Technologies for mining in the deep sea

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International Workshop for Students
"Seafloor Mineral Resources: scientific, environmental, and societal issues"

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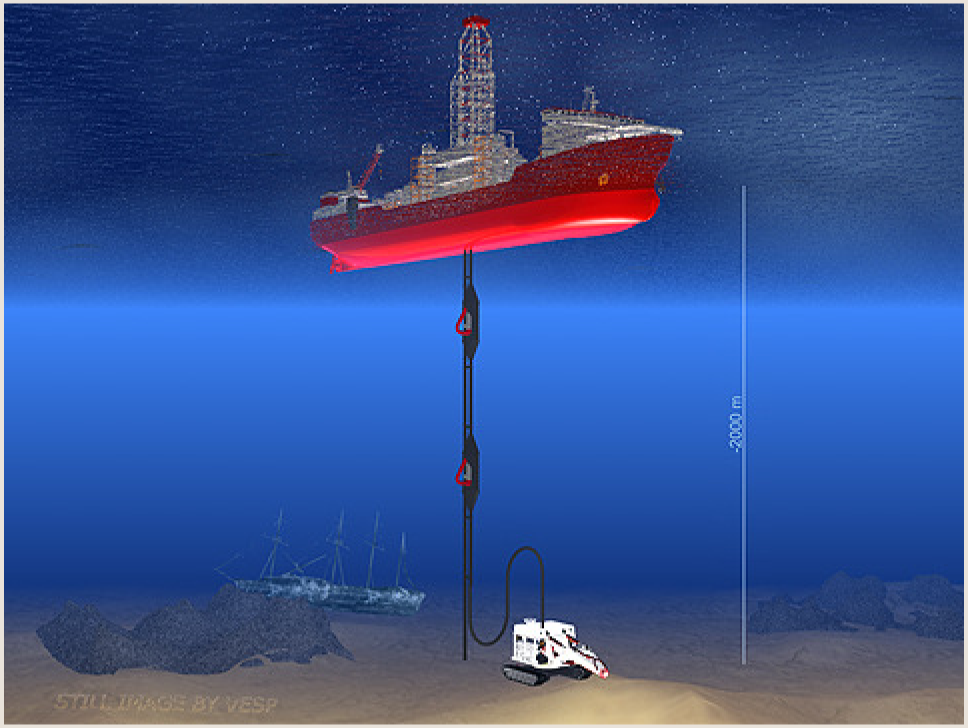
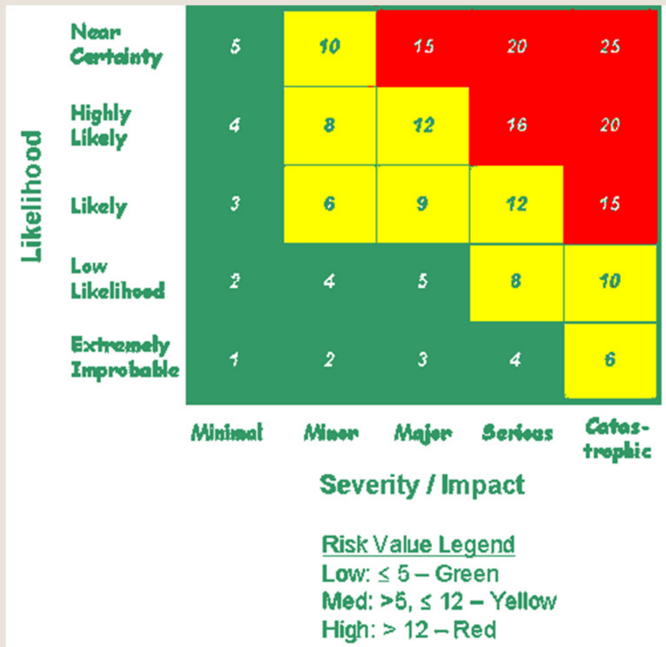
The technology innovator.

DEEP SEA MINING



General Risk Analysis:
identification of the key risks followed by the development of prevention/mitigation strategies

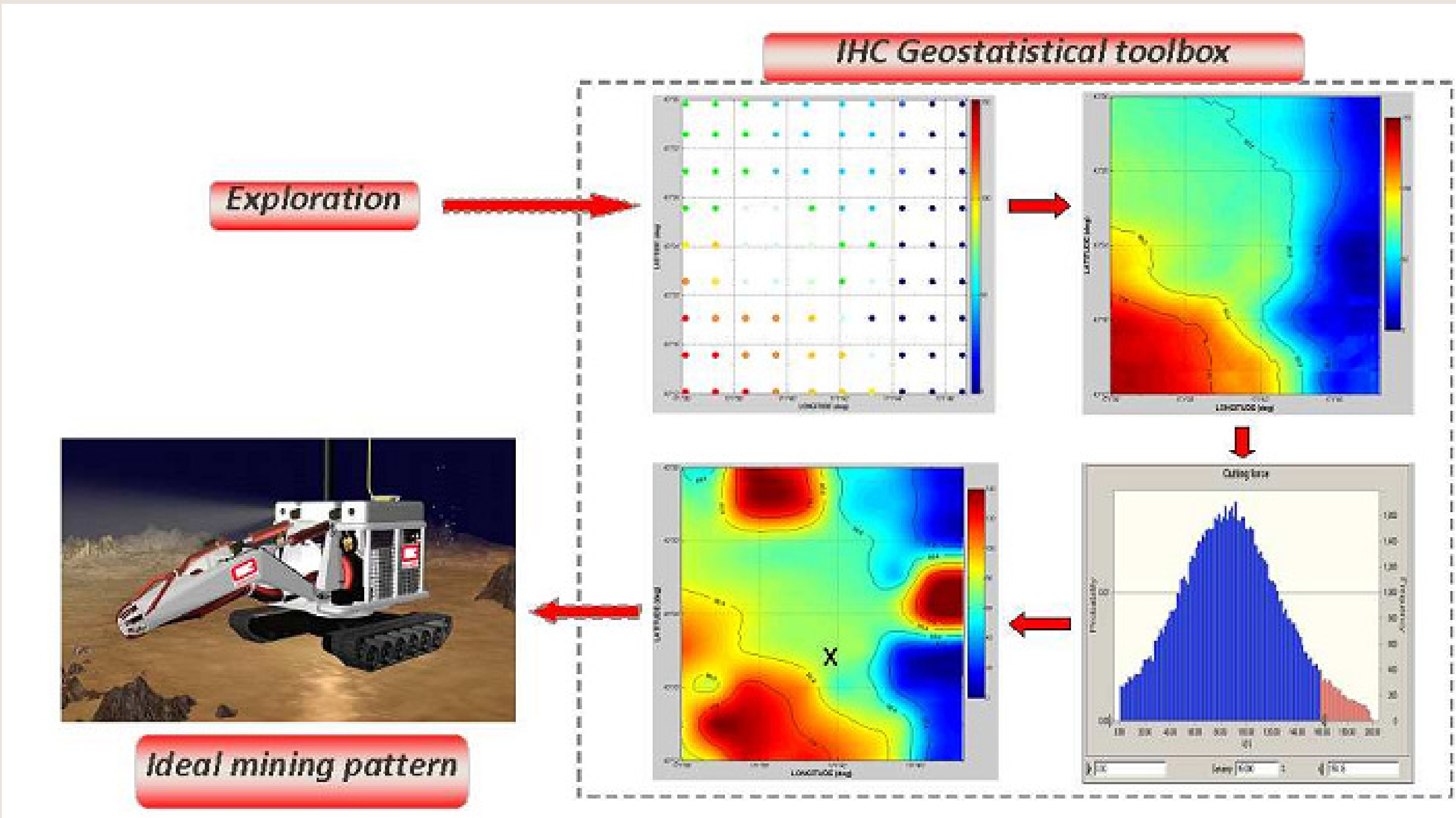


PROBLEMS → SOLUTIONS

1. Geostatistical toolbox and SWORD
2. Hyperbaric cutting
3. Vertical hydraulic transport
4. Dynamics of the vertical transport system
5. Water hammer
6. Wear
7. Environmental impact

1.Geostatistical toolbox

core sampling → Kriging interpolation → geotechnical model of the area → 2D/3D maps → cutting forces and mining pattern

