New approaches to Deep-sea Mineral Exploration: Data acquisition, assimilation and interpretation

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PRESENTING WORK OF:

BLUE MINING AND MARINE ETECH PROJECTS (PI: PROF BRAMLEY MURTON)
COMMONWEALTH MARINE ECONOMIES PROGRAMME (INC. DRS DANIEL JONES, ERIK SIMON-LLEDO, CHRISTOPHER PEARCE)

The Net-Zero Carbon Economy

Rare earth elements

Rare earth elements

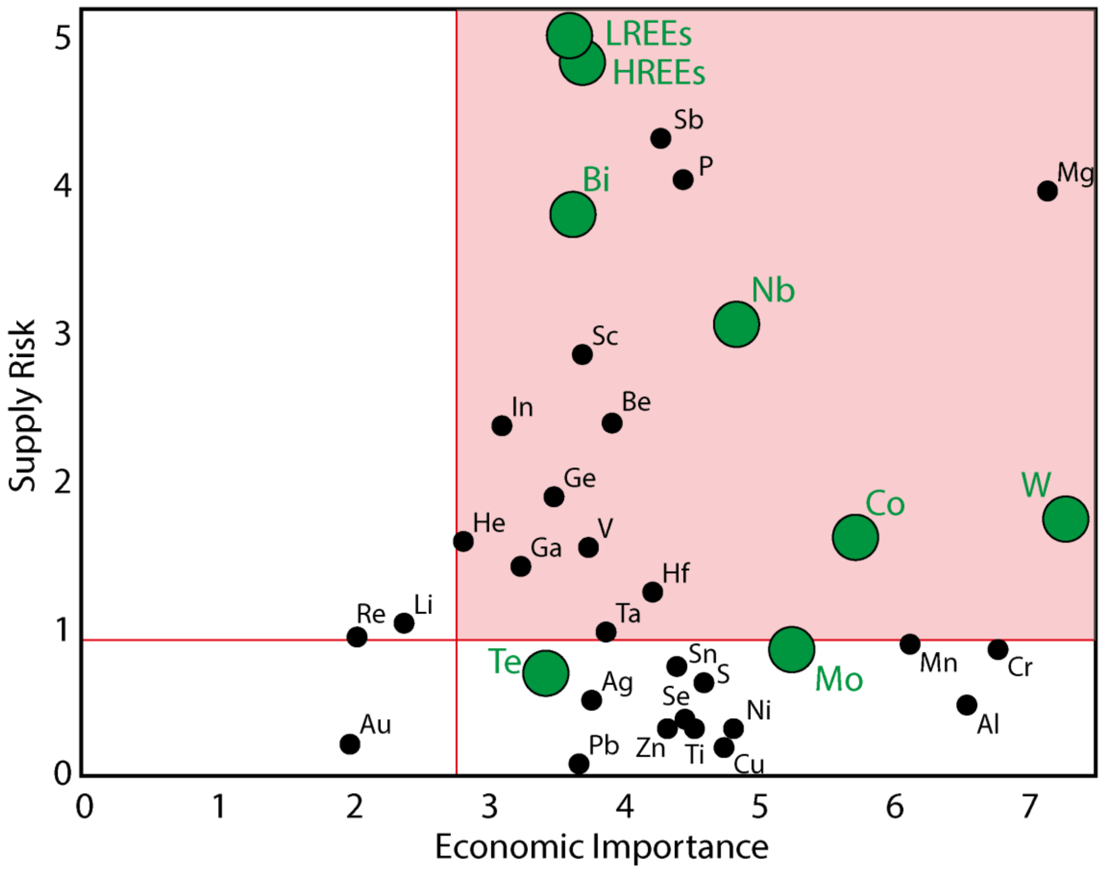
Tellurium

Indium

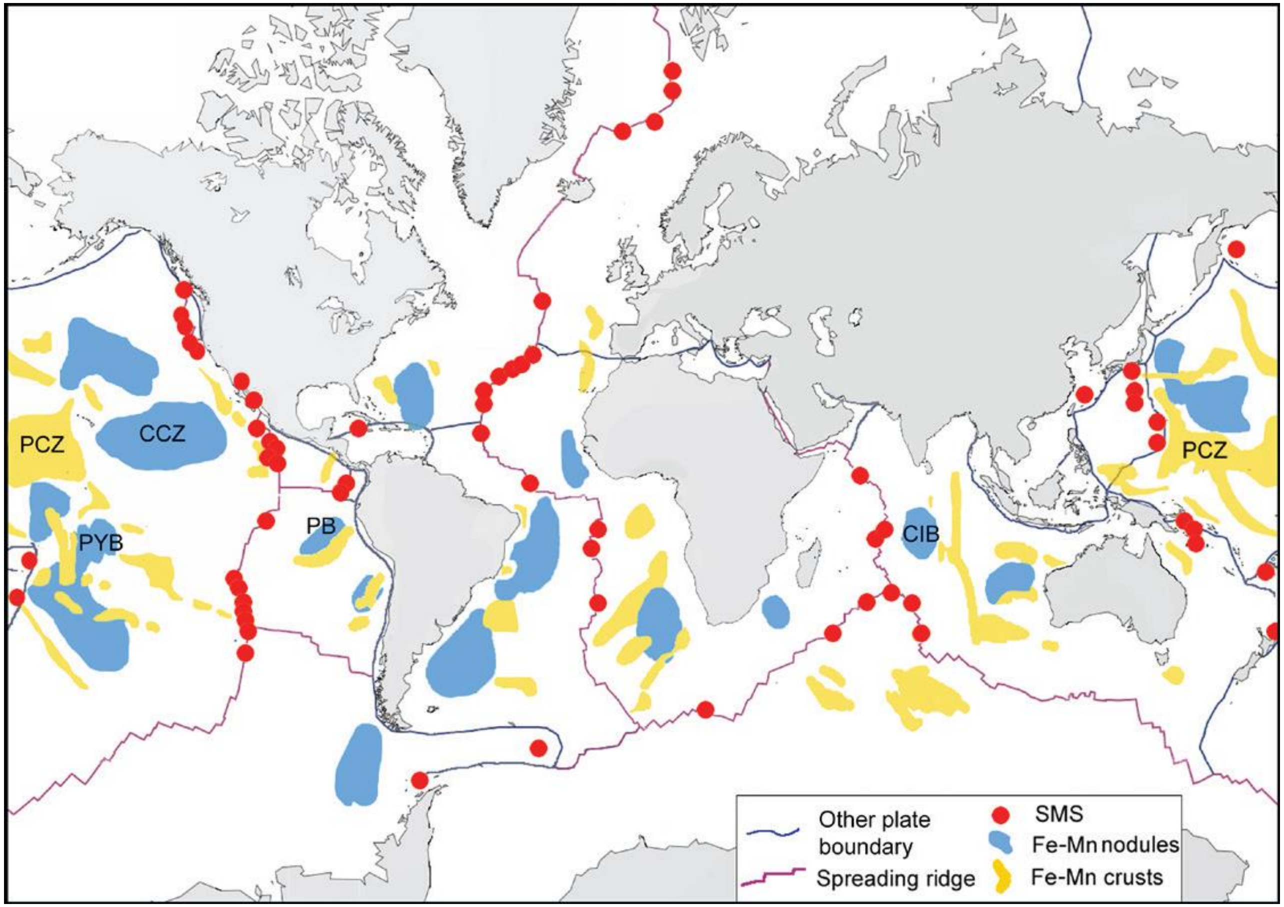
Cobalt

Lithium

Motivations: Critical Elements- Deep Sea Opportunities?

