

Exploration for and
Pre-feasibility of mining
Polymetallic Sulphides -
a commercial case study.

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Nautilus Minerals Limited
Submission to ISA workshop
September 2004



Nautilus Minerals Ltd

David Heydon

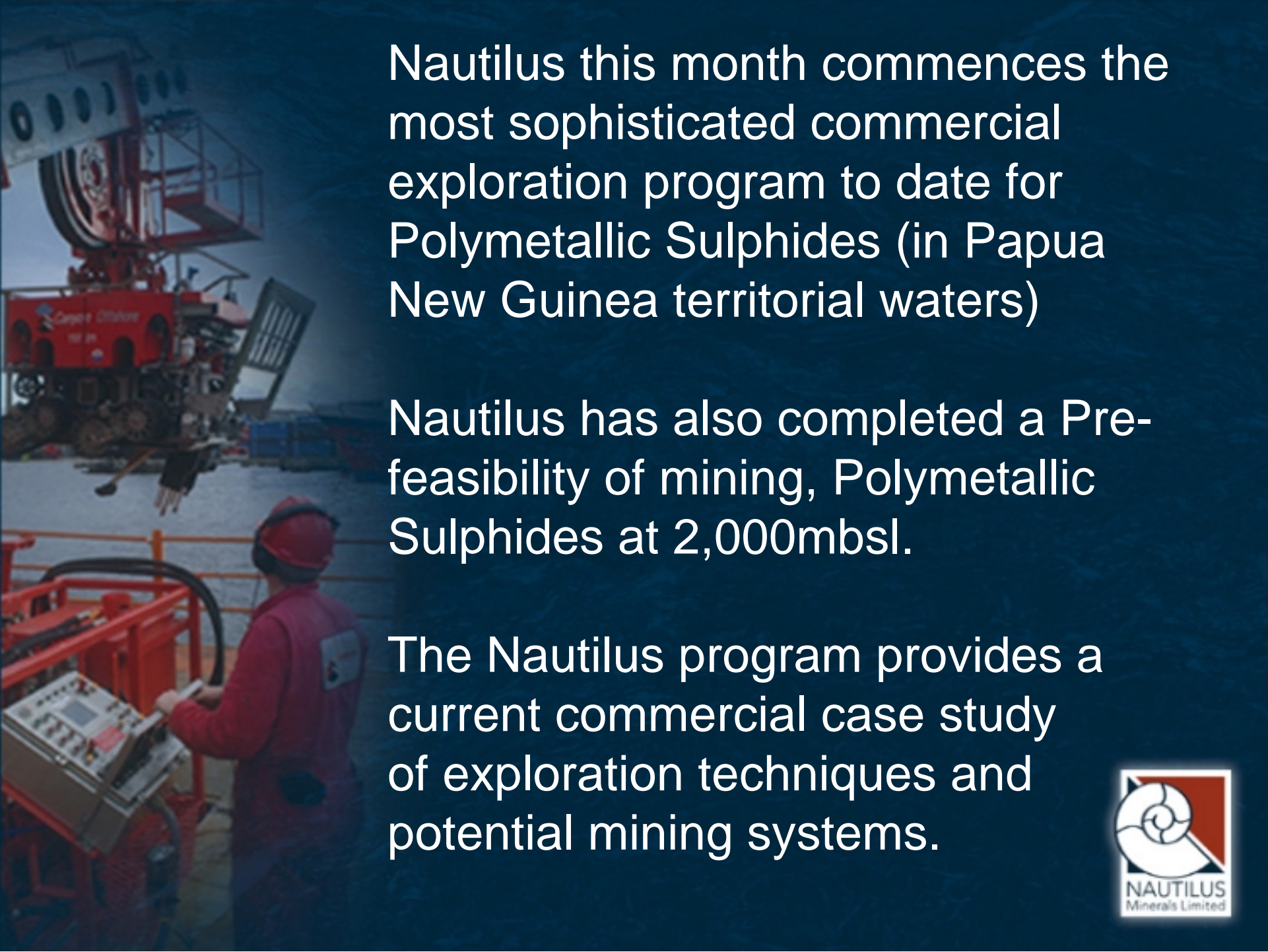
Chief Executive Officer.



25 years in the mining and exploration industry, with a strong record in technical innovation and project management.



www.NautilusMinerals.com



Nautilus this month commences the most sophisticated commercial exploration program to date for Polymetallic Sulphides (in Papua New Guinea territorial waters)

Nautilus has also completed a Pre-feasibility of mining, Polymetallic Sulphides at 2,000mbsl.

The Nautilus program provides a current commercial case study of exploration techniques and potential mining systems.



Nautilus Minerals Limited

Technical Alliance Deep Sea Mining



- Project Manager, Owner's engineer



- Remote Operated Vehicles

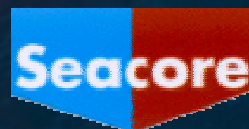


VOEST-ALPINE
BERGTECHNIK

- Miner cutting tool – technology

SIEMAG

- Ore Hoisting



- Resource Drilling



- Resource Geophysics

Exploration – Polymetallic Sulphides

An actual case study

- **This month, Nautilus is mobilising ships and survey equipment for a major exploration program in Papua New Guinea**
- Unlike on land, the exploration will not require a camp, nor land clearing for roads. Exploration will be conducted from a vessel where all equipment, rubbish wastes, sewerage wastes, fuel etc will be securely contained and removed upon completion of exploration program, leaving the area undisturbed



