Activities of the IOM within the scope of geological exploration for polymetallic nodule resources

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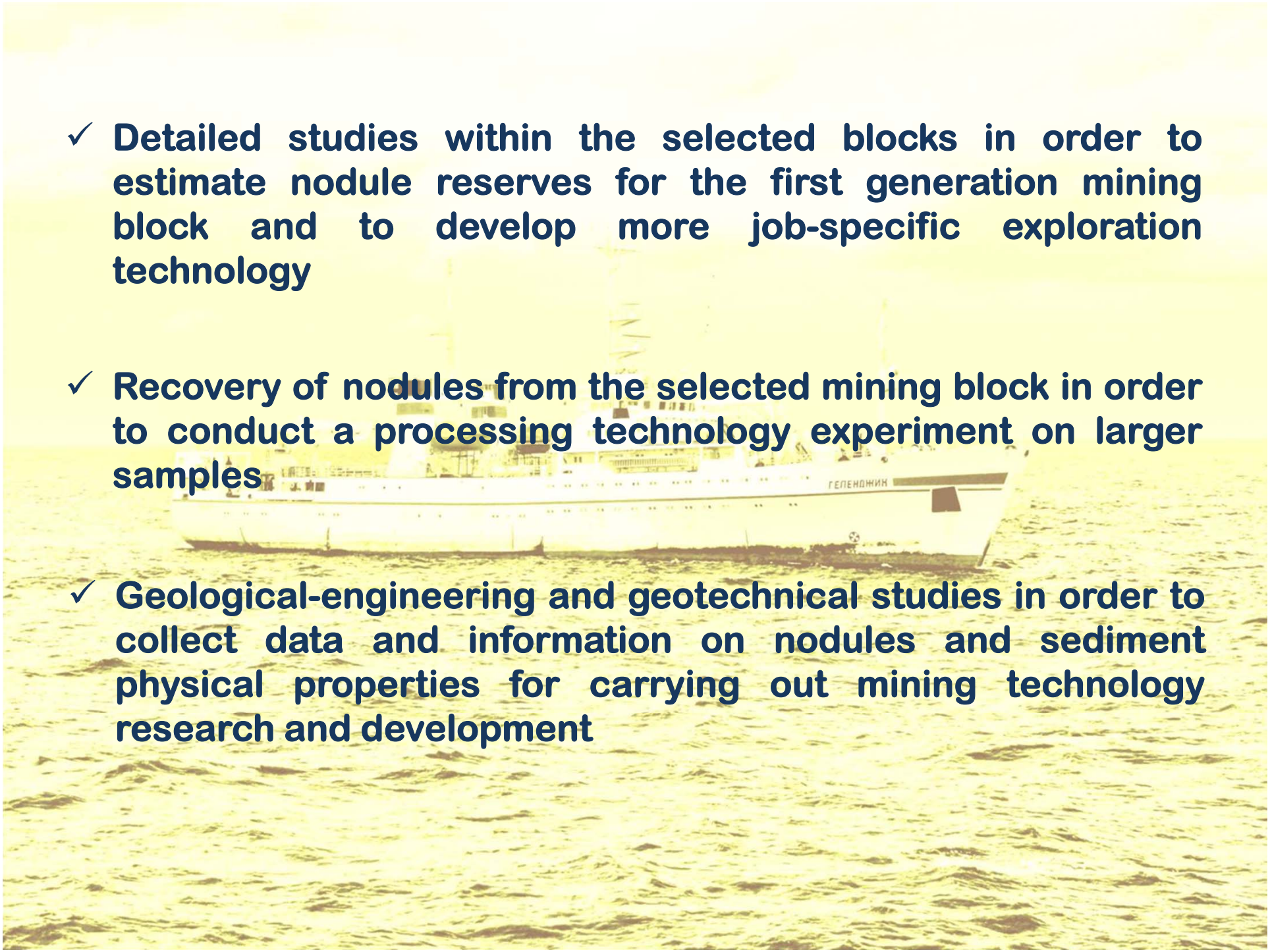
IOM

interoceanmetal

JOINT ORGANIZATION

The main objectives of the IOM exploration during the present phase of research are defined by the provisions of the ISA approved *Plan of work for exploration* and *the programme of activities for five-year periods*. They include:

- ✓ Identification of nodule deposit resources that have the potential to be commercially mined as well as the delineation of nodule deposits.
- ✓ A pre-feasibility study in order to define the possibility of proceeding with the nodule mining project in Sector B2 of the exploration area
- ✓ The selection of potential mining areas/blocks within the delineated nodule deposits



- ✓ Detailed studies within the selected blocks in order to estimate nodule reserves for the first generation mining block and to develop more job-specific exploration technology
- ✓ Recovery of nodules from the selected mining block in order to conduct a processing technology experiment on larger samples
- ✓ Geological-engineering and geotechnical studies in order to collect data and information on nodules and sediment physical properties for carrying out mining technology research and development