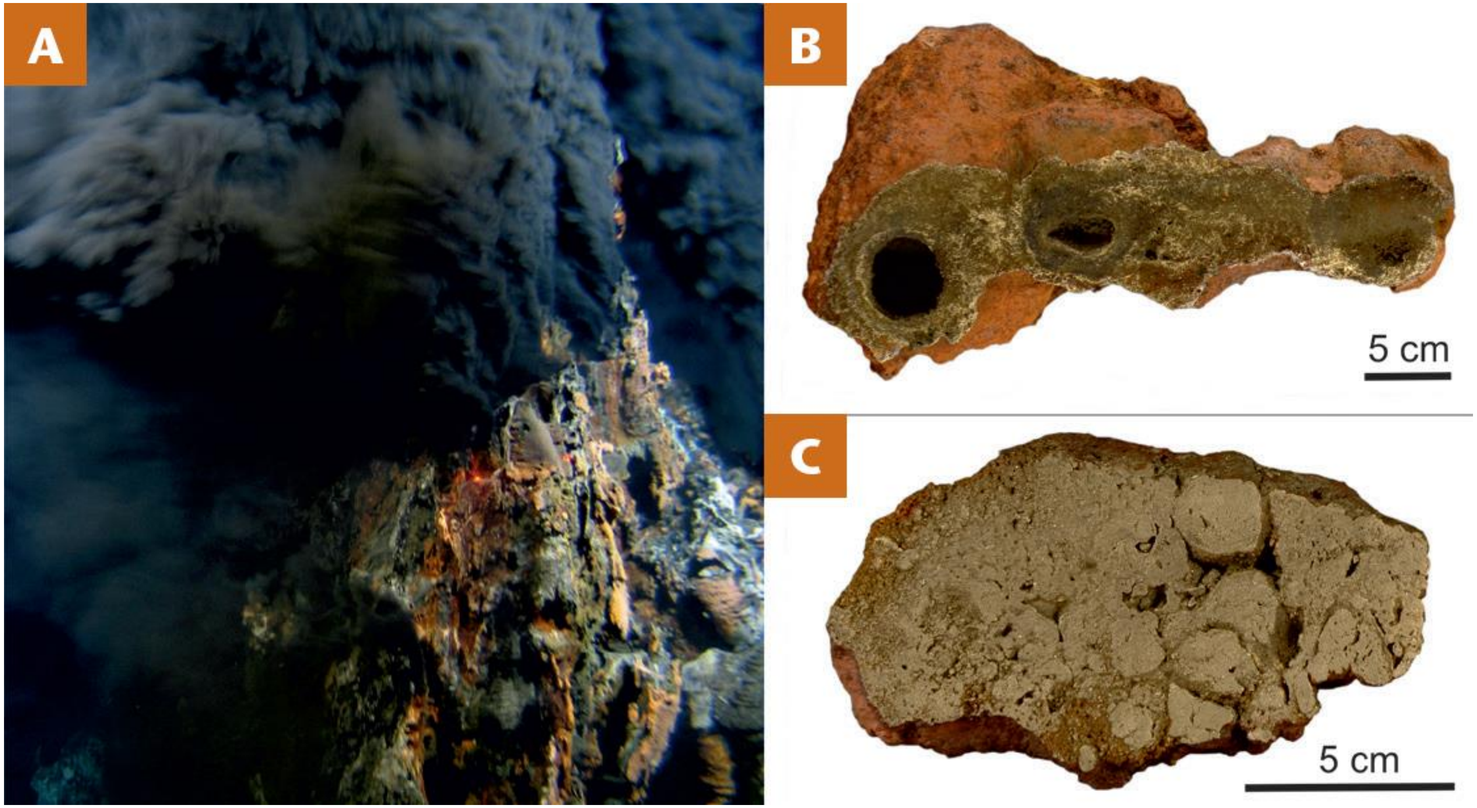


Deep sea mineral deposits



Source: Elements. 2018;14(5):301-306. doi:10.2138/gselements.14.5.301

Seafloor Massive Sulphides



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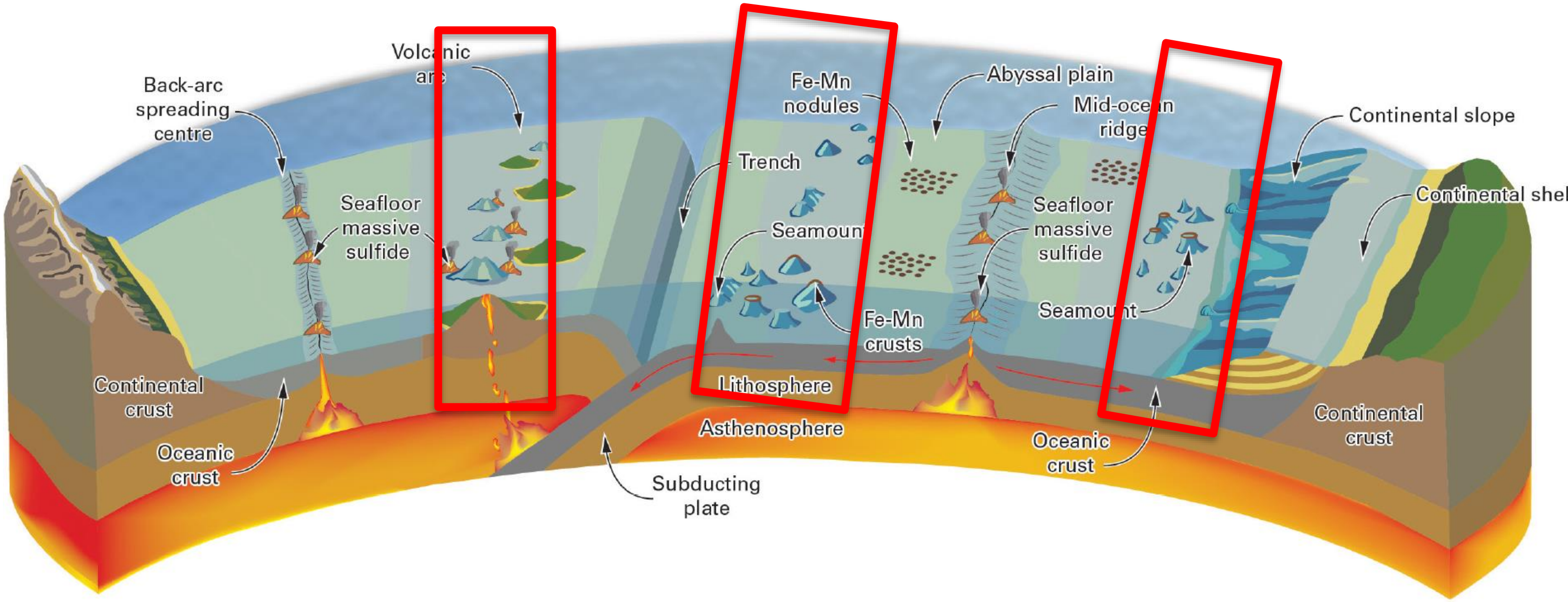
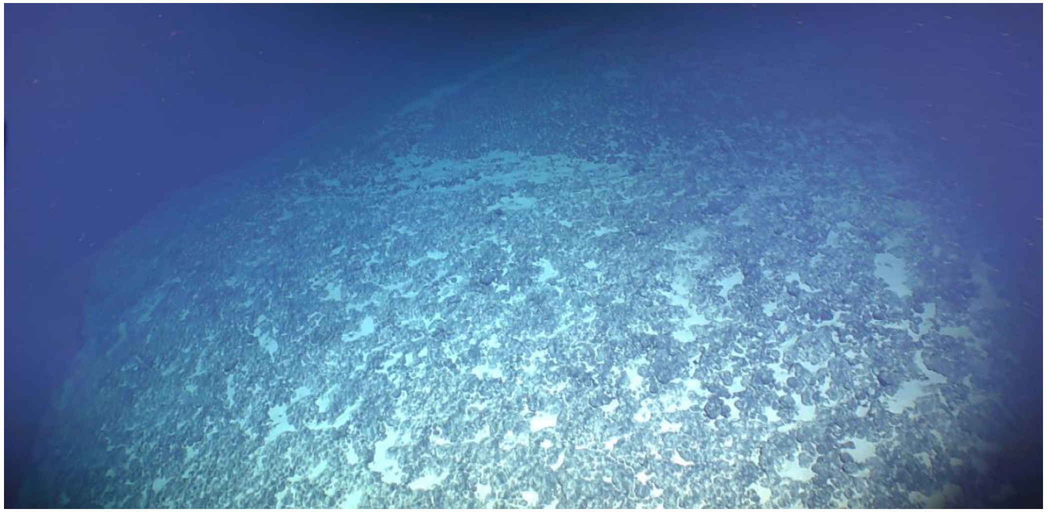
Seafloor Massive Sulphides



Source: Elements. 2018;14(5):301-306. doi:10.2138/gselements.14.5.301

- Cu, Zn, Pb, Au, Ag.
- Potential for significant ore below seafloor:
  - Assumed occurrence is 1 – 4 per 100 km of spreading axis.
  - Potential for more undiscovered sites.
  - Also potential in older, inactive sites.

