Exploration Techniques: Geochemical and Geophysical and GIS Based. Maritime Exploration

Younus Ahmed Khan, *PhD*

- Within the concept of deep-sea mining, six main stages from exploration to sales are:

- 1. Exploration;
- 2. Resource assessment, evaluation and mine planning;
- 3. Extraction, lifting and surface operations;
- 4. Offshore and onshore logistics;
- 5. Processing stage;
- 6. Distribution and sales

Exploration

- Technology assessment

a. Successful limits/limitations of the emerging technologies
b. Companies which are developing technologies and able to provide them
c. Overall stage of development of each technology: need ranking of such technology.

   Ranking may be assessed by Technology-Readiness-Levels (TRL) to assess the maturity of the evolving techniques to be used within deep-sea mining activities.

- Technology Readiness Levels

TRL	Definition
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment[5]
TRL 6	Technology demonstrated in relevant environment
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment

Source: European Commission (2013) Horizon 2020 Work programme

Exploration Techniques

- Exploration

a. Locating

b. Sampling

c. Drilling

Technology assessment: Locating

The techniques available and used for locating and mapping the seafloor are the following:

Research vessels;

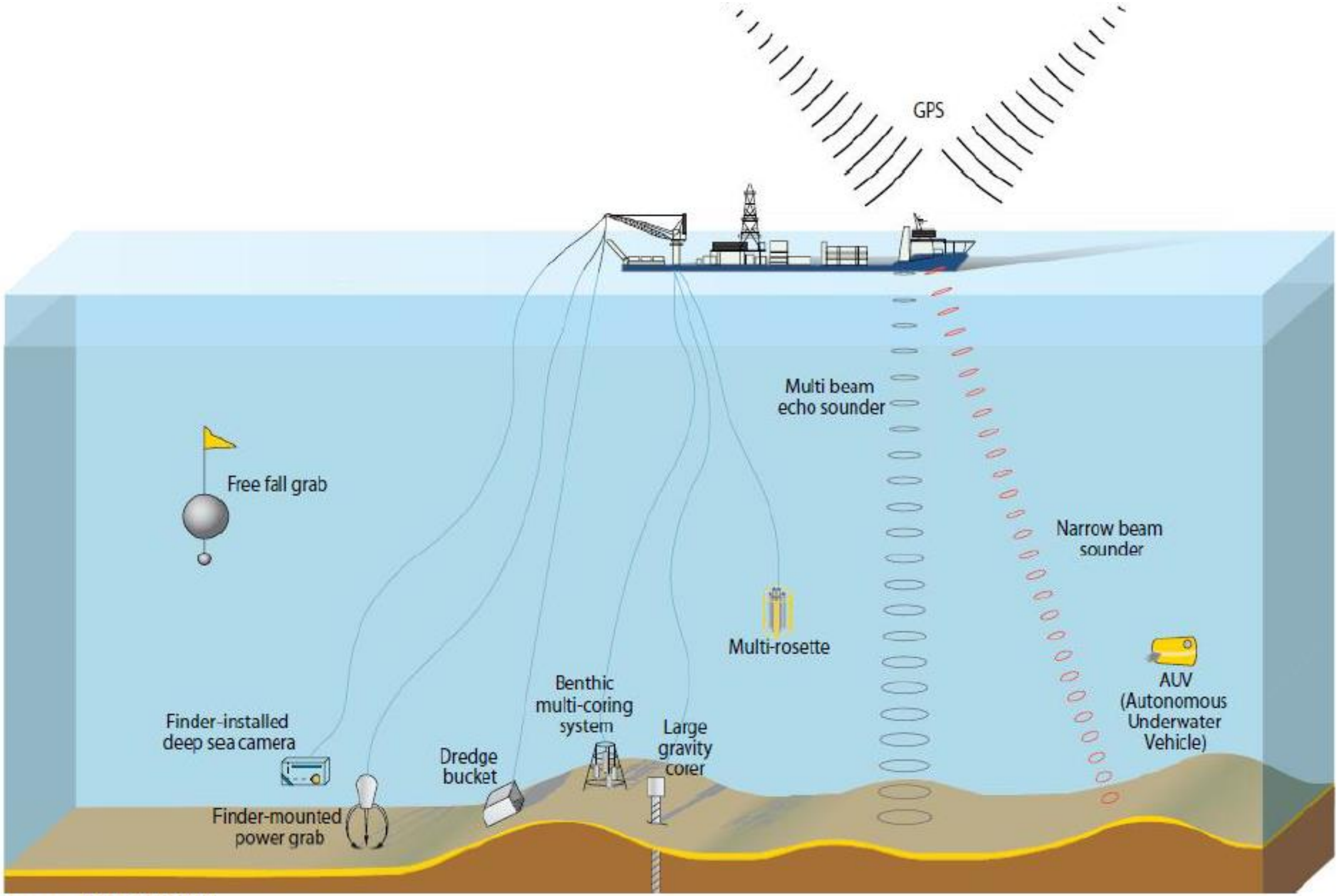
Echo sounder bathymetry (single beam, multibeam, sidescan);