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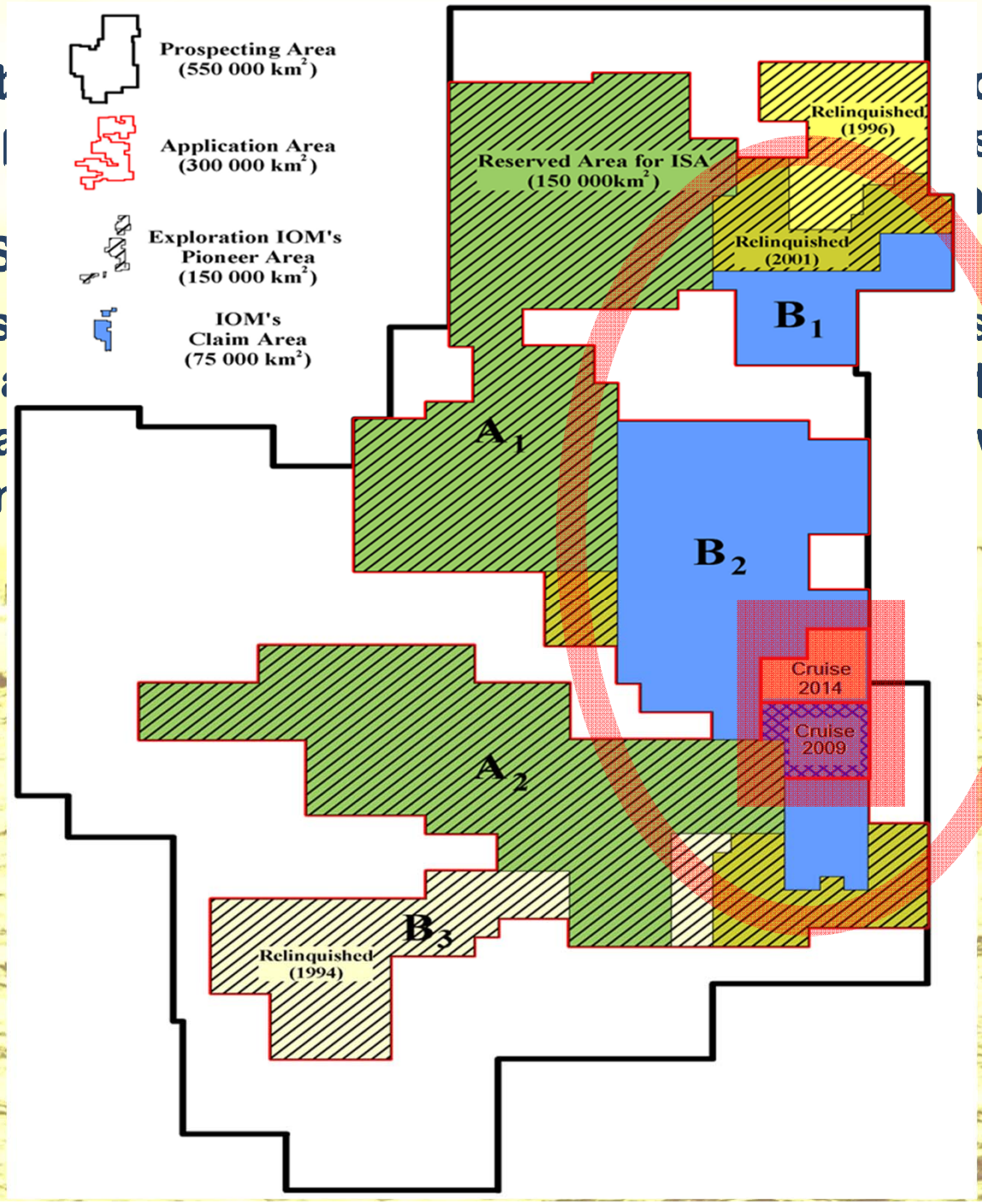
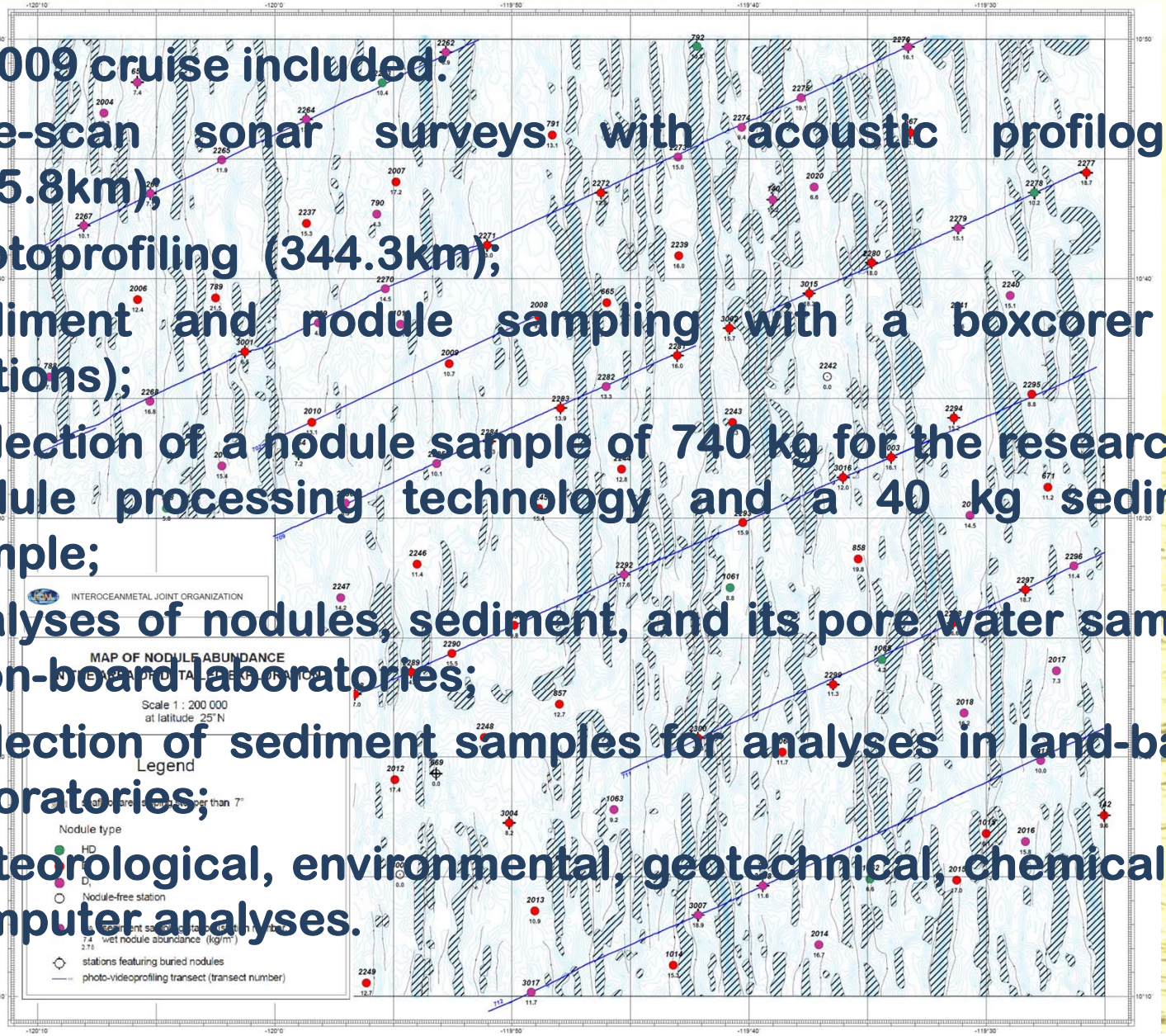


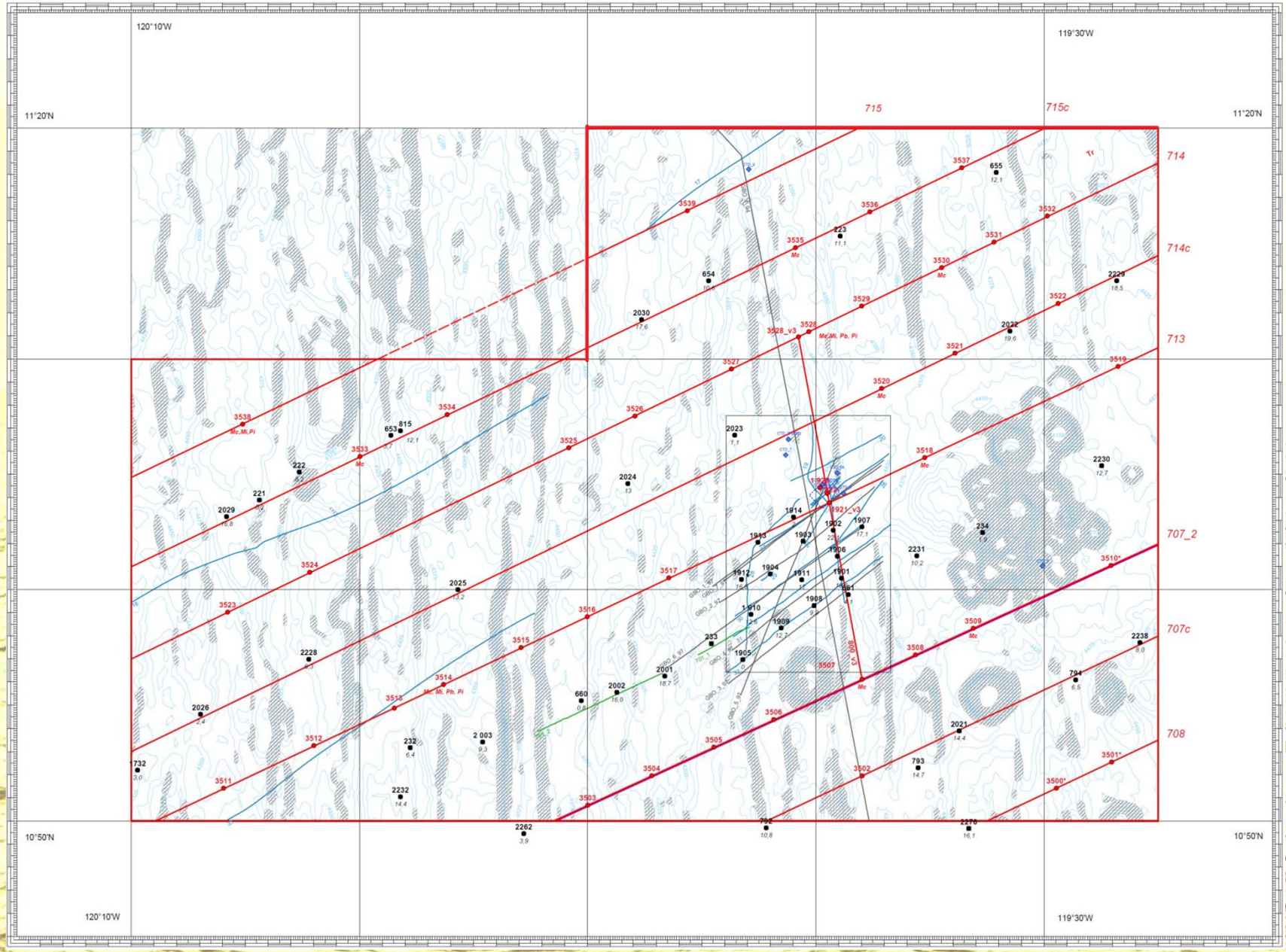
Summary of the 2009 exploration project – the H11 area

