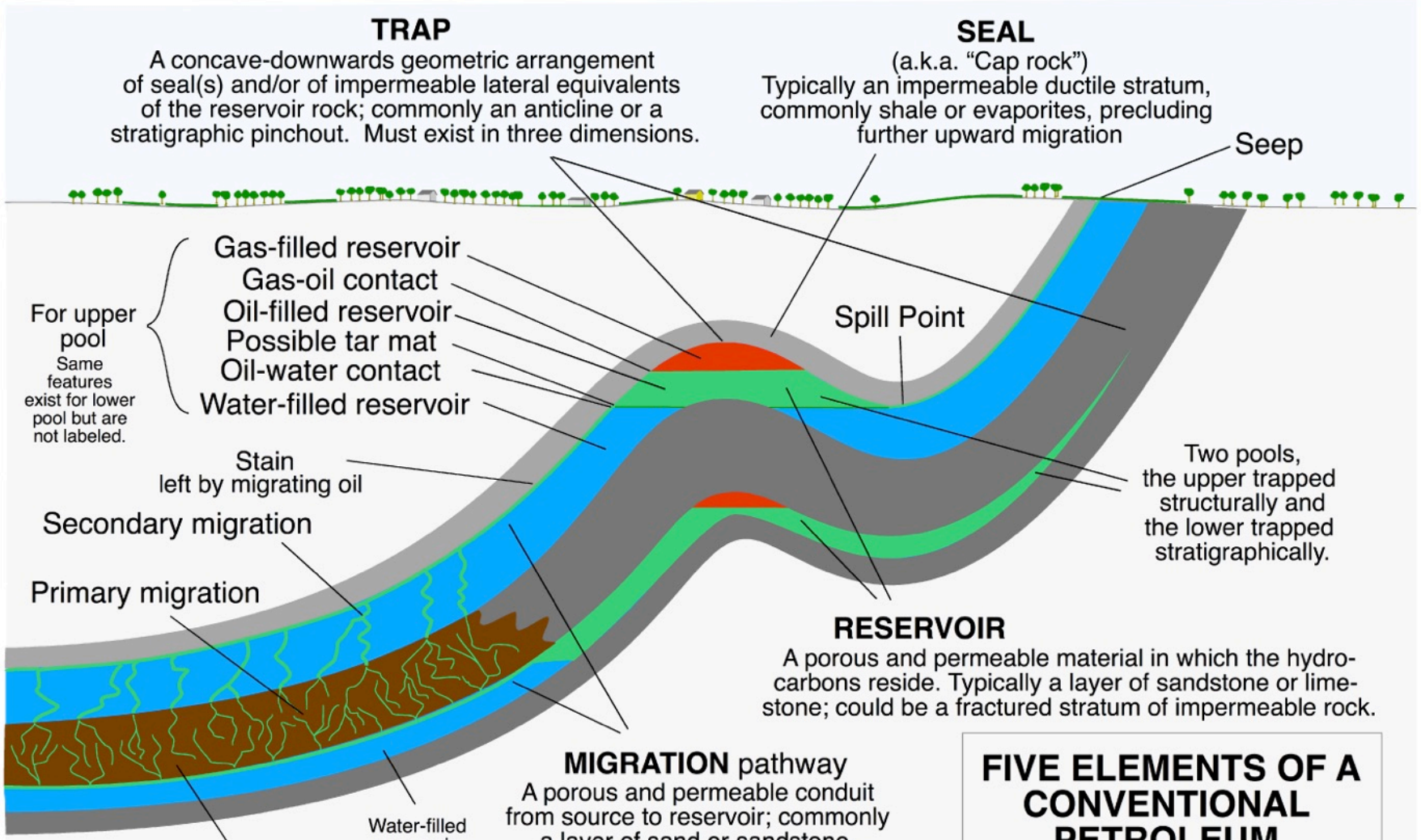
gas window

thermogenic oil & gas

Source: Tissot and Welte (1992) – Petroleum Formation and Occurrence (Springer)

