decarbonICE™


• Everybody fights for green fuel
• Why CCS for shipping
• The technology
• Capture
• Descent
• Storage
• Perspectives
• Partners and project


Primera

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Alternatives


If all used in shipping:
Biofuel would cover 39%


If all used in shipping:
Biogas would cover 8%

If all used in shipping:
Ammonia would cover 46%


If all used in shipping:
Hydrogen would cover 55%

All the Worlds alternatives would cover 1,5 times shipping's requirement (at much higher cost)

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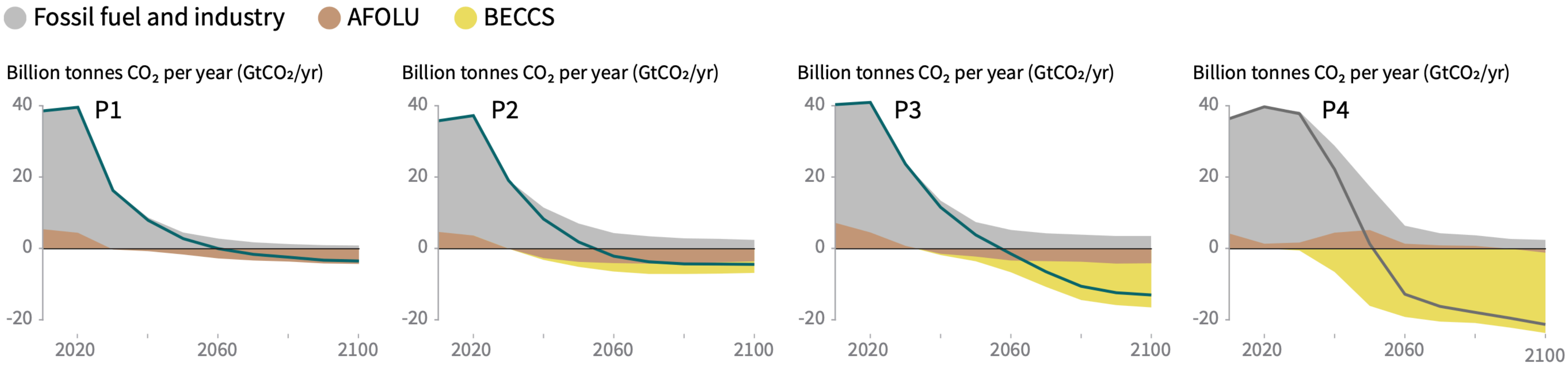
Why?


+1,5°C

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



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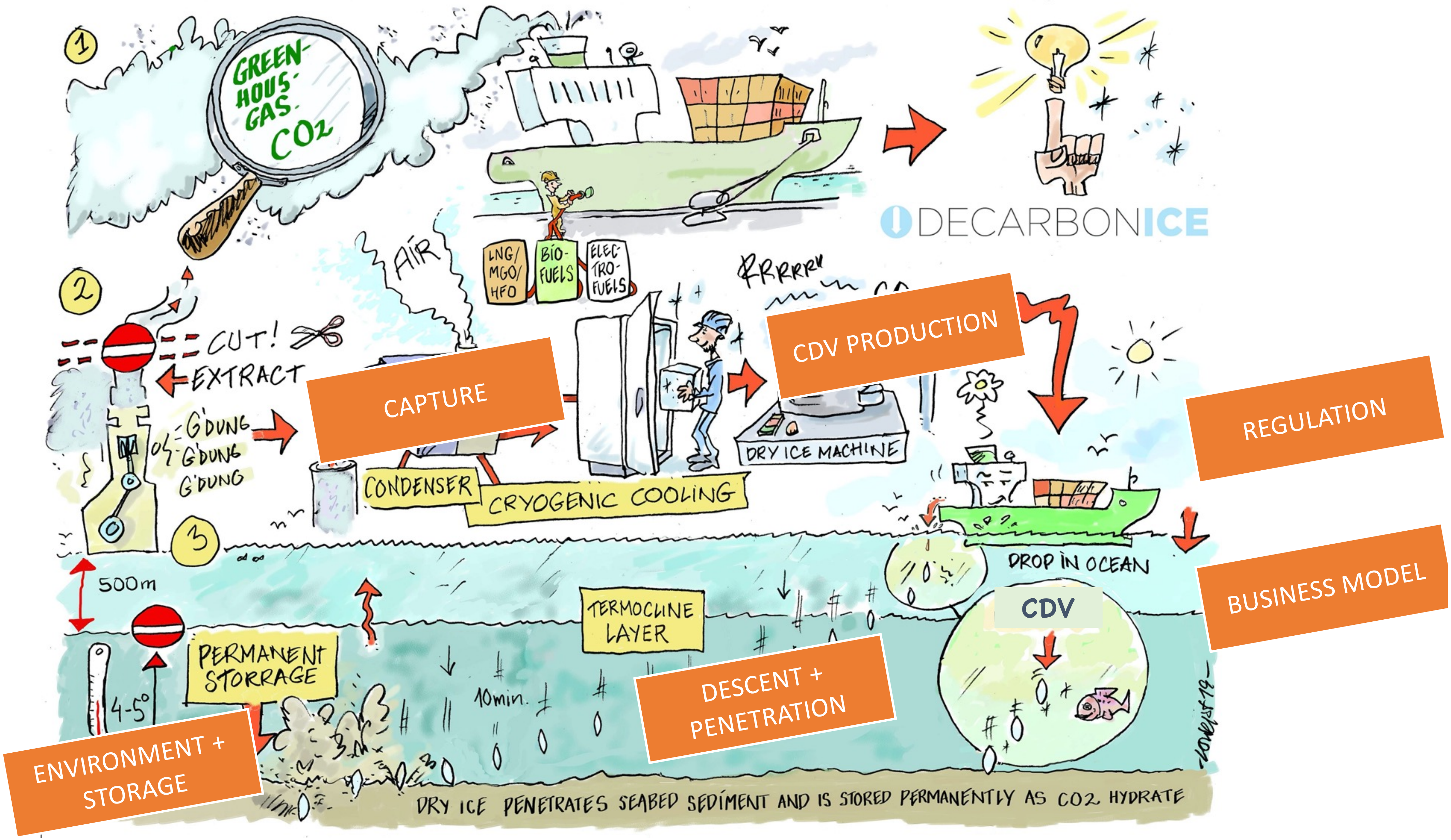
From carbon capture to carbon negative shipping


1
GREEN-HOUS-GAS
CO_2
2
CUT!
EXTRACT
G'DUNG G'DUNG G'DUNG
AIR
LNG/ MGO/ HFO
BIO-FUELS
ELEC-TRO-FUELS
RRRRR
CAPTURE
CONDENSER
CRYOGENIC COOLING
CDV PRODUCTION
DRY ICE MACHINE
DECARBONICE
REGULATION
3
500m
4-5°
PERMANENT STORRAGE
10min.
TERMOCLINE LAYER
DROP IN OCEAN
CDV
BUSINESS MODEL
DESCENT + PENETRATION
ENVIRONMENT + STORAGE
DRY ICE PENETRATES SEABED SEDIMENT AND IS STORED PERMANENTLY AS CO_2 HYDRATE

We will:

- Prove the concept is possible and realistic
- Prove that GHG's can be captured and stored with low energy panalty
- Initiate an approval process for maritime CCS
- Invite and involve industry partners to design and develop the technology