IOM'2009 cruise included:

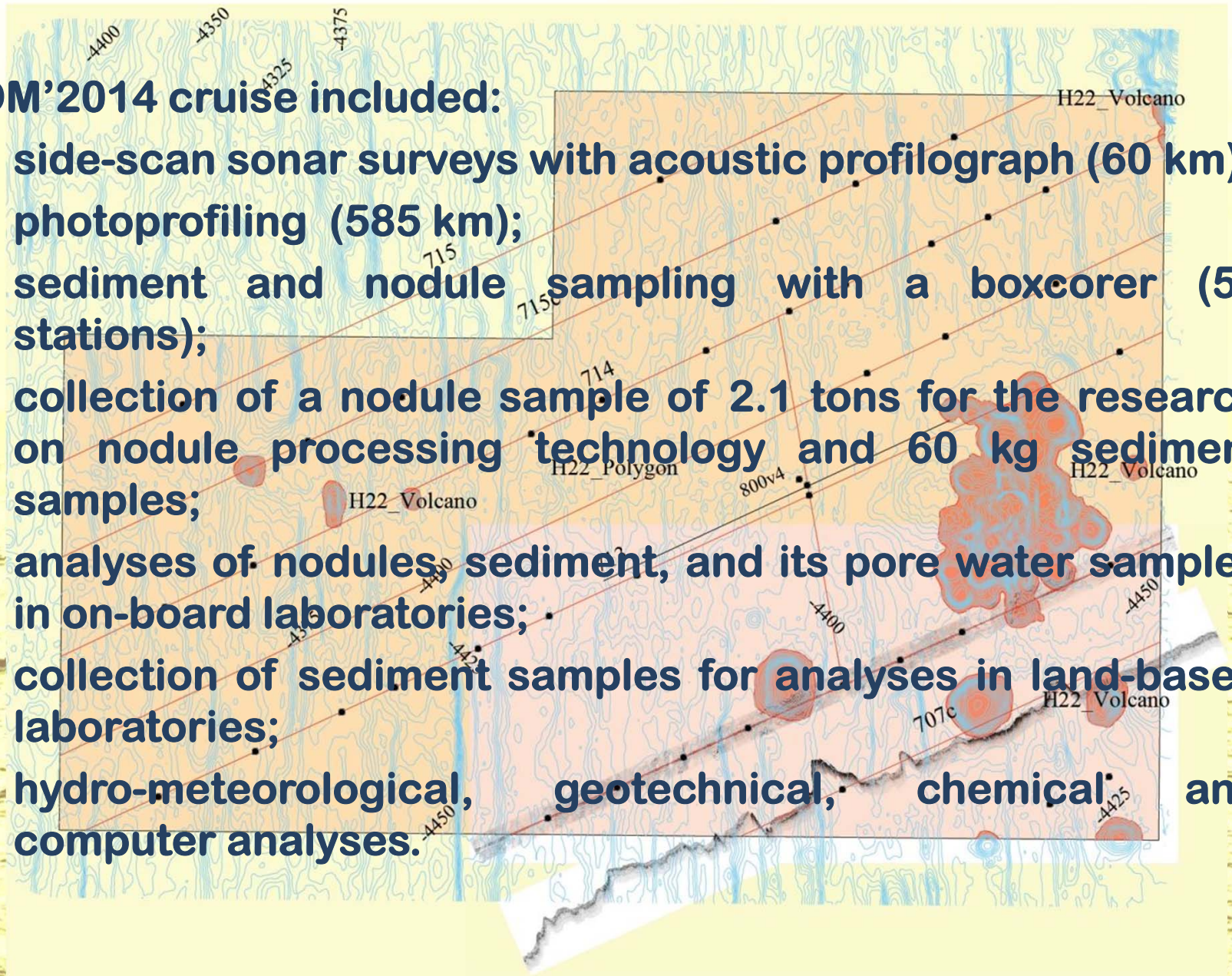
- ✓ side-scan sonar surveys with acoustic profilograph (295.8km);
- ✓ photoprofiling (344.3km);
- ✓ sediment and nodule sampling with a boxcorer (51 stations);
- ✓ collection of a nodule sample of 740 kg for the research on nodule processing technology and a 40 kg sediment sample;
- ✓ analyses of nodules, sediment, and its pore water samples in on-board laboratories;
- ✓ collection of sediment samples for analyses in land-based laboratories;
- ✓ meteorological, environmental, geotechnical, chemical and computer analyses.



2014 exploration project – H22 area – with BIE area in the center



Summary of the 2014 exploration project – the H22 area



IOM'2014 cruise included:

- ✓ side-scan sonar surveys with acoustic profilograph (60 km);
- ✓ photoprofiling (585 km);
- ✓ sediment and nodule sampling with a boxcorer (55 stations);
- ✓ collection of a nodule sample of 2.1 tons for the research on nodule processing technology and 60 kg sediment samples;
- ✓ analyses of nodules, sediment, and its pore water samples in on-board laboratories;
- ✓ collection of sediment samples for analyses in land-based laboratories;
- ✓ hydro-meteorological, geotechnical, chemical and computer analyses.

Resources of H11 area have been estimated, the results from 2014 project are presently under processing. Most likely after the workshop we will consider reestimation for the two united areas. For the time being the results for H11 are ready for reporting.