Geophysics is a 'passive' non destructive survey



Exploration – Polymetallic Sulphides

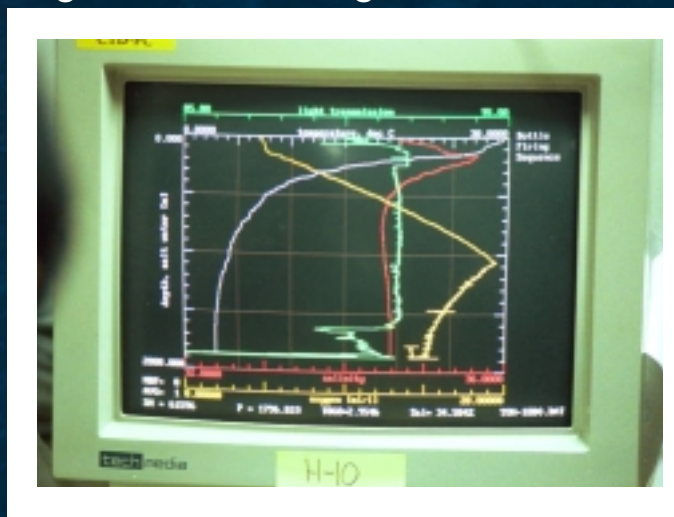
Water column testing

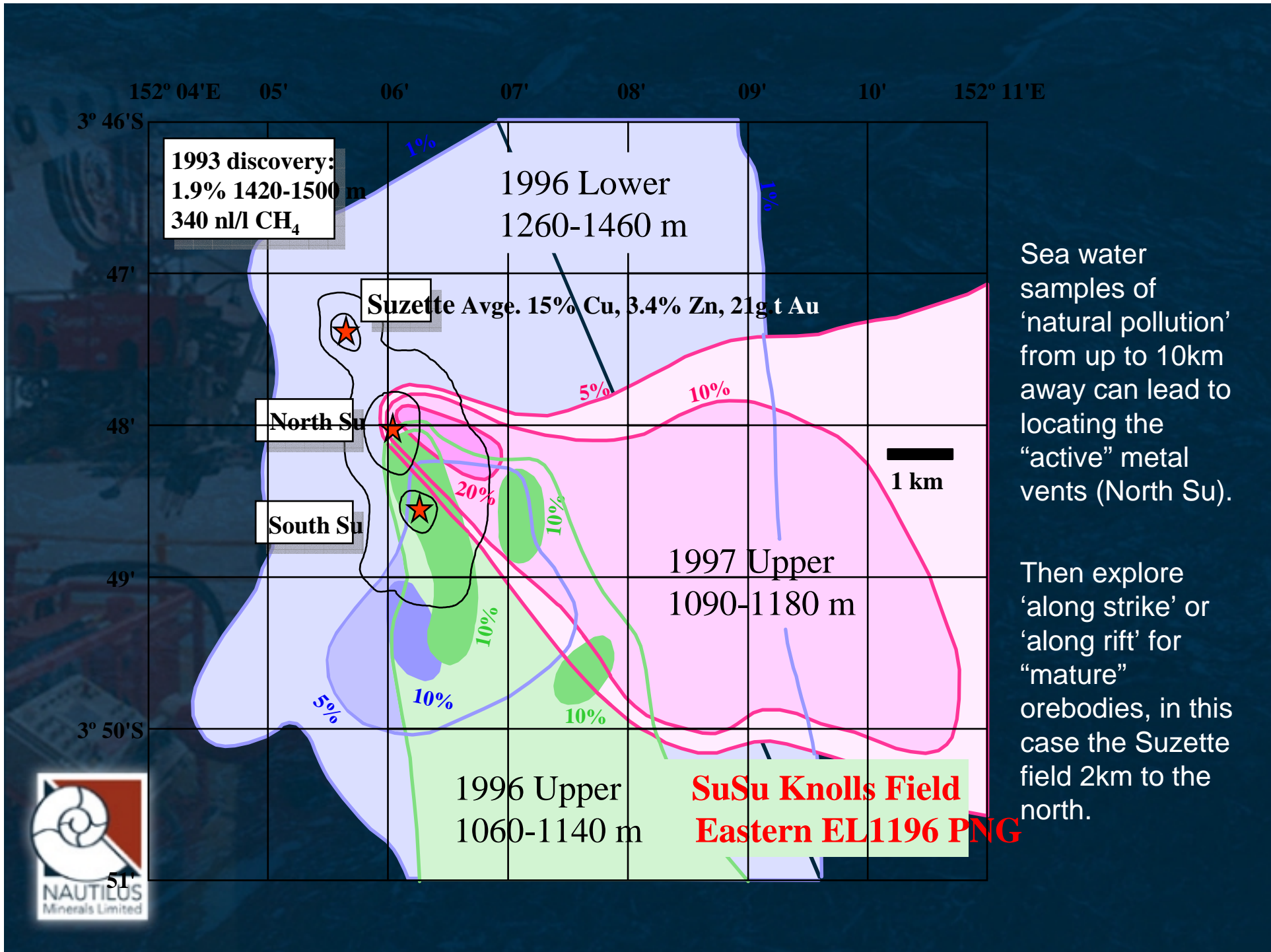
– efficient first pass exploration

Locates evidence of active plumes (“vent smokers”).

Uses natural ‘pollution’ to locate mineral fields

- Rapidly cover a prospective regional area
- Basis is that an “active vent field” may indicate a region where mineralisation may have been active in recent geological history and older, mature ‘ore bodies’ may occur ‘along strike’ or ‘along rift’





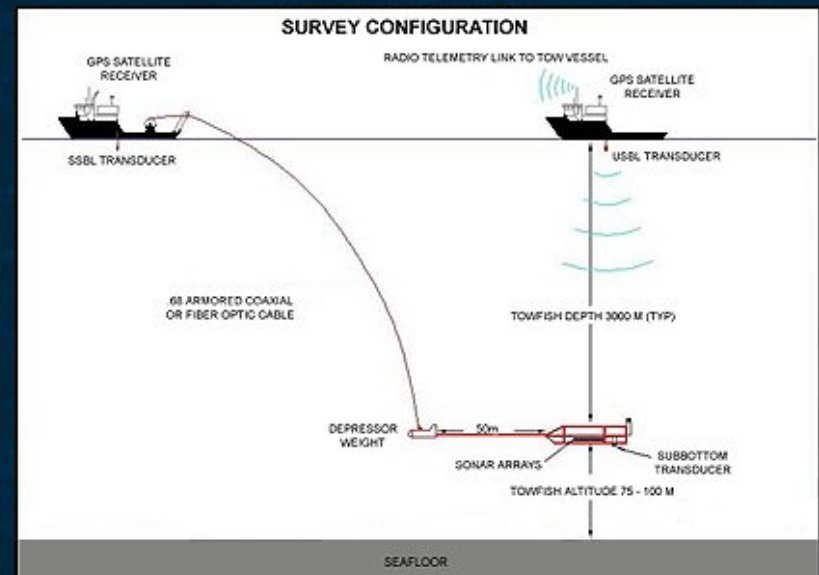
Sea water samples of 'natural pollution' from up to 10km away can lead to locating the "active" metal vents (North Su).

Then explore 'along strike' or 'along rift' for "mature" orebodies, in this case the Suzette field 2km to the north.

Geophysics

An array of geophysics tools can be employed for polymetallic sulphides given their physical and 'metallic' properties, including;

- Resistivity
 - Self Potential
 - Magnetics
 - Induced Polarisation
 - Video camera
 - Gravity
- Based on these surveys, the areal extent of an orebody can be determined and with gravity measurement, the mass or tonnage can be estimated.



Exploration – **Sampling**

A geophysical anomaly can be 'ground truthed' to confirm the source of the anomaly is in fact sulphides and also to determine the style and surface grade of mineralisation. Simple dredges (right) or sophisticated grabs (left) can recover samples.



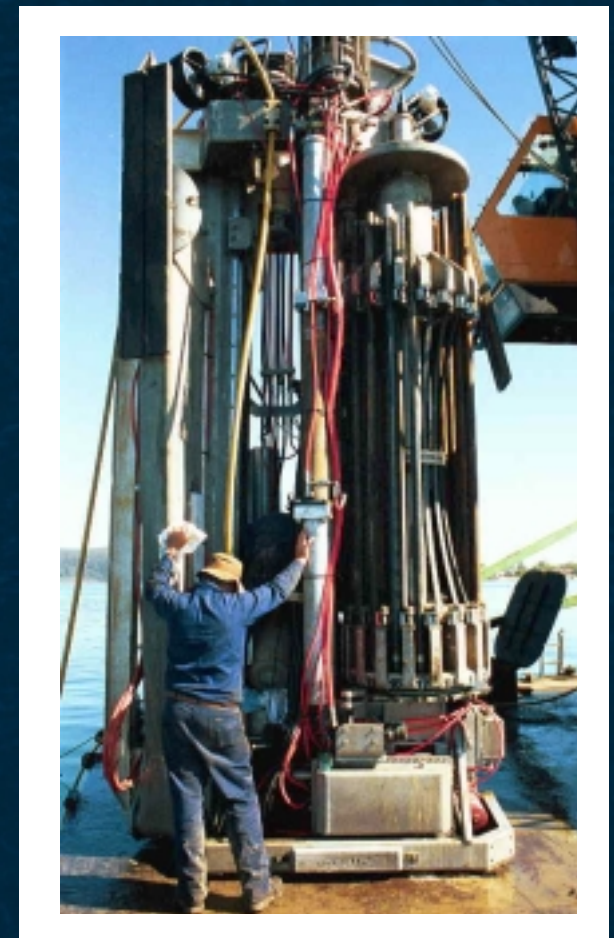
Exploration – **Drilling**

Unlike crusts or nodules which lay on the sea bed surface, Polymetallic Sulphides require drilling to test the vertical or depth extent of the mineralisation and to test any buried body.