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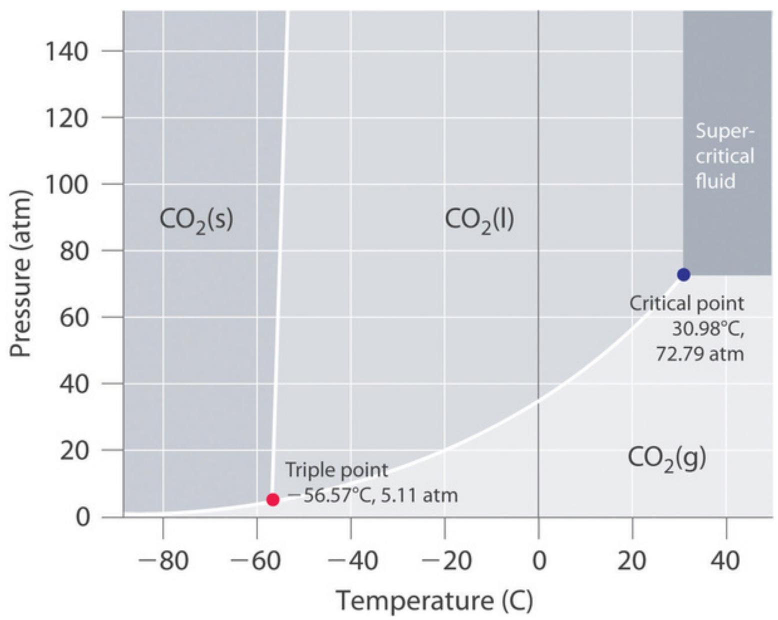
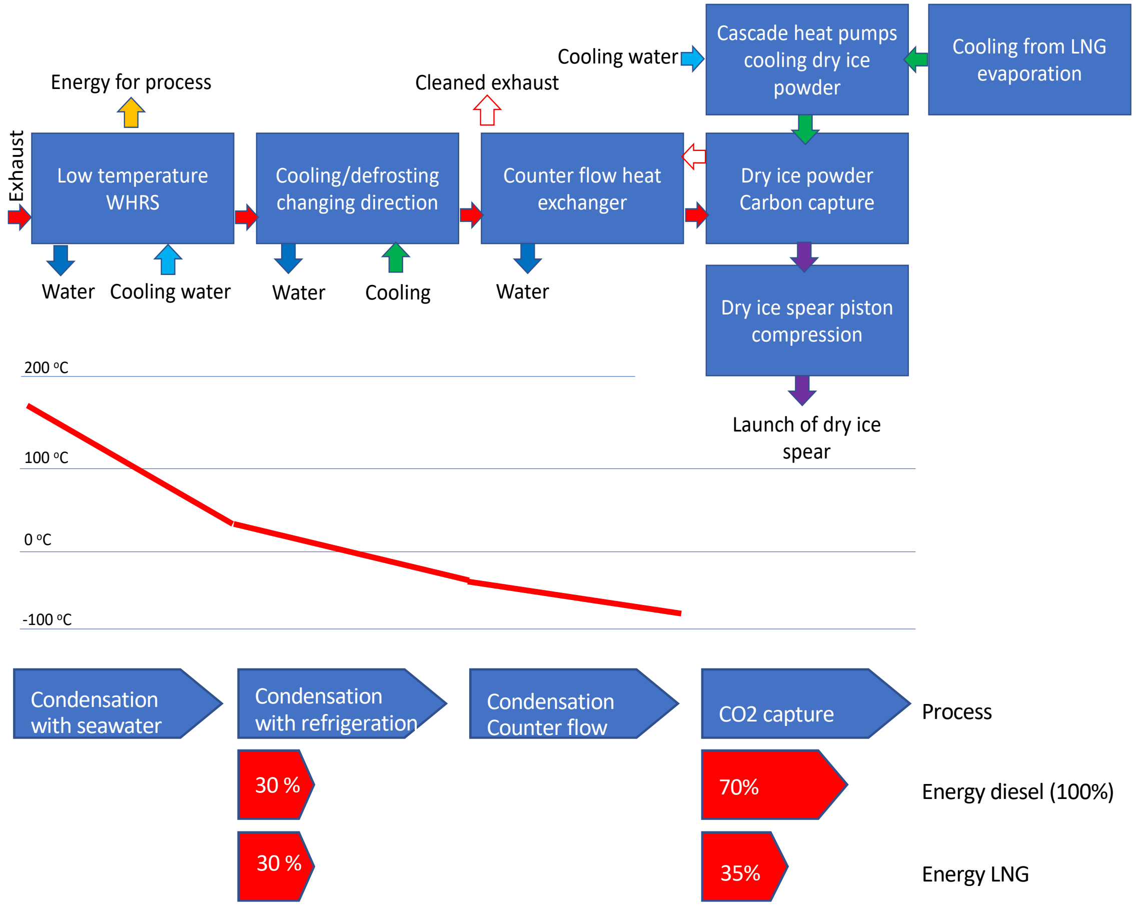
Capture

Cryogenic cooling





Example: Chillers and heat exchanger

	0.1% sulphur oil	LNG
MAN diesel	6S70ME-C	6S70ME-GI
	ton exhaust pr ton fuel	ton exhaust pr ton fuel
water	1,250	2,501
N2	36,162	36,162
CO2	3,414	2,655
O2	041	7,976
CO	04	0,005
	9	0,052
	1	0,002
		0,000
		0,002

Join:
Capture workshop in Copenhagen
29/1-20 (next week)

Removing
sulphuric acic
water with sea
water cooling

absorption chiller
powered by
exhaust energy

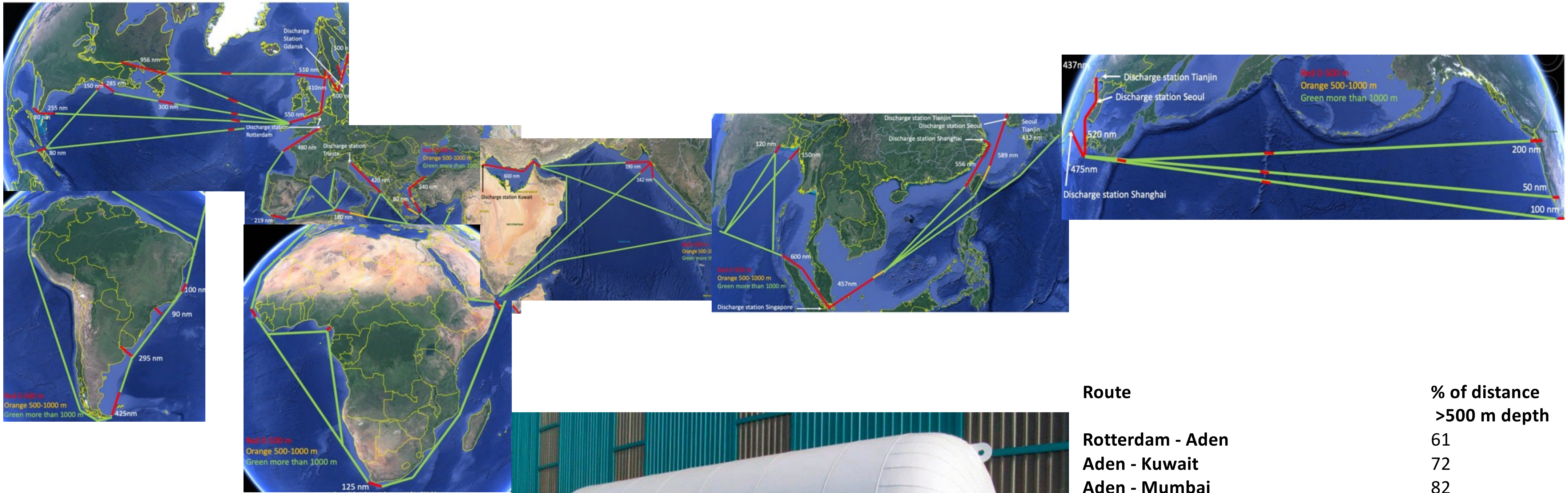
Regaining cooling
energy in counter
flow heat exchanger