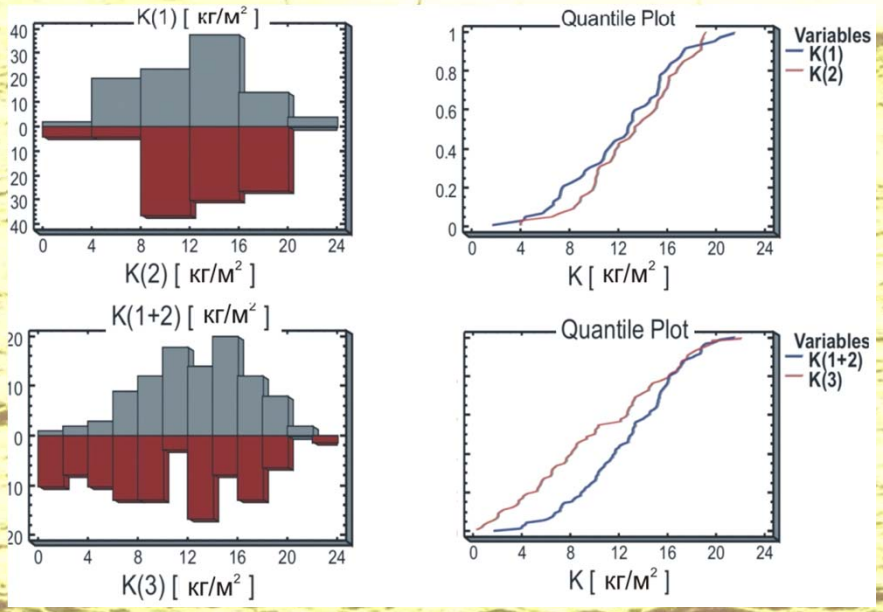
Information was processed using geostatistical methods, with assessment of resources of nodules and metals - manganese, nickel, copper, and cobalt. The analysis was based on sampling carried out in area H11 (5372 km2) in 2009 as well as 2004.

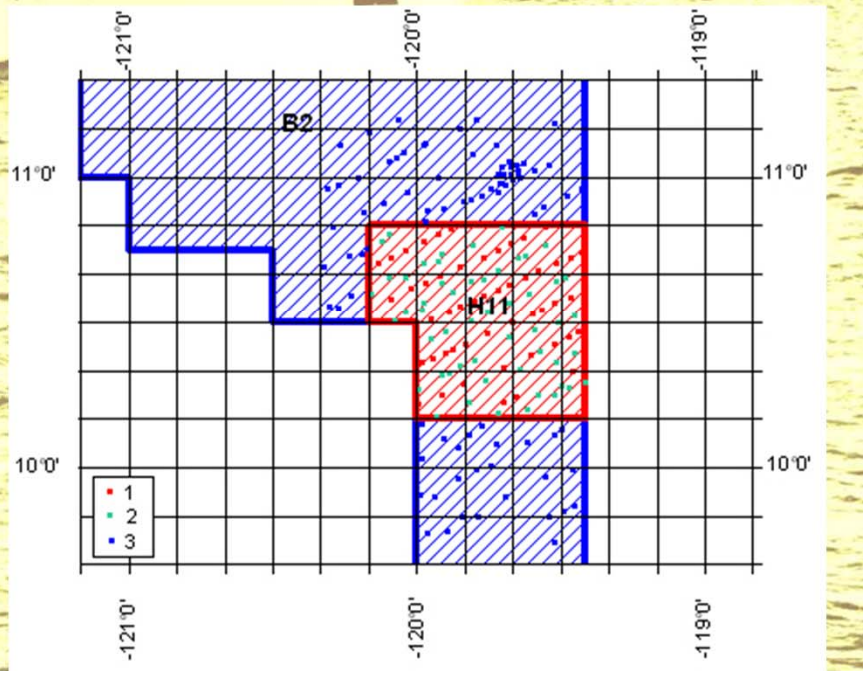
The data processed reflected the wet weight-based nodule abundance and contents of 4 metals (Mn, Ni, Cu, Co) in 101 samples collected with a boxcorer on the two sampling events: 51 samples were collected in 2004 and 50 samples were obtained in 2009; during the latter sampling campaign, areas with slope >7° were contoured.

For estimation the mean nodule abundance and mean metal concentrations as well as nodule and metal resources in the seabedblocks, the ***block kriging*** method was used;

The procedure takes into account:

- ✓ distribution of sampling sites relative to the mining block being sampled and relative to each other,
- ✓ shape and size of the block,
- ✓ structure of the variability of a parameter in question, as expressed with the geostatistical variability model (semi-variogram model).





In area H11, a total of 21 ore deposits were identified; these comprised a total of 66 ore fields (area of 3800 km2) identified for computation purposes. The parameters estimated using the geostatistical model equations applicable to ordinary kriging were:

- ✓ overall resources of polymetallic nodules (wet and dry) and resources of metals, along with estimation of relative standard errors of kriging
- ✓ mean values of ore deposit metrics: nodule and metal abundance as well as percentage concentration of metals
- ✓ resources of polymetallic nodules (wet and dry), along with estimation of relative standard errors of kriging, separately for each of the 66 ore fields identified
- ✓ resources of metals, for each of the 66 ore fields identified
- ✓ mean metal concentrations [%] in each of the 66 ore fields identified.

Resources of polymetallic nodules and metals in area H11

Parameter	Resources	Relative standard error of the estimate (%)
Polymetallic nodules	33.7 MT tonnes (dry) 48.1 MT tonnes (wet)	4.3 4.3
Manganese (Mn)	11 MT tonnes	4.5
Nickel (Ni)	$443*10^3$ tonnes	4.6
Copper (Cu)	$435*10^3$ tonnes	4.3
Cobalt (Co)	$53*10^3$ tonnes	4.6

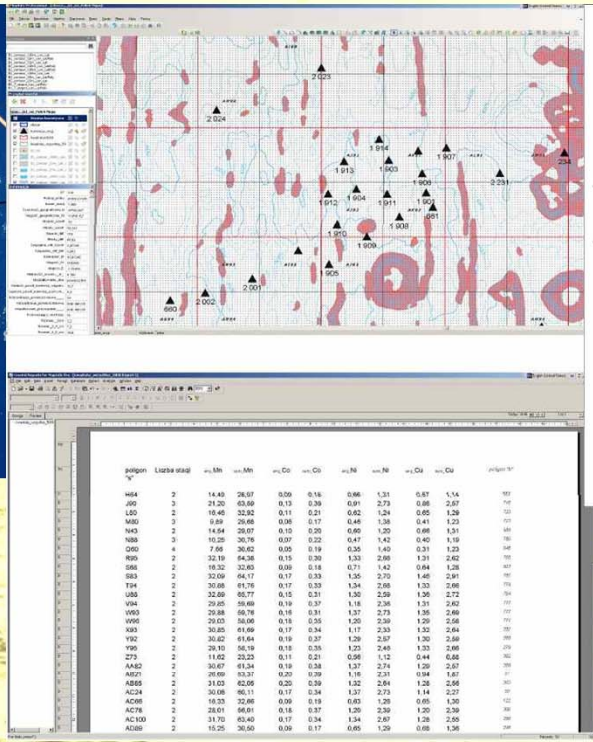
The mean abundance of nodules was estimated for blocks of different surface areas (1x1 km, 10x10 km, and 20x20 km), based on data collected at the first stage of sampling in area H11 as well as on the pooled data from the first and the second stage. The results showed the nodule abundance assessment to be sufficiently reliable for the basic 1x1 km blocks (relative and absolute relative errors of 2.9 and 12%, respectively). For the larger blocks (20 x 20 km), the reliability of assessment was increased (the relative and absolute relative errors of 2.5 and 5%, respectively).