- As they form, they migrate →

Railsback's *Petroleum Geoscience and Subsurface Geology*



Sedimentary Basin Analysis vs Petroleum System Analysis

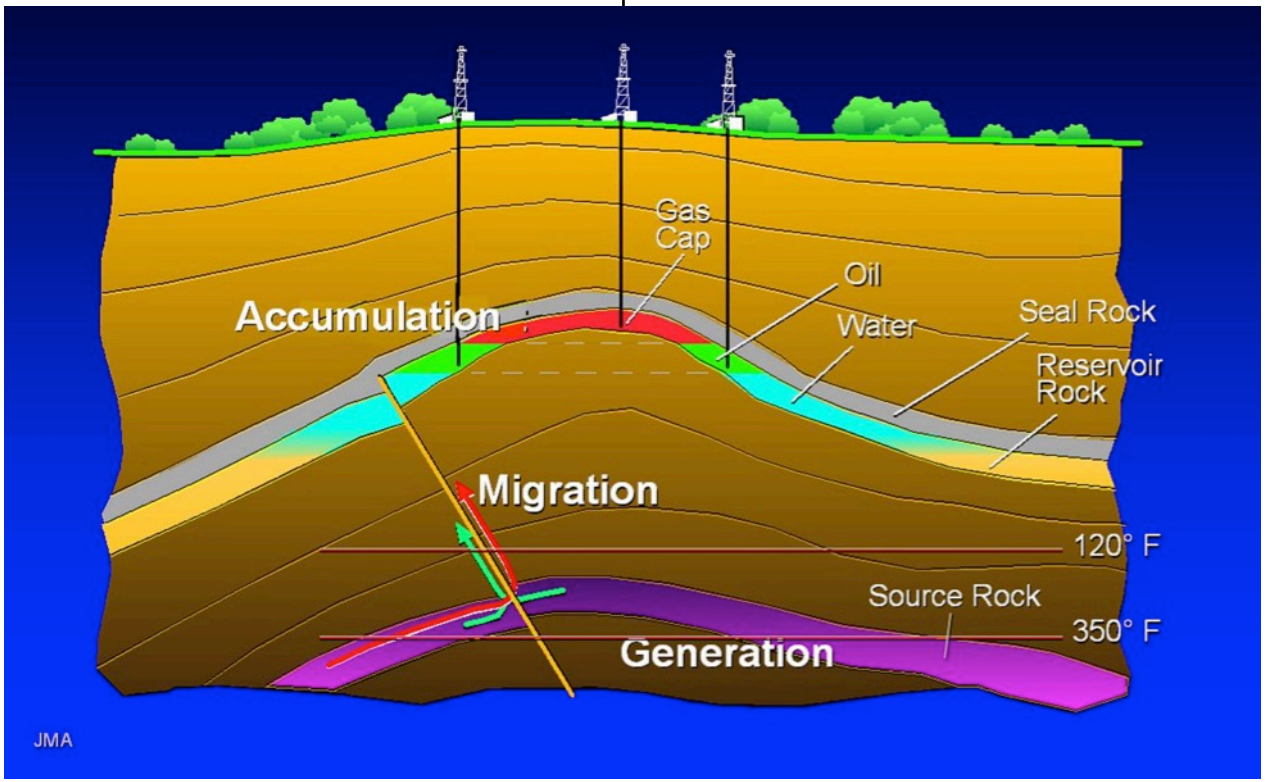
The academic geologist sees…

- 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



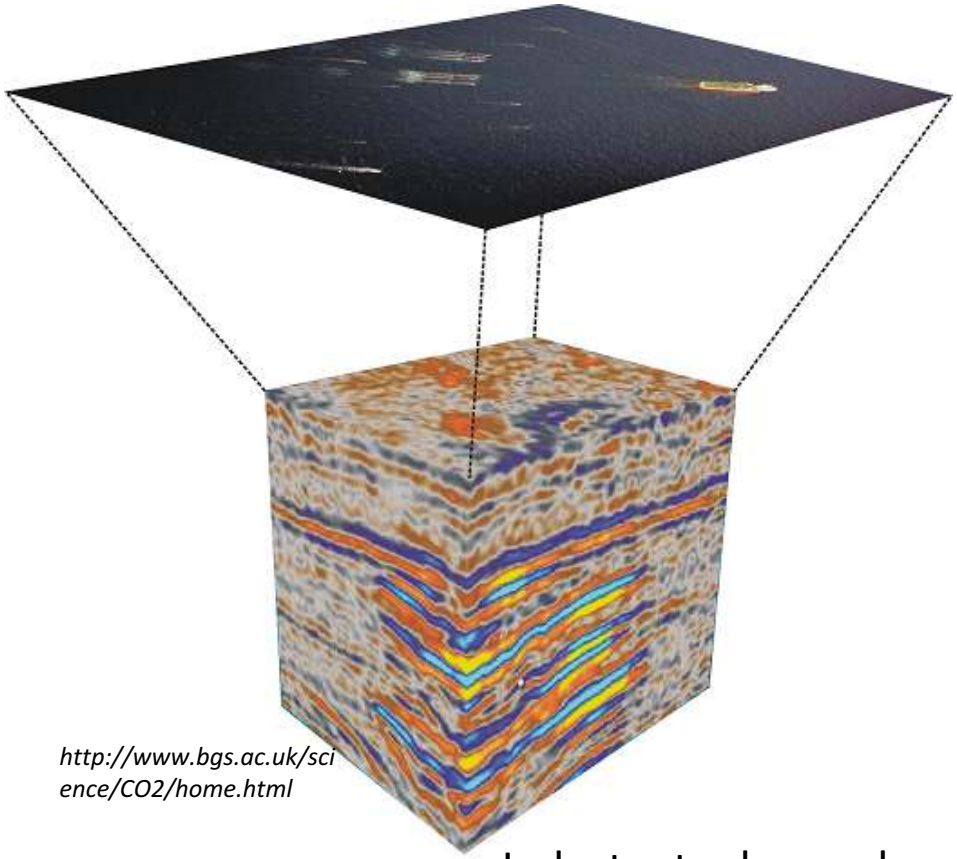
Finding oil & gas

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

Academic and petroleum geologists use basically the same tools…

Geophysics (remote)

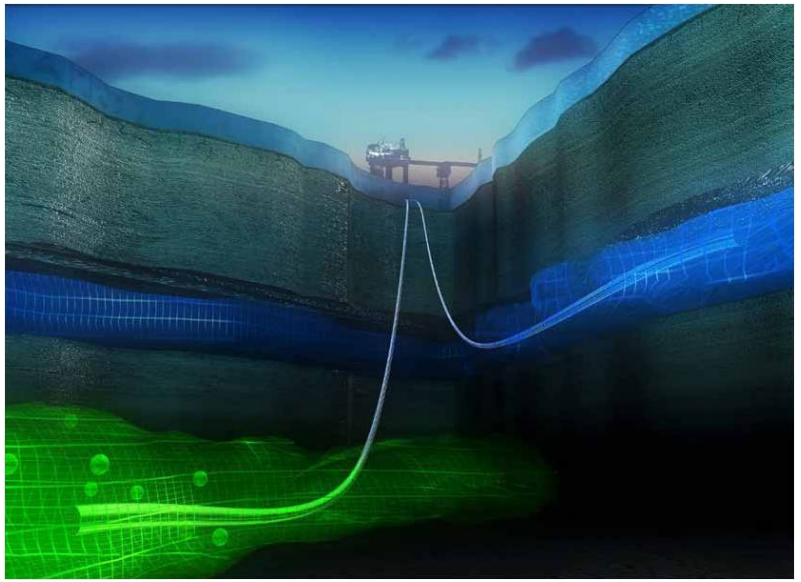
- Gravity & magnetic fields
- Seismic data (2D & 3D)



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

Geology/geochemistry (samples)

- Sediment cores
- Drillsites/wells



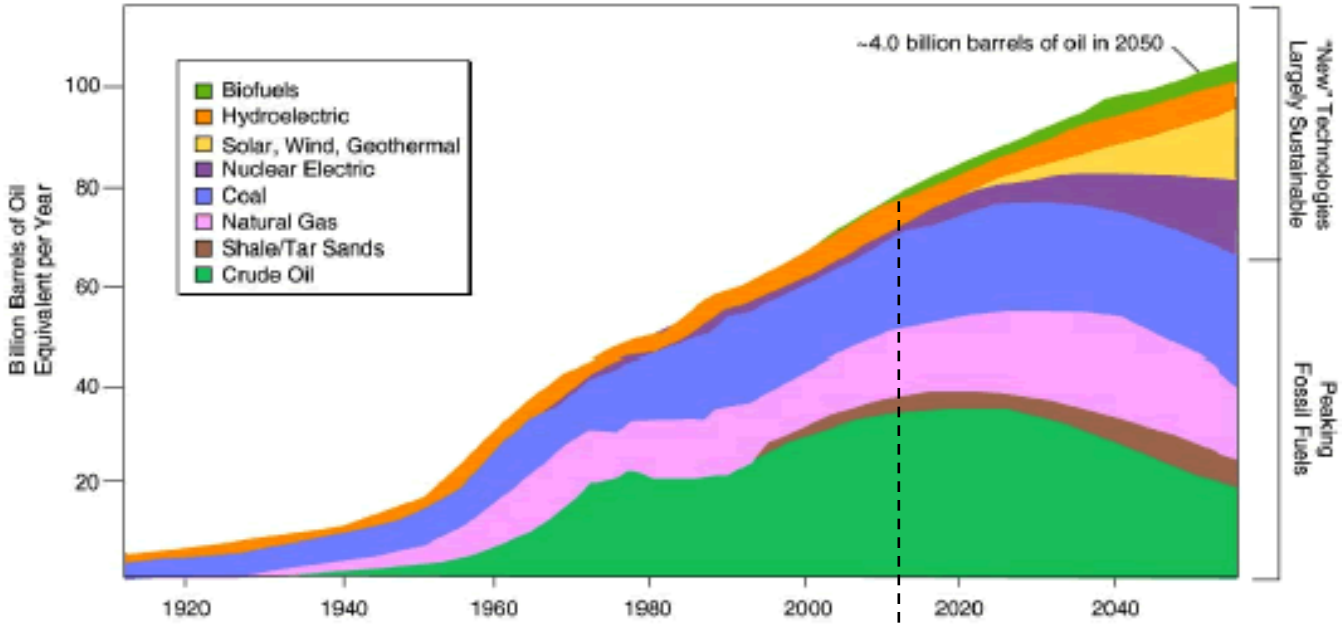
Source: seriousgamesmarket.blogspot.it/2010/09/serious-games-as-oil-drilling-3d.html

