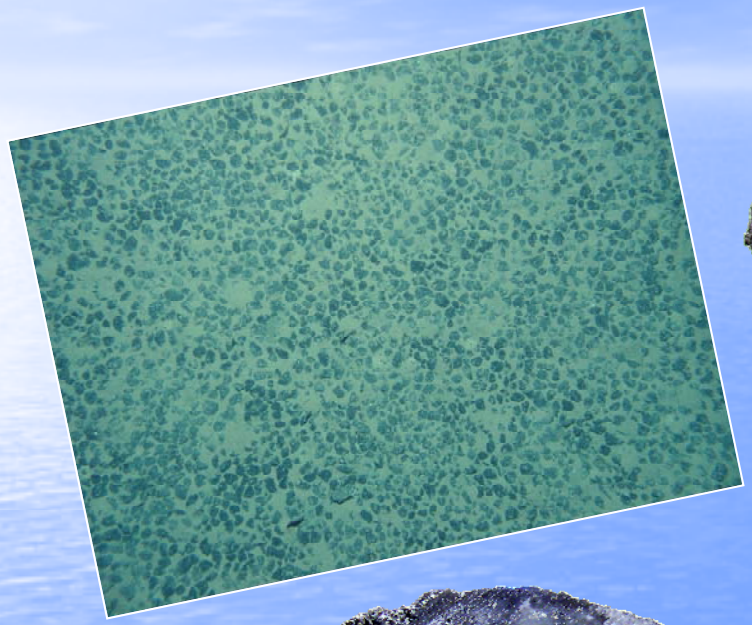
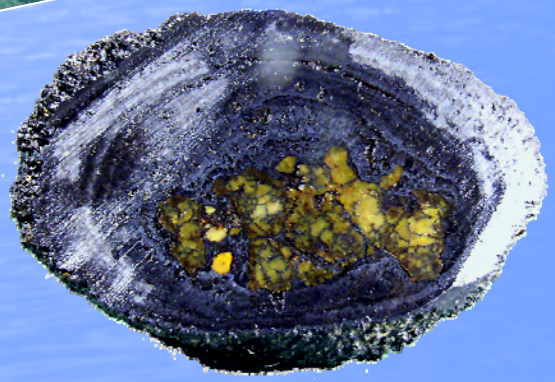
RELATIONSHIP BETWEEN NODULE COVERAGE, MORPHOLOGY & DISTRIBUTION IN THE EASTERN CCZ





R. Kotlinski and V. Stoyanova
[1]Interoceanmetal Joint Organization, Szczecin, Poland
[2]Institute of Marine Science, University of Szczecin

Outline

- **Objectives:**
  - Establishment the relationship between nodule coverage and abundance and the depths of the sea bottom and its morphology in the eastern part of CCZ
  - Estimation of the regional variability of nodule abundance and coverage vs water depth and seafloor morphology
- **Basic Parameters:**
  - Nodule coverage (%);
  - Nodule abundance (kg/m^2);
  - Types of nodules and their distribution;
  - Mn/Fe ratios
- Resent research of the Interoceanmetal Joint Organization (IOM) in the exploration area

Study Area

Area ~ 810,000 km^2

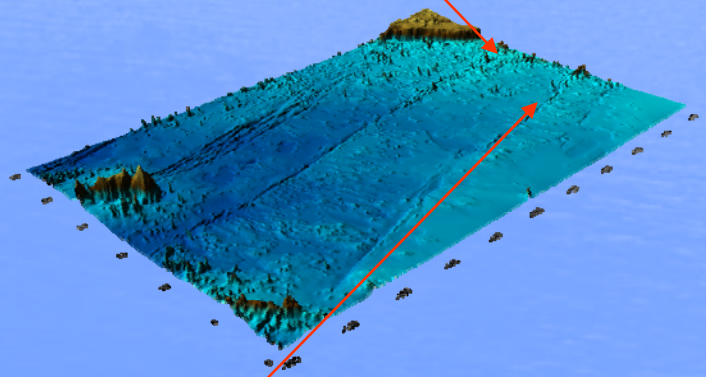
Latitude:

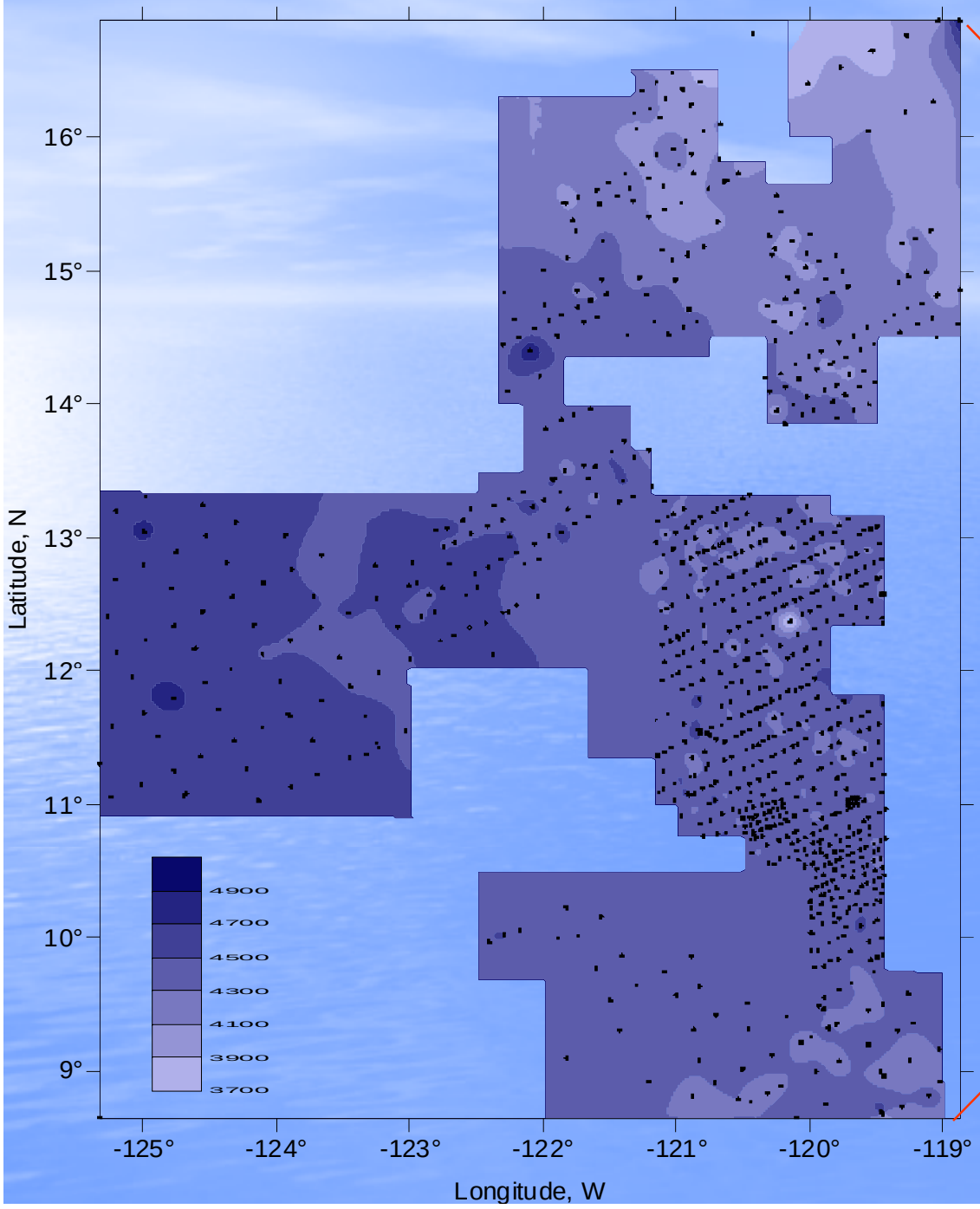
8^{0}38.77’ - 16^0 52.76’N

Longitude:

118^{0}52.5’–125^0 19.75’ W

Depth: 3,470 - 4,940 m



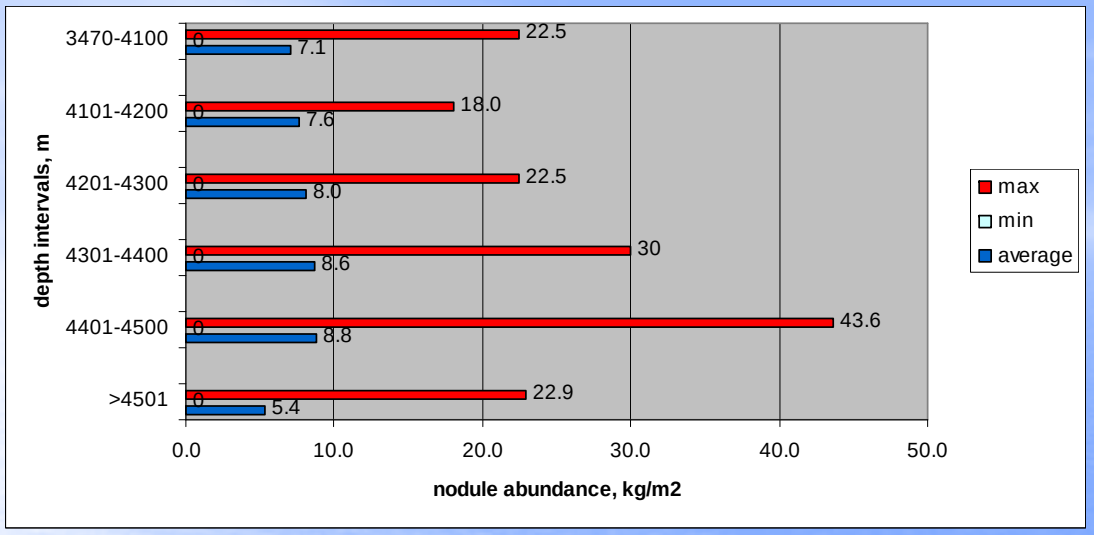


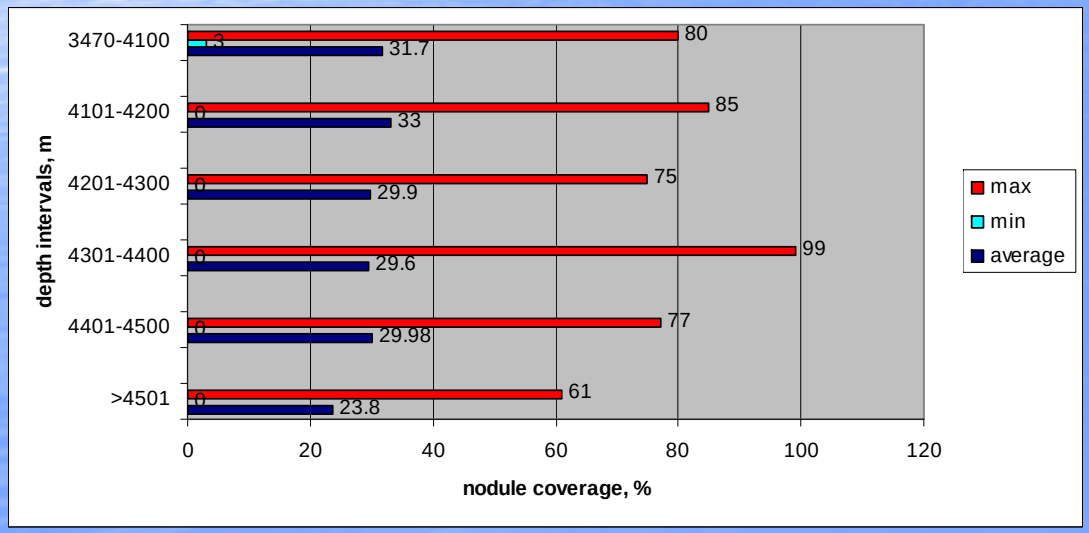
Amount of Stations used:

985

Sampled by IOM during 1990 – 2009 period

Nodule Abundance and Coverage vs Water Depth





Nodule abundances:

mean 8.27 kg/m^2

max of 43.6 kg/m^2;