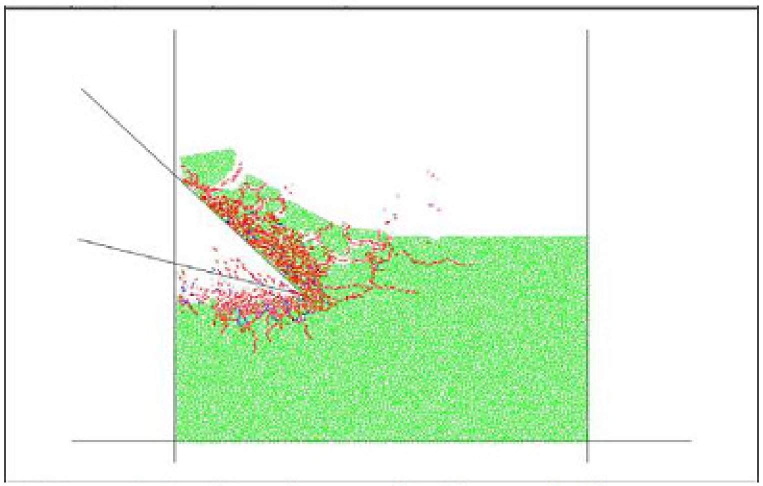


Key Features of the SWORD

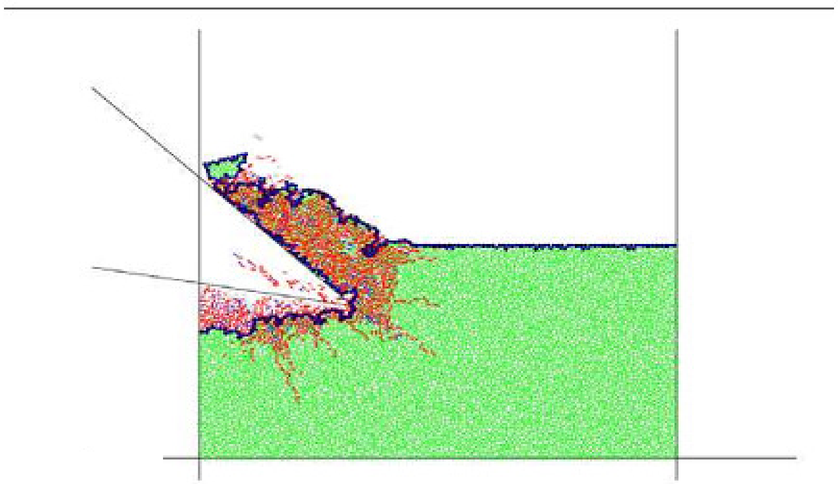
- Sample sizes up to 4 inch.
- Operating depth up to 2 500m.
- Ground penetration up to 50m.
- Target sample integrity > 95%.
- Remote operation from vessel-based control center.
- Combines conventional rotary drilling with sonic drilling capability which is typically up to 5 times faster than conventional sampling methods.
- Wire-line system for down hole tooling and CPT tests.

2. Hyperbaric cutting

ductile vs. brittle → cutting forces → experiments → modeling → optimal deep sea mining tool



Rock cutting mechanism at shallow water (brittle cutting process).



Rock cutting mechanism at deep water (ductile cutting process).

3. Vertical hydraulic transport

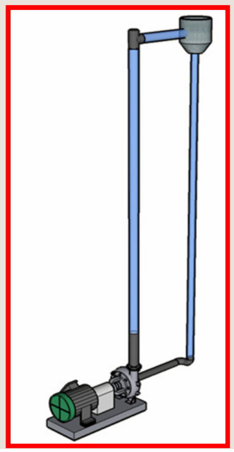
Fluidization tests at MTI Holland B.V.