Exploration – information flow – connection between exploration and economic feasibility

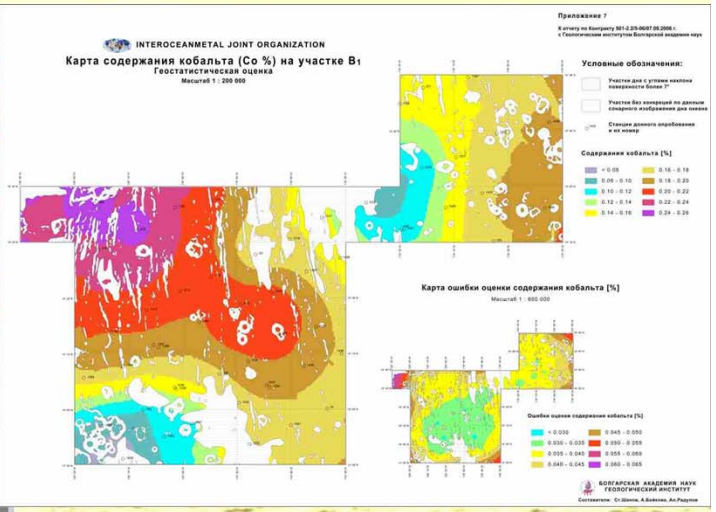
Experiment at sea → **Results processing** → **Documentation**