Freezing CO_2 with
methane chiller

Switching to second
freezing unit, pressurising
to 6 bar, and defrosting CO_2

Energy consumption

Cooling	6,20%	3,80%
Fans	0,50%	0,50%
Pumps	0,50%	0,50%
Total	**7,20%**	**4,80%**



Route	% of distance >500 m depth
Rotterdam - Aden	61
Aden - Kuwait	72
Aden - Mumbai	82
Aden - Singapore	84
Singapore - Shanghai	53
Singapore - Seoul	60
Singapore - Tokyo	85
Tokyo – Los Angeles	98
Shanghai – Los Angeles	88
Seoul – Los Angeles	87
New York - Rotterdam	65
Miami - Rotterdam	77
New Orleans - Rotterdam	81
Rio de Janeiro - Rotterdam	88

Bridging the gaps with CO_2 storage
600 nm storage will be enough on most routes

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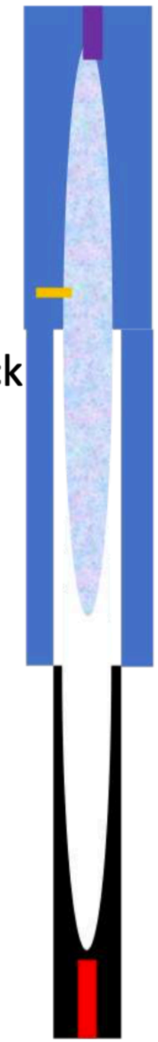
Launch & descent

Piston compactor

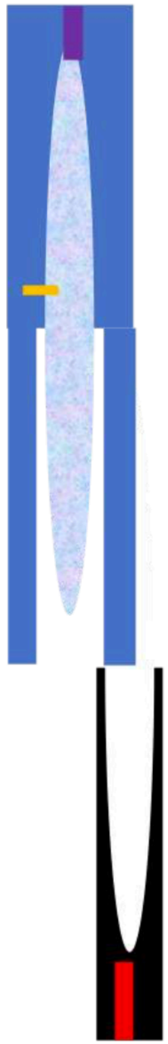
Dry ice powder is filled into the piston

The piston moves up with 14 MPa pressure and compacts the dry ice powder

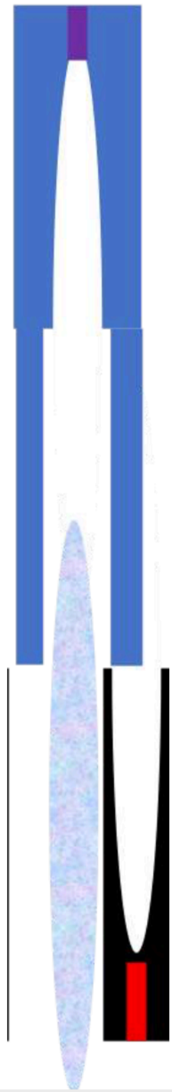
The yellow device lock the dry ice spear while the piston moves all the way back



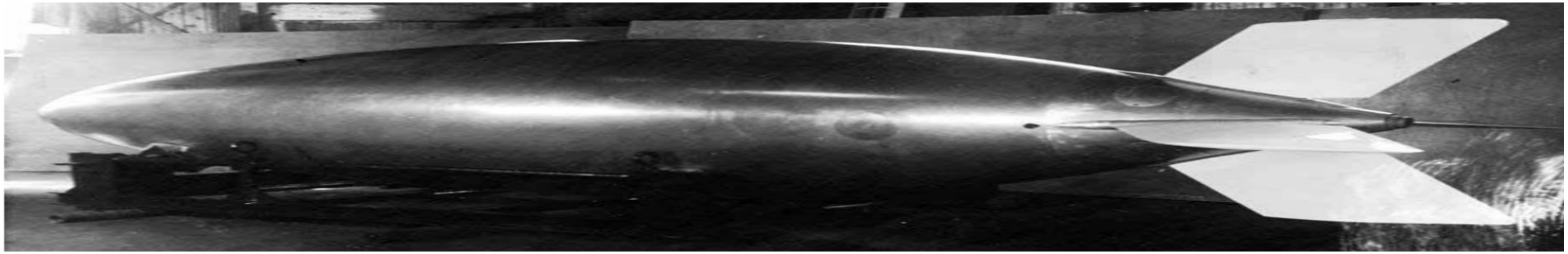
The piston is hinged and swings away from the cylinder



The dry ice spear is launched



Carbon Descent Vehicle (CDV)



CO_2 is frozen under 5,1 atm. pressure in a process similar to making ice cubes in you fridge

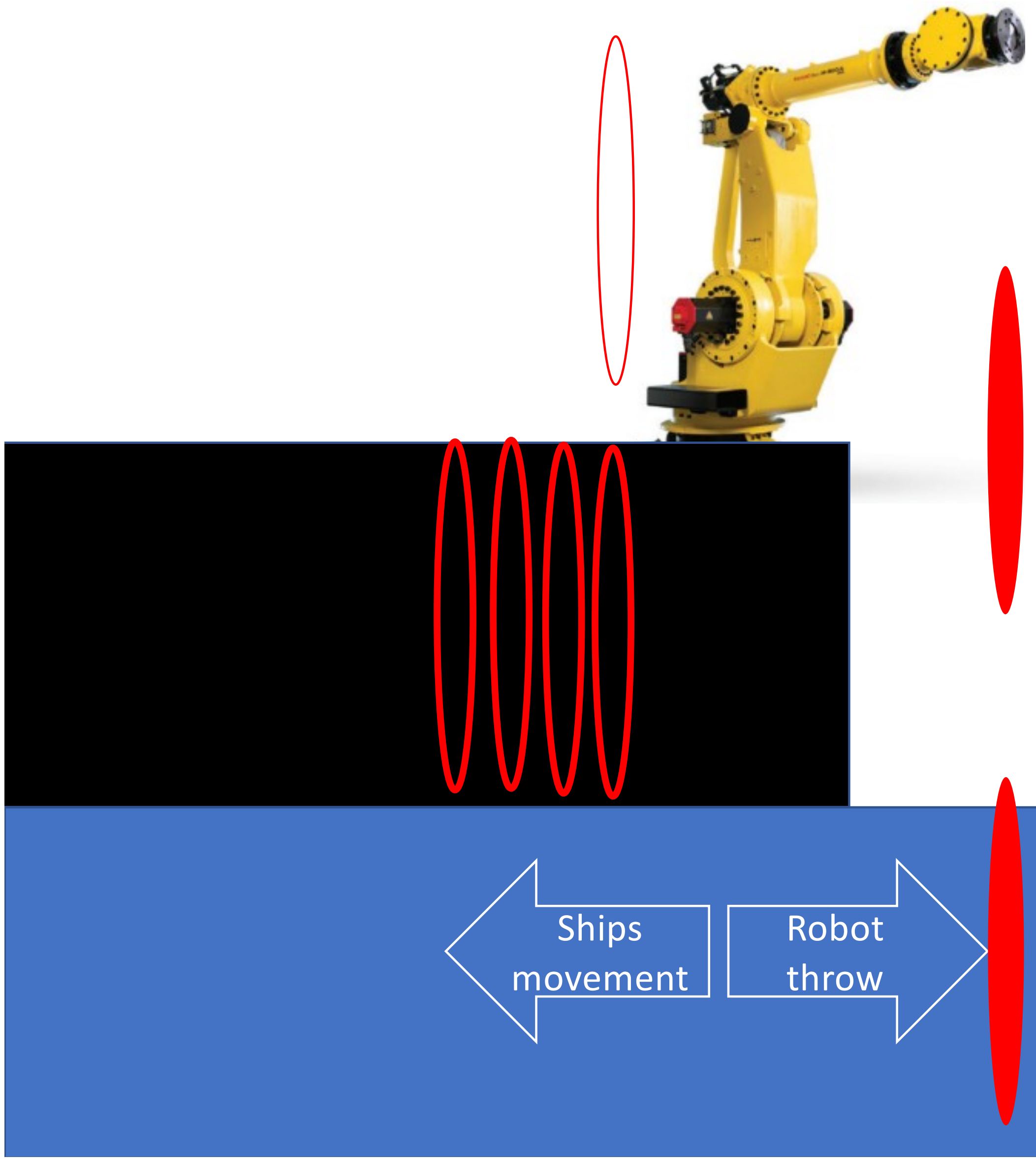
CO2 is insulated and contained in a CO2 hydrate shell made before launch