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



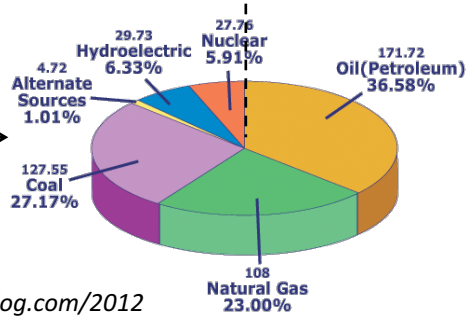
Sources: Lynn Orr, *Changing the World's Energy Systems*, Stanford University Global Climate & Energy Project (after John Edwards, American Association of Petroleum Geologists); SRI Consulting.

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

World Energy Use 2012:

87% fossil fuels

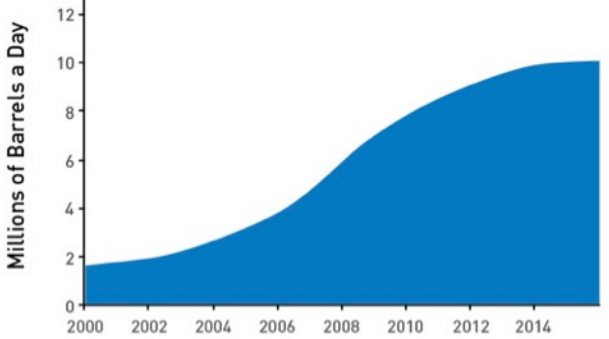
60% oil & gas



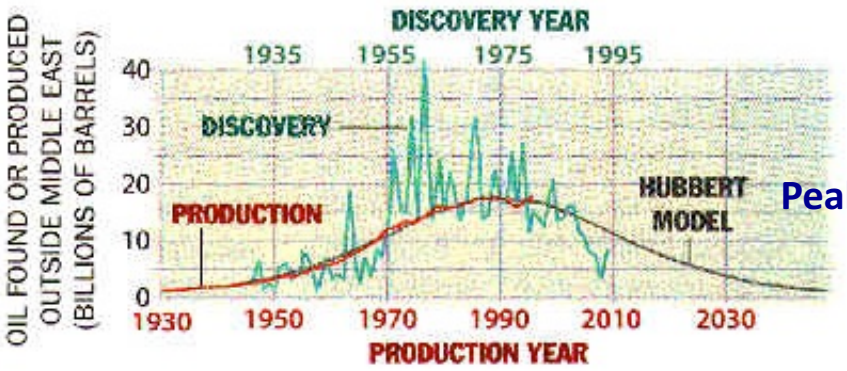
Source: triplehelixblog.com/2012

DEEPWATER PRODUCTION

Source: www.total.com

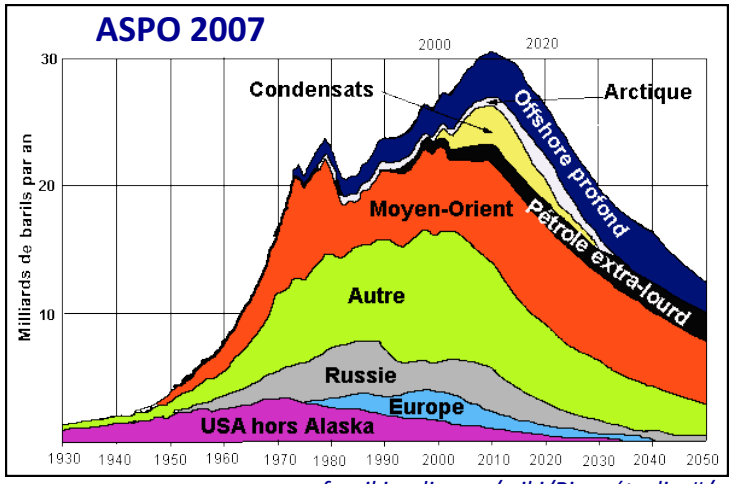


Hydrocarbons – are we at peak production?