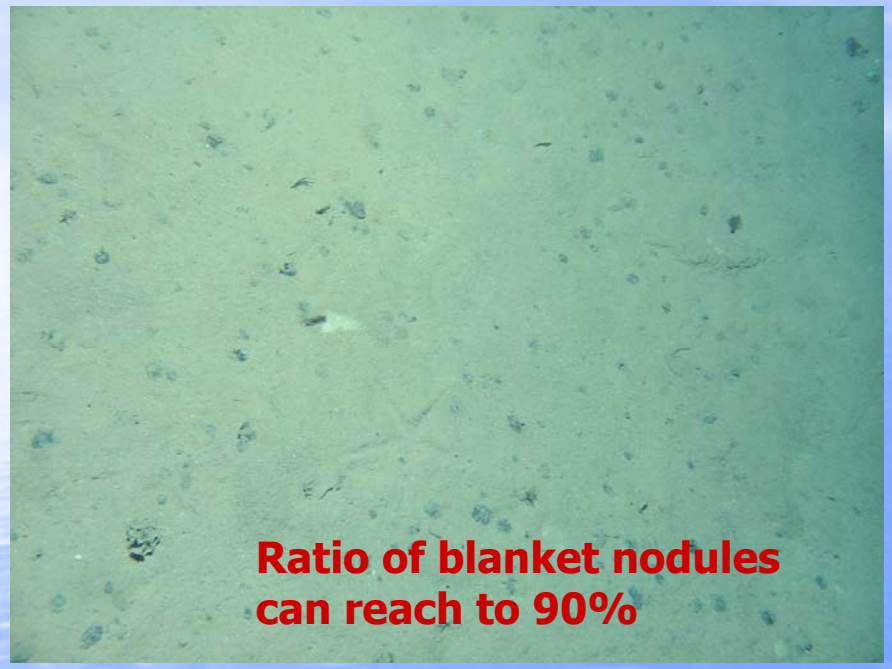
At 372 (about 38 %) stations abundance was higher than 10 kg/m^2.

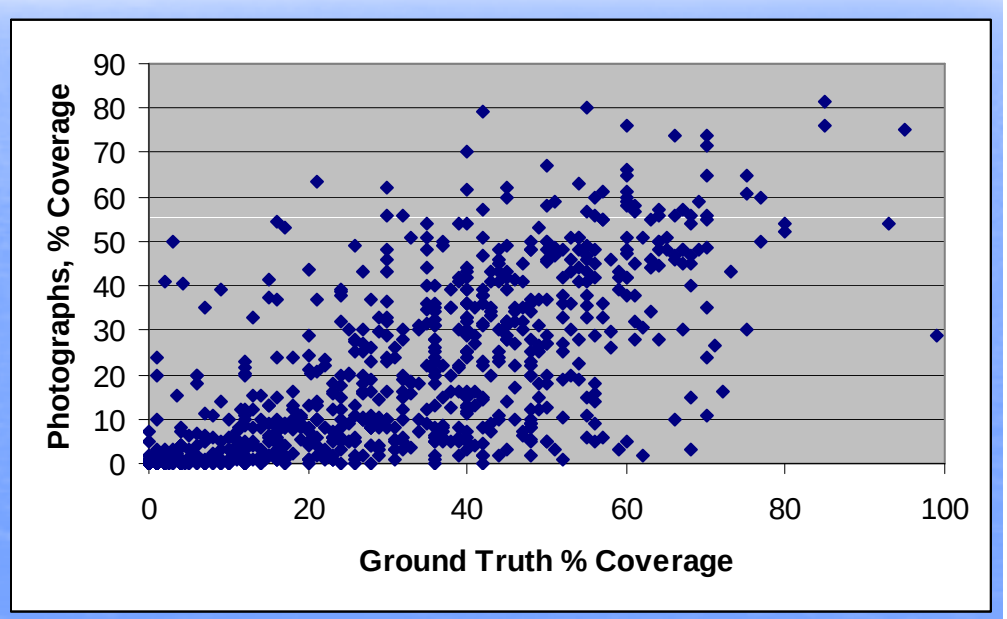
The most productive depth intervals: 4,300 – 4,500 m