Length: 10 m

Diamter: 0,6 m

Weight: 2,5 t

Vertical speed: 19 m/s (38 kn)



Robot neutralize ship movement

The robot launch unit neutralise ships

- **Speed**
- **Roll**
- **Pitch**
- **Heal**
- **Trim**

As well as

- **Waves**
- **Wind**

Dropping the CDV vertically into the ocean with no horizontal speed

Resistance to penetration is reverse proportional to pore water %
Pore water is reduced with both depth and by penetration

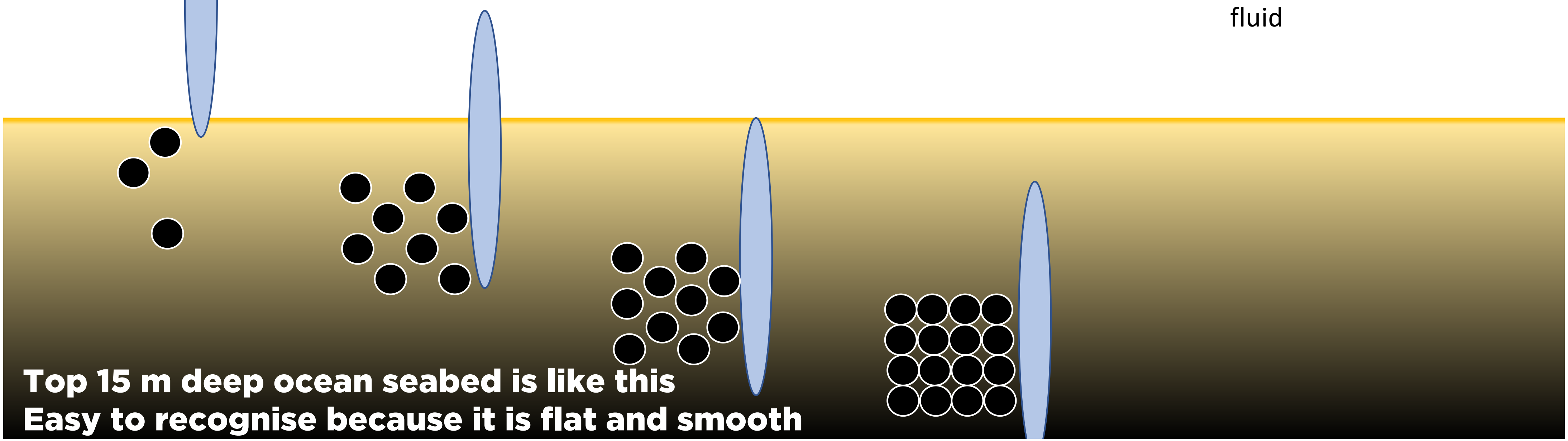
The top 0,2-1 m -the **Viscous Liquid** layer - is fluid so impact is pushing the sediments away like a stone falling in water

A little deeper the **Viscous plastic** sediments contain 55-70% water and are like wet mud. The water is pressed out and the resistance depends on hydraulic impedance

Semi solid state
Below 55% the sediments are like quick sand with resistance depending on flow water speed from impact

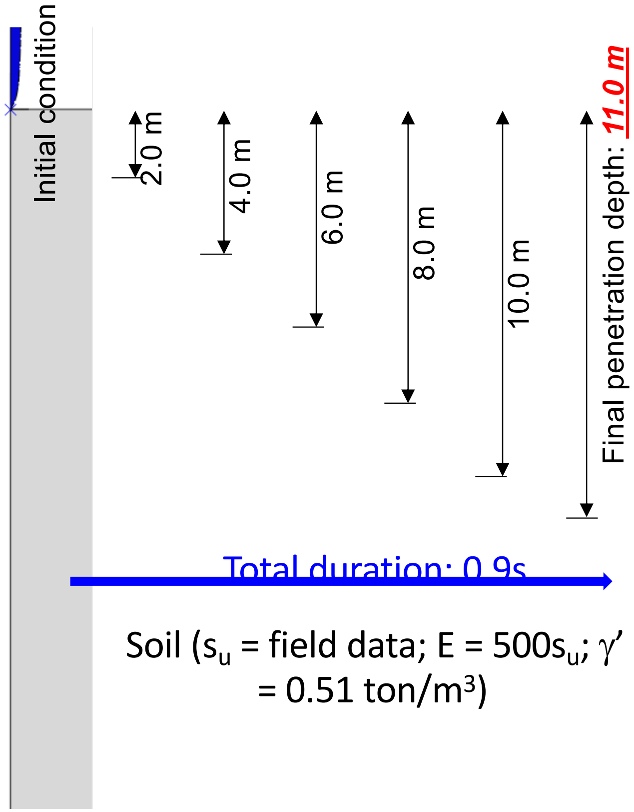
Solid state
When the water content get below 30% the sediments grains touch is other and the sediments are hard and the resistance depends on friction

Impact from the dry ice compact the sediments and make them a class harder, but the flow of the water squeezed out makes the adjacent part of the sediments more fluid



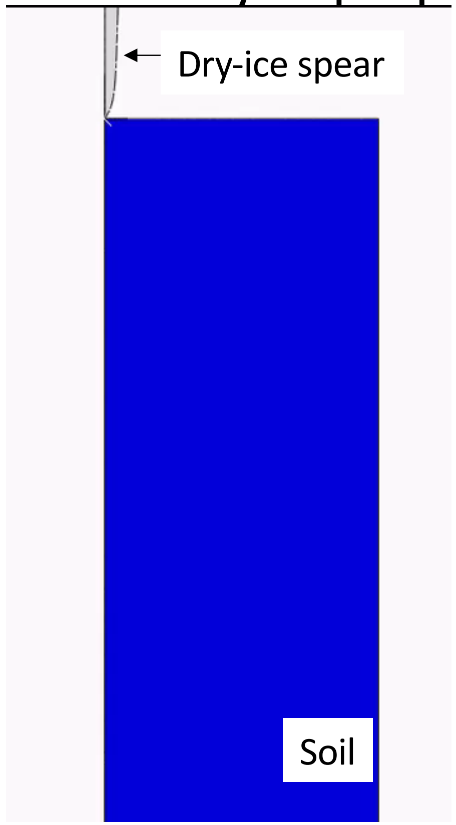
Results of analysis spear mass = 2.56 t

- Dry ice spear (m_{spear} = 2.56 ton; v = 18.26 m/s)