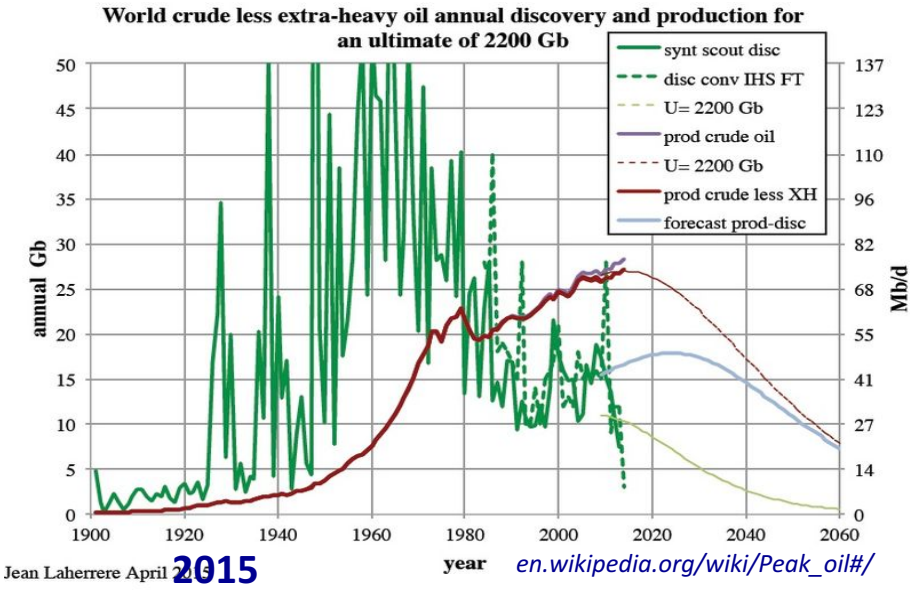


Peak Oil

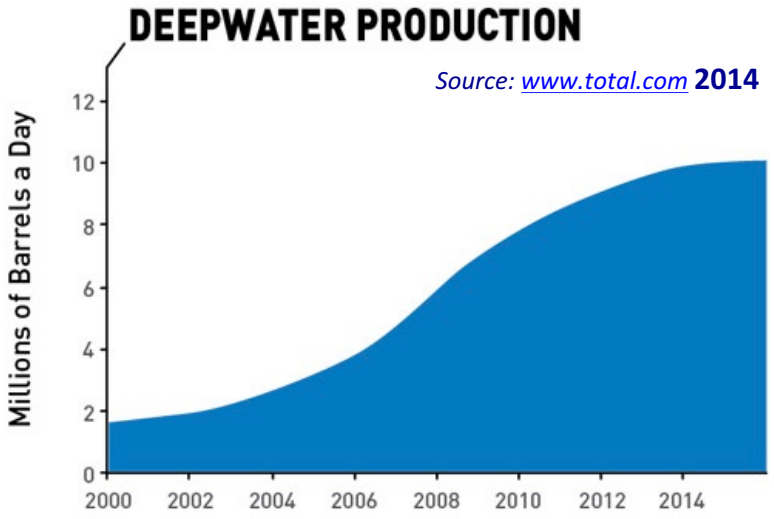
*Campbell & Laherrre **1996**, Scientific American – The End of Cheap Oil*



fr.wikipedia.org/wiki/Pic_pétrolier#/



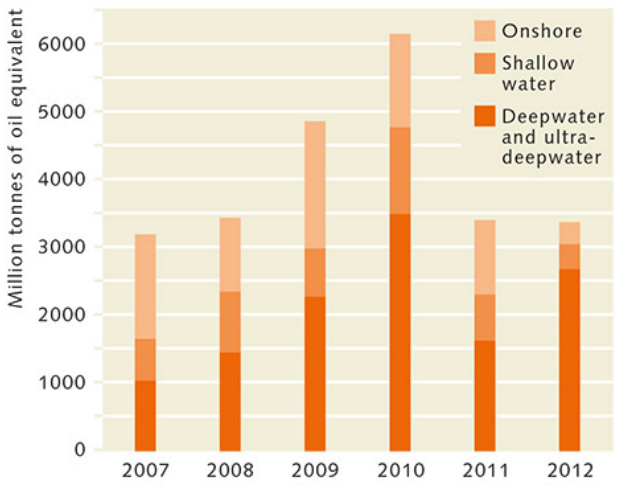
en.wikipedia.org/wiki/Peak_oil#/



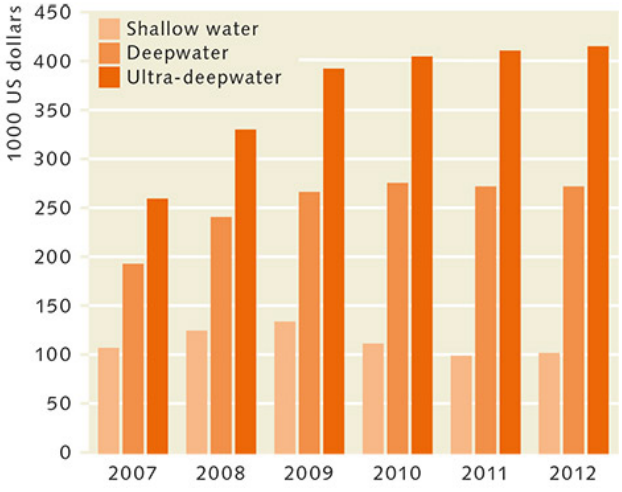
Green: discoveries peaked in the 1960s
Red: production peaking now?

Deep water production is peaking?