Drilling assists in determining an average grade of the body.

Drilling can be by remote operated drill rig lowered to the sea floor. There are less than 6 of these currently in operation worldwide.

Core recovery by these rigs has to date been unacceptable for commercial ore grade assessment.



Exploration – **Drilling**

There has been very limited drilling in water depths from 1,500m to 2,000m, let alone deeper waters of the “Area”. There are only a couple of ship based operators with capability to drill in 2,000m water. The Ocean Drilling Program (ODP) has not successfully recovered continuous core from the top 20 metre of the seabed where these sulphides may first be mined.

Drilling technology needs to be advanced to meet the standard of core recovery required for commercial ore grade assessment.



Nautilus's partner SEACORE (right) is a leading deep sea drilling company



Exploration - **Drilling**

Nominal Mineral Deposit

200 metres x 200 metres x 18 metres
deep = 2 million tonnes

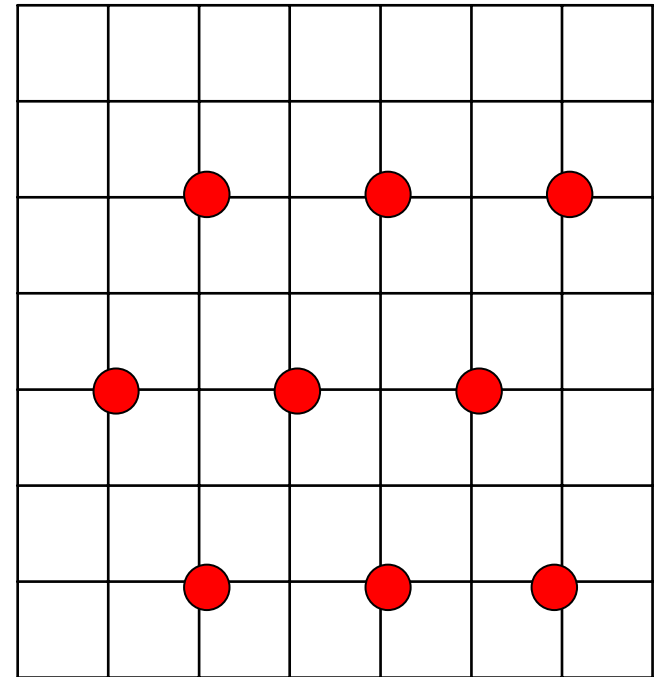
First Phase Exploration:

Nominal Program

- 9 holes to start at approx 60m spacing, drilled to 20m depth
- 70mm core diameter
- Include one or two 300mm (12") holes reamed for larger sample for first phase metallurgy testing.



0 25 55 85 115 145 175 200



Exploration - **Drilling**

Mineral Deposit

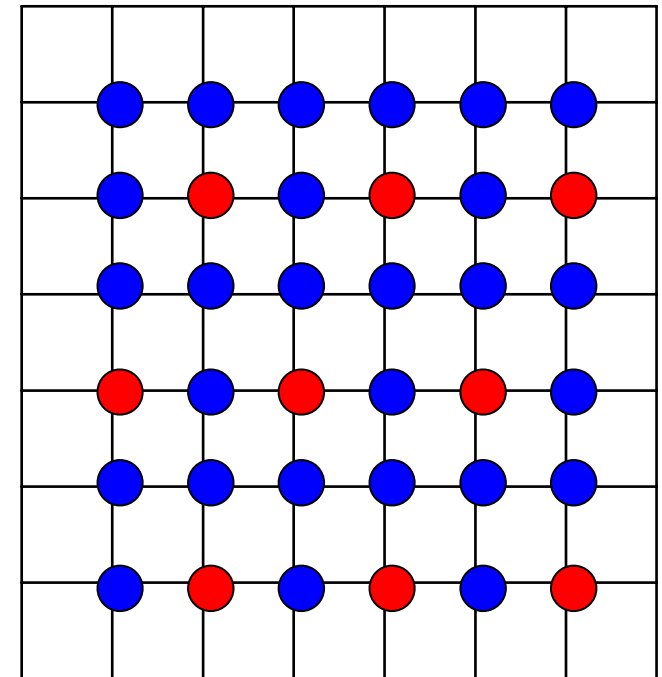
200metres x 200metres x 18metres deep
= 2 million tonnes (nominal size orebody)

Pre Mining Phase – For detailed Grade Control and pre Mine Planning

- Infill up to 27 holes (30m spacing) depending on variability of geology and grade. Less holes if geology and grade are consistent.
- May include more larger reamed holes for metallurgical samples.



0 25 55 85 115 145 175 200



Exploration – **MSR activity**

Exploration as described herein is 'passive' and no more than is already being done by Marine Scientific Research groups ("MSR"). In fact MSR work often focuses on a few known 'active fields' like TAG, Juan de Fuca etc with repeated surveys over these fields at a greater intensity level than would result from commercial exploration. MSRs have already drilled, grab sampled and conducted geophysics on polymetallic sulphides in the Area just as described herein.



Exploration – **Crusts vs Sulphides**

- Crusts are thin average 40mm
- Polymetallic sulphides are relatively thick lenses average 15 – 20 metres
- 2 million tonnes of crust covers a surface area of **16 square KILOMETRES** whereas 2mt of sulphides is **only 200 METRES square**
- To sample a 2mt ore body of crusts therefore requires disturbing a large surface area.
- To sample Polymetallic sulphides disturbs a relatively small surface area as most of the sample is sub surface drill core (max 36 x 70mm holes over 200m x 200m area)



Trial Mining

- Advantage of trial mining is it allows both parties data, and the ISA gets info on which to make regulations & embody conditions into any subsequent Mining Lease based on this trial work.
- Logically you would not go to trial mining until you had a sufficiently large resource indicated to show sufficient mine life to justify future capital eg a minimum resource of 10 years at full scale production.
- Accordingly this implies you have found a large mineralised area and as such trial mining would only disturb a small portion eg 1/20th of this area leaving the remaining environment undisturbed. So trial mining by definition does not destroy the environment just a very small subset of a mineral environ.