Electromagnetics;

Water-chemistry testing;

ROV (remotely operated vehicles);

AUV (autonomous underwater vehicles)



Source: SPC (2013)

Research vessels

Deep-sea exploration is facilitated though the use of modern research vessels. These vessels facilitate and host the multi-purposes research activities for exploring the seafloor. Almost all techniques used for locating, sampling and drilling require some sort of support from the research vessel.

A typical research vessel is capable of operating for a maximum of 200 days per year due to passage time, maintenance and port time. Often, these vessels are chartered out for multiple purposes, not only deep-sea research

If 30% of that time is allocated to deep-sea research then 60 scientific days per ship represents the limit of current capability, per year. Through the use of multiple autonomous vehicles and techniques at once, research time is maximized as much as possible[6]. This poses substantial equipment control requirements for these mother ships.

Research vessels

Literature[7] provides the following common requirements for modern deep-sea research vessels:

- wide operation range throughout all climatic zones;
- protected deck areas with sufficient space;
- a high number of cabins for technical and scientific crew;
- a wide range of winch- and crane-based operability;
- multipurpose laboratories;
- excellent seafloor mapping and environmental sensing capabilities;
- advanced data distribution, storage and communication systems;
- dynamic positioning and navigation systems

Research vessels

Features	
Principal features	
Gross Tonnage	5099 GT
Built	Gdansk, 1997
Length	100m
Breadth	18m
Depth	7m
Accommodations	
Cabins	42 single + 6 double
TV Lounge	2
Labs	Survey, Geological, Exploration, Technical and Scientific
Other	
	Refrigerated storage of samples and cores
	Water chemistry lab
	Briefing room
	Gym
	Seafloor Drill
	Launch and Recovery System

Source: Odyssey Marine Exploration

As an example of a dedicated research vessel for exploring polymetallic sulphides, the Dorado Discovery is shown here. Being chartered by Odyssey Marine Exploration (U.S.), this 100mx18m vessel is exploring the seabed for SMS deposits. Odyssey provides these year-round exploration services for Neptune Minerals (US).

Research vessels

Availability/companies

N/A

Currently only a few European ships, most of them owned/operated by research institutions, meet these requirements and they need strategic replacement and improvement. Since the research fleets are operated and planned on a national level, an effort is needed on a European level to improve access, management and strategic planning of ship replacement and innovation.

Europe's research fleet is its main asset for realising the scientific goals and tasks associated with understanding deep-ocean processes

Technological Readiness Level (TRL)=9, means:
actual system proven in operational environment

Echo sounding (sonar) bathymetry

Echo sounding technologies are being used since the 1930s to investigate the topography of the ocean bottom. Echo sounders emit sound waves in a broad-angle cone and from the time interval separating the emission of a sound pulse and the reception of its echo from the seabed, the depth can be calculated. Acoustic methods are ubiquitous in marine applications, since electromagnetic radiation is rapidly attenuated in the ocean so radio waves and visible light for example, which are used extensively in air, are of little use.