Ferromanganese nodules

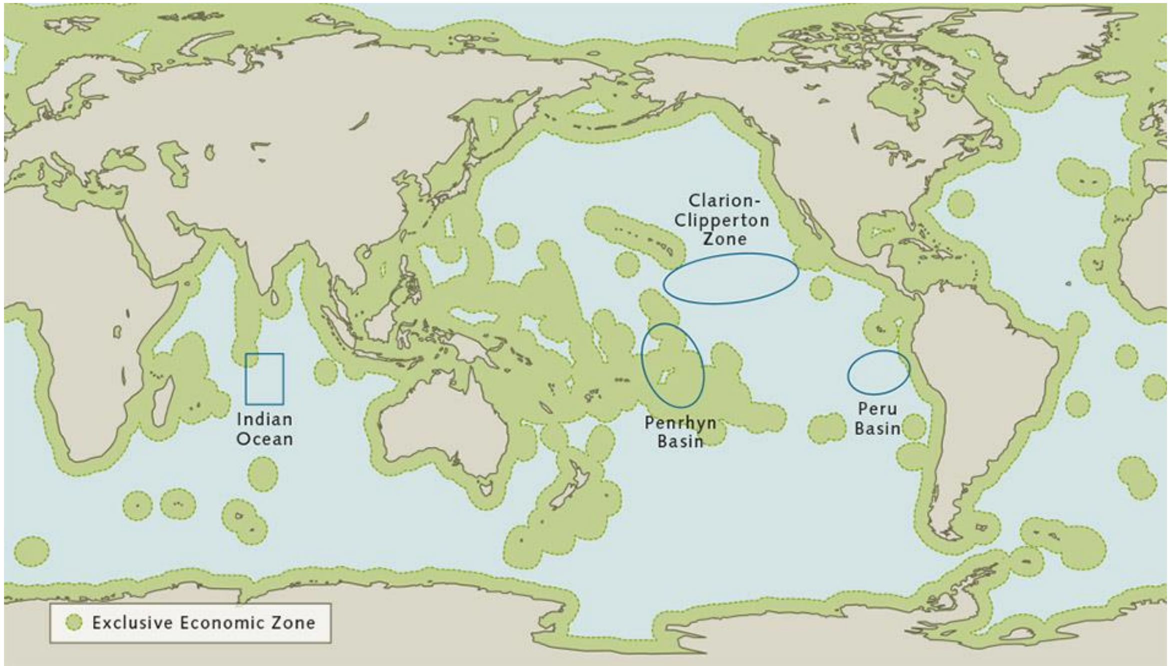


Source: Journal of Ocean Tech. 2015; 10(1). BGR.

Source: NERC.

- Co, Mn, Ni as well as Mo, Li, REE + Y.

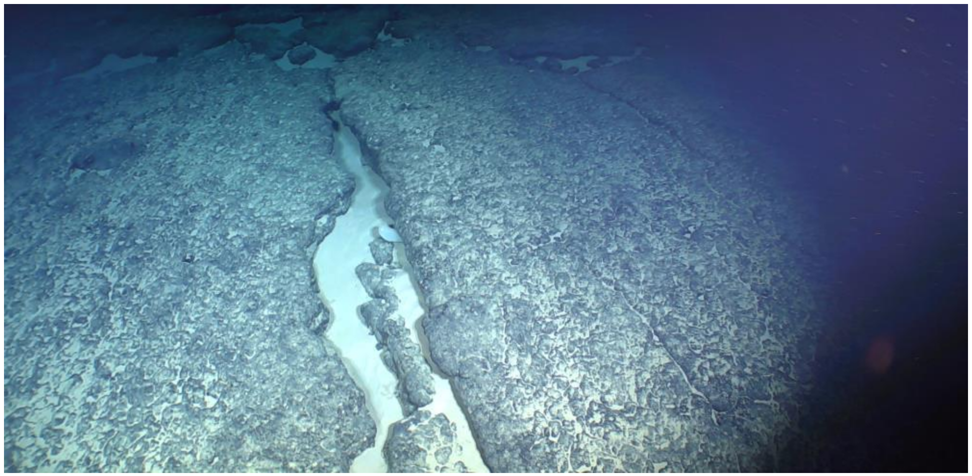
Ferromanganese nodules

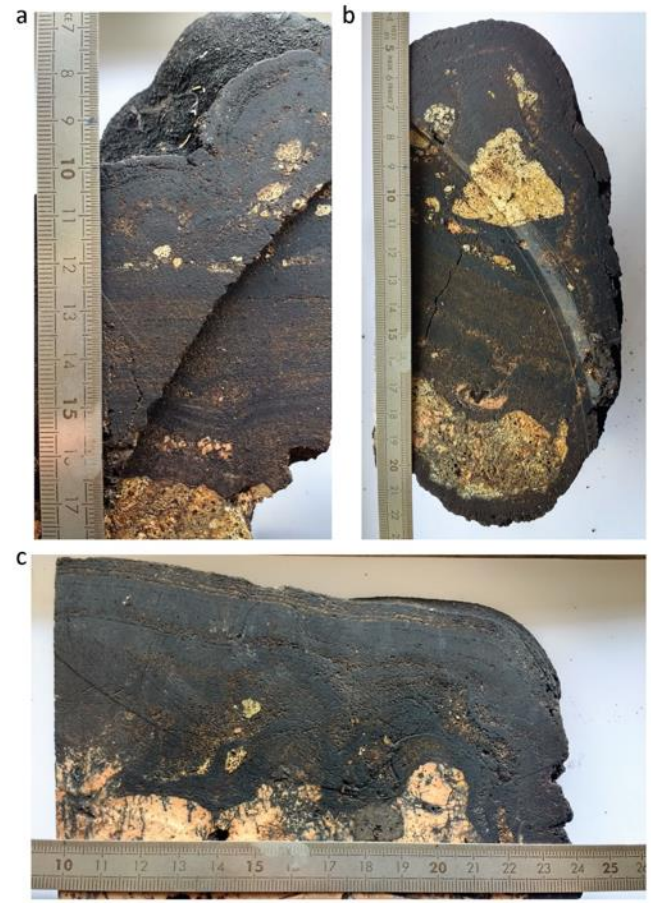


Source: World Ocean Review

- Vast areas left understudied
- Resource estimates difficult over these large scales

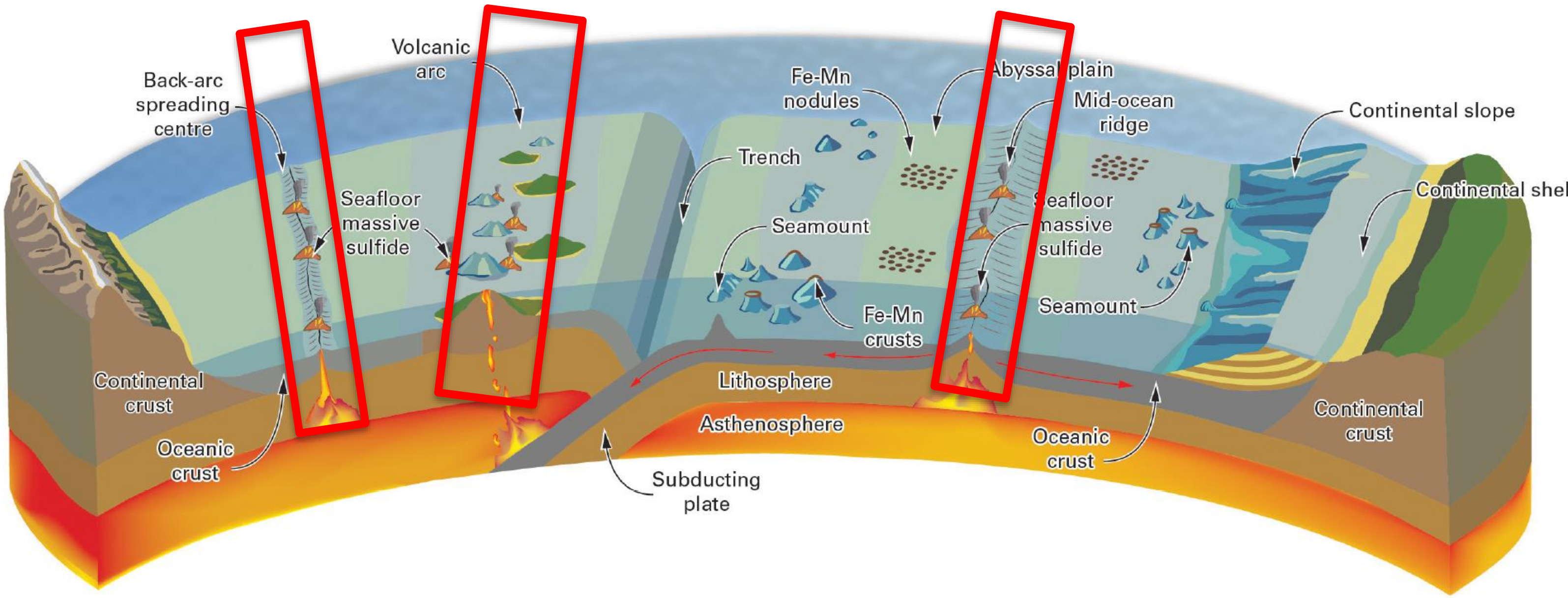
Ferromanganese crusts





Source: NERC.

Ferromanganese crusts



Source: Elements. 2018;14(5):301-306. doi:10.2138/gselements.14.5.301

- Co, Te, Pt, REEs
- Specifics of formation, distribution and composition are still poorly understood at the scale of the seamount.
- If resource estimates rely on tonnage and grade, how can we map tonnage (occurrence and thickness) efficiently?

Data collection and interpretation

- Knowledge gaps for all marine mineral deposit types remain- these need addressing to generate accurate and useful resource assessments and feasibility studies.