Marbles

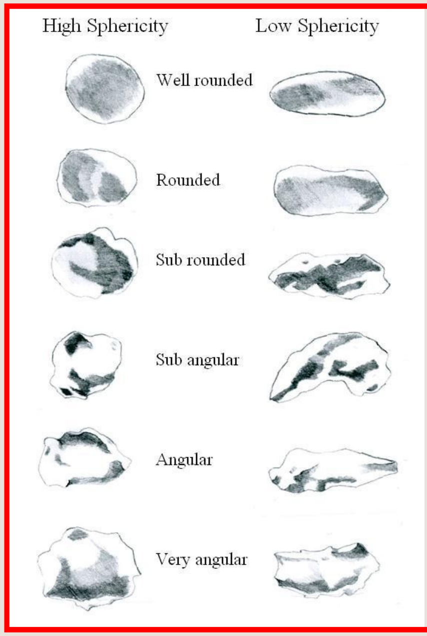
Gravel

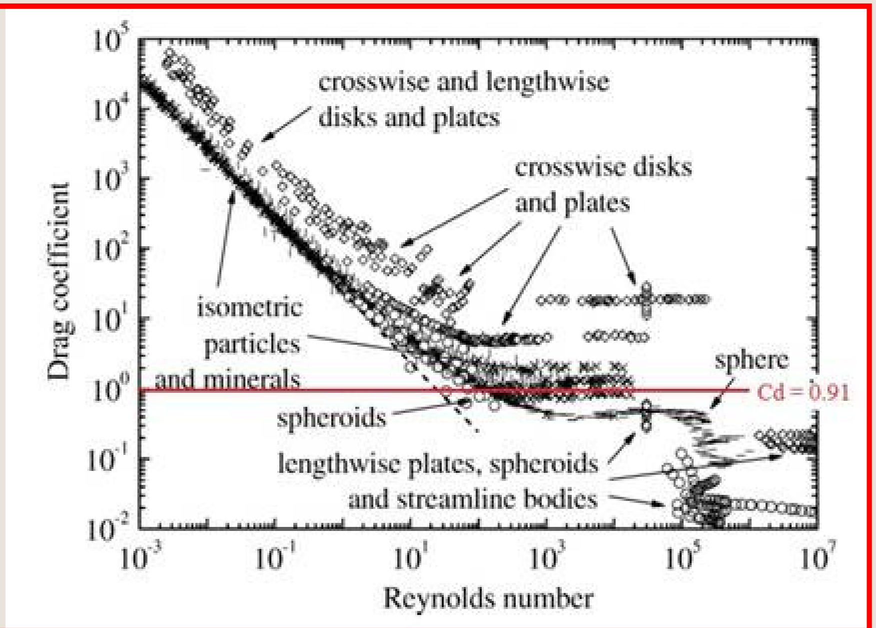
Rock blast gravel

Decreasing sphericity, increasing angularity

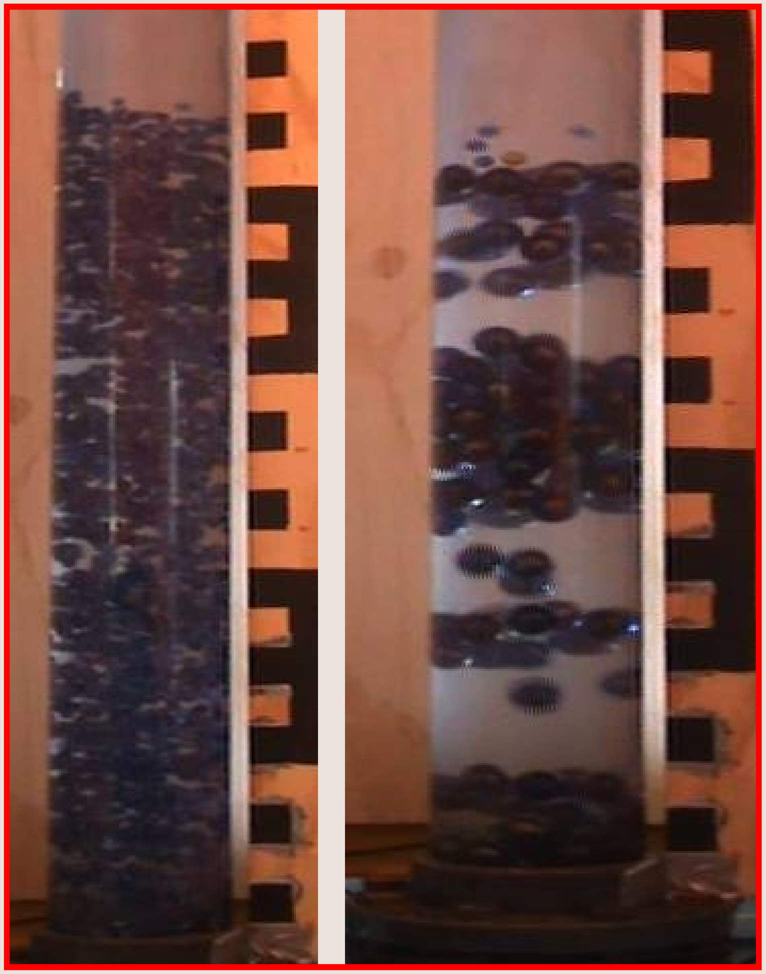


Shape and transport velocities



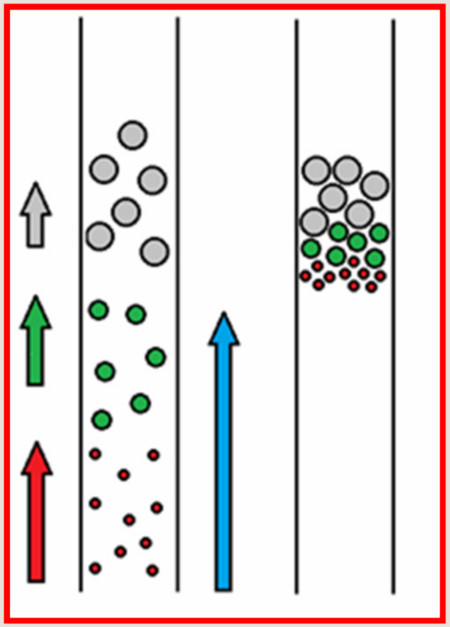


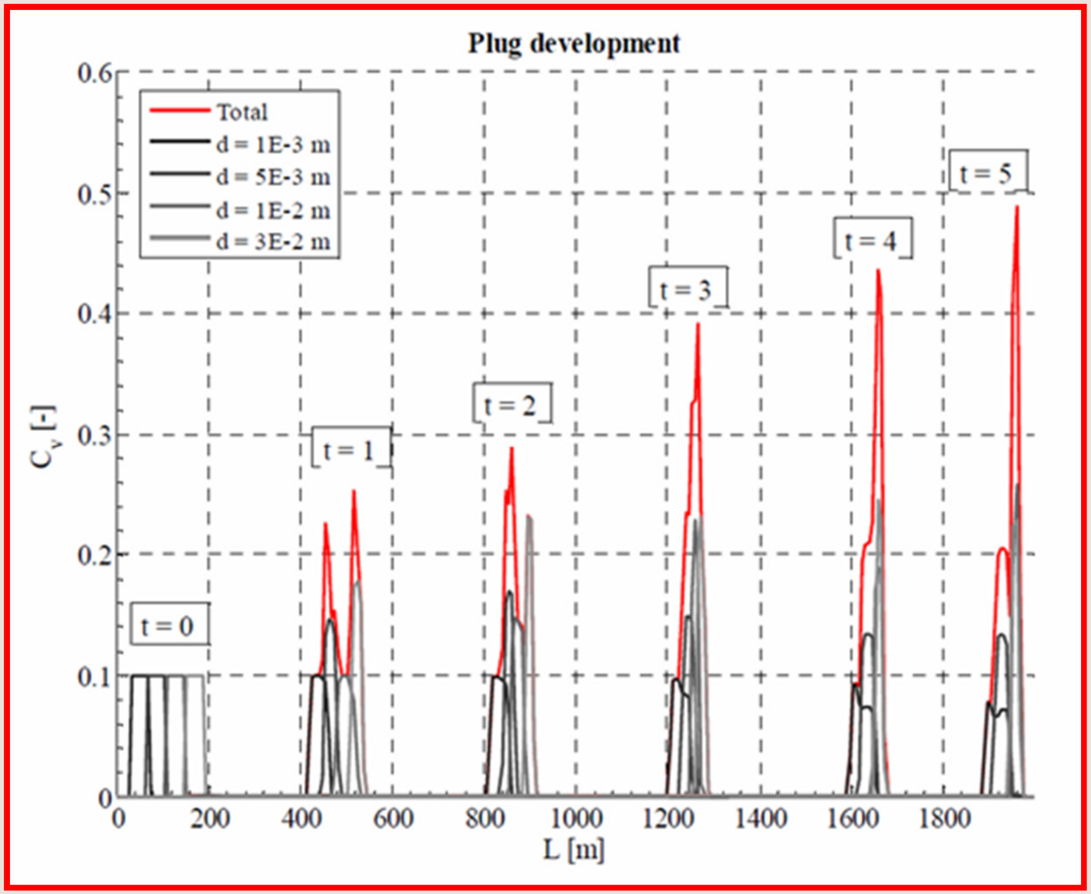
Experiments



Simulations

Concentration peak development





4. Dynamics of the vertical hydraulic transport system

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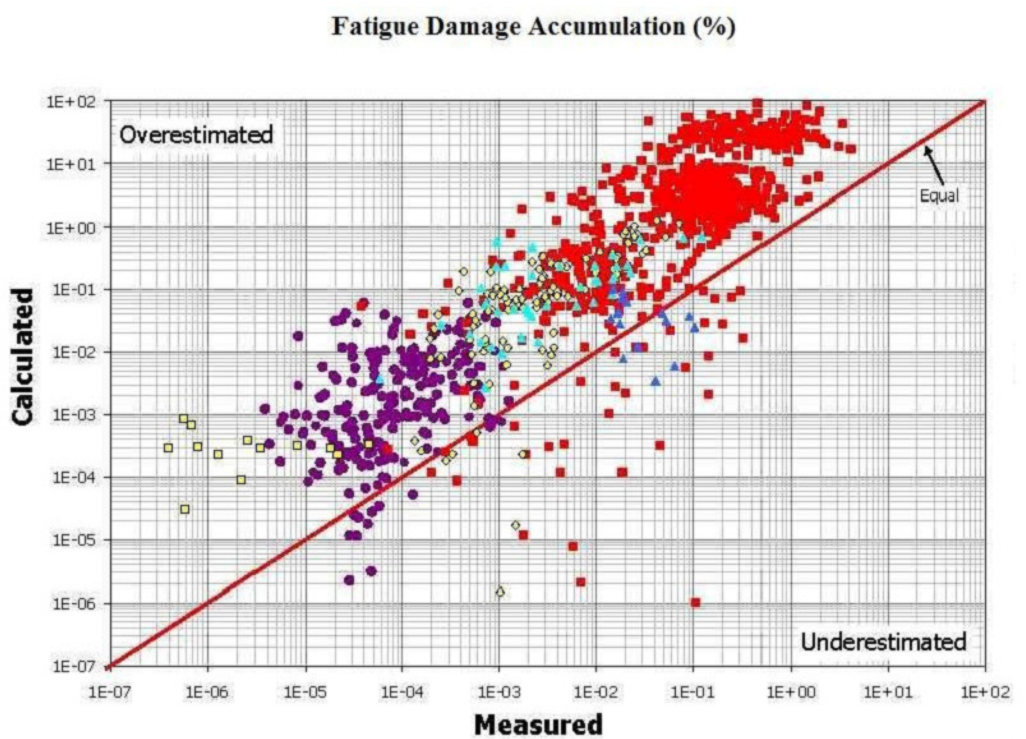
Booster Stations (submersible dredge pumps)

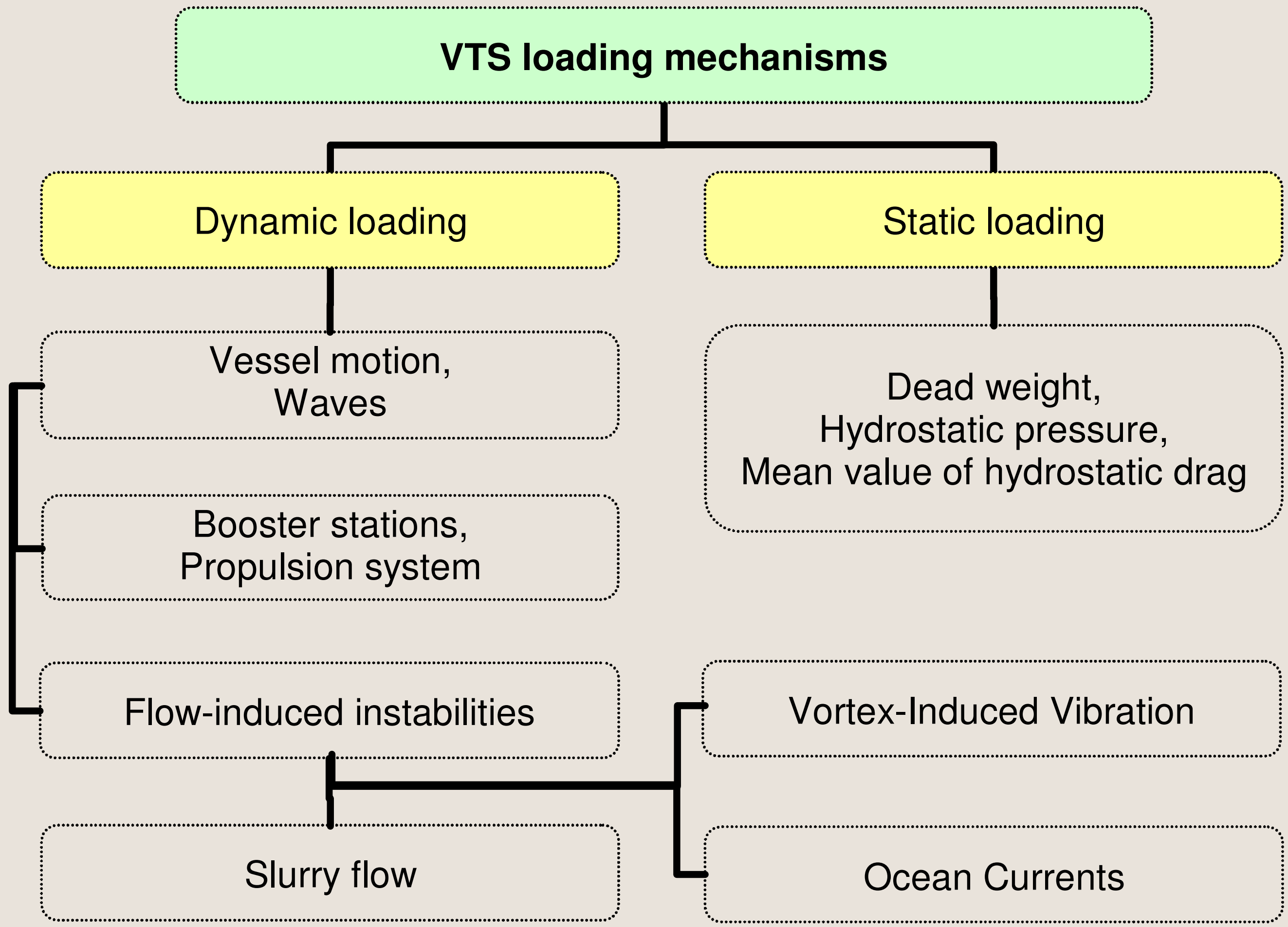
Why correct modeling of dynamics is important?