Soil failure mechanism (velocity)

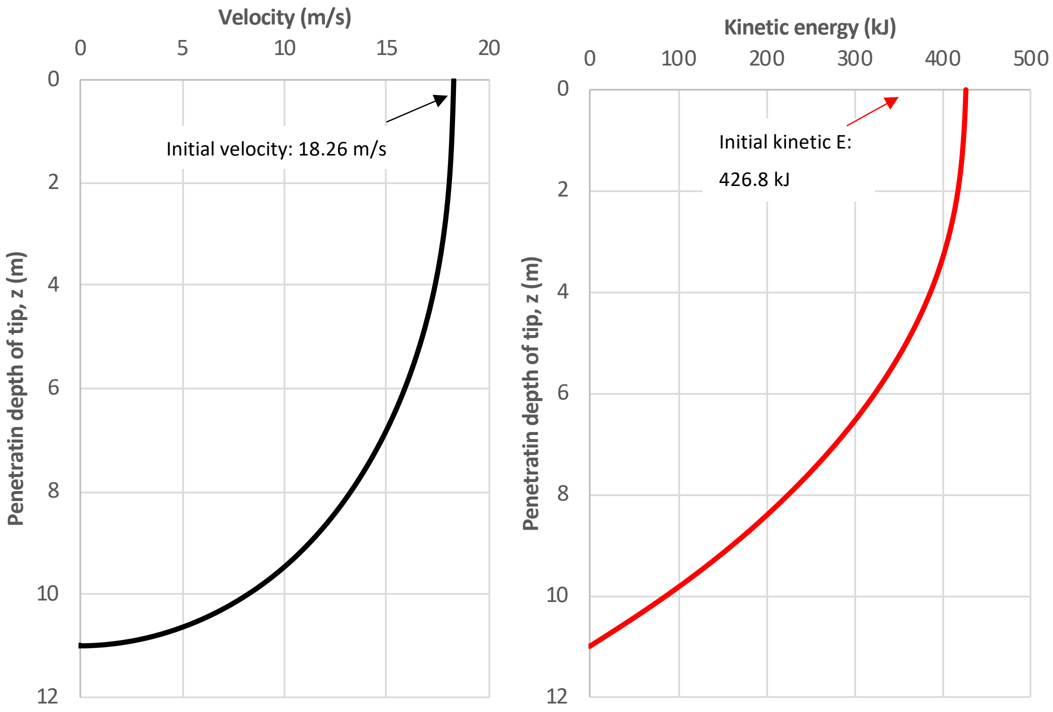
- **Video for Dry-ice spear penetration into soil**



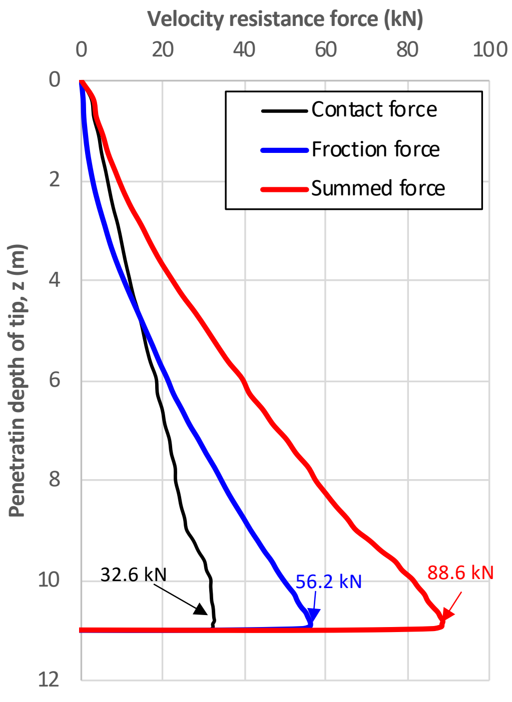
Von-Mises stress

Results of analysis case 1- velocity, kinetic energy and vertical resistance force

- Velocity and kinetic energy*



- Vertical resistance force



Note: *Kinetic energy: 0.5 x mass x velocity^2

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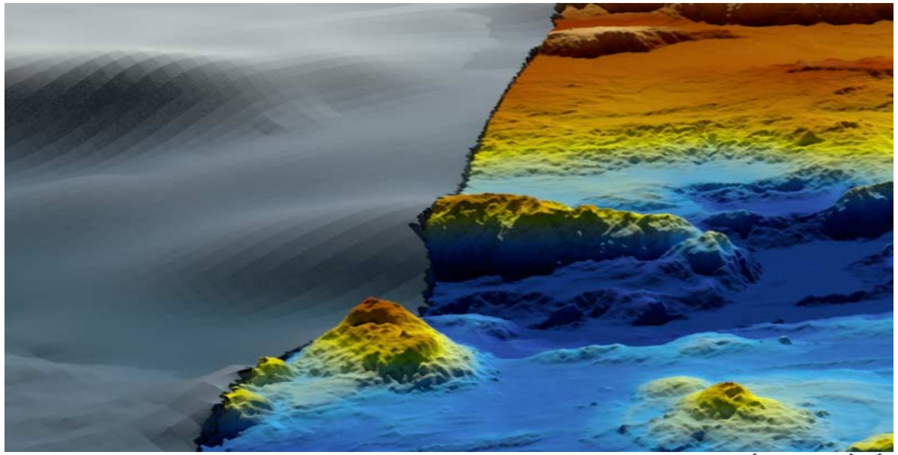
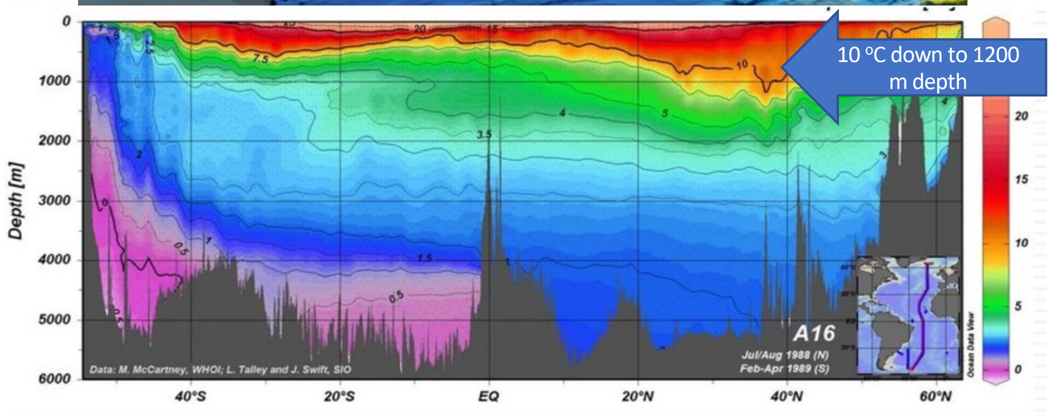
Storage site considerations