Global oil & gas discoveries



Costs of drilling



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

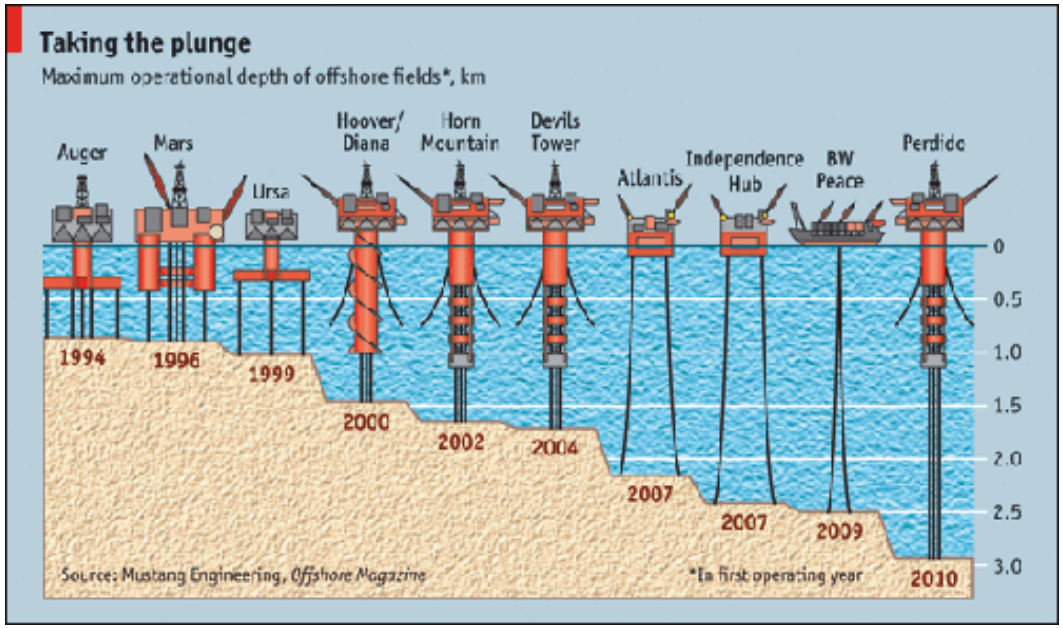
Shallow : 0-400 m

Deep : 400-1500 m

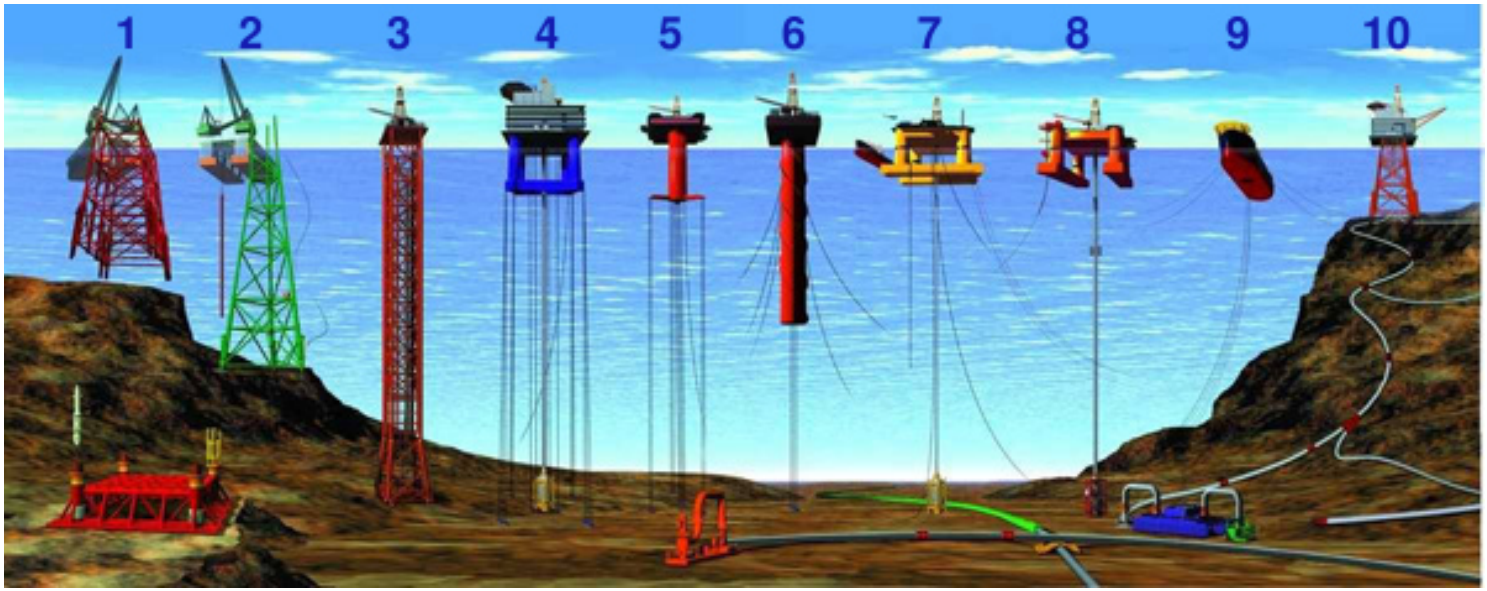
Ultradeep : >1500 m

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/



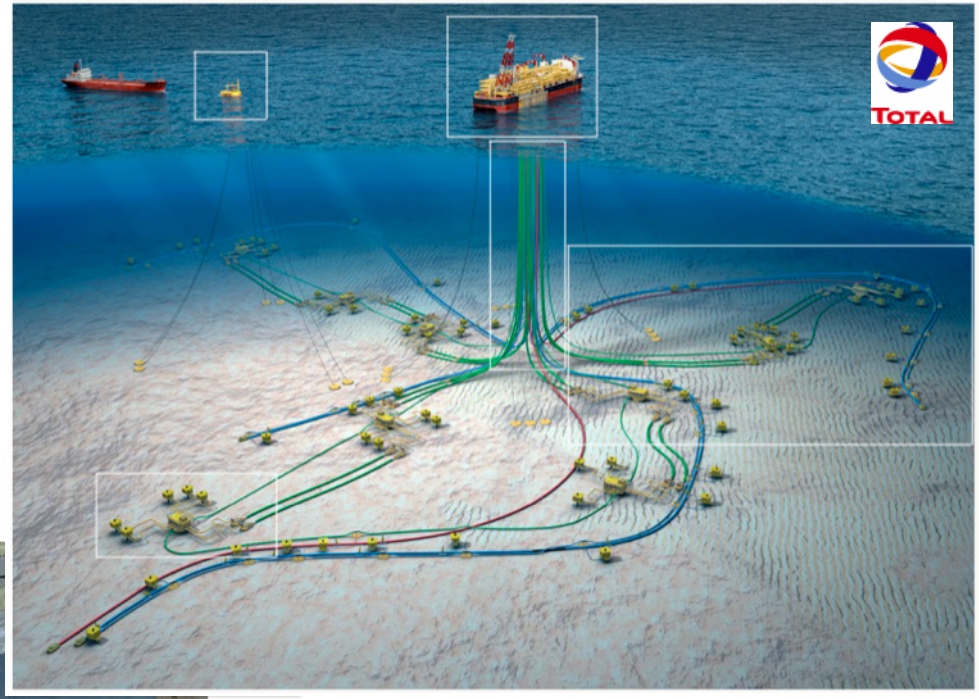
Types of Offshore Oil and Gas Structures (in 2005)

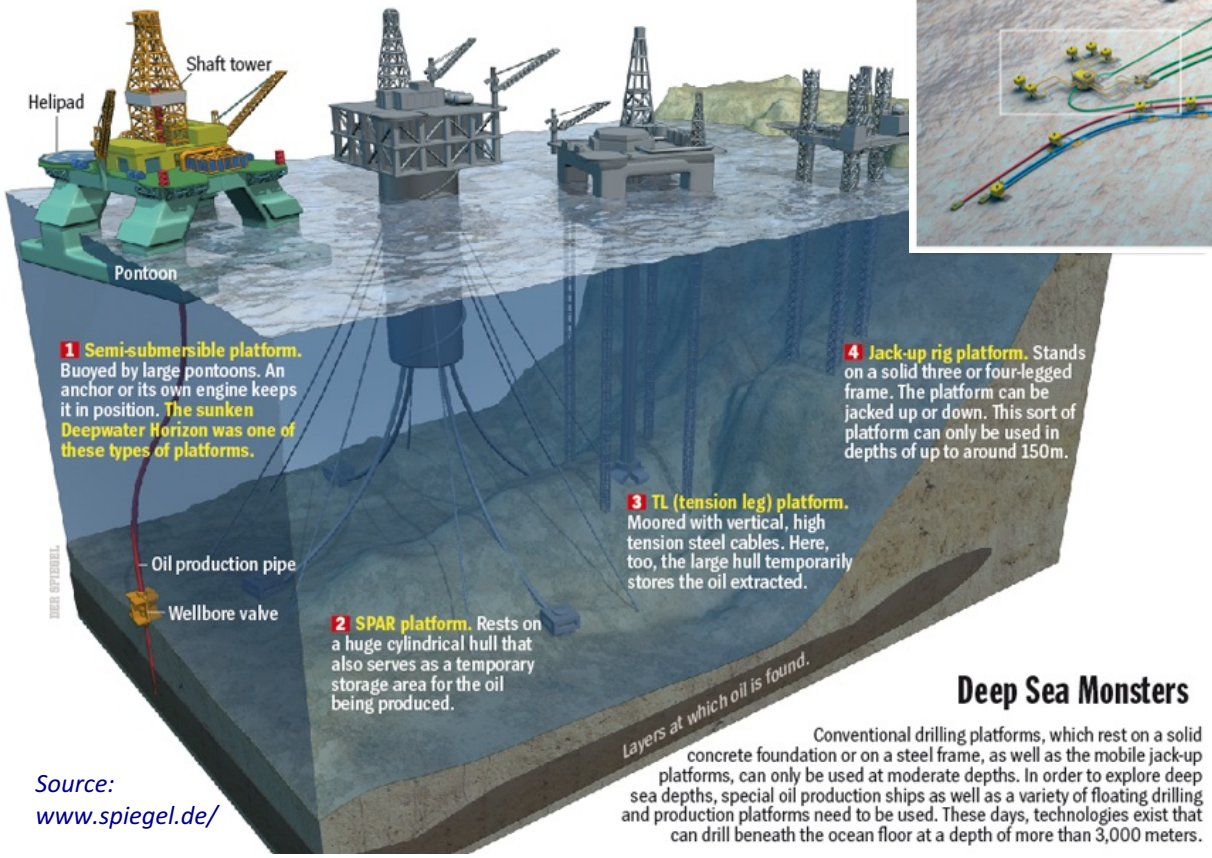
1 & 2) Conventional fixed platforms (deepest: 412 m GOM, 1991)
3) Compliant tower (deepest: 534 m GOM, 1998)
4 & 5) Vertically moored tension leg platforms (deepest: 1,425 m GOM, 2004)
6) Spar (deepest: 1,710 m GOM, 2004)
7 & 8) Semi-submersibles (deepest: 1920 m GOM 2003)
9) Floating production, storage, 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/