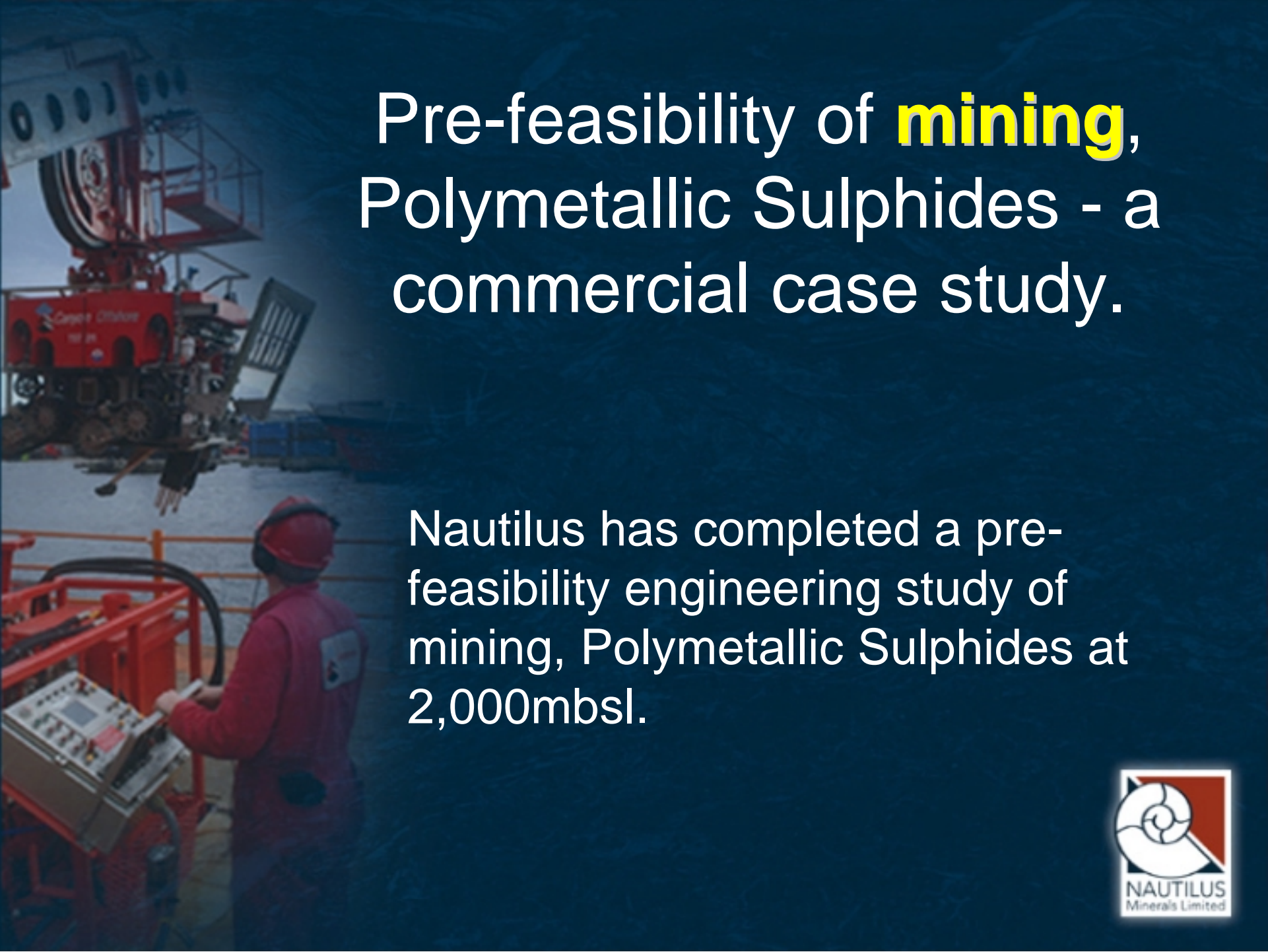
(Right – trial mining nodules 1978)



Trial Mining – **crust vs sulphides**

- A trial mining program may entail mining 1 million tonnes trialling a 2mtpa mining system.
- 1 million tonnes of crust covers a surface area of 8 square KILOMETRES whereas 1 million tonnes of polymetallic sulphides to 20m deep disturbs only 140 METRES square of surface area.
- Trial mining production should be allowed to be sold to a processor to determine process characteristics, recover costs of trial and ensure material from trial is not wasted but used by man.





Pre-feasibility of **mining**, Polymetallic Sulphides - a commercial case study.

Nautilus has completed a pre-feasibility engineering study of mining, Polymetallic Sulphides at 2,000mbsl.



Exploitation – **The Mine**

Parameters:

- Mine 2 million tonnes per annum
- Mine life plus 10 years = + 20mt
- Orebodies average 2mt
- 2mt is 200m x 200m x 20m thick
- “Mine” may stay in one spot anchored for a year or more over a field containing several deposits
- “Mine” then relocates to another area which may be several kilometres away to aggregate the +20mt required.



Exploitation – **Surface Assets**

The Mine

- A floating 'top side asset' either ship or semi submersible (right)
- Purpose is to provide a work platform, power, support, sub sea deployment, also for 'off take' of product.
- Nautilus study shows size and cost of ship/platform to either process or store at sea is prohibitive, uneconomic.
- Massive sulphides in one area lead to operating in one area for 12 months so can deep moor instead of dynamic positioning



Exploitation – **Remote Operated Mining**

ROV Miner

- 1,000hp ROV's (equivalent to a D11 bulldozer – right) exist
- ROV's are used for cable and pipe lay trenching. They are already 'mining' just not recovering the material.
- Nautilus study based on 5,000 hr pa operation and 2million tonnes pa = 400t per hour.
- Two mining vehicles per platform, powered by electric umbilical each mining 200t per hour.
- Nautilus partner Perry Slingsby Systems is largest manufacturer of ROV's



Exploitation – **Remote Operated Mining**

ROV Miner

- Polymetallic Sulphides have strength of coal.
- Nautilus study proposes drum cutters as used in coal mining
- Drum cutter miner is 5m wide & cuts a 2m high 'face'.
- Each miner advances only 7 metres per hour. (1 track turn)
- Cutting teeth designed not to produce fines but average 50mm particles (up to 70mm)
 - Nautilus partner Voest Alpine is a leading manufacturer of cutters & road headers



Exploitation – **Material Handling**

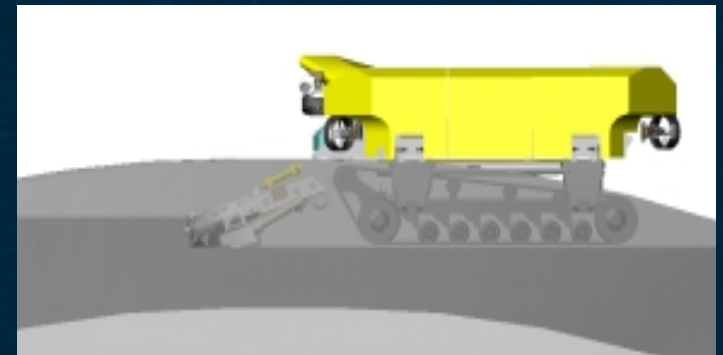
ROV Miner

- The ore body is 'rock' on a volcanic ridge so no silt - mud so no plume of fines as for nodules.
- The miner has a pump located near the cutting head & positive suction in to this pump ensures no fines are lost.
- This pump transports the material from the miner to the vertical ore hoisting system.
- This system can either be a wire rope hoist system like in underground mines or a hydraulic pump system up a riser pipe