Approved storage sites: Depth and temperature

- Below 500 depth in the flat soft abyssal plains
- 71% of the ocean is abyssal plains
- Top layers 70-80% water

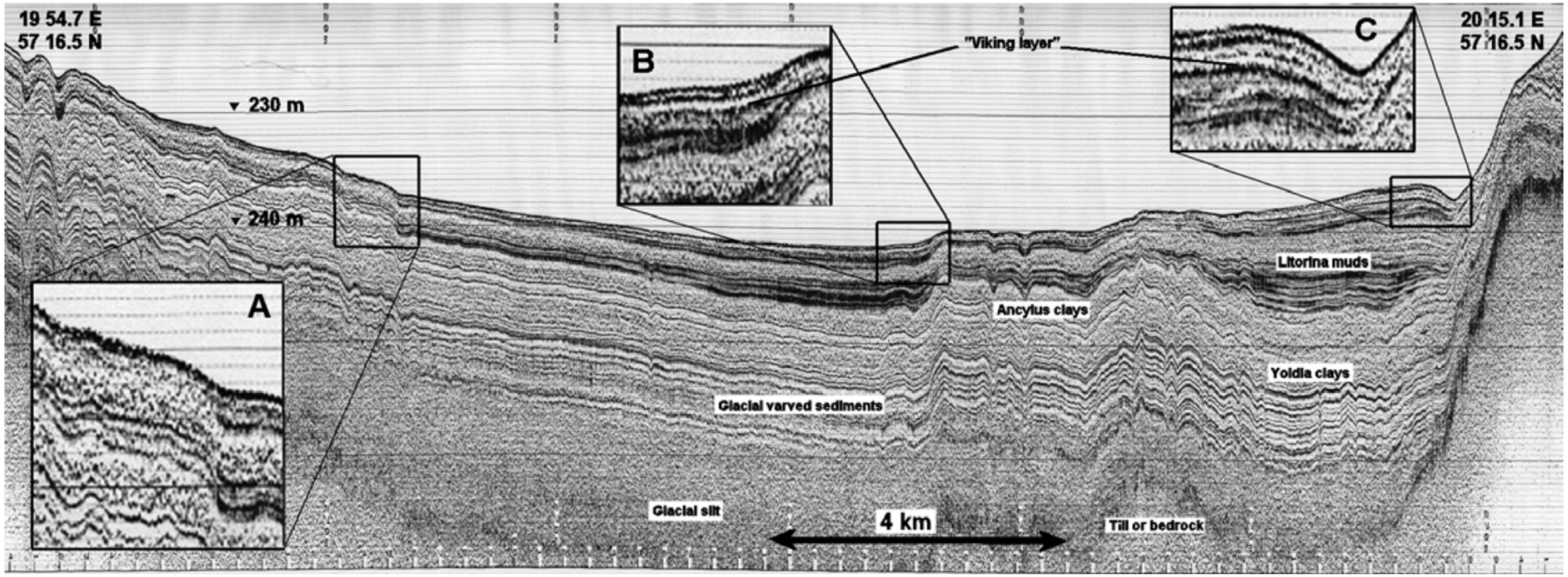


- Below 10 ^oC (hydrate formation)



Ecco sounder scanning of sediments

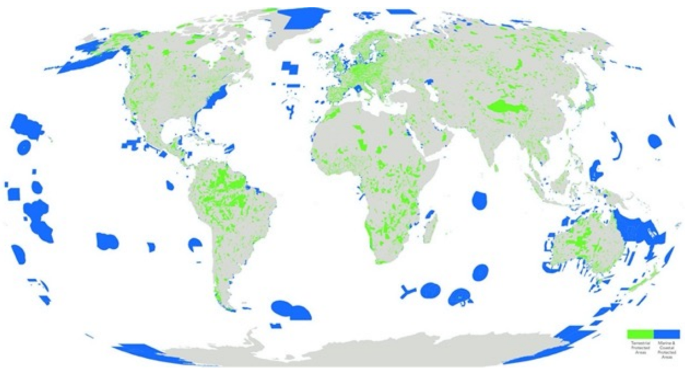
Mapping sediment type, depth, density, poisons ratio, Young's modulus

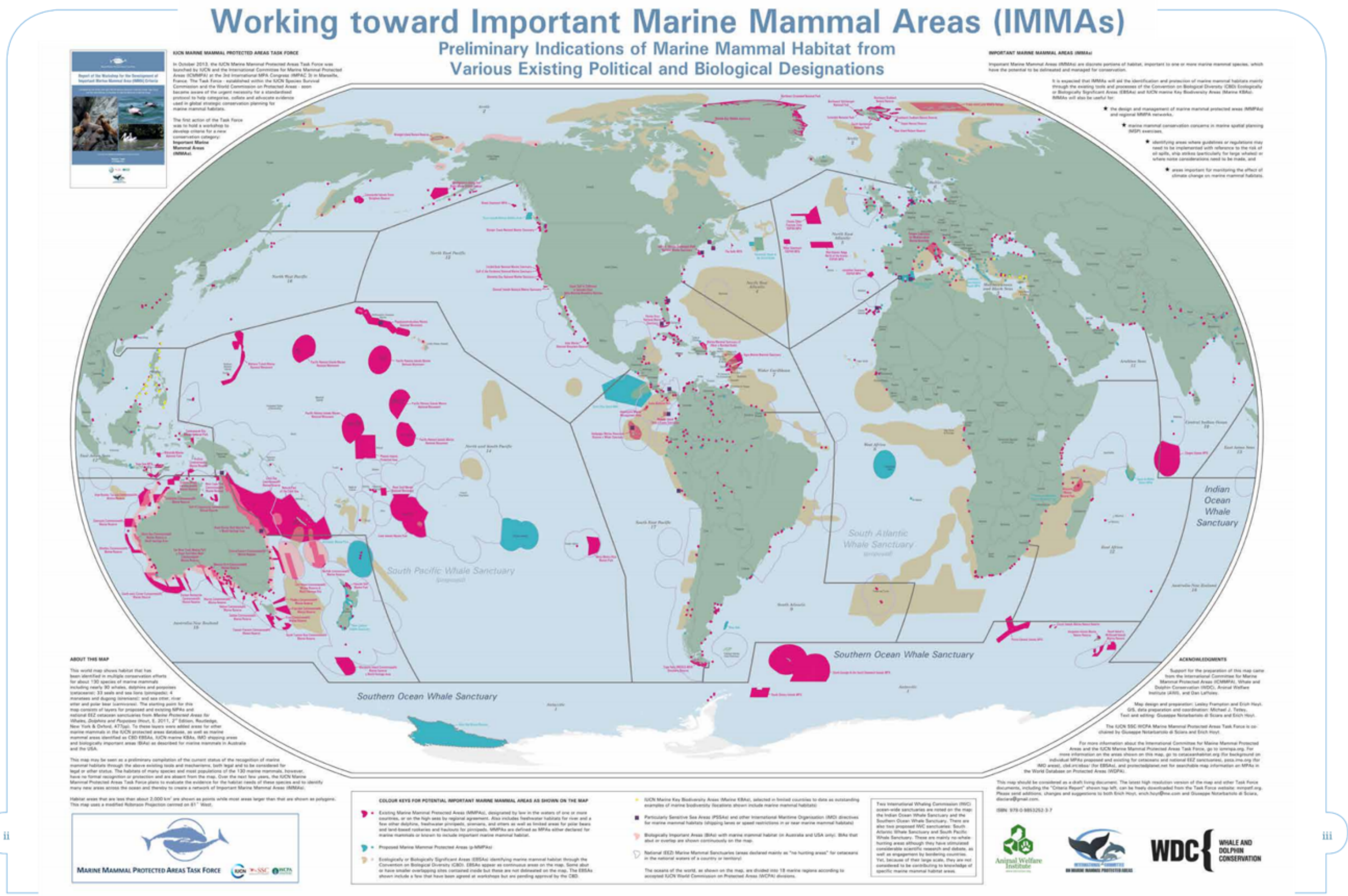


Microphones and Sonar detecting and protecting whales

Red and Blue areas are no go for decarbonICE
Brown areas are habitat for mammals, but decarbonICE don't hit whale as they are born with "sonar"