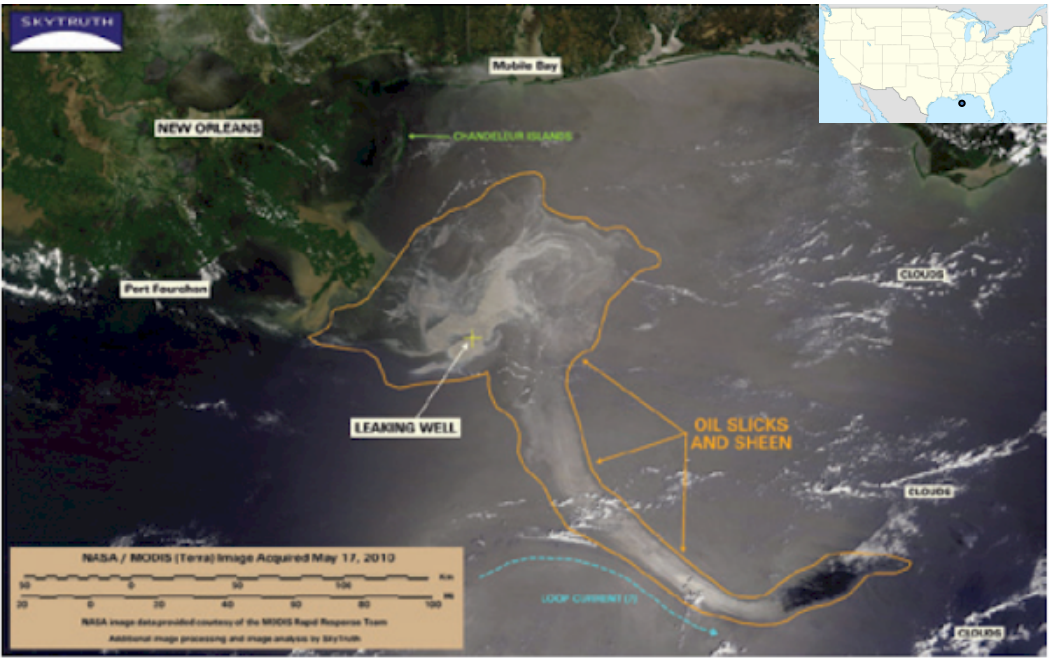
"The conquest of the deep offshore, the oil industry's latest and perhaps most extra-ordinary adventure…" (www.total.com)

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

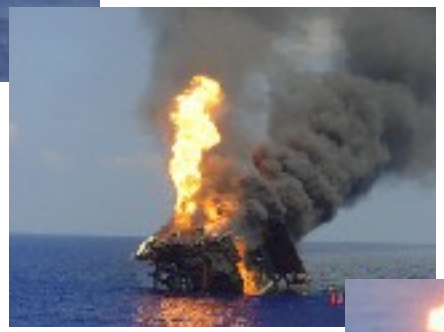


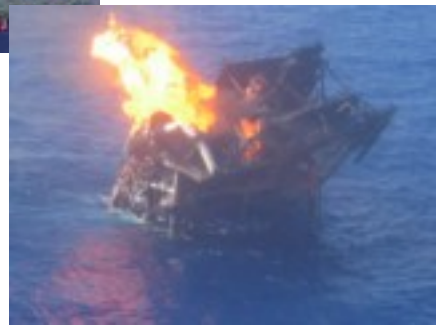
Explosion, fire, 11 deaths, massive oil spill…

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



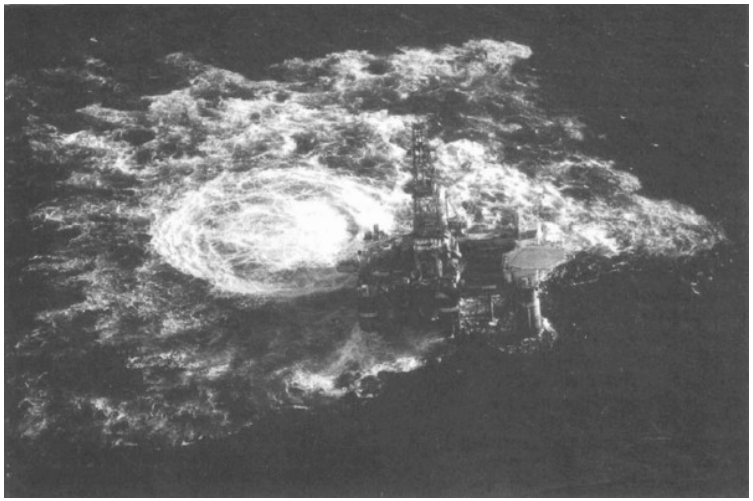


Blowout → explosion, fire, rig sank (no loss of life)