In particular, three types of equipment can be distinguished:

- Single beam echo sounder
- Multibeam echo sounder
- Sidescan sonar

Echo sounding (sonar) bathymetry

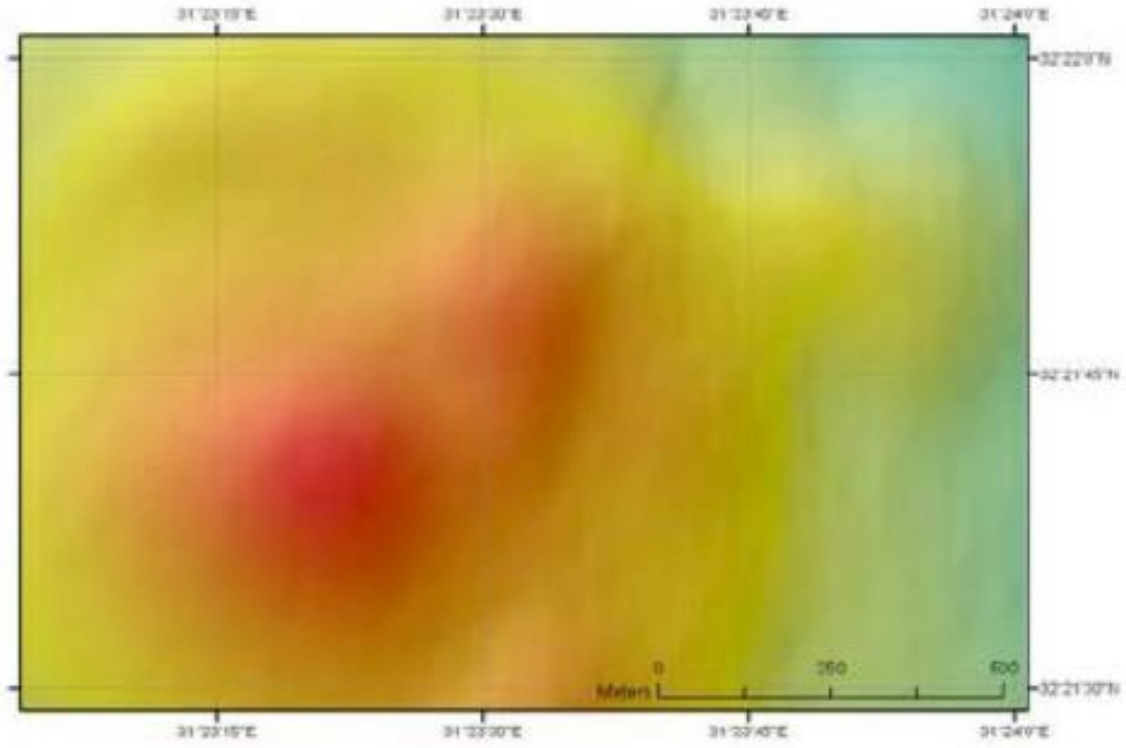
The single beam echo sounder sends a single acoustic signal vertically below the vessel. The signal returns local depth information. The echo is picked up by the transducer located on the hull of the vessel.