- The key to all of this is **data**;
    - Identify the biggest uncertainties in deposit studies
    - Design best data practice, from preparation to archive.
    - Ensure that the data collected answers identified uncertainties.

The Data workflow:

- Preparation
- Acquisition
- Processing
- Interpretation
- Delivery
- Completion
- Archive

Marine minerals: data

- All data need:
    - Unique sample IDs
    - Information on how the data was collected (e.g. sampling device/methodID)
    - There are different examples of how to store your data that are available.

- Different data repositories have different guidelines for data but best practice would include the following:
    - Need raw data files
    - Processed data files
    - Metadata that allows you to duplicate the exact process so should get the same result

Marine minerals: exploration

Some of the key equipment that past studies have had their disposal include:

- Ship-based systems; shipboard multibeam and backscatter.
- Observational equipment; towed cameras/camera sleds, cameras mounted on Remotely Operate Vehicles (ROVs) and Automated Underwater Vehicles (AUVs) for photography and video footage.
- Geophysical equipment; e.g. magnetic susceptibility, active and passive source seismic equipment, resistivity measurements.
- Sampling equipment; e.g. dredges, box-corers, rock-drills, CTD rosettes for water column data.

Lots of different data types, and data collection should be refined for the deposit type and study aims.

SMS: The hunt for extinct seafloor massive sulphides

CONTEXT: Active SMS sites found from plume signals but are known to be transiently active on geological timescales. Have analogues for inactive sites on land- what is the potential of these inactive sites in the ocean?

Unlike FeMn crusts and nodules, all about assessment in the 3rd dimension.

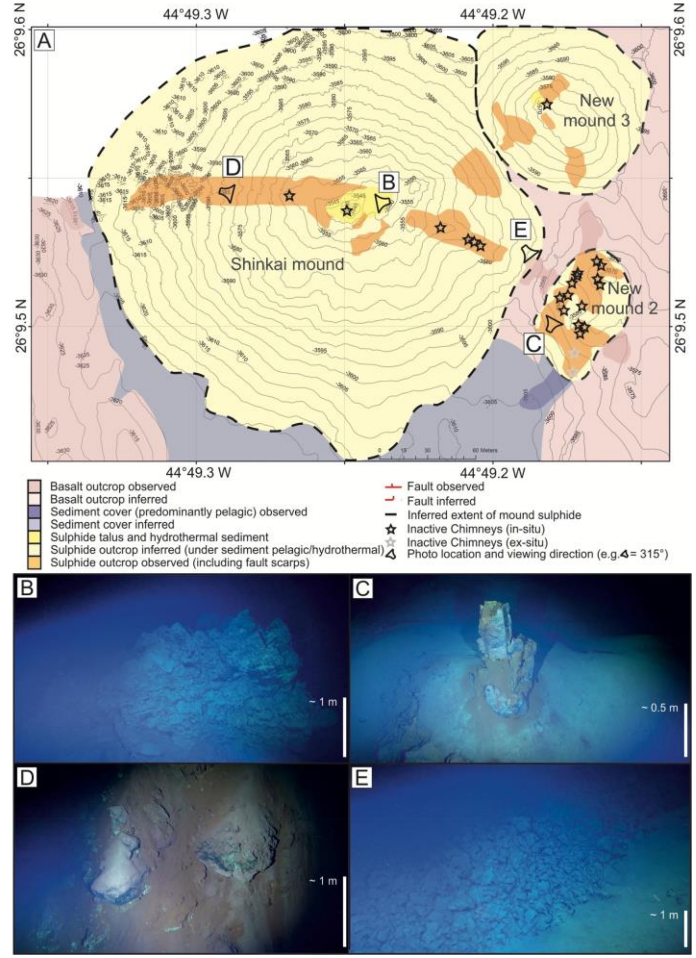
The hunt for extinct SMS- surface mapping

Blue Mining Project:

- 17 partners
- 9 work packages from resource discovery to exploitation strategies
- 2 research cruises: M127 (2016) and JC138 (2016)
- 470 samples
- Funding: €15 million (€10 million EU)

The hunt for extinct SMS- surface mapping

Source: Ore Geol. Rev. 2019; 107: 903-925



Observational techniques:

- Study cover rocks from video and calibrate with grab samples for predictive mapping

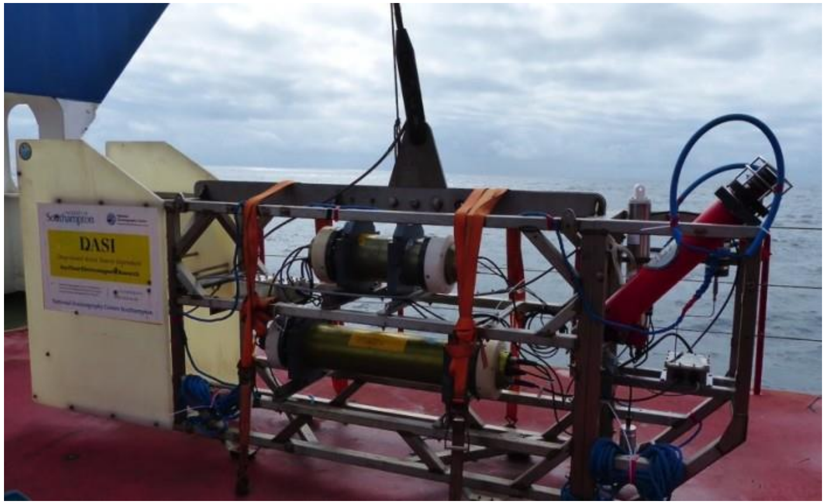
Source: NERC.

The hunt for SMS- the 3rd dimension

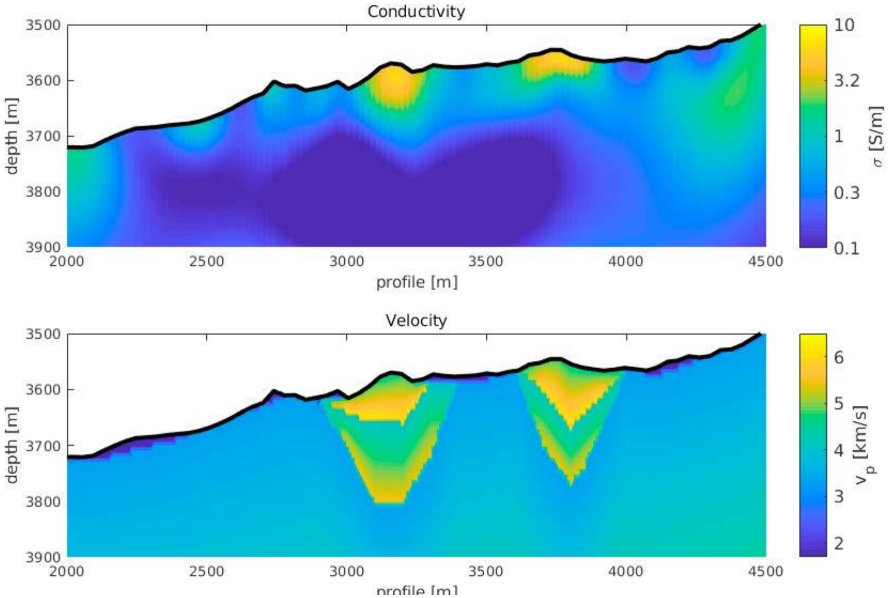
Geophysical techniques:

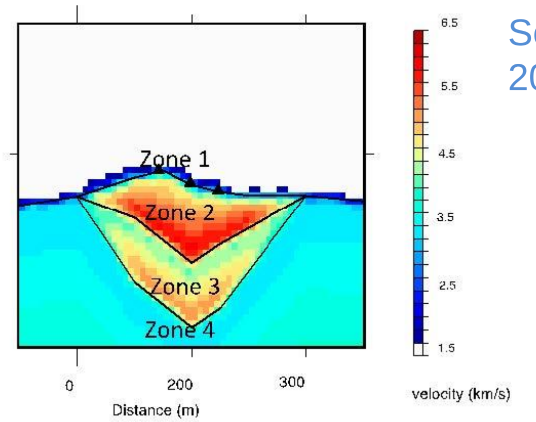
- Electromagnetic surveys
- Self-potential

- Need to calibrate with samples for physical properties



Source: NERC.