- according to OREDA 2009, 16-24% of the total failures of the offshore oil production risers are fatigue-related failures;
- knowledge on maximal displacements and moments is critical for the design of joints and couplings;
- the model that accounts for all the aforementioned excitation sources has never been built and analyzed yet.

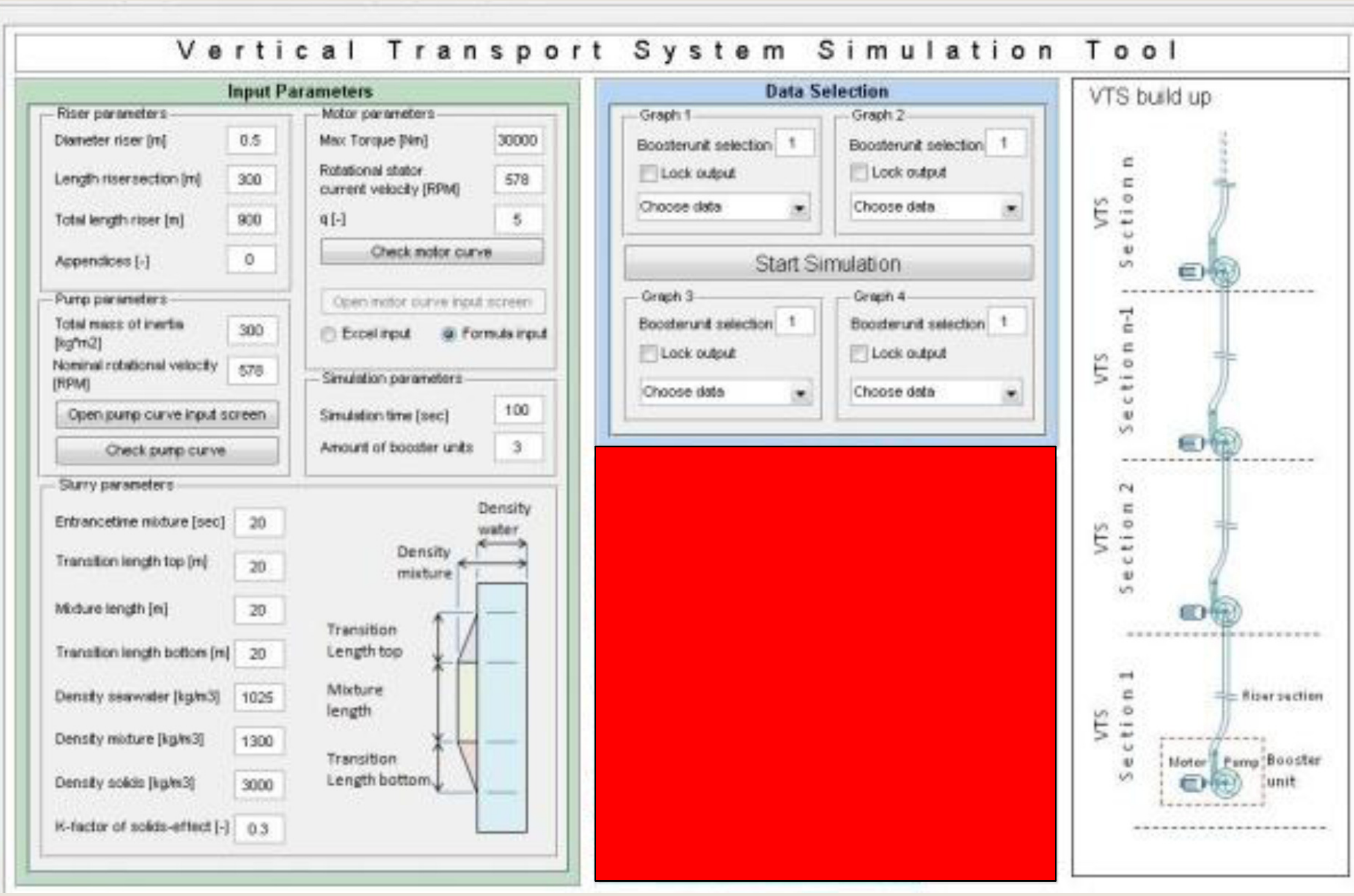


OMAE2008-57046 Tognarelli et al.

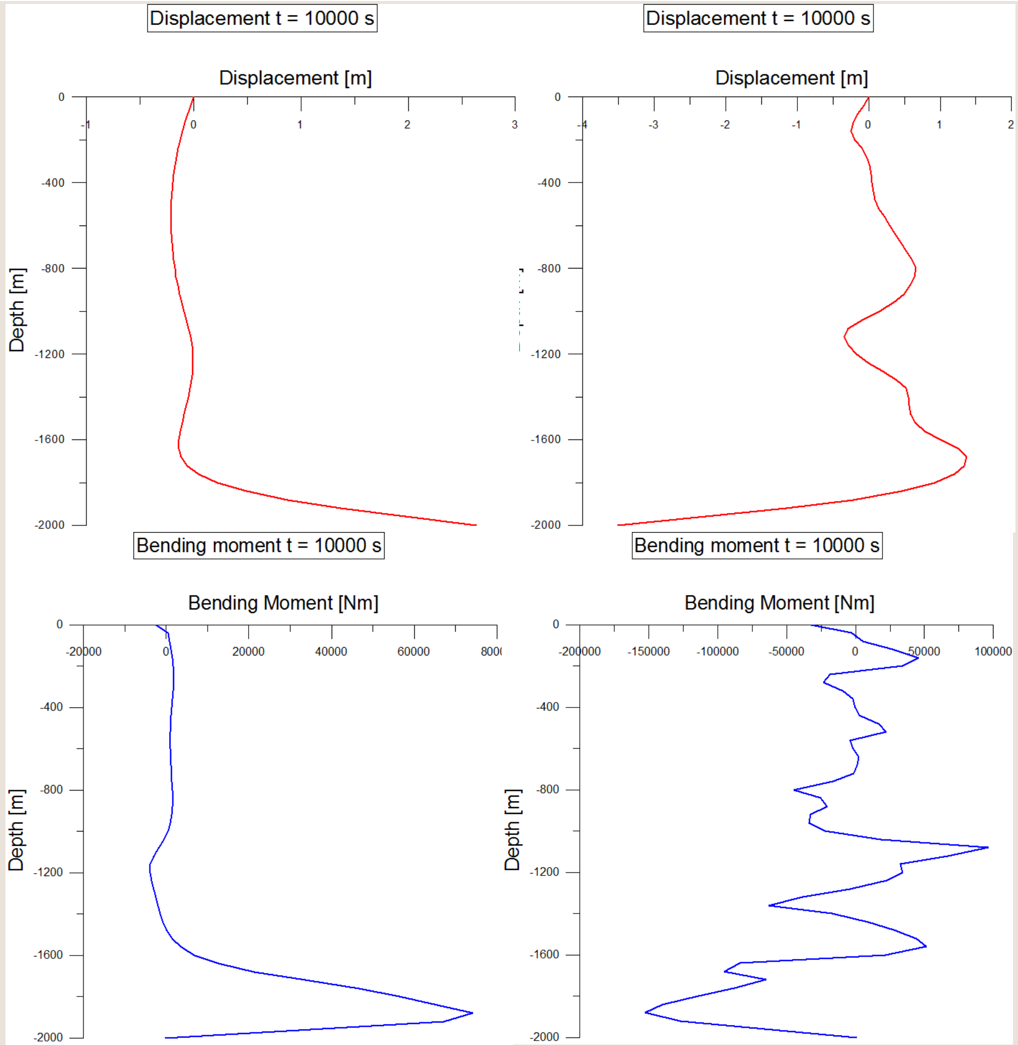
Internal and External Loads



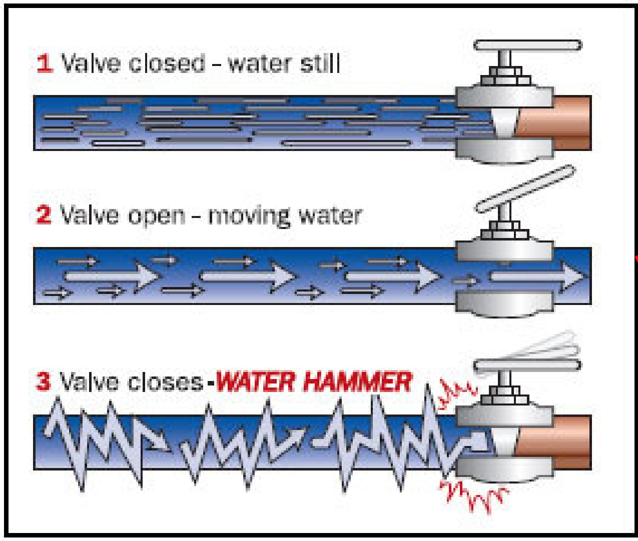
Dynamical Pressures as a Result of Inhomogeneous Slurry Flow