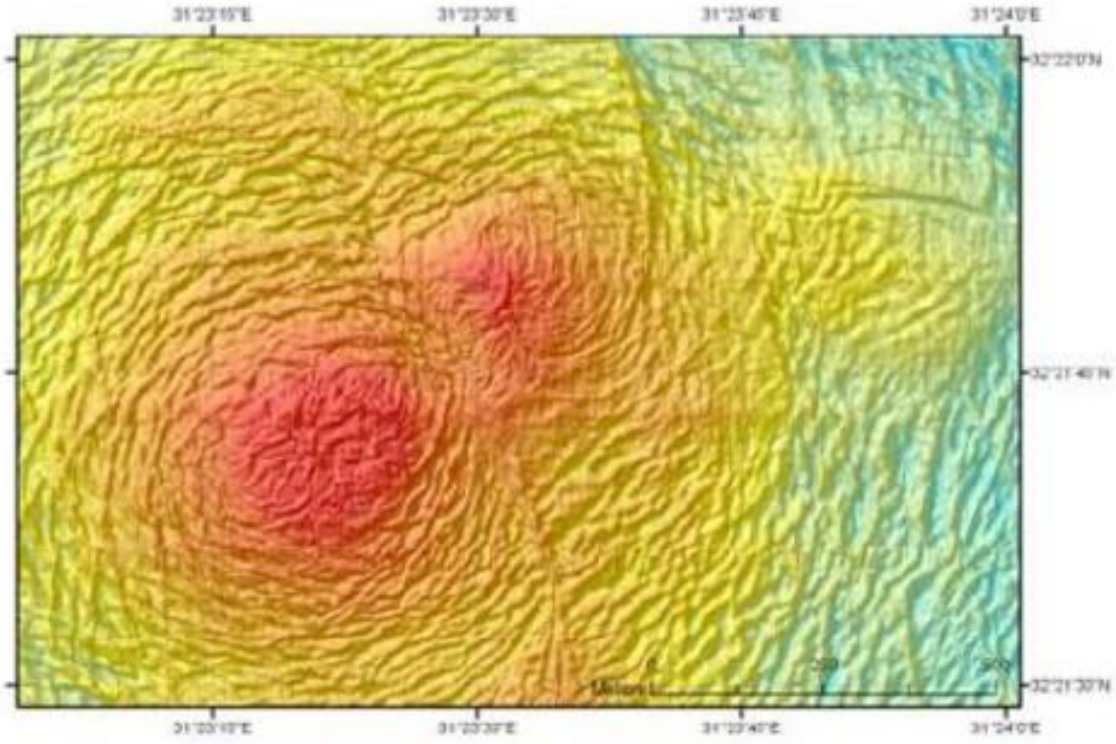
The multibeam echo sounder however transmits multiple echo sounds with a different gradient to the seafloor and therefore collects info on a wider scale at either side of the vessel’s track. For mapping exercises, the multibeam has therefore superseded the single beam applications. The ship-based multibeam systems are used to map shallow and deep water. However, when used on an AUV (Autonomous Underwater Vehicle), more detailed mapping can be acquired. These multibeam echo sounders make it possible to produce a map of the ocean floor on board the ship within a minute, making it possible to ‘read’ the topography of a strip of ocean bottom in real time.

An example of the different images of the seafloor from ship-based and AUV based sonars is shown below.

Echo sounding (sonar) bathymetry

Bathymetry maps of a mud volcano at 1000m depth with left: ship-based multibeam and right: AUV application





Echo sounding (sonar) bathymetry

The third application is the sidescan sonar. These sonar systems are best used on a ‘towed’ fish which is connected with the vessel. By having the sonar close to the seafloor, the angle of which the sonar hits the floor is small.

This allows to identify shapes on the seabed. In addition, some information on the morphology and substrate can be gathered as well by measuring the reflectivity of the signal

Source: Acoustic Techniques for Seabed Classification (2005)

Electromagnetics

Offshore electromagnetic exploration technologies include: controlled-source electromagnetic (CSEM) surveying and magnetotelluric (MT)surveying.

In CSEM surveying, a powerful horizontal electromagnetic transmitter is towed about 30m above the seafloor. The transmitter source transmits a carefully designed, low-frequency electromagnetic signal into the subsurface. An array of electromagnetic seabed receivers measure the energy that has propagated through the sea and the subsurface.

Data processing, post-modelling and inversion are performed to produce 3D resistivity volumes. These datasets are integrated with other subsurface information such as to enable to make important drilling decisions with greater confidence.

SOLWARA 1 ELECTROMAGNETIC CONDUCTIVITY AS RECORDED BY THE OFEM MKIII FROM THE FUGRO SOLSTICE IN THE BISMARCK SEA, PAPUA NEW GUINEA