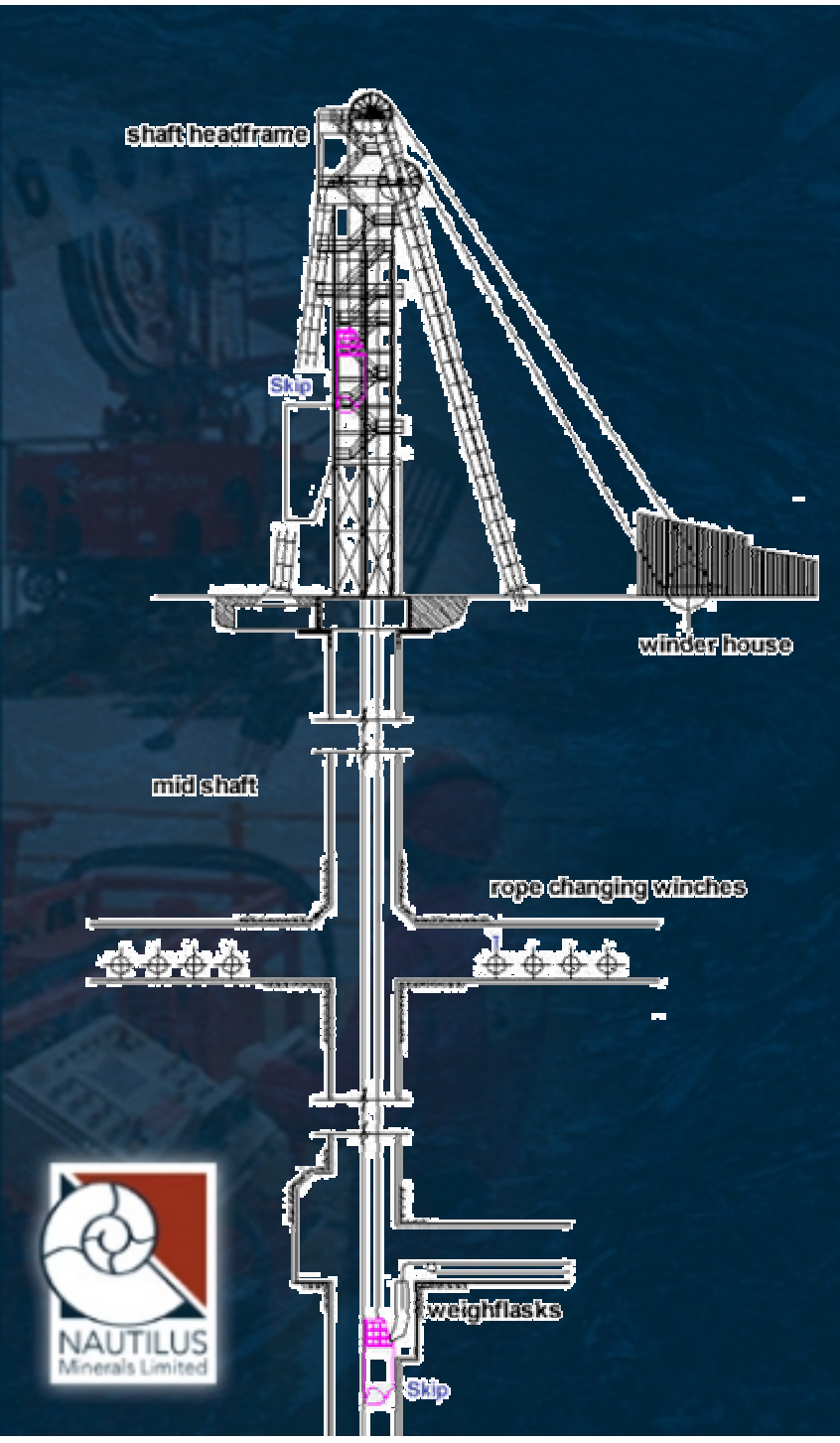
Compare Cobalt Crust

Crust is 40mm thick on an uneven surface. To mine just 40mm (without dilution) means leaving the surface uneven so 'miner' cannot operate on flat road surface whereas for polymetallic sulphides the 'miner' after one track length has made a flat 'road' to operate on.





- World leader in hoisting ore from deep underground
- Systems to 3,000m
- SIEMAG have proposed a system to hoist at rate of 400 tonnes per hour from 2,000mbsl.
- Hoist 100t kipples at 1.8 metres per second. (on land run at 16m/s)



Exploitation – **Pumping Option**

- Nautilus engineering study considered both slurry pumps (Warman) and positive displacement pumps (SIEMAG) which may be assisted by airlift.
- Electric powered Pumps located on sea bed.
- 70mm maximum particles up a 300mm internal diameter riser pipe.
- System offers efficient continuous mining and material handling.



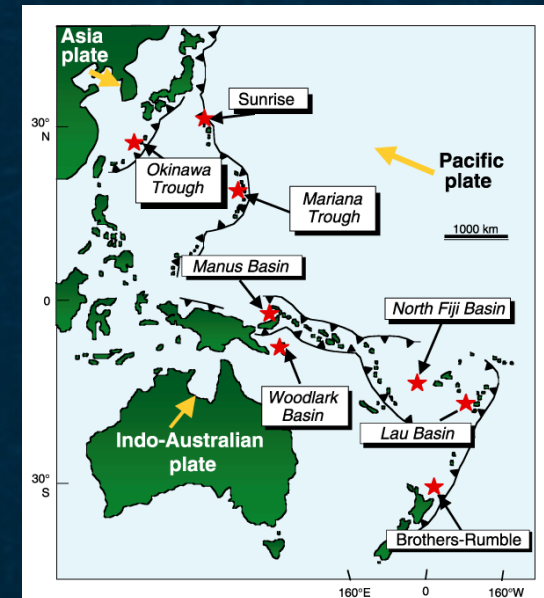
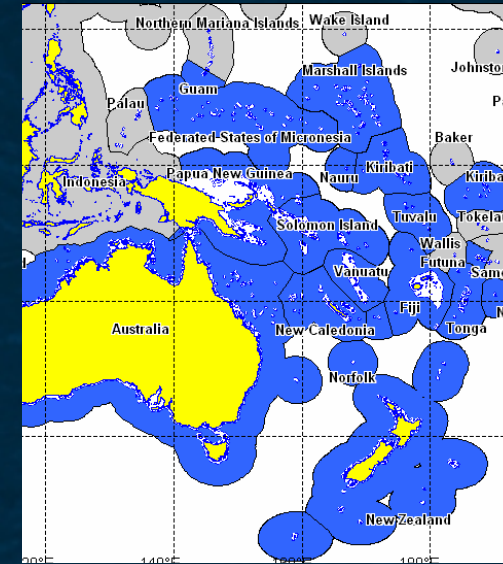
Exploitation – **Mineral Processing**

- In EEZ or territorial waters, ore would be processed on land given the size of a 2 million tonnes per annum processing plant and ‘cost’ of land vs displacement (floating).
- In the AREA this issue may be a critical factor & require higher grade material to either justify cost of direct shipping large distance to a land plant or onsite processing (unlikely as extremely high cost for such large displaced ship)
 - **Key factor why EEZ likely mined before AREA**