Sample taken

Nodule abundance
Chemical analysis for metal content analysis

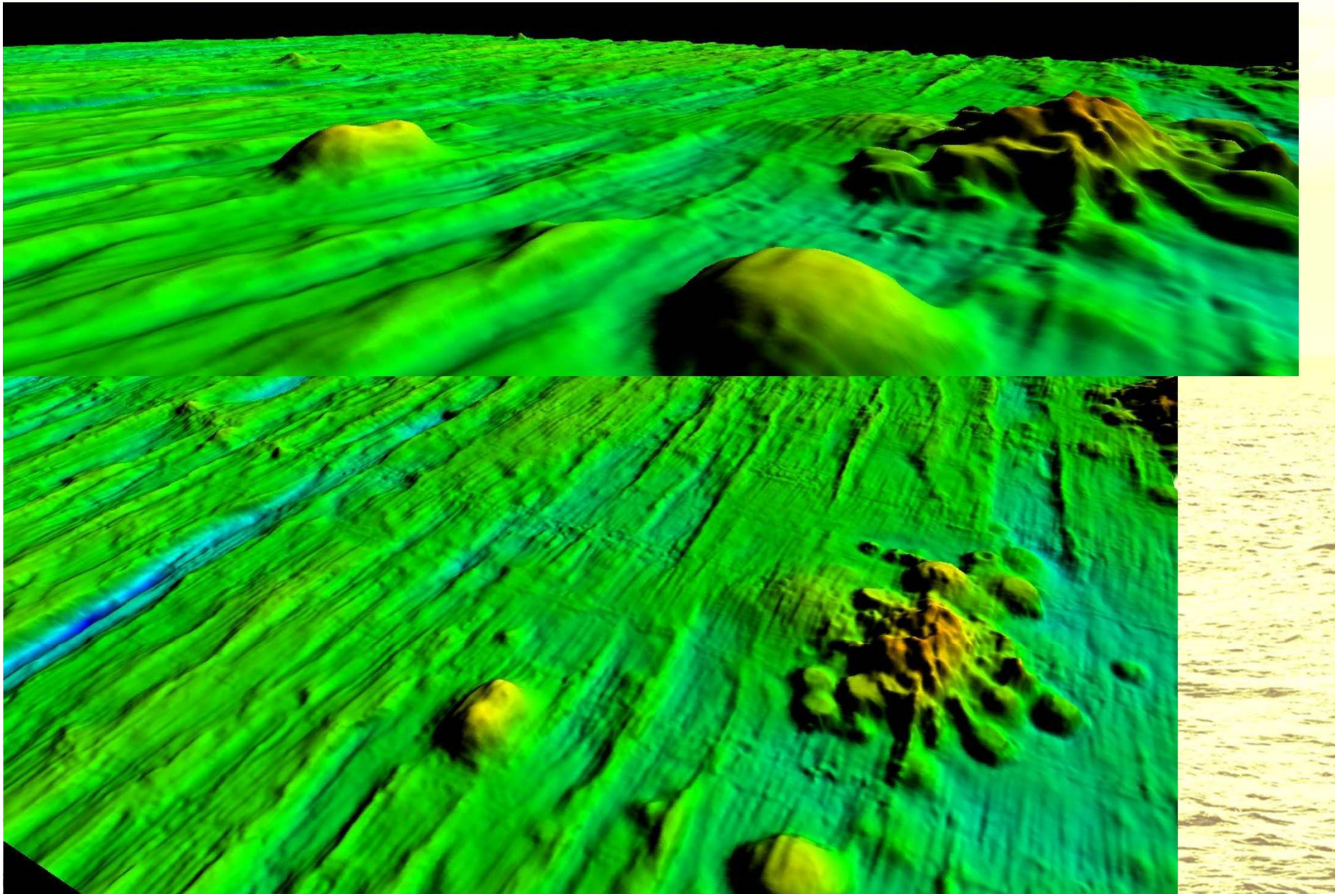


Data processing
GIS database

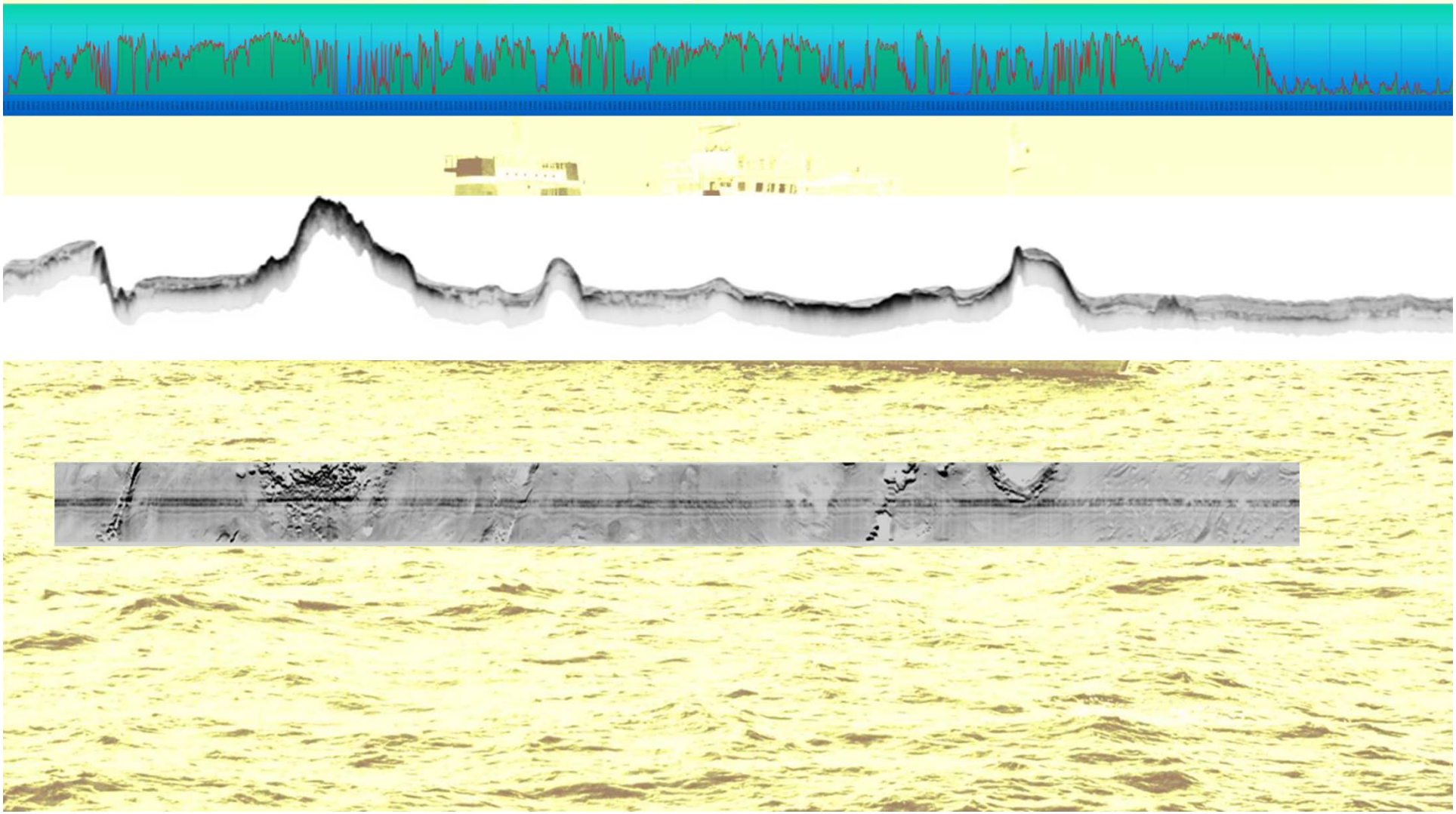


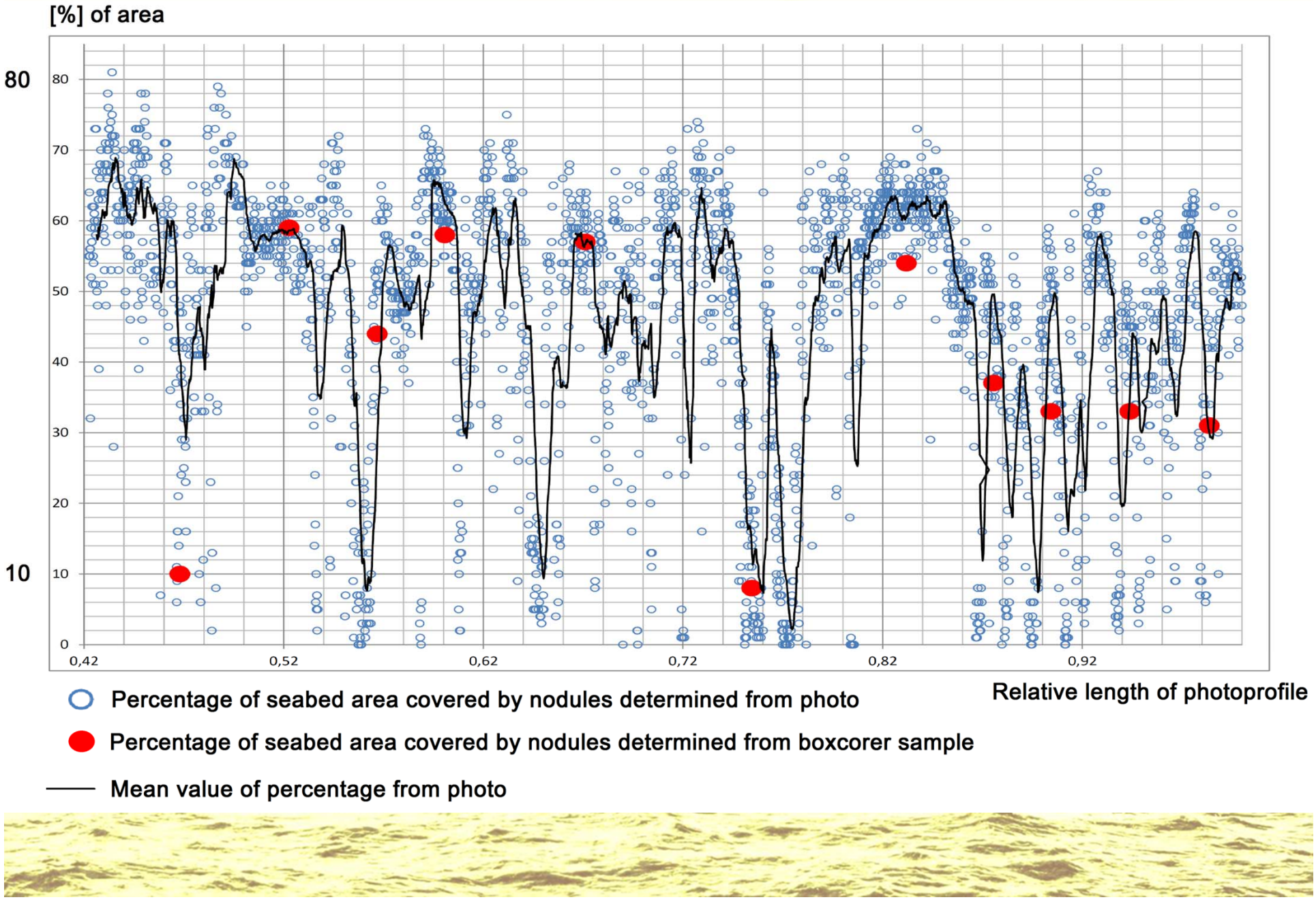
Estimation of nodule resources and metal distribution