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

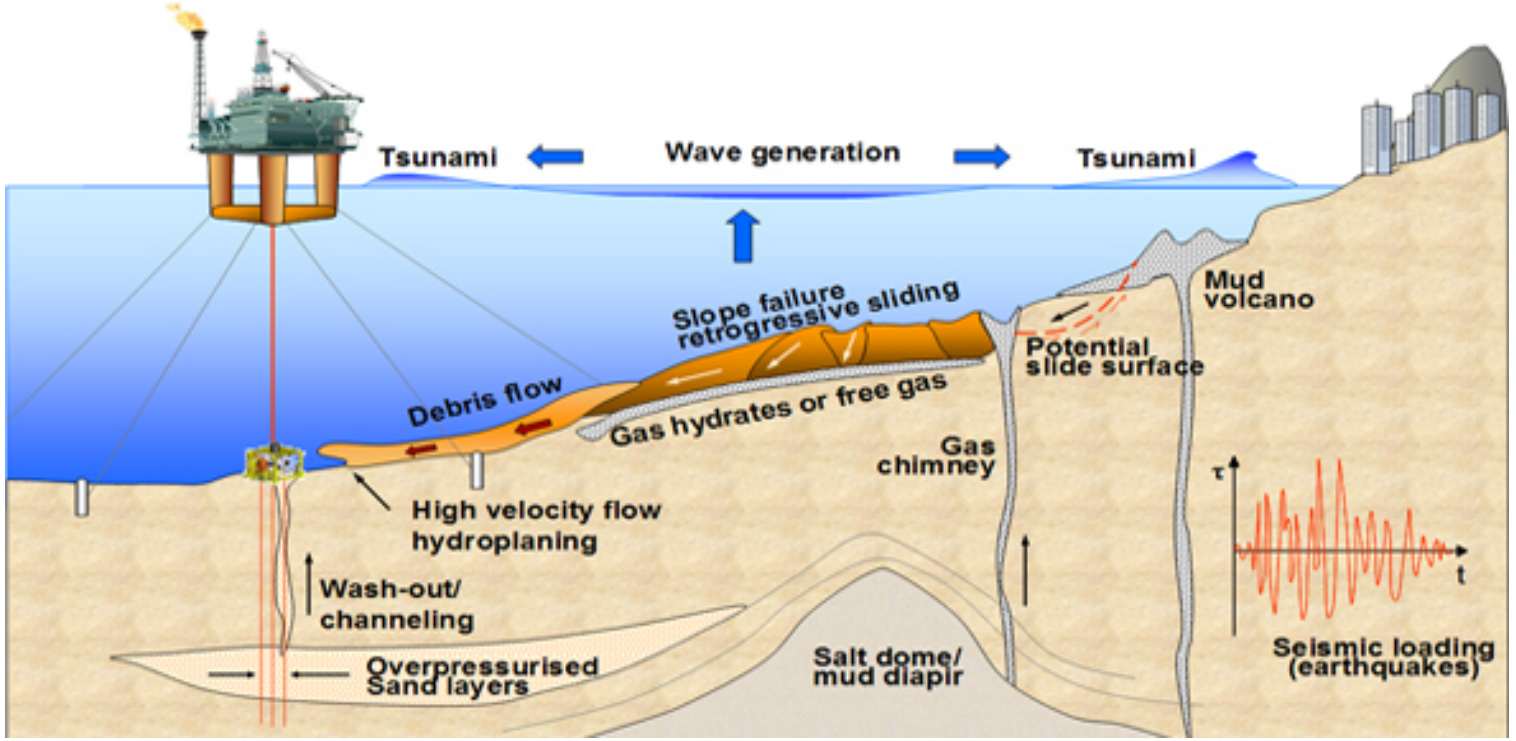
Rig: Petromar V Drillship
Date: 27 Aug 1981
Location: Off Natuna Island, South China Sea
Operator: Mobil

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

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

Site surveys & submarine geohazard assessments

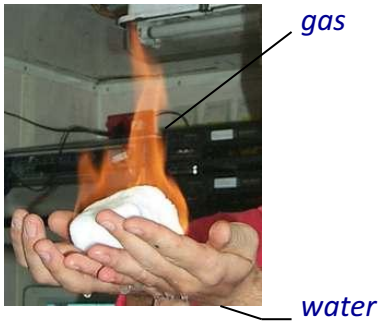
- Purpose: to try to avoid blowouts and other unwanted consequences of drilling
- Examine seabed and sub-seabed conditions at drilling sites to assess whether potential hazards exist (and take steps to avoid or address them)
- We are in the world of seabed surveying (some of the same service companies), but more concerned with geological understanding of past & future near-seabed processes
- Pore fluids are key in all processes: fluid migration and escape to seabed, their role in triggering submarine landslides, and sediment responses to seismicity.

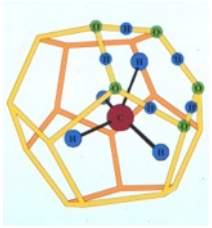


http://www.ngi.no/en/Geohazards/Content/Shortcuts/Research-and-development/to-be-filled-1/

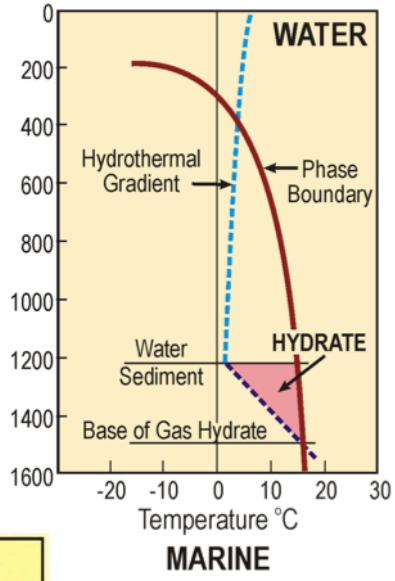
Shallow gas & methane hydrates

- Gas (bubbles and/or dissolved in water) common in near-seabed sediment
- Gas + water at high pressures and low temperatures leads to something unlikely but very interesting…



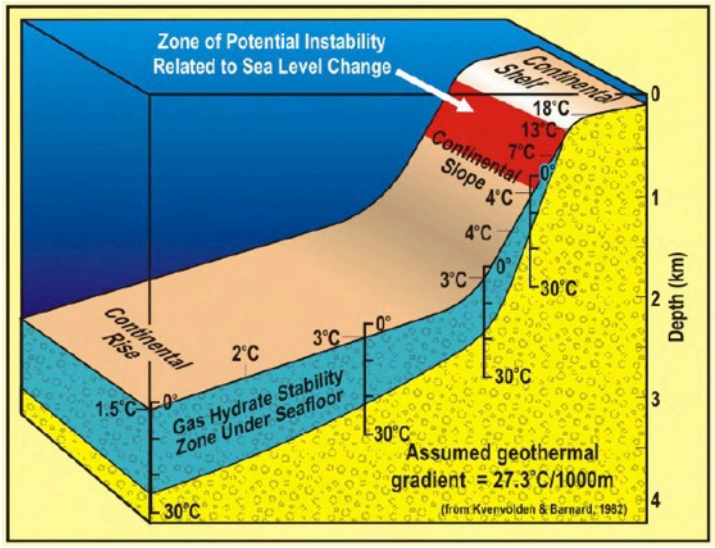


1 m³ solid yields up to 160 m³ of gas



Gas hydrates (ice that burns)