Exploitation – **EEZ vs the AREA**

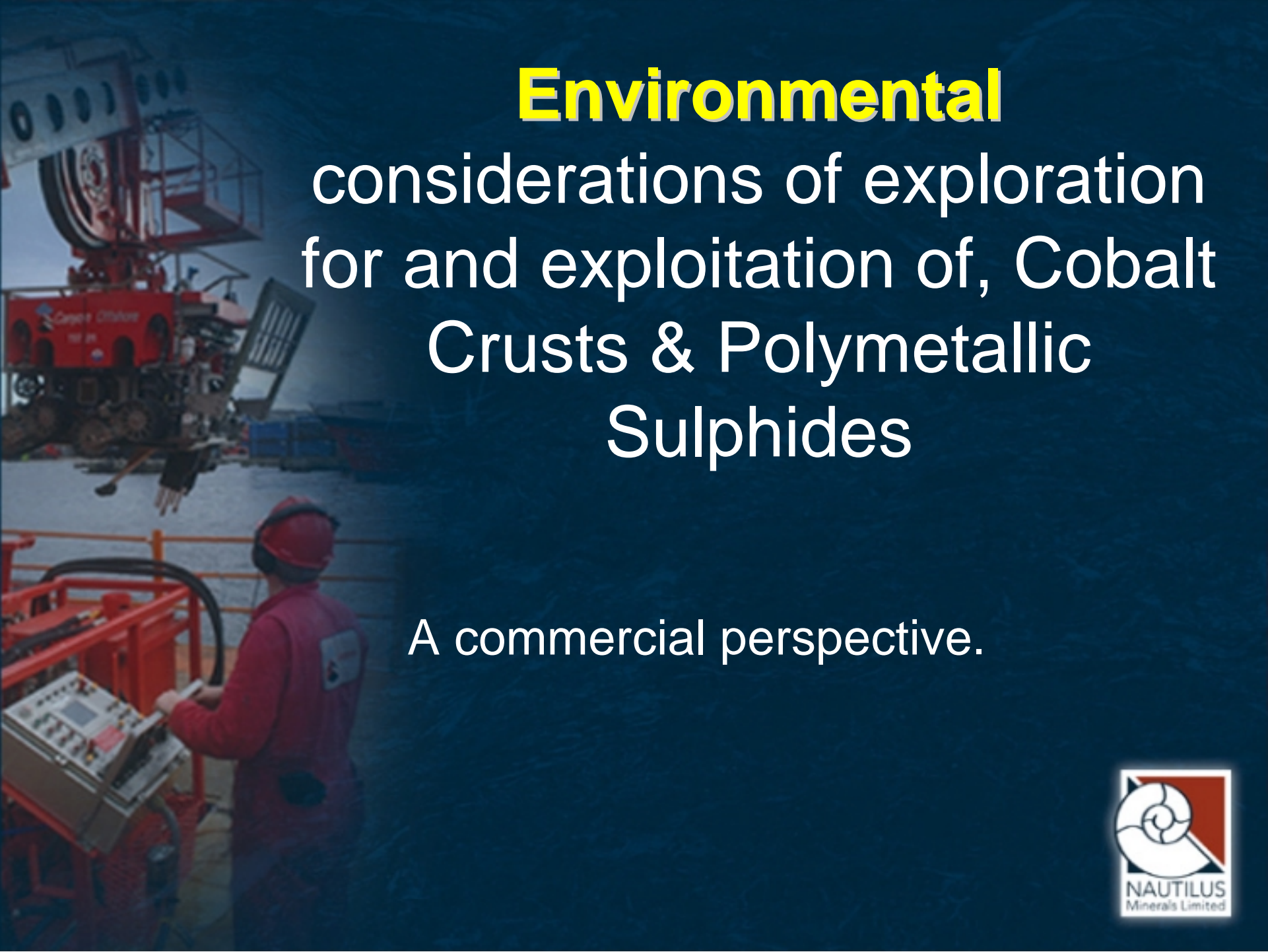
- Polymetallic sulphides occur in many EEZs and in the AREA
- It is likely those in an EEZ will be developed before those in the AREA providing the ISA with environmental information on which to develop its own regulations.
- ISA terms (i.e. “taxes”) are less attractive to development than many State EEZ’s with ISA demanding an onerous 50% participation or 50% product sharing.



Exploitation – **EEZ vs the AREA**

- By definition EEZ, continental shelf & territorial water resources are closer to land and as such costs to develop them may be less than in the AREA, given transport of 'ore' to land for processing, provision of supplies and fuel etc.
- Accordingly ore grades in the AREA would need to be higher to cover these higher costs.
- **Question: Does the ISA want to be competitive with EEZ resources? Lower its 'taxes'?**





Environmental considerations of exploration for and exploitation of, Cobalt Crusts & Polymetallic Sulphides

A commercial perspective.



Environmental – **crust vs sulphides**

Comparison based on a 2 million ton per annum operation

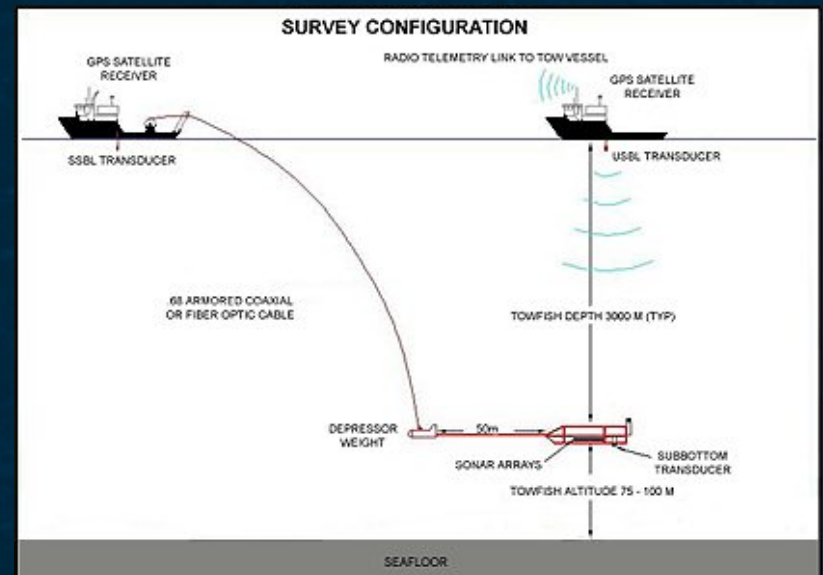
	<u>Nodule</u>	<u>Co Crust</u>	<u>Sulphide</u>
<u>Attribute</u>	25 kg/m ³	40mm	20m deep
<u>Surface area</u>	80 sq kilometres	16 sq kilometres	200m x 200m
<u>Surface Environ</u>	silt, mud abyssal plain	volcanic seamount	volcanic ridge
<u>Depth</u>	>4,000mbsl	>500mbsl	>1,000mbsl
<u>Metal</u>	Ni, Co, Cu	Co, Ni, Cu	Cu, Au, Zn, Ag



Given the above differences it is clear that each resource requires different environmental regulations

Environmental – Exploration

- **GEOPHYSICS:**
- Mostly 'non grounded' ie no contact with seabed. (like airborne survey over land)
- Passive measurement of natural features



Environmental – Exploration

- **SAMPLING:**
 - Disturbance of a very limited area
 - In practice whilst commonly used by MSR's along with the grab, this tool is not overly used for commercial exploration as it provides limited information – only surface samples which may not represent the 'mass'.
 - Can also provide valuable biological information