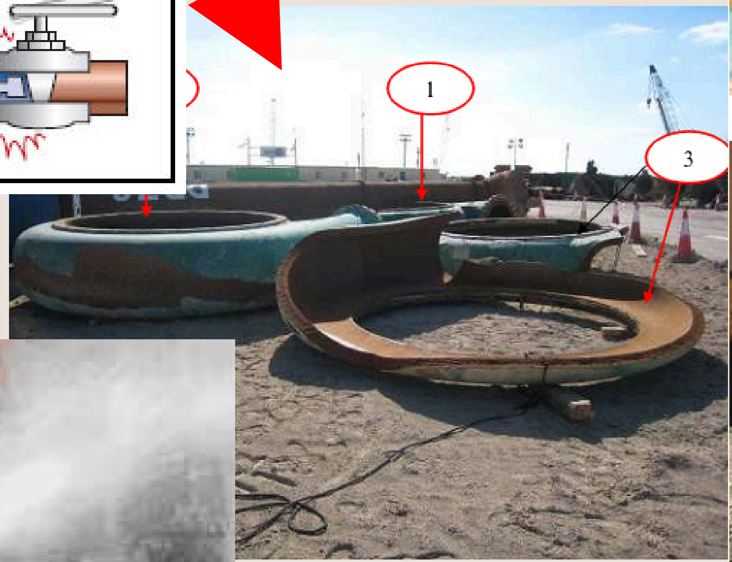


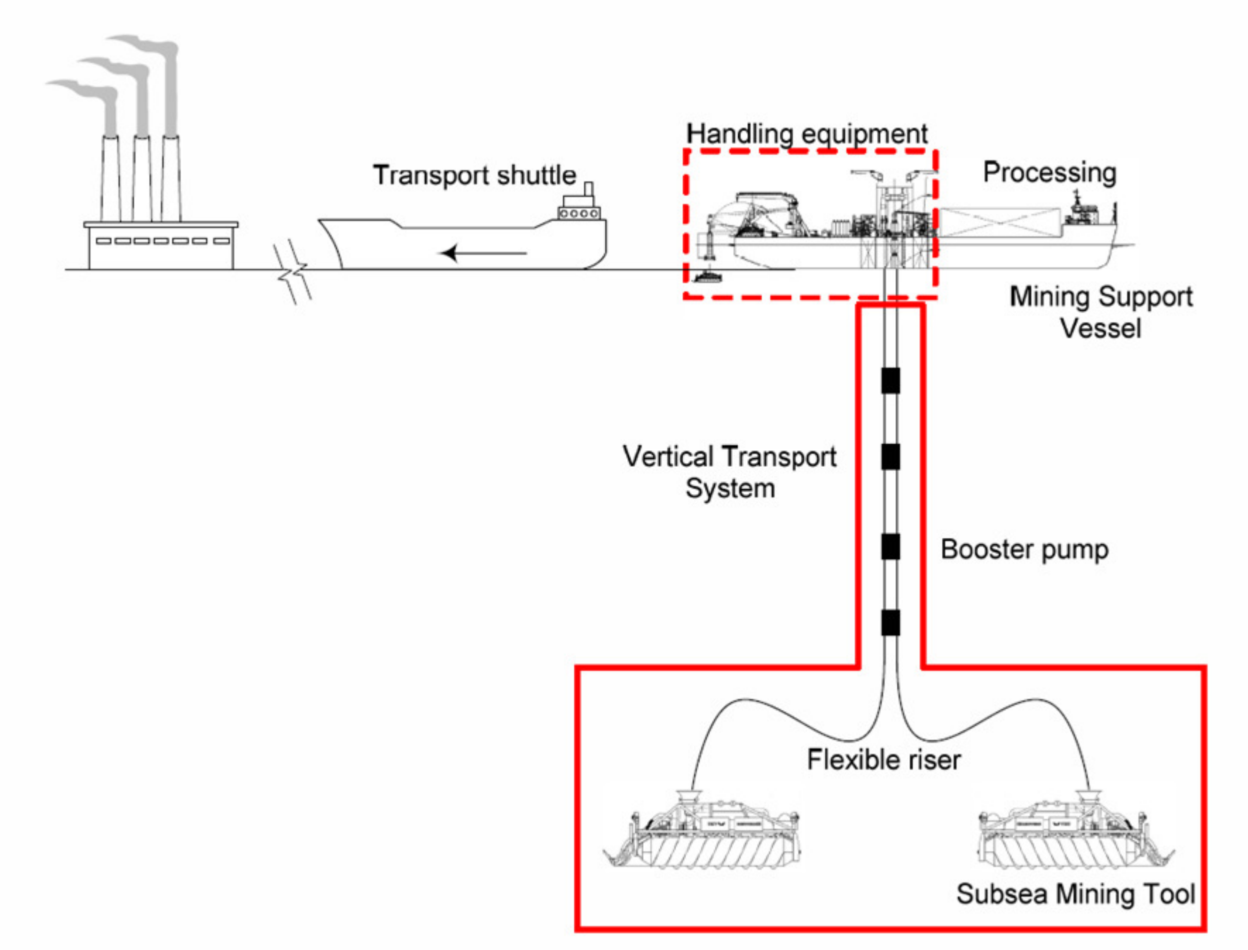
Example of the output



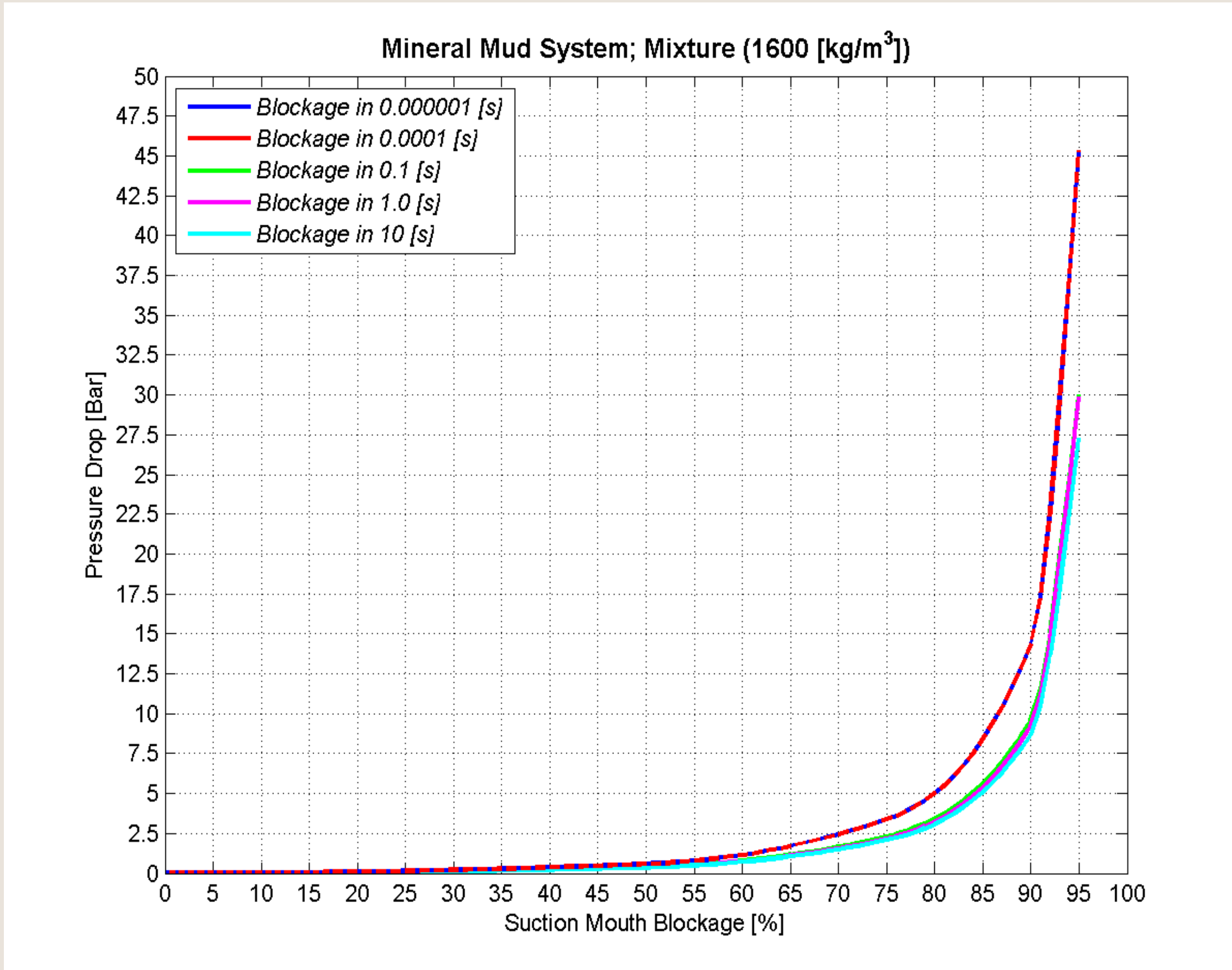
5. Water hammer







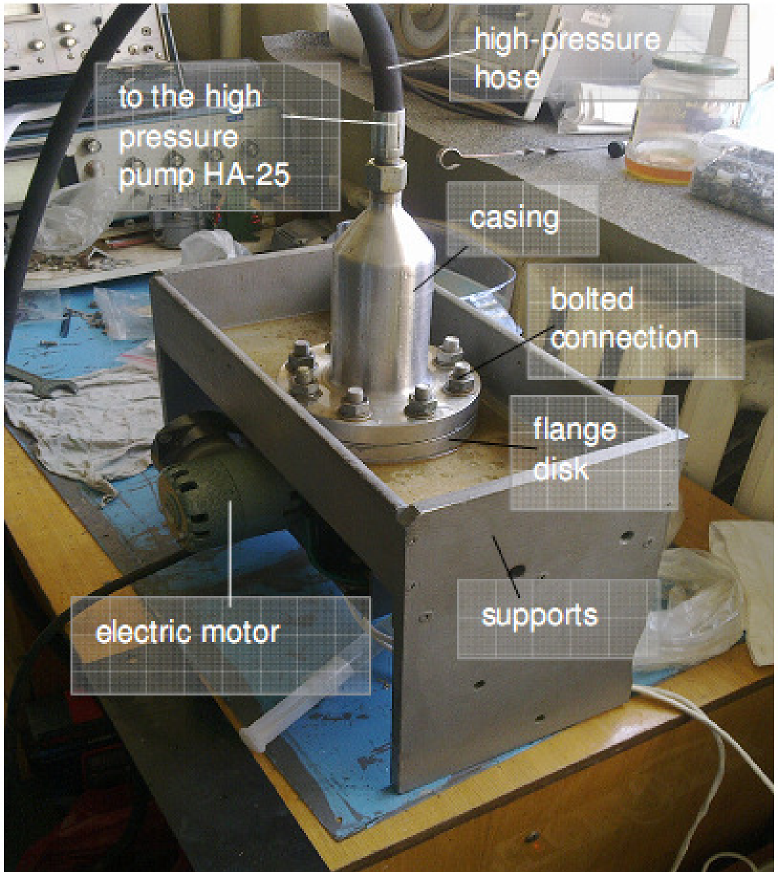
Handling equipment
Transport shuttle
Processing
Mining Support Vessel
Vertical Transport System
Booster pump
Flexible riser
Subsea Mining Tool

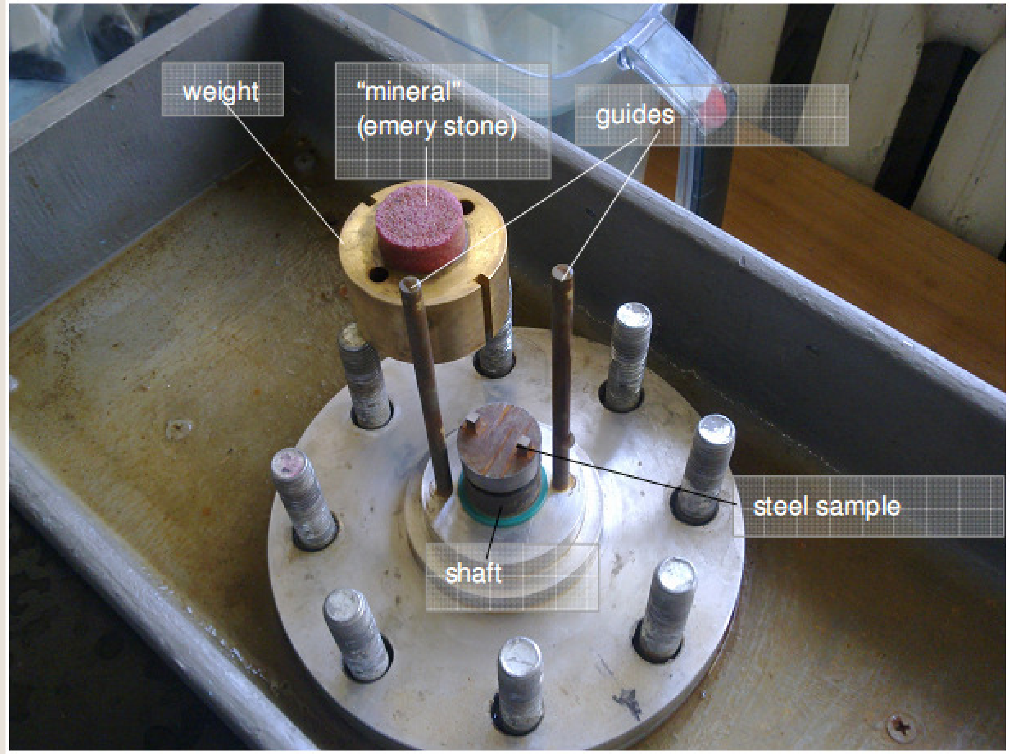

Mineral Mud System; Mixture (1600 [kg/m3])
Blockage in 0.000001 [s]
Blockage in 0.0001 [s]
Blockage in 0.1 [s]
Blockage in 1.0 [s]
Blockage in 10 [s]