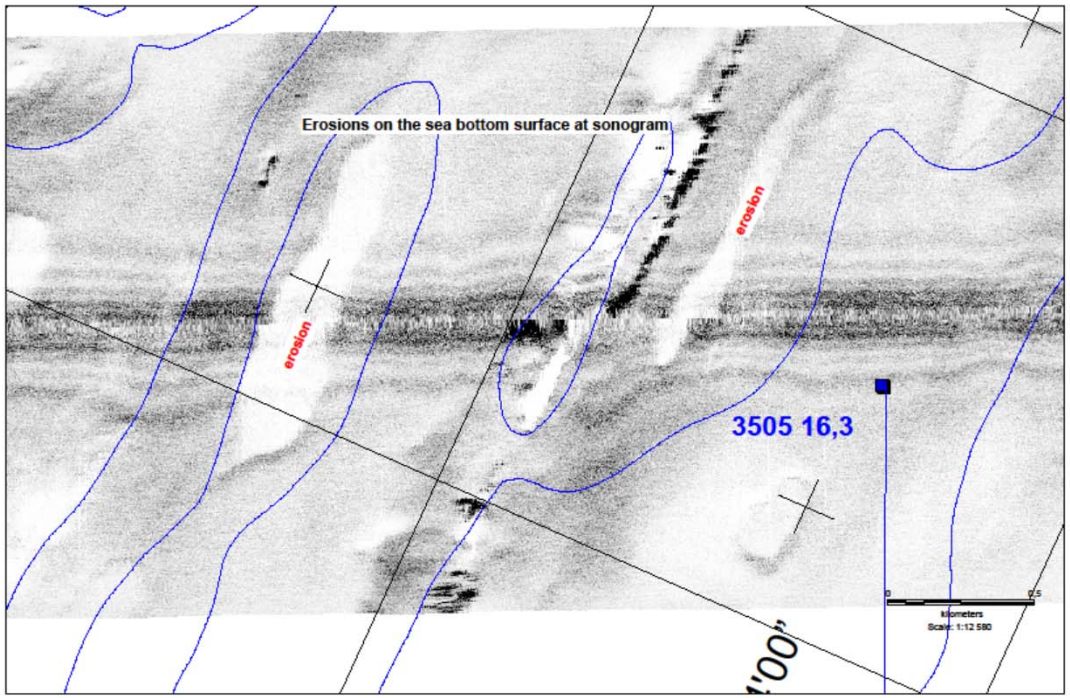
Bathymetry processing



Nodule coverage determined on the basis of digital recognition of photos taken at dense intervals and side scan sonar image



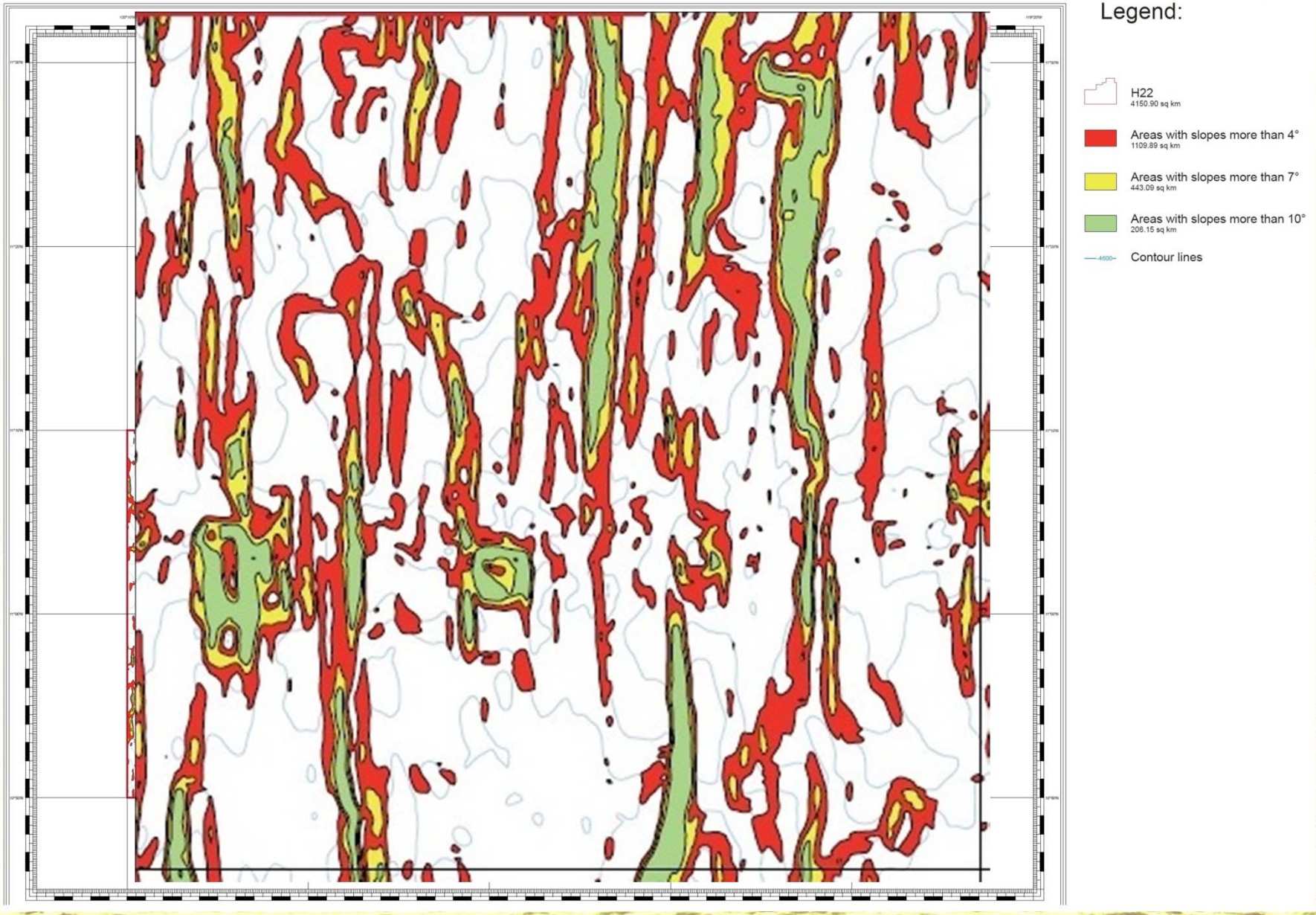

[%] of area
80
10
0
10
20
30
40
50
60
70
80
0,42
0,52
0,62
0,72
0,82
0,92
Relative length of photoprofile
Percentage of seabed area covered by nodules determined from photo
Percentage of seabed area covered by nodules determined from boxcorer sample
Mean value of percentage from photo



Delineation of mining blocks by compiling information from boxcorer, side scan sonar, photo-coverage profiles and bathymetry.

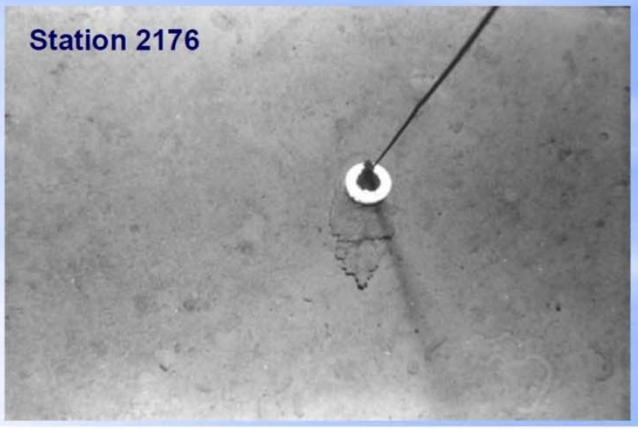
Results are then confronted with boundary conditions such as slope angles, obstalces and cut-off conditions.

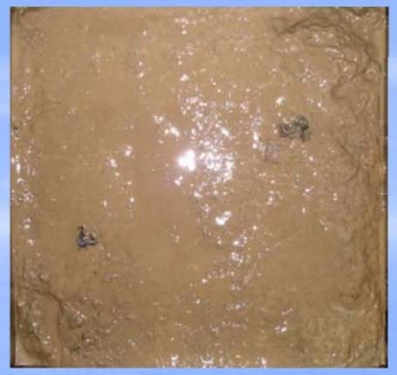
Infuence of assumed slope angle on mining areas.