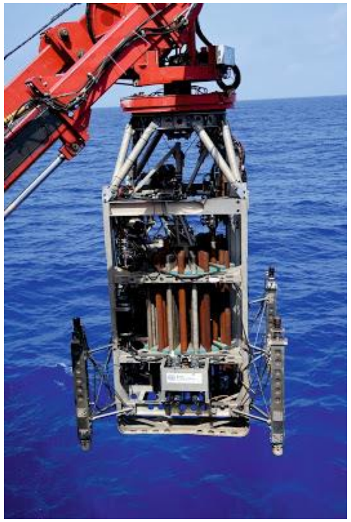


Source: Ore Geol. Rev. 2019; 107: 903-925

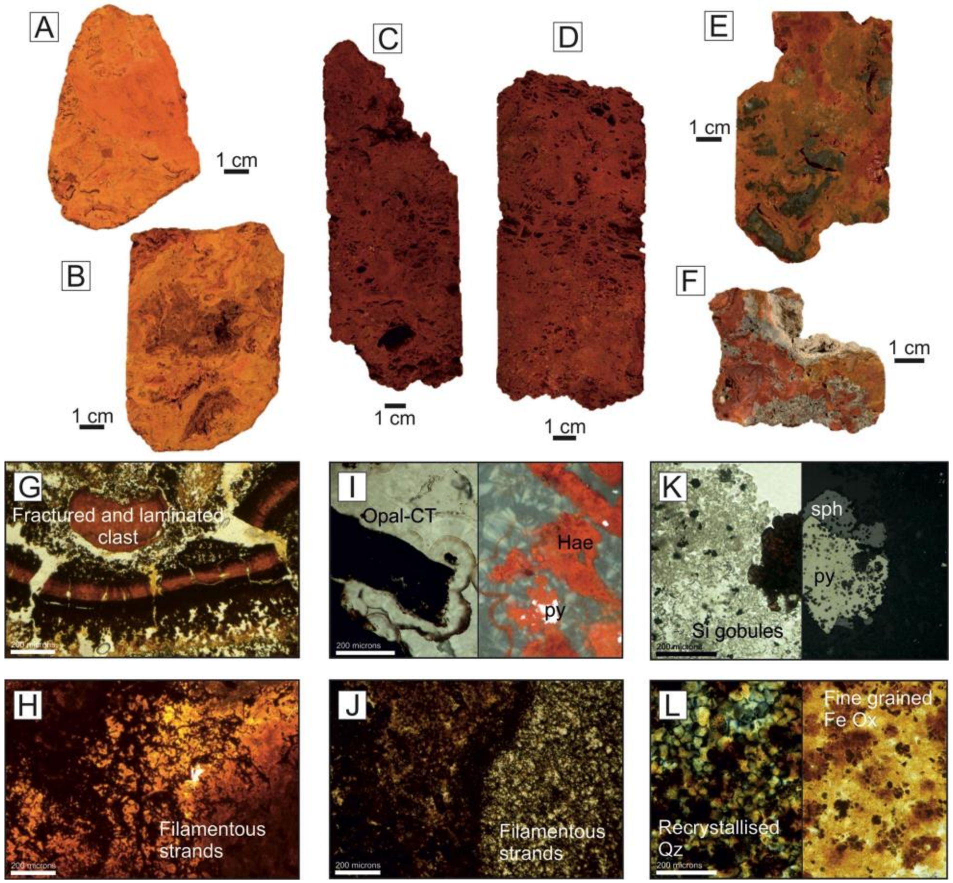
The hunt for SMS- the 3rd dimension

Need drilling to understand structure at depth:

- Either ship-based e.g. IODP drill campaigns, JOIDES Resolution, Chikyu.
- Landers deployed from multi-purpose vessels e.g. RD2 from the British Geological Survey.



Source: NERC.



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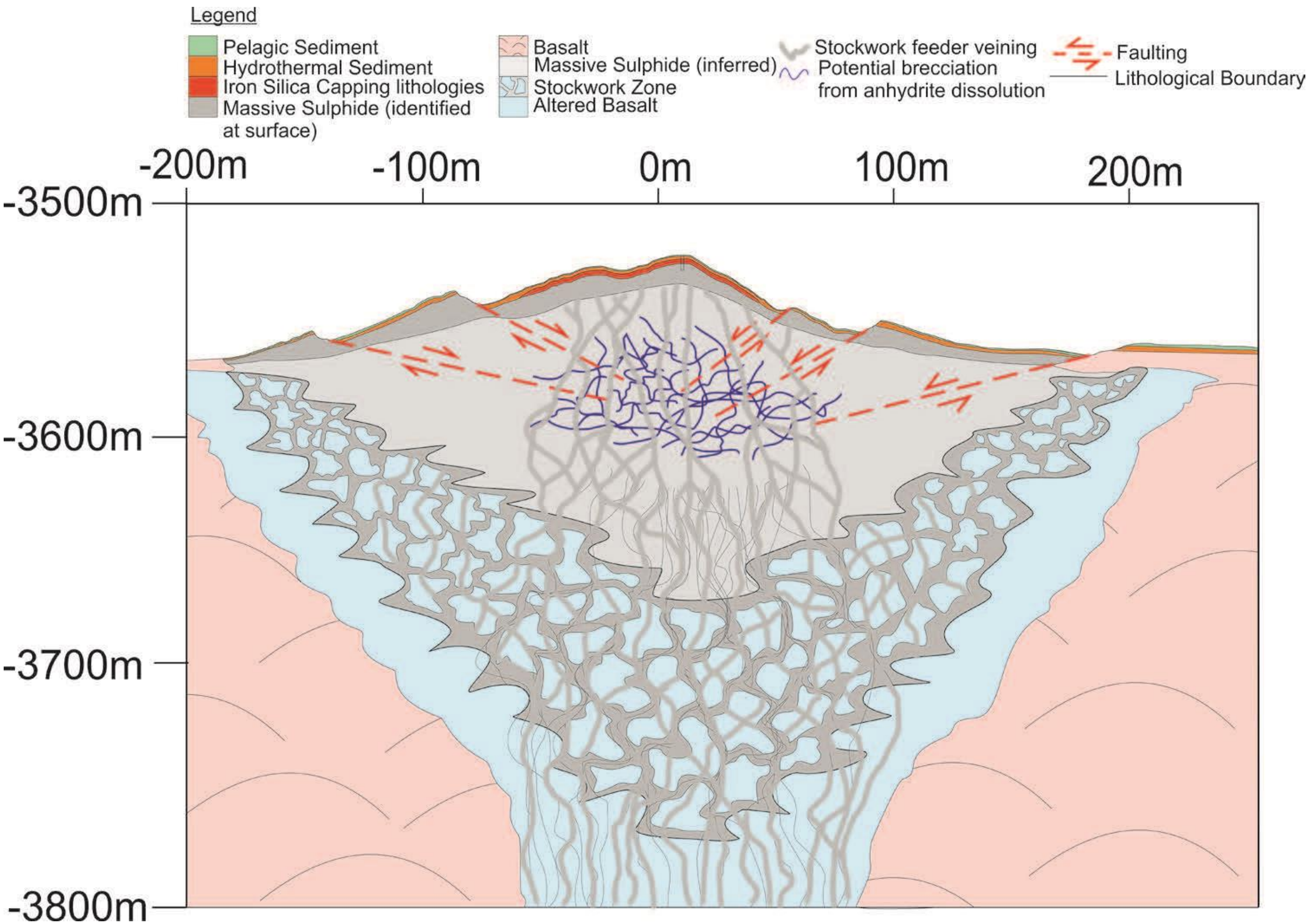
Composite models: surface geology + drilling + geophysics



Source: Ore Geol. Rev. 2019; 107: 903-925

FeMn Nodules: resource estimates

CONTEXT: We have lots of information and data for specific regions (e.g. CCZ) but these 2D deposits cover vast areas. How can we improve data coverage across our ocean basins to improve resource estimation?

Ideally we want rapid and reliable remote mapping tools.

Remote mapping of FeMn nodules: acoustic backscatter

Nodule density variation is the biggest factor for resource estimation:

- Acoustic backscatter promising exploration tool.
- Acoustic backscatter = the intensity of the sound reflection response from the seafloor.
- Created a spectral characterization model for the multi-frequency sonar backscatter response.
- Tested against seafloor photography and box-cores.

Source: NERC.

Biggest factor in backscatter strength = nodule size distribution.