Pressure Drop [Bar]
50
47.5
45
42.5
40
37.5
35
32.5
30
27.5
25
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Suction Mouth Blockage [%]

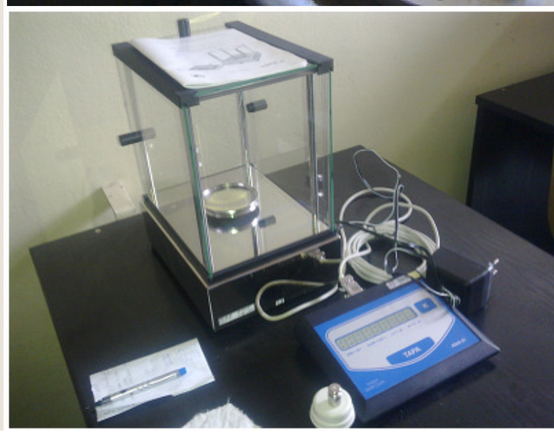
Subjects to be investigated for water hammer:

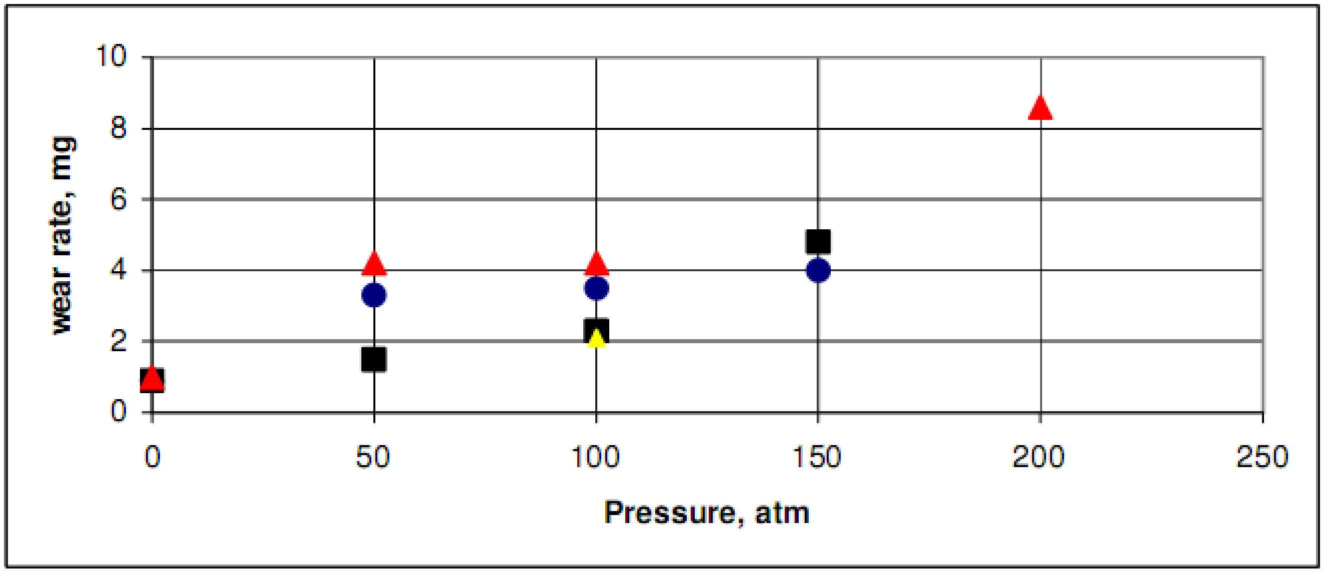
- Pump failure
- Bulk modulus mixture (under dynamic conditions)
- Model verification/validation
- Water hammer mitigation
- Other possible water hammer scenarios:
  - Breakage of a flexible hose
  - Startup & shutdown of the system
  - Valve failure
  - Free gas/gas hydrates handling, etc.