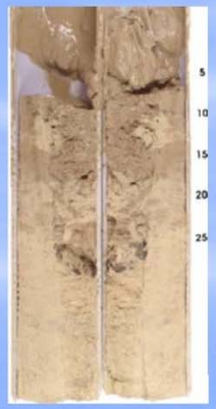


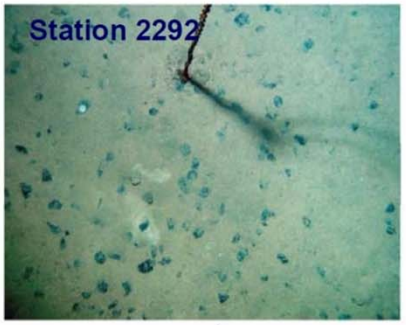
Uncertainity factors – buried and deposit covered nodules

Buried Nodules









A

B

C

D

E

Station 2176: Depth – 4,449 m;

Surface nod. abundance - 0.1 kg/m^2;

Buried nod. abundance - 9.9 kg/m^2;

Station 2292: Depth – 4,530 m;

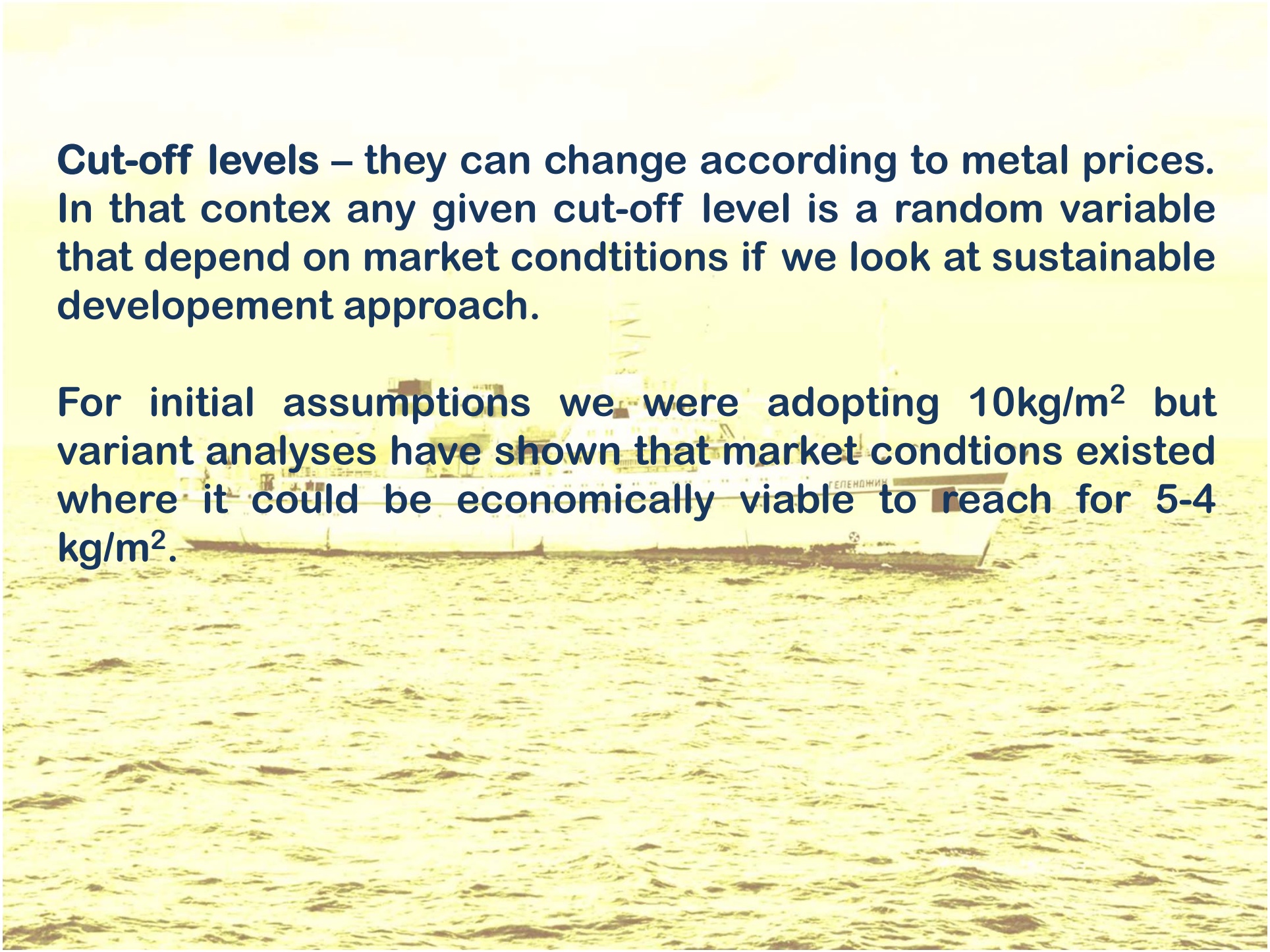
Surface nod. abundance – 8.9 kg/m^2;

Buried nod. abundance - 11.3 kg/m^2

Large sample abt. 2t – 2014 cruise

Production rate – it was adopted earlier that the project would be prepared for the processing of 4 MT of wet nodules yearly. However, in present market conditions we prefer to consider an approach that is based on analysis of various alternatives. Production rate understood as an intitial assumption is a parameter affecting both CAPEX and OPEX. Perhaps an optimization model can be formulated maximizing economic factors with production rate being a design variable. Such approach ensures sustainable developement.

Duration – in terms of geological exploration and various IRR and NPV analyses resources should be indicated for the duration of 15-20 years of production with an option for farther exploration when the production is commenced.



Cut-off levels – they can change according to metal prices. In that contex any given cut-off level is a random variable that depend on market condtitions if we look at sustainable developement approach.

For initial assumptions we were adopting 10kg/m^2 but variant analyses have shown that market condtions existed where it could be economically viable to reach for 5-4 kg/m^2.

Conclusions

The IOM has accomplished several exploration objectives and has sufficient information to formulate a report and comply with any of international and professional standards that are to be adopted by the ISA for the purpose of contract extension. But the KISS would be welcome.

Exploration methods are mature enough to conclude that resources can be estimated with sufficient reliability and accuracy. Innovative techniques can improve the process. Modern statistical methods do not require regular grid and developments of exploration procedures like AUVs or underwater laser scanning and recognition can improve the efficiency.

But can we move up to reserves without a pilot mining experiment?

Do the previous mining experiments from 70's and 80' give us sufficient information?

The results of those experiments have proved explicitly technical and functional feasibility but there is lack of reliable economic factors especially in present market conditions.

In parallel to a mining experiment environmental monitoring should be commenced. The environmental concern is one of the most important from the list of the MODYFYING FACTORS for deep sea mining. It has mostly a nature of psychological barrier and the results are expected to give evidence that deep sea mining is less harmful for the environment that some of the land-based projects.

What does it mean „a pilot mining experiment" for a deep sea mining project?

DoE (Design of Experiment) parameters:

- ✓ **Expected productivity**
- ✓ **Duration**
- ✓ **Maneuvering abilities and efficiency of a collector**
- ✓ **Operational requirements and safety factors**
- ✓ **Size and type of affected area**
- ✓ **Scope of environmental investigation**
- ✓ **Reliability issues**

Collaborative work of contractors the ISA itself?

Thank you very much.