Remote mapping tools for FeMn nodules

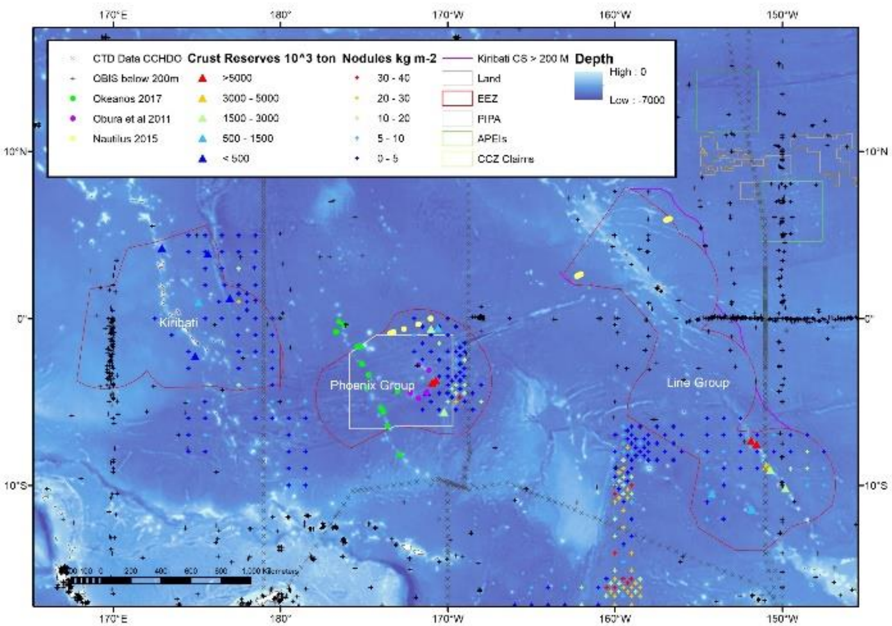
Nodule density variation is the biggest factor for resource estimation:

- AUVs give large-scale, high-resolution coverage.
- Optimise flight speed and height for both resource assessment and faunal mapping.
- 100,000s images generated.
- Automated Object-based image analysis (OBIA).
- Future: AUV fleets for simultaneous mapping.

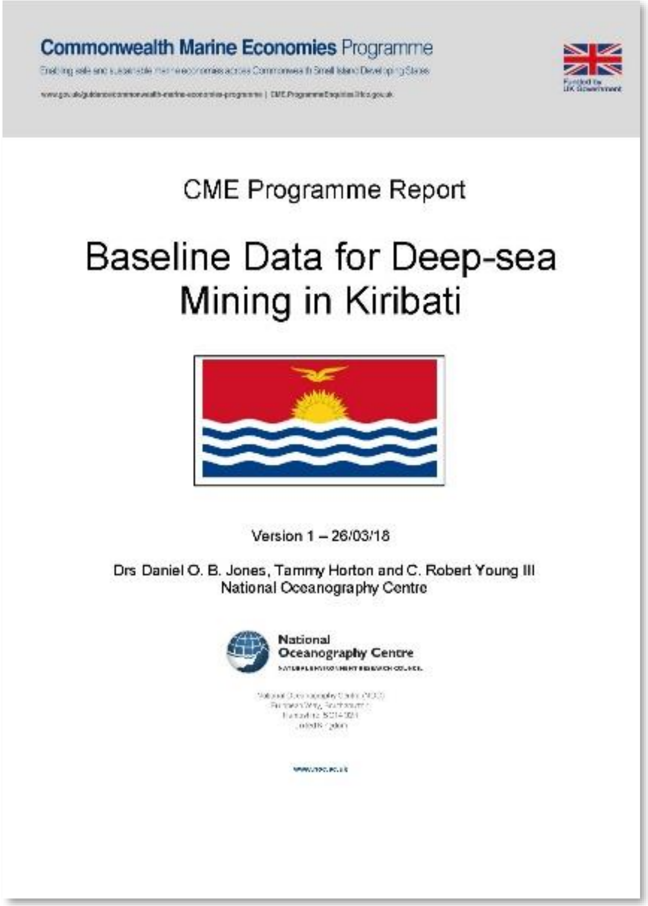
Source: NERC.

Capacity building case study: Kiribati 2017 - 2020

- Focus on baseline data acquisition strategy in Kiribati.
- Nov 2017: GIS database of known baseline data report with recommendations for gathering baseline data. (Daniel Jones, NOC)



Source: CMEP.



Commonwealth Marine Economies Programme

CME Programme Report

Baseline Data for Deep-sea Mining in Kiribati

Version 1 – 26/03/18

Drs Daniel O. B. Jones, Tammy Horton and C. Robert Young III
National Oceanography Centre

National Oceanography Centre

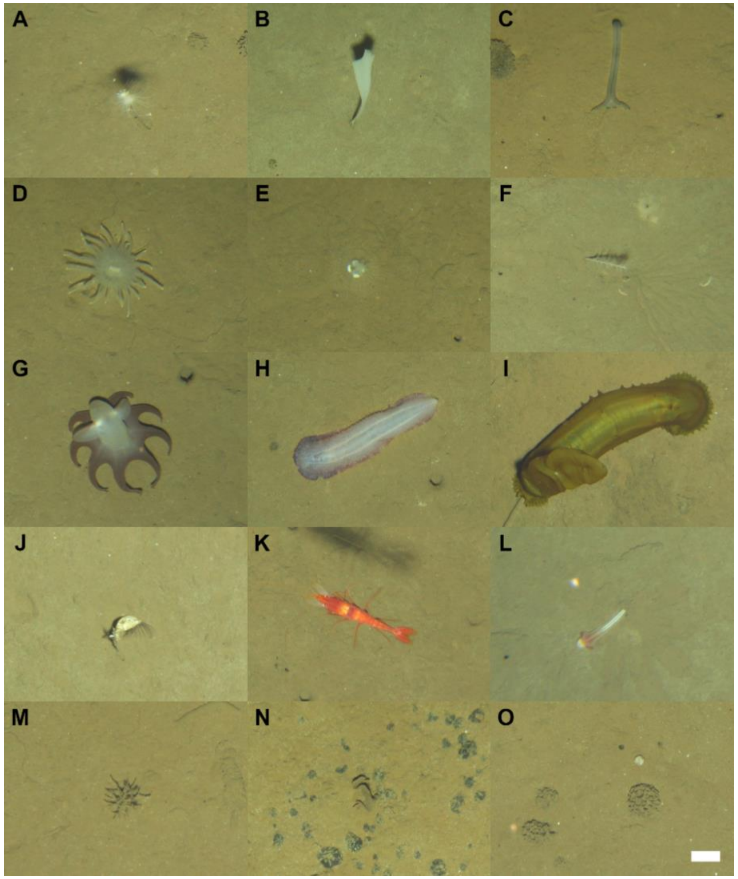
Source: CMEP.

Capacity building case study: Kiribati 2017 - 2020

- Workshops in Nov 2018 (led by Daniel Jones and Erik Simon)

- Focus on Kiribati and Tonga.
- Several unprocessed deep-sea image datasets identified:
  - Kiribati abyssal plain areas
  - TOML claim areas at the CCZ

- Environmental aspects and exploration of deep sea habitats in the context of deep-sea mining
  - Seabed baseline data collection
  - GIS applications
  - Habitat mapping and benthic ecology



Source: Frontiers in Mar. Sci. *In Review*.

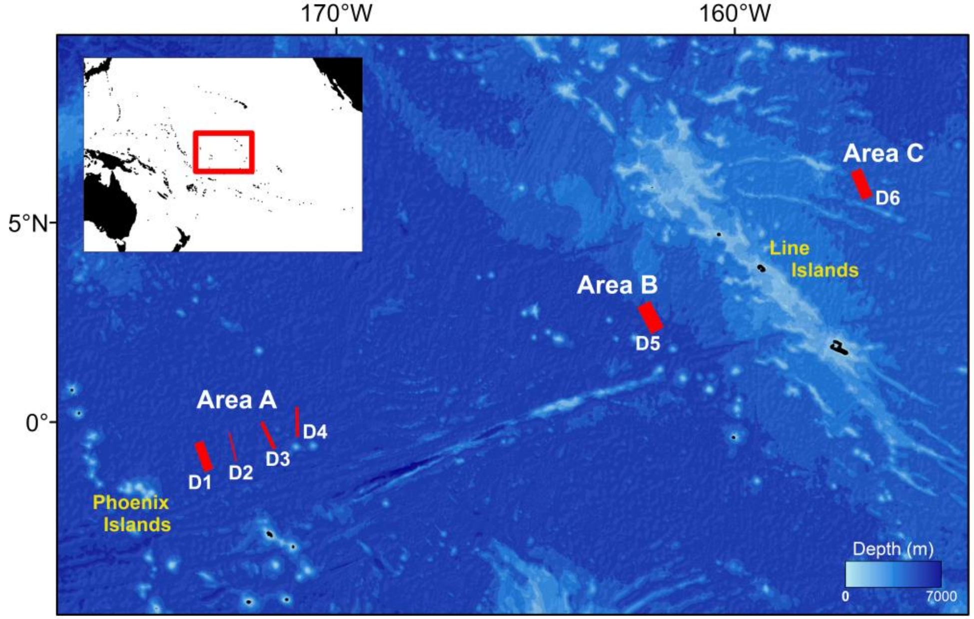
Overview, Kiribati's abyssal diversity

First quantitative biological assessment of the Kiribati abyss. **Depth: 4600-5600 m.**

Data = imagery, collected by *Nautilus Minerals* in 2015 for mineral resource assessment

4071 seabed photographs collected across 6 stations (3 sites) within the Kiribati EEZ

Images obtained using a **towed bouncing camera** at 3 m above the seabed (area: 3.6 m^2)**.**



Source: CMEP.