Abrasive wear at hyperbaric conditions









Wear rate vs. pressure. Low carbon steel m 1020 + emery stone, 1 h, N=1600, f=0.44 Hz, 2x0.7 kg

7. Environmental impact

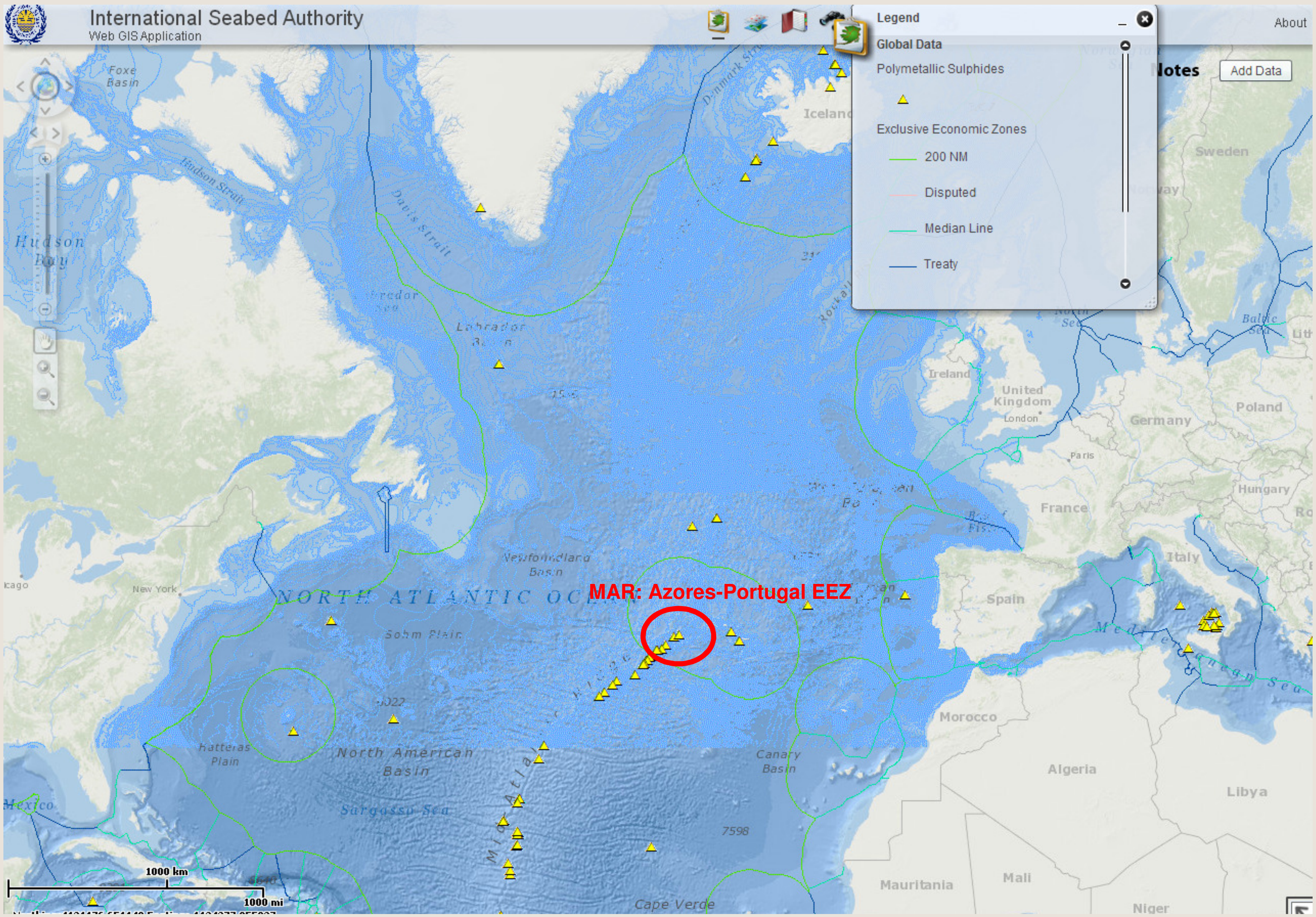
JIP project

“Towards Zero Impact Approach for Deep Sea Offshore Projects”

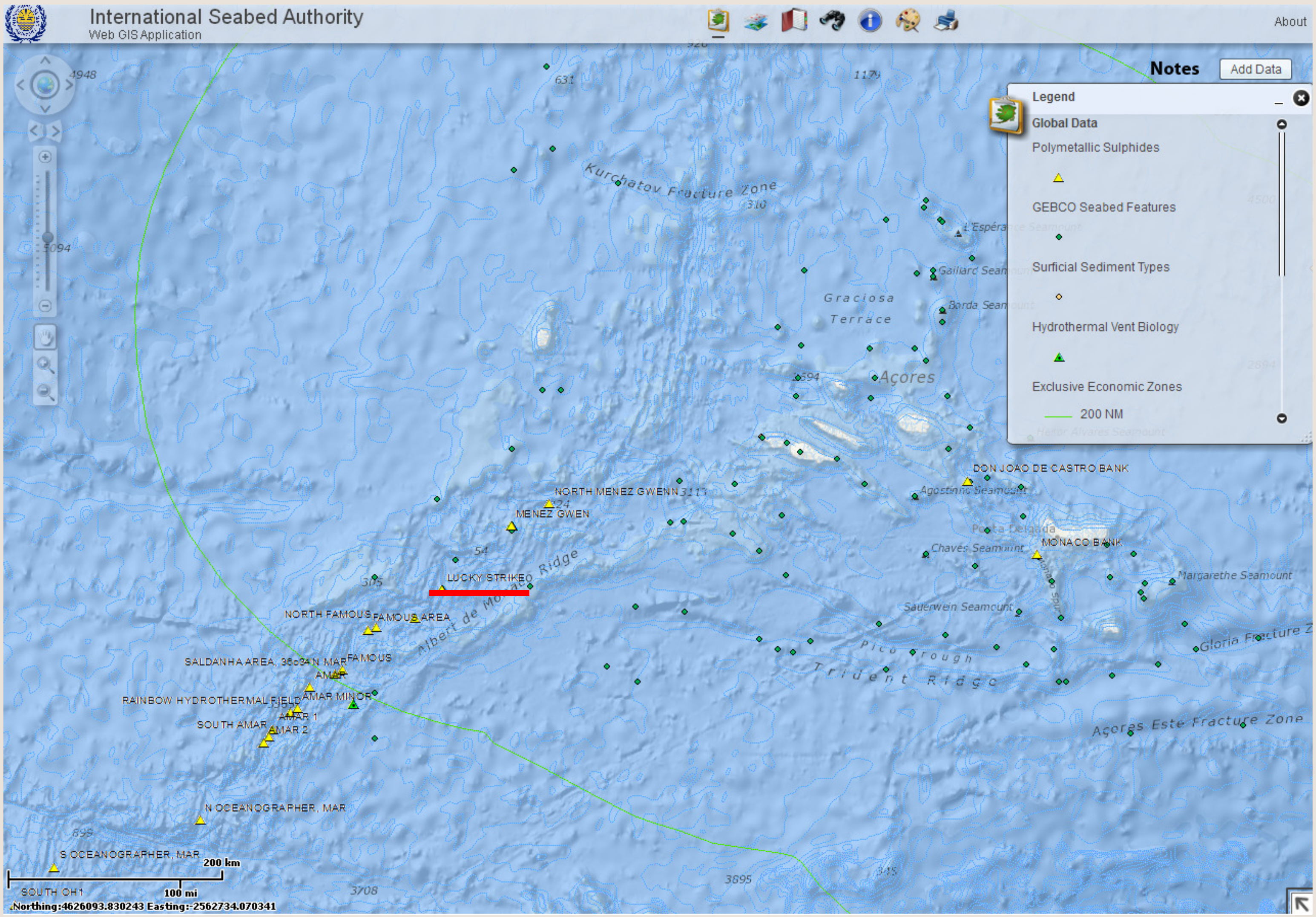
Project objectives

- To develop a framework to be used as a preliminary impact assessment of the mining activities in the deep sea
- To determine the uncertainties of the methodology and to determine the sensitivity of the assessment framework to these uncertainties

Location


International Seabed Authority
Web GIS Application
Legend
Global Data
Polymetallic Sulphides
Exclusive Economic Zones
200 NM
Disputed
Median Line
Treaty
About
Add Data
MAR: Azores-Portugal EEZ
NORTH ATLANTIC OCEAN
Iceland
Ireland
United Kingdom
France
Spain
Germany
Poland
Italy
Morocco
Algeria
Libya
Mauritania
Mali
Niger
Sweden
Hungary
Hudson Bay
Labrador Basin
Newfoundland Basin
Sohm Plain
North American Basin
Sargasso Sea
Hatteras Plain
Canary Basin
Cape Verde
New York
1000 km
1000 mi