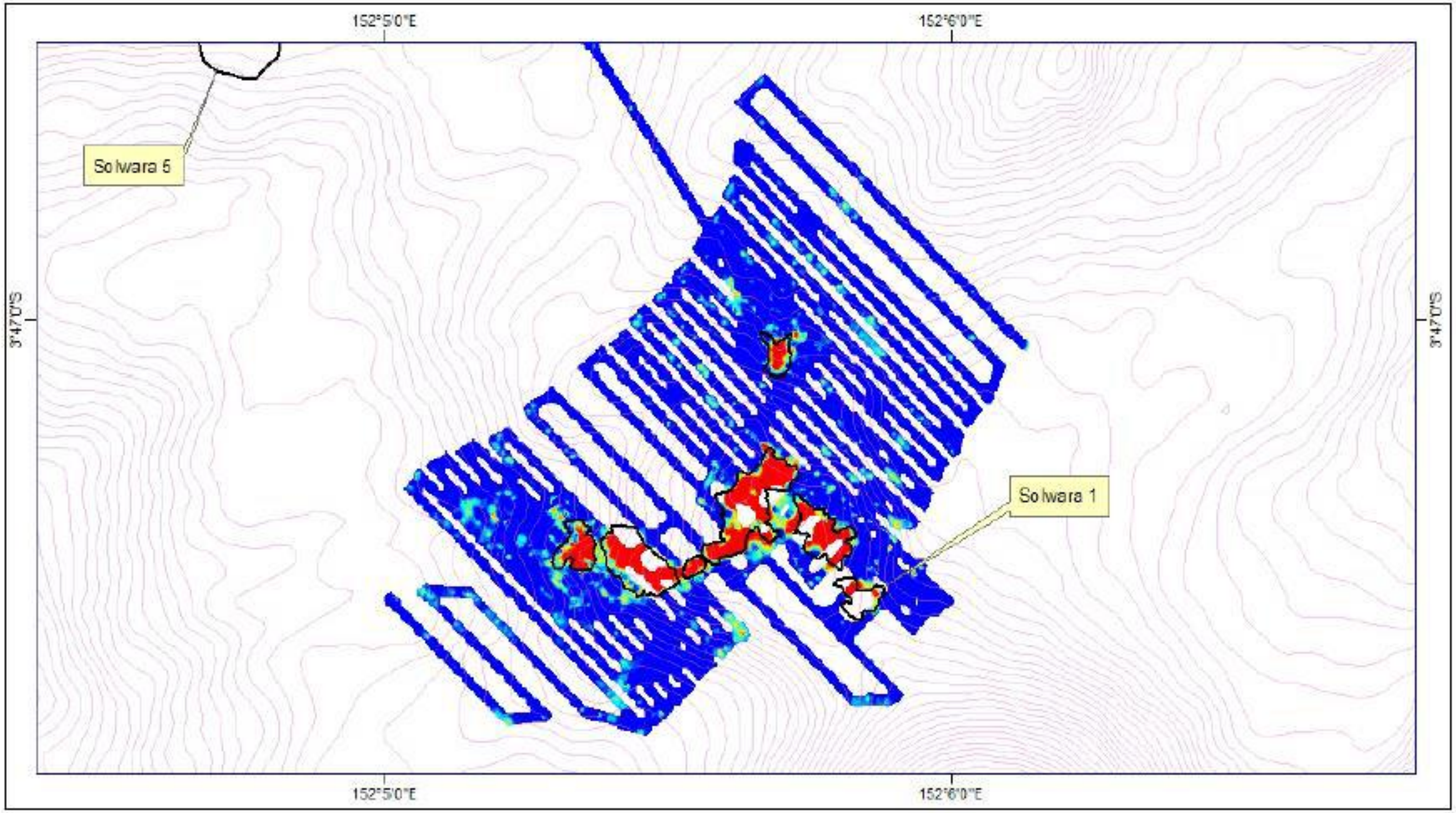
NAUTILUS Minerals Inc.