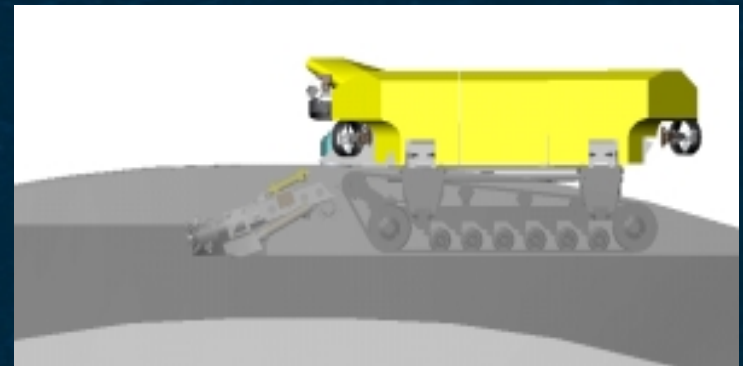
Environmental – Exploration

- **DRILLING:**
 - Limited surface disturbance (70mm – 2” core holes) as majority of sample material is gathered from depth.
 - May also take several larger diameter holes for metallurgical samples eg ream hole 300mm – 12” diameter but once more limited surface disturbance.



Environmental – Exploration

- **TRIAL MINING** :
 - In practice would only involve disturbing 1/20th or 1/40th of the resource.
 - Accordingly the majority of the mineralised environ is left undisturbed.
 - Provides valuable data for State or ISA upon which regulations be based before any mining lease is granted.
 - For cost reasons, elements of trial mining may first be conducted in another environ eg land quarry or a harbour channel.



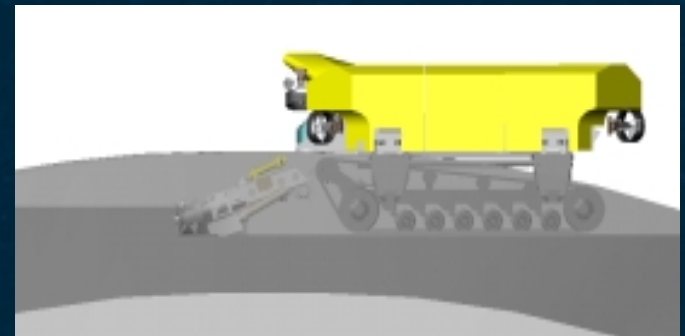
Environmental – **Exploitation**

- **MINING PLATFORM:**
 - Platform is self contained with services and is re-supplied by ship.
 - Probably moored in one spot for a year at a time supporting a mining operation
 - Ore is dewatered and fines removed by cyclones and recovered as product
 - Ore is transferred hydraulically (pipe) or mechanically (conveyor) to a barge or ore carrier for shipment to port.
 - Can act as a weather station for a weather network etc.



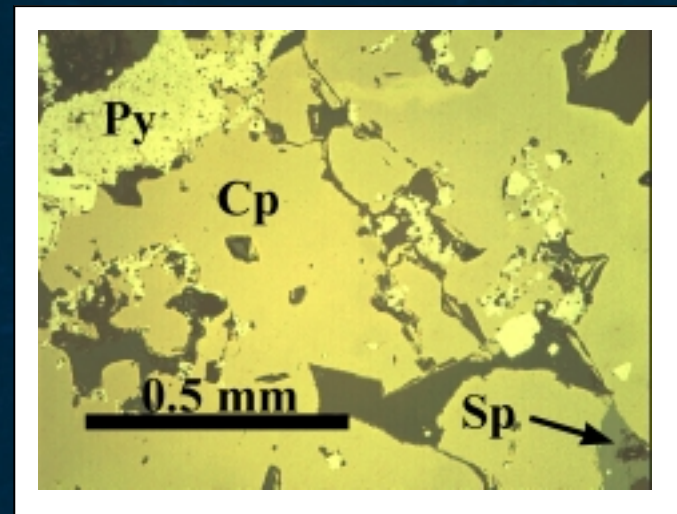
Environmental – **Exploitation**

- **MINING OPERATION:**
- Electric powered Remote Operated Miners use similar technology to those already operating in the AREA laying telecommunication cables etc.
- Operate on volcanic ridges (not muddy abyssal plains so no plumes).
- Rock Cutting heads designed to not make small fragments.
- Positive suction pump draws in any fines produced to the pump system & to the surface.



Environmental – Exploitation

- **OTHER ELEMENTS:**
- Deleterious elements that might exist naturally in the ore such as lead and arsenic remain in the same stable mineralogy during mining. The mineral is not broken down from its stable constituent, the mass of ore is simply removed for further processing on land at a concentrator and then a smelter or similar.



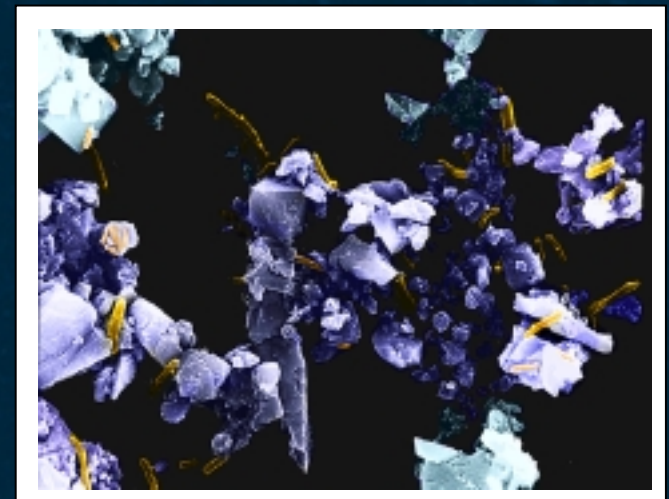
Environmental – **Exploitation**

- **PUMPING - RISER:**
- Ore is pumped to the floating platform up a 300mm riser (pipe).
- On the platform it is dewatered and fines removed by cyclones and recovered as product.
- Water can then either be
 - returned down a second pipe to an appropriate depth such as 500m where mixing can occur.
 - If it is seen as a positive to the environment eg fish breeding as in Hawaii around the OTEC plant, this nutrient rich water can be discharged at other levels.



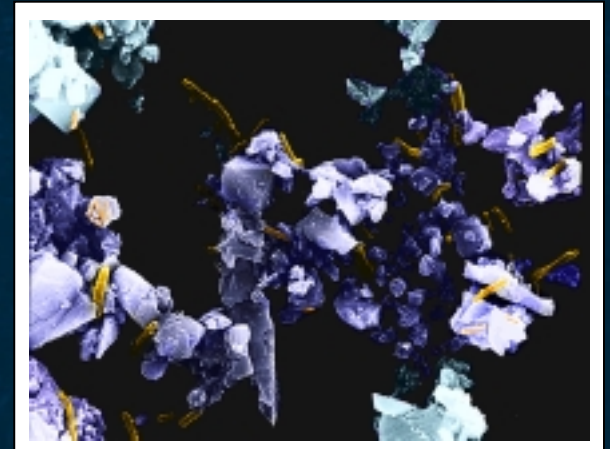
Environmental – Questions

- **“Bugs” Bacteria Question:**
 - Who administers the “bugs” contained **in** the material that would be mined, ie not those in the water column but those contained **within the seabed**?
 - This bacteria appears in samples of NON active vents and appears to survive in a dormant state in the samples recovered to surface until a heat and food source is introduced by culture medium.