Location



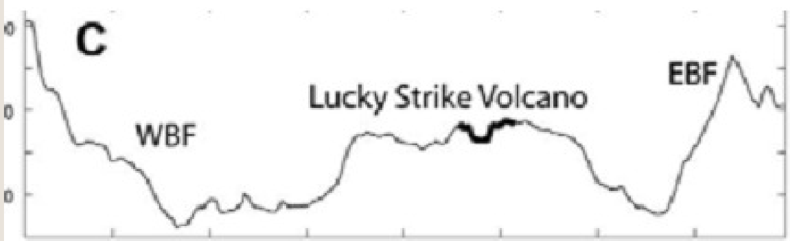
International Seabed Authority
Web GIS Application
About
Notes
Add Data
Legend
Global Data
Polymetallic Sulphides
GEBCO Seabed Features
Surficial Sediment Types
Hydrothermal Vent Biology
Exclusive Economic Zones
200 NM
Kurchatov Fracture Zone
Graciosa Terrace
Açores
DON JOAO DE CASTRO BANK
NORTH MENEZ GWENN
MENEZ GWEN
LUCKY STRIKE
MONACO BANK
Margarethe Seamount
Gloria Fracture Z
Sauerwein Seamount
Pico Trough
Trident Ridge
Açores Este Fracture Zone
NORTH FAMOUS
FAMOUS AREA
FAMOUS
SALDANHA AREA, 36o34N MAR
AMAR
RAINBOW HYDROTHERMAL FIELD
AMAR MINOR
AMAR 1
SOUTH AMAR
AMAR 2
N OCEANOGRAPHER, MAR
S OCEANOGRAPHER, MAR
SOUTH OH1
200 km
100 mi
Northing:4626093.830243 Easting:-2562734.070341

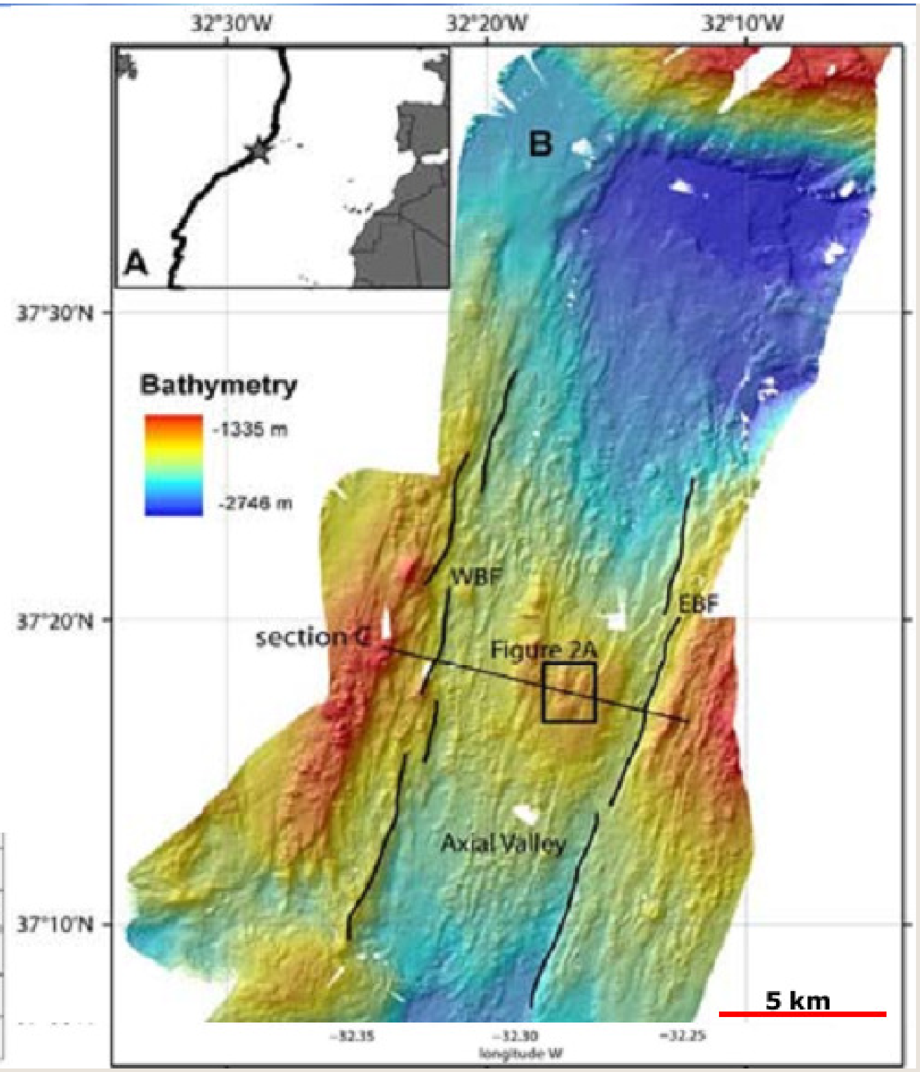
Accurate grid of 4x4m cells

Positioned in a valley in MAR

Vents occur in a area of 300 by 700m on top of a vulcano

Depth ~1650m



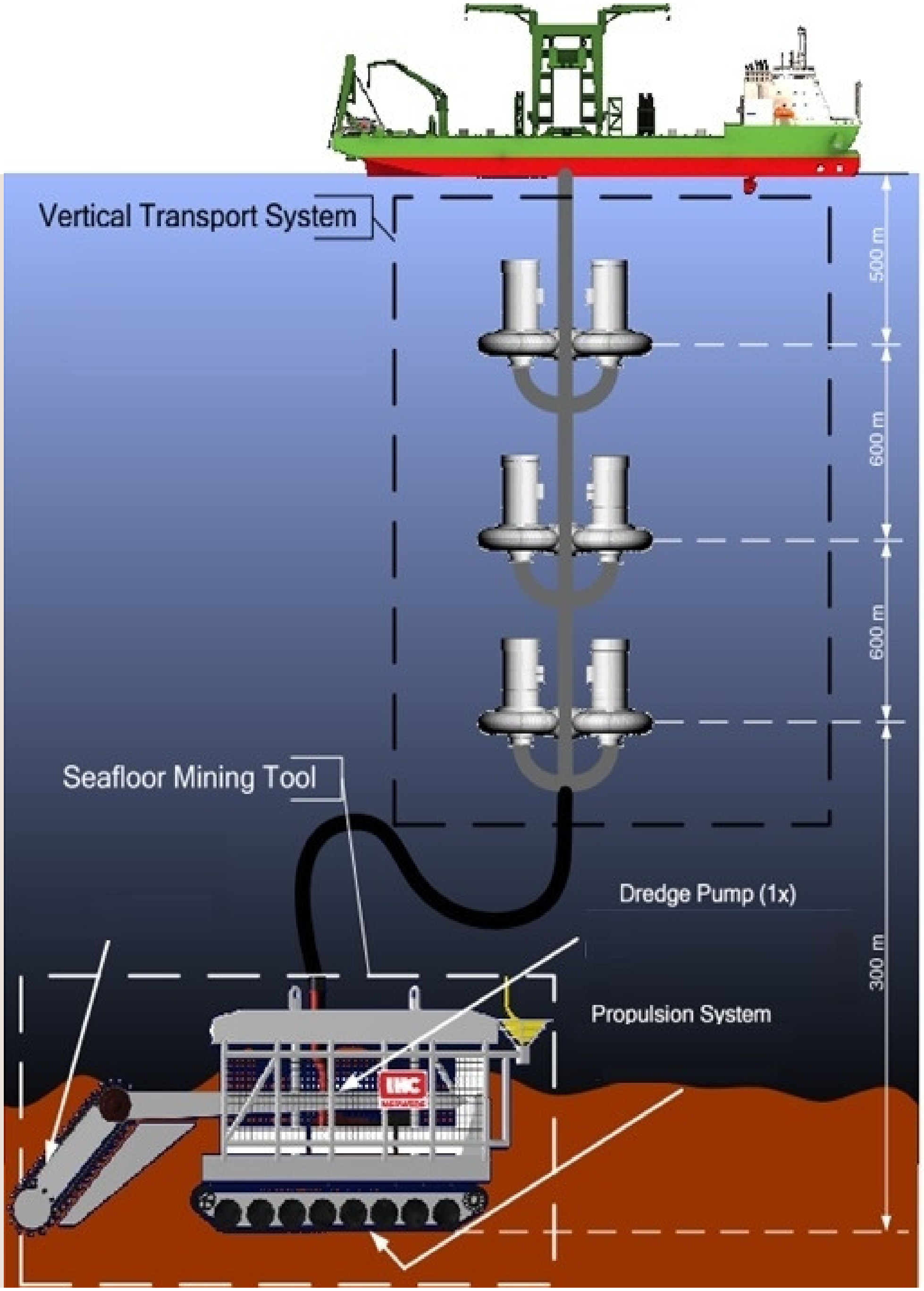


Mining system

(Derived from "Nautilus" and "IHC's" available data)

1. Soil conditions
SMS deposit scenario: Solid soil type "Solid Rock".

This scenario implies working with small volumes and high slurry mixture concentrations.



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