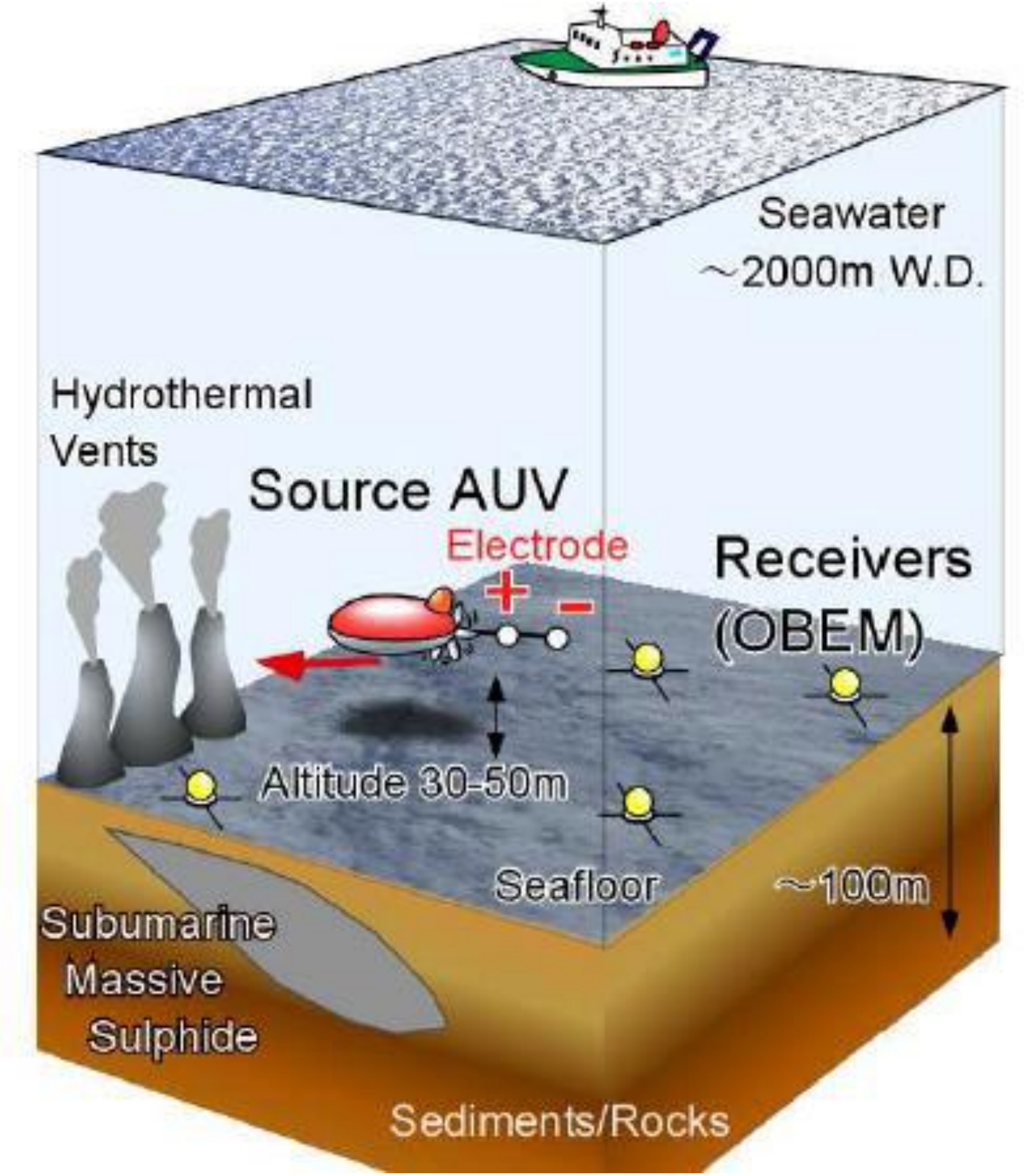
Contours are at 10m interval, from bathymetry collected by Teck Cominco in 2008 from the Sepura

0 0.25 0.5 1 km

N

Red indicates areas of conductive response.





In a similar way to CSEM surveying, the MT technique is sensitive to resistive bodies in the subsurface. Marine MT surveys map subsurface resistivity variations by measuring naturally occurring electric and magnetic fields on the seabed.

The sensitivity of receivers enables to acquire high-quality MT data inherently as part of a CSEM survey when the controlled source is inactive.

The low-frequency, deep-sensing nature of MT surveying makes the technique excellent for mapping and interpreting regional geology.

MT technology does not have the same sensitivity towards thin horizontal resistors as the CSEM technique; rather it can penetrate the thicker resistive layers that might otherwise be challenging for CSEM and seismic techniques.

Technology readiness level

The technology has been proven as ship-mounted operation (TRL-9), for electromagnetics applied at AUVs, there has so far only been tested (TRL-7).

Technological Readiness Level								
TRL - 1	*TRL - 2*	*TRL - 3*	*TRL - 4*	*TRL - 5*	*TRL - 6*	*TRL - 7*	*TRL - 8*	*TRL - 9*

TRL 7 - system prototype demonstration in operational environment

TRL 9 - actual system proven in operational environment

4.2.4 Water-chemistry testing

To be elaborated. PM