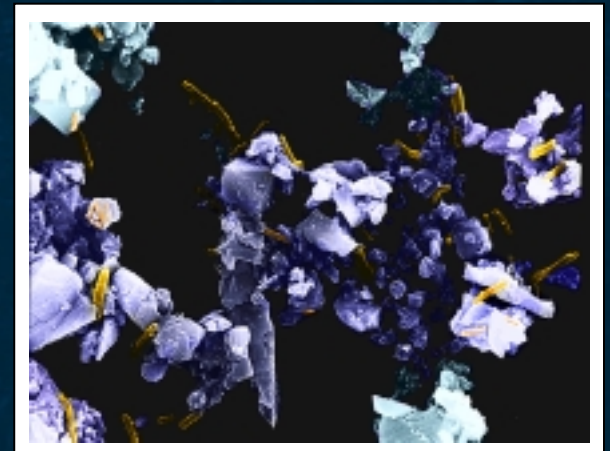
Environmental – Questions

- **“Bugs”** :
- If an active vent field was ever mined and the overlaying material removed, would not the vent continue as less overlaying material/pressure?
- If so then the vent post mining would remain an active site, food source for vent fauna.
- The ‘bugs’/bacteria appear to be dormant in the water column awaiting the right environment in which to ‘spawn’. Evidence of this is clear from vent fields that have come and gone in recent geological time eg TAG periods of activity and inactivity.



Environmental – Questions

- **“Bugs”** :
 - Possible to mine an active field such that post mining the vent continues to be active.
Reintroduce fauna from another nearby vent field to the mined out ‘reactivated’ field prior to mining the second one.



Environmental – UNCLOS

- Is all the data that has been gathered by MSR groups operating in the Area available to the ISA?
- ISA regulates that all Contractors exploring in the Area must provide data to ISA of all results etc. The rationale for this regulation should be applied to MSR data which if collected in the AREA should be managed by someone for “the good of mankind”.
- The more data the ISA has the better it can manage and administer the AREA.



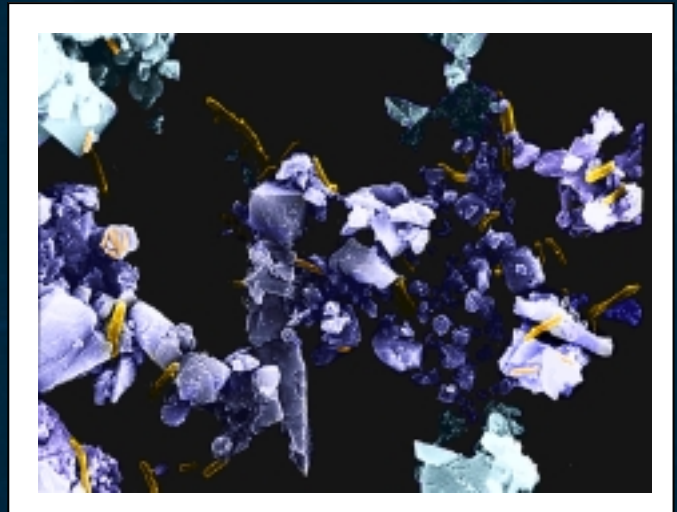
Environmental – **UNCLOS - MSR**

- **DISCUSSION :**
- The Regulations in UNCLOS (see following) state that MSR shall provide the Coastal State with access to all data, samples, results, conclusions for work in EEZ.
- Are MSR's also bound to provide such data, samples etc to ISA (or similar body) for work in the AREA?
- Is there a central repository of all this data to be 'managed' for the 'good of mankind'?



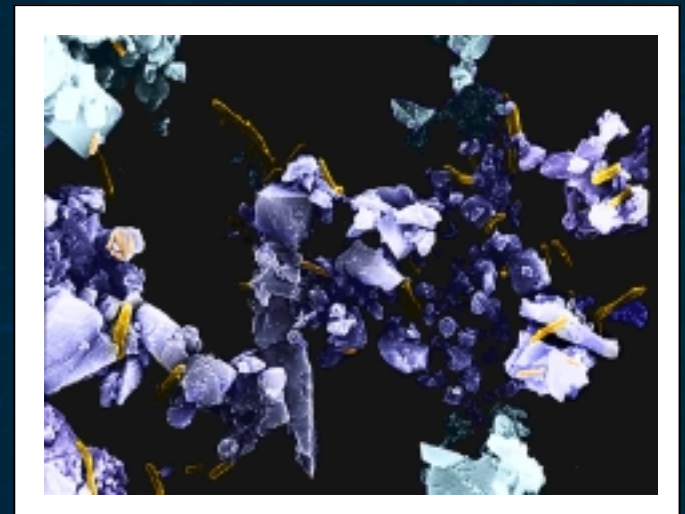
Environmental – **UNCLOS**

- UNCLOS regulations state that the MSR's shall:
- (b) provide the coastal State, at its request, with preliminary reports, as soon as practicable, and with the final results and conclusions after the completion of the research



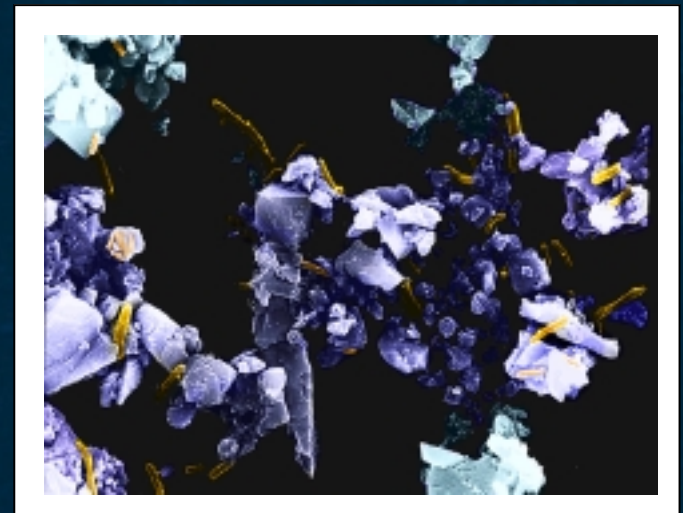
Environmental – **UNCLOS**

- (c) undertake to provide access for the coastal State, at its request, to all data and samples derived from the marine scientific research project and likewise to furnish it with data which may be copied and samples which may be divided without detriment to their scientific value,



Environmental – **UNCLOS**

- (d) if requested, provide the coastal State with an assessment of such data, samples and research results or provide assistance in their assessment or interpretation



Environmental – **UNCLOS**

- If copies of ALL the MSR data gathered in the AREA (and subsets of all samples – rock, benthos etc,) had to be provided to the ISA (as MSR must do for the Coastal State) then the ISA would have a very valuable asset of data on which to;
 - 1. formulate its regulations eg enviro baseline data we are discussing today
 - 2. promote/market its resources to & attract potential Contractors
 - 3. A data base that may allow the ISA to ‘tender’ out areas to Contractors



Nautilus Minerals Ltd

Whilst I cannot attend your workshop, I welcome the opportunity to discuss these thoughts further with any delegate who may wish to contact me.

With its forthcoming cruise & exploration program over next 12 months, Nautilus also seeks to collaborate with MSR groups to study the data collected.



David Heydon

Contact: Office@NautilusMinerals.com