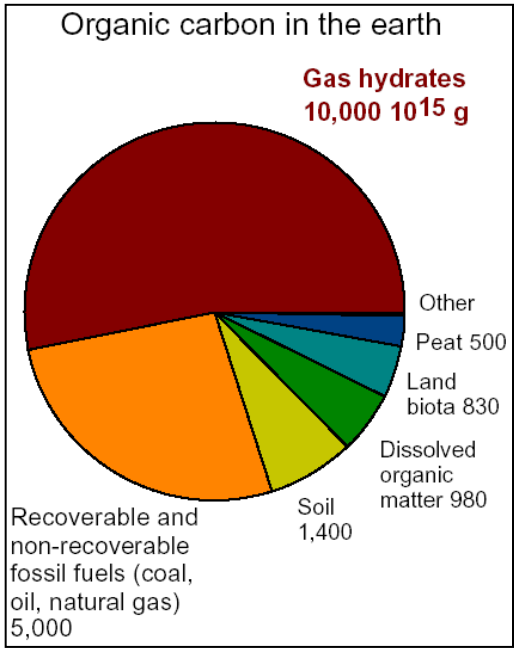
- ice-like compounds of water (molecular cages) + natural gas
- gas concentrators (mainly methane, a potent greenhouse gas)
- stable in permafrost settings on land, or in submarine settings below water depths of c. 300-1000 m
- can occur offshore on continental margins in a zone up to 1 km thick (depending on subbottom temperatures)



Fillon & Roberts (2007)

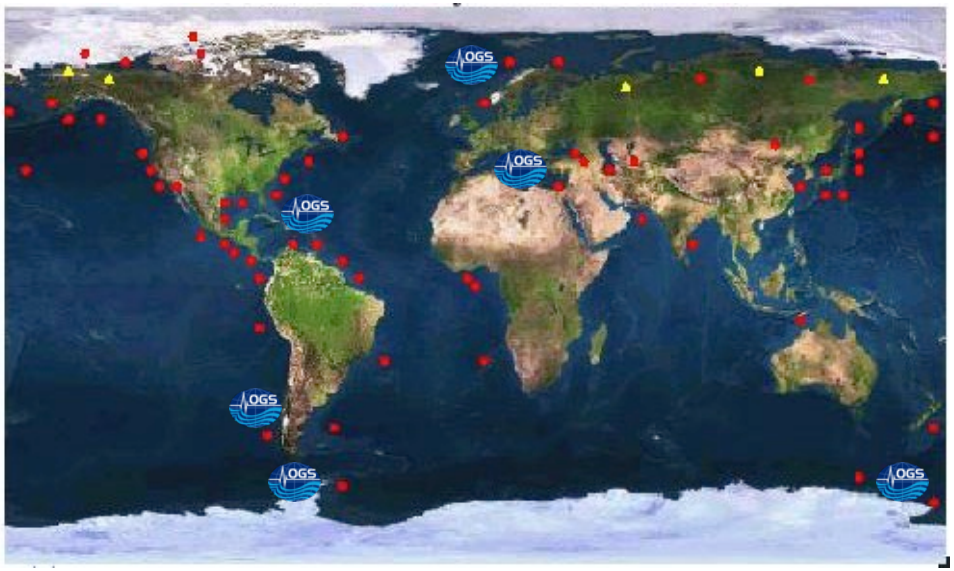
Gas hydrates – a future energy resource?

- On conservative assumptions, estimated offshore occurrences (continental margins) = the largest reserve of hydrocarbons on Earth…
- Mainly dispersed and only likely to be economic where concentrated (like most minerals)
- Efforts to exploit concentrated deposits underway in Japan, China, India, South Korea and Taiwan…



Source: Geological Survey of Canada, after Kvenvolden

GLOBAL GAS HYDRATE LOCATIONS



(▲ permafrost; ● submarine)

March 12 2013: JOGMEC (Japanese state company) announces world's first tests to extract natural gas from methane hydrate deposits are successful; commercial production planned from 2018 (www.pennenergy.com)

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**


DS³F
www.deep-sea-frontier.eu
The
Deep Sea
and Sub-Seafloor
Frontier
Responsible use of deep sea
Resources

Climate

Ocean floor sediment cores help to reconstruct past climate, understand Earth system processes, and mitigate future change.

Geohazards

Large magnitude earthquakes and associated landslides and tsunamis require monitoring and disaster prevention.

Resources

The deep sea offers raw materials, fuels and biological resources, but a thorough understanding is crucial for their responsible use.

Ecosystems

A veritable explosion in the discovery and exploration of deep sea marine ecosystems leads to utilizing their goods and services.

Implementation

Investigating the deep sub-seafloor remains a technological challenge, and infrastructure needs coordination on the European level.

Grand Challenges

Deep sea research requires a serious commitment to tackling societal challenges and strengthening European scientific and educational networks.

CONCLUDING REMARKS

- Besides improving the basic knowledge of seafloor dynamics in sedimentary and volcanic basin evolution, submarine landslide research is important to reduce the risk related the increasing use of the seafloor for economic activities.

- The use of the seafloor is spreading across the oceans, reaching geologically complex areas.

- It is important to discriminate between hazard assessment and risk assessment

CONCLUDING REMARKS

- The approach required by companies is a 'phased approach', where geoscientists have to address hazard assessment, risk assessment and mitigation measures through a highly cross-disciplinary team work.

- Baseline maps of hazard assessment are useful to better planning and monitoring of activities.

CONCLUDING REMARKS

- At a European level, the Marine Strategy Framework Directive and the Directive on safety of offshore oil and gas operations introduce the concept of hazard to productive and non-productive structures.
- Much work is needed at a national level for the implementation of the directives
- The deep sea is still a frontier

Career Paths for Marine Geoscientists

Academia	Offshore Industries
• Public institutions (universities, research institutes)	• Private companies (petroleum, mineral, service industries)
• Slow career progression to tenure	• Rapid intra-/inter-sector mobility
• Modest remuneration	• Bigger salaries
• 'Pure' science	• Applied science
• Intellectual freedom/satisfaction ? (understanding the Earth…)	• Satisfaction of clear objectives and the tools to reach them
• Long-term projects (years)	• Short-term problems (days-weeks)
• You take your work home	• You leave your work on your desk

Recommended Reading

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)*