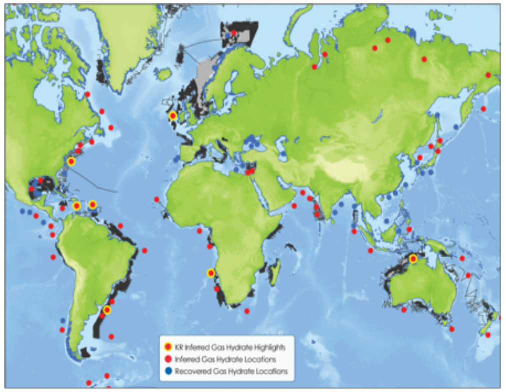
Protected areas on map below

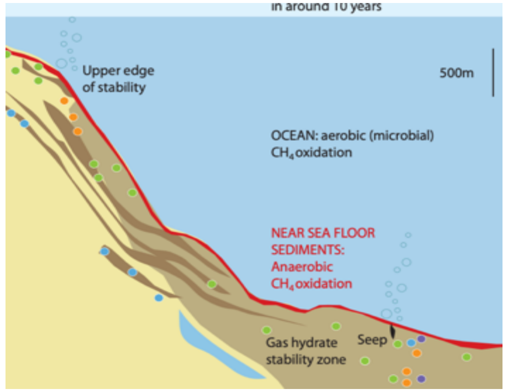




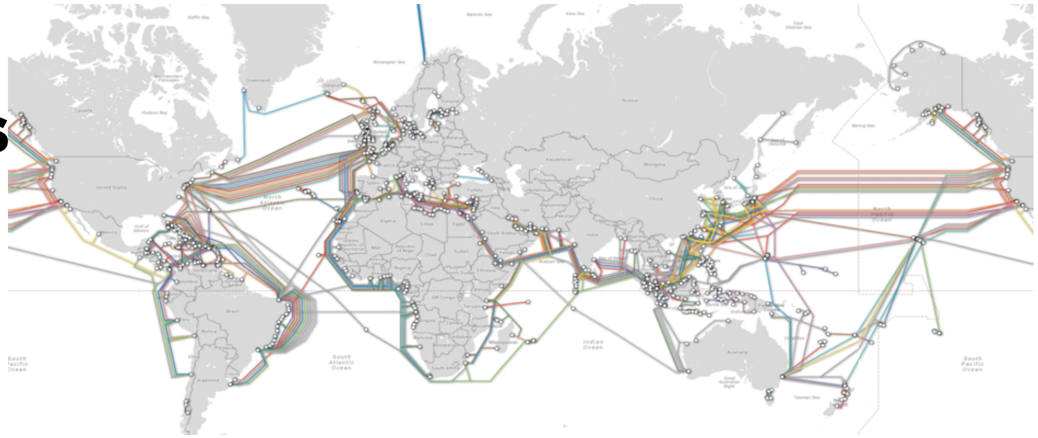
Approved storage sites: Avoiding cables and hydrate