Outputs: Cadastral map of Kiribati EEZ for licensing and MSR, preliminary assessment of Kiribati's abyssal diversity (paper submitted to Frontiers in marine Science).

FeMn Crust: resource estimates on seamounts

CONTEXT: FeMn crusts extensively sampled from dredges etc., but the specifics of formation, distribution and composition are still poorly understood at the scale of the seamount. How can we improve resource understanding at this high-resolution?

FeMn Deposit Modelling

- Limited knowledge of crusts on seamount-scale

Resource models need:

- Tonnage estimates
- Grades e.g. Mn, Fe, Co, Te

- What is the distribution of crust and elements?
- What controls these distributions?

Marine E-Tech Project: JC142

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

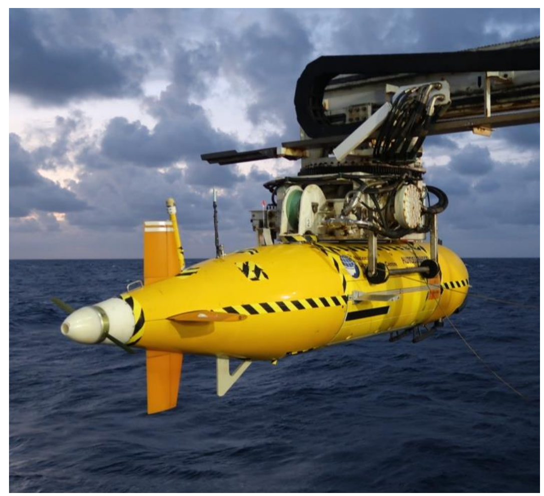
HR Wallingford
Working with water

UNIVERSIDADE DE SÃO PAULO
IO Instituto Oceanográfico

Instituto Geológico y Minero de España

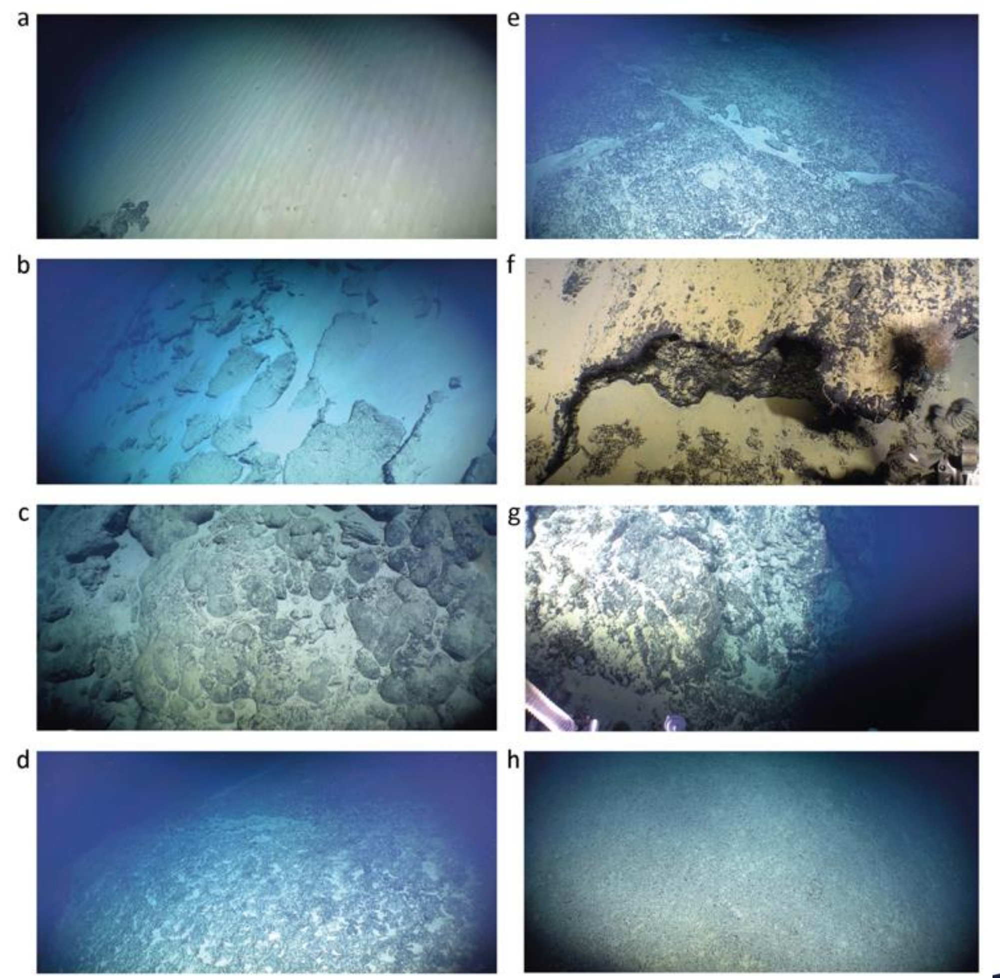
Photos: NERC

- Partners include industry, academia e.g. University of Sao Paulo, British Geological Survey.
- £4.4 million research programme.
- Multi-disciplinary- geologists, geophysicists, marine biologists, oceanographers.



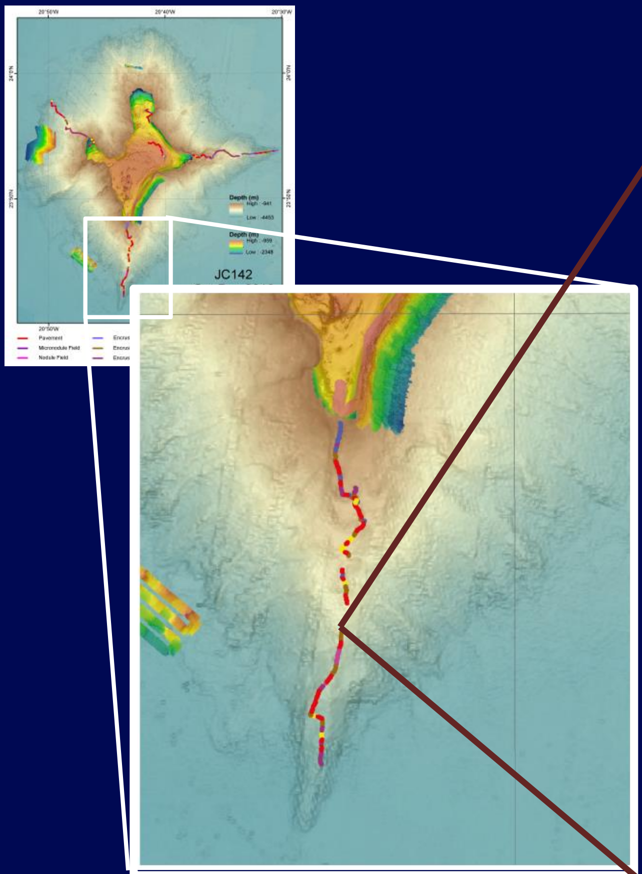
Mapping seamount environments

a) Sand Plains
b) Slab Fields
c) Encrusted Lobate Fields
d) Nodule Fields
e) Pavement
f) Encrusted Carbonate Step
g) Encrusted Debris Slope
h) Micronodule Field

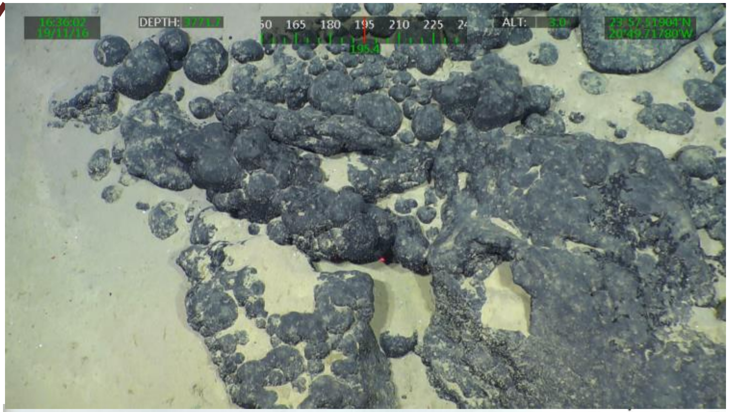


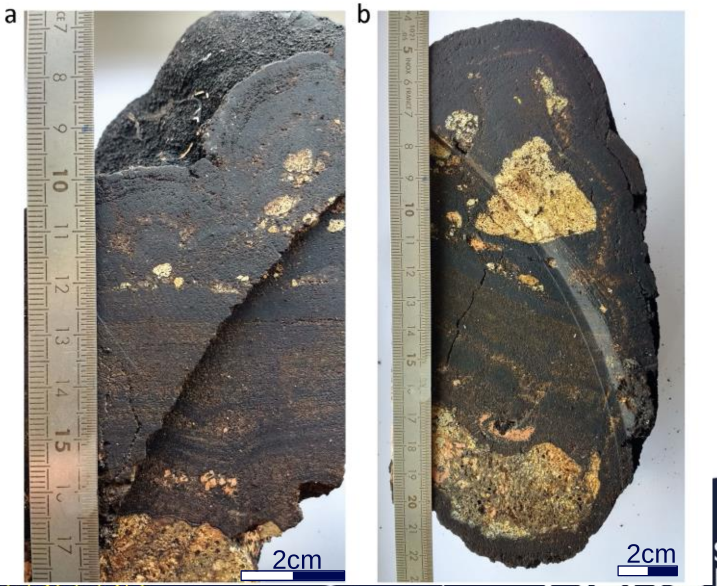
Field of view ~ 3 m (Photo F ~ 1 m)

Example of transect mapping of crust distribution

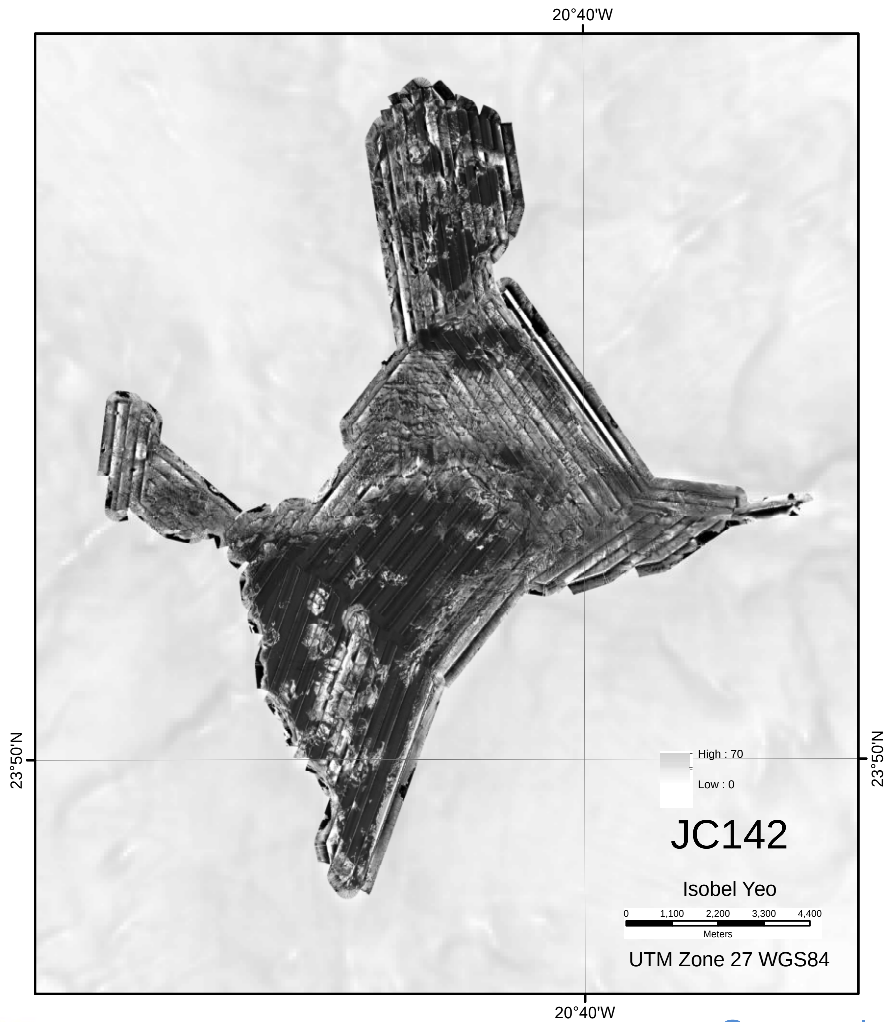


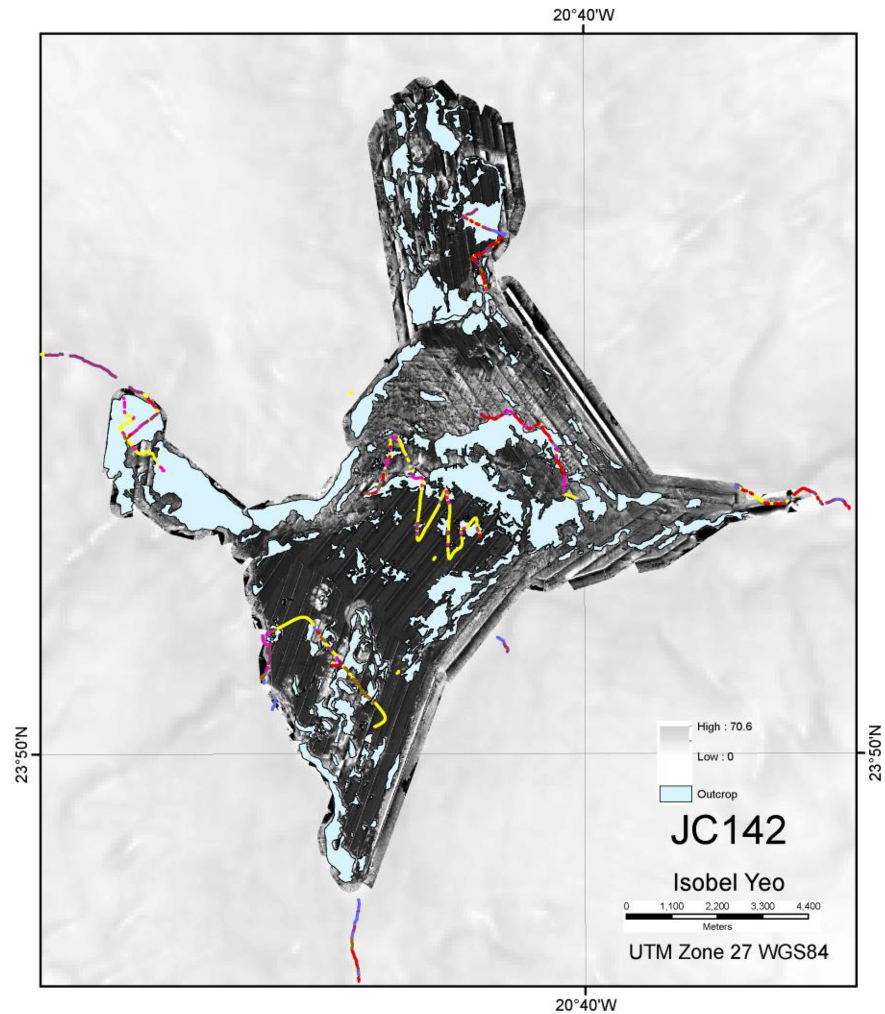
Field of view ~ 1 m





Mapping FeMn crust outcrop





Source: Isobel Yeo, NOC.

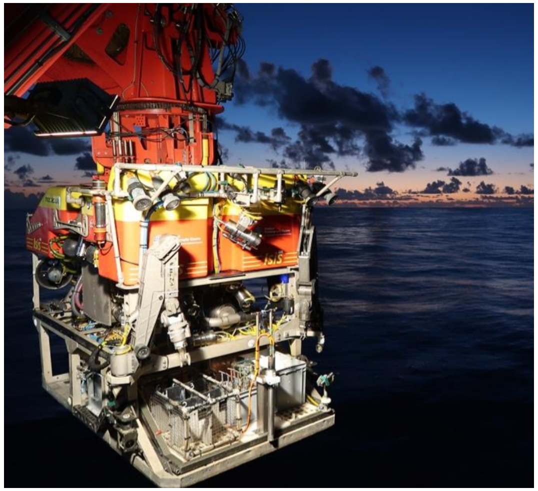
FeMn Deposit Modelling

- Limited knowledge of crusts on seamount-scale

Resource models need:

- Tonnage estimates
- Grades e.g. Mn, Fe, Co, Te

- Biggest remaining unknown is the variation in crust thickness.
- Future studies will ideally include a tool for remote thickness measurements.



Source: NERC.

Summary

- Data collection should be driven by specific questions and aims to fit gaps in MSR.
- All research cruises are **multidisciplinary** and ideally want **overlapping datasets** for geology, geophysics, biological studies etc.
- **Remote mapping tools** are vital to improve data collection in terms of coverage and efficiency, but the large datasets generated means **data management and improved automated analyses** will be key.

- For 2D deposits (FeMn nodules and crusts) ideal datasets:
    - Regional seafloor characteristics and morphology- shipboard multibeam and backscatter.
    - Water column structure- rosettes, moorings.
    - In-situ observational data- seafloor photography, select appropriate resolution for resource estimation or benthic ecology.
    - Remote measuring techniques- towed or AUV/ROV mounted equipment.
    - Sampling- constraining physical and chemical properties.
- For 3D deposits (SMS) ideal datasets:
    - As above, but with sampling at depth (drilling).