- **Avoiding methane hydrate**





- **Avoiding sea cables/pipelines**



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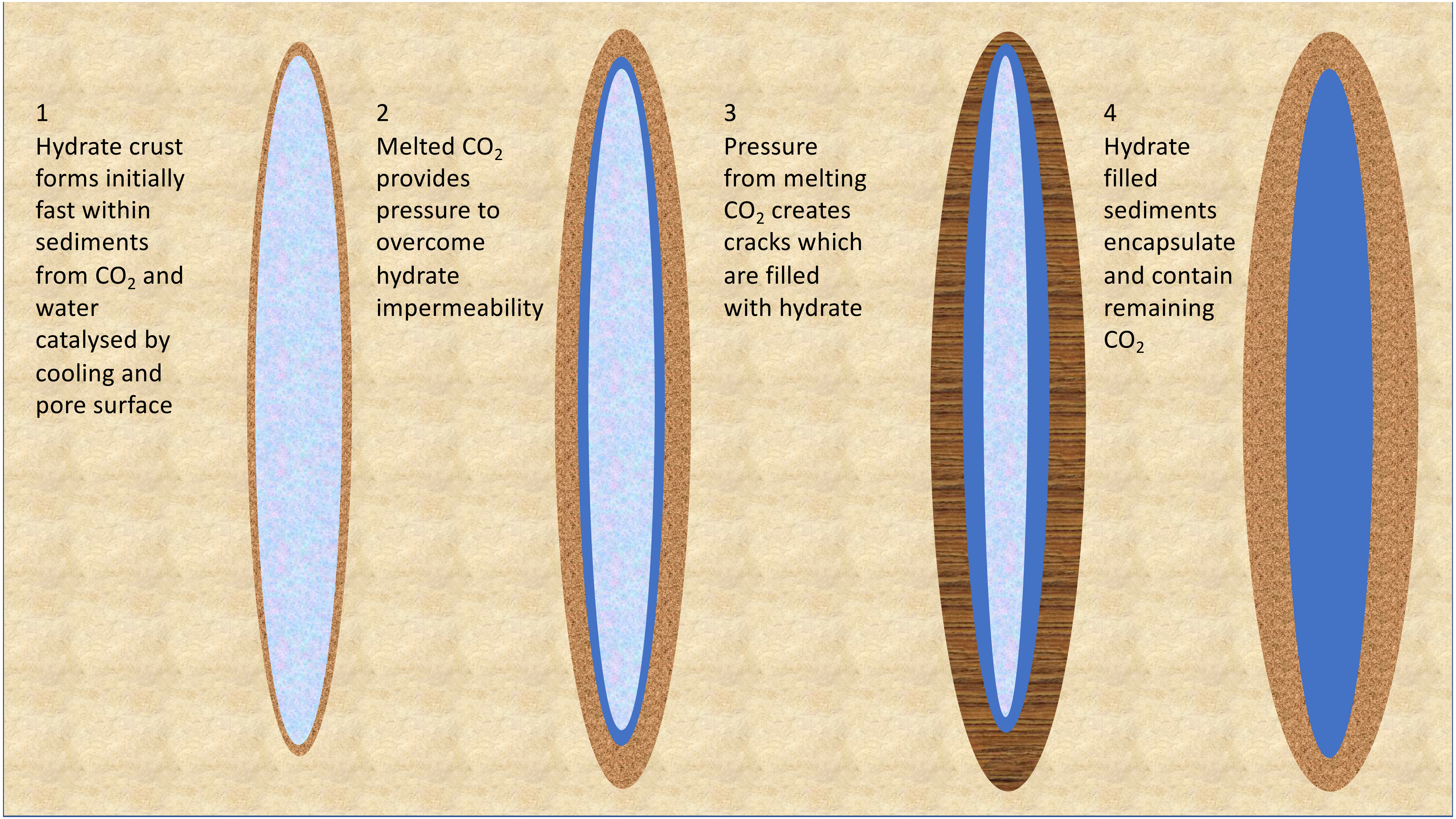
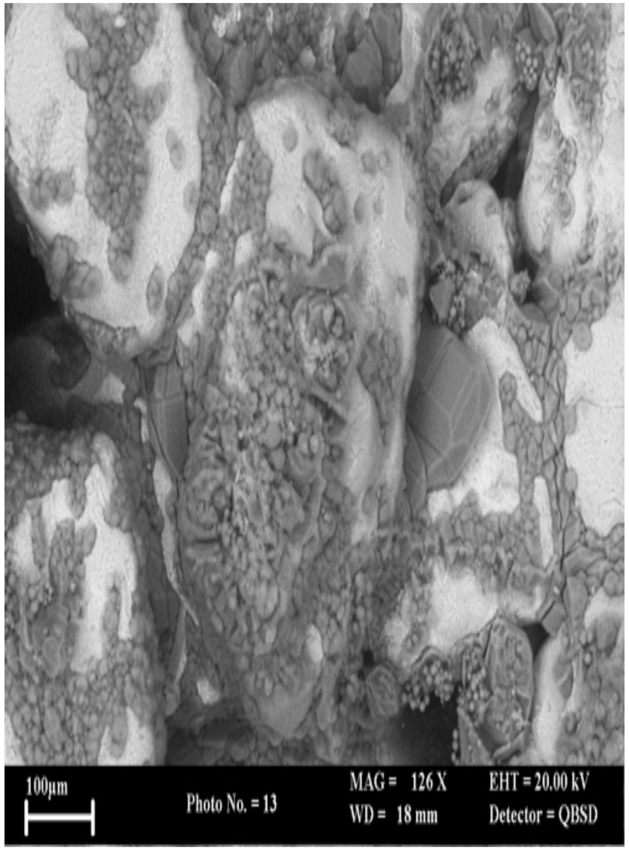
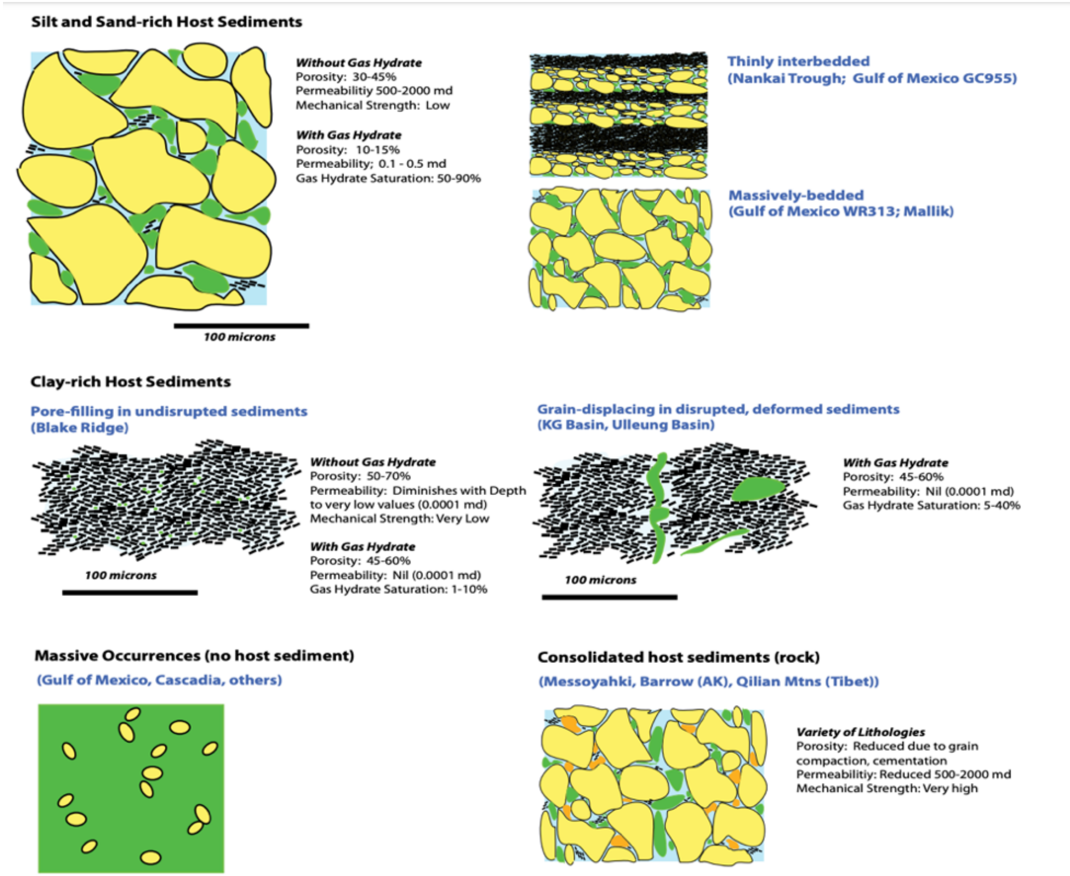
Storage


1
Hydrate crust forms initially fast within sediments from CO_2 and water catalysed by cooling and pore surface
2
Melted CO_2 provides pressure to overcome hydrate impermeability
3
Pressure from melting CO_2 creates cracks which are filled with hydrate
4
Hydrate filled sediments encapsulate and contain remaining CO_2

Hydrate fill the gaps





Permanent double secured storage

- The partial CO_2 pressure at the outer skin of the CO_2 hydrate crust is higher than in the surrounding pore water. Over time, some CO_2 is eroded from the crust and enters the pore water.
- The speed of this erosion will be extremely slow as there is almost no flow in the pore water. This contrasts with the situation where liquid CO_2 is stored on the sea floor.
- The pore water can dissolve the eroded CO_2. Some of the eroded CO_2 will remain as stable CO_2 (aq.) while a part will react with limestone in the sediments and form stable calcium carbonate.
- At depth below 2780 meter CO_2 is heavier than sea water and sinks further into the sediments

In summary, we believe that it is safe to say that the CO_2 is permanently stored in the sea bed sediments.

IMO

2012 SPECIFIC GUIDELINES FOR THE ASSESSMENT OF CARBON DIOXIDE FOR DISPOSAL INTO SUB-SEABED GEOLOGICAL FORMATIONS Adopted 2 November 2012 (LC 34/15, annex 8)

IMO has not considered storage in sub sea-bed sediments layers

- Delivered by CO_2 hydrate covered dry ice CDV
- Delivered as small size units –a few tons each
- Permanent containment in CO_2 hydrated sediments
- Stored in validated deep sea zone

- We assume that IMO is the international body to approve our storage solution – IMO is the custodian of the London Convention

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Perspectives

Consider this…

- The timeframe for drastic reduction of shippings GHG emissions
- Second hand value of ships
- Investors riskpicture
- Energy (fuel prices)
- The public image of shipping
- Energy/fuel supply chain
- Retrofitting as well as newbuildings
- What will the business case be: today – and tomorrow?

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Partners

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Backed by leading shipowners and yards

NYK LINE
NIPPON YUSEN KAISHA

VALE

DSME

SCF
Sovcomflot

Knutsen OAS Shipping

TK

Large N-European/ Asian shipowner

Large Japanese shipbuilder

MDC

Ardmore Shipping Limited

Large Chinese shipowner

CLEAN MARINE

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Join:
Capture workshop in Copenhagen
29/1-20 (next week)

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