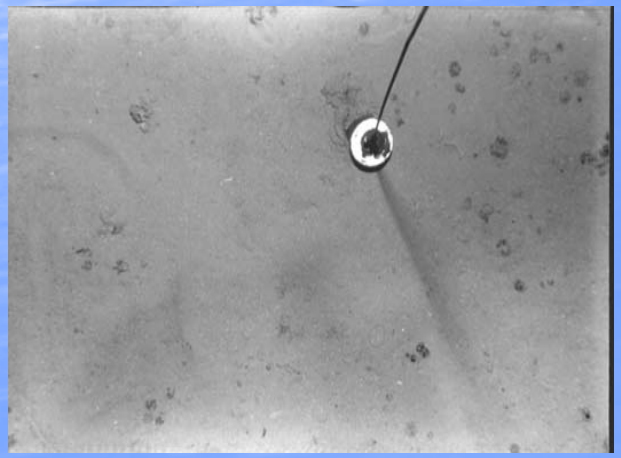
Nodule coverage varied between 0 to 99%

The highest nodule coverage were observed within 4,300-4,400 m

Nodule Coverage Determined from Photos and Sample Recoveries

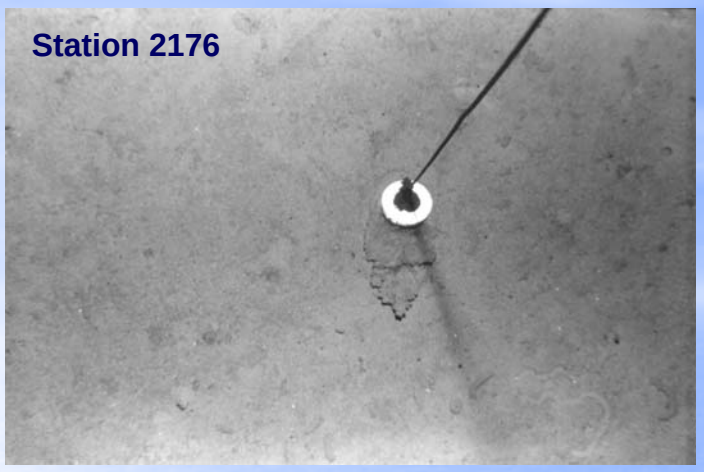


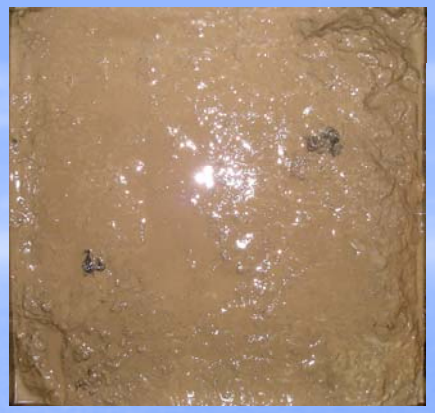


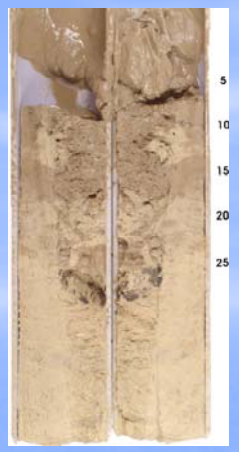


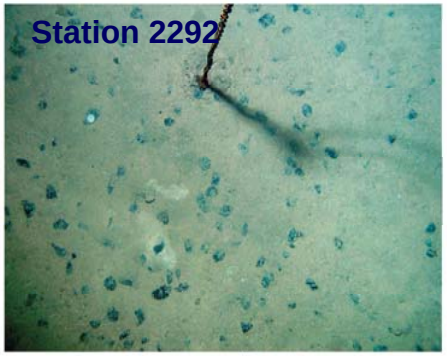
Nodule blanketing by the sediment is a more characteristic feature of the northern part

Buried Nodules









A

B

C

D

E

Station 2176: Depth – 4,449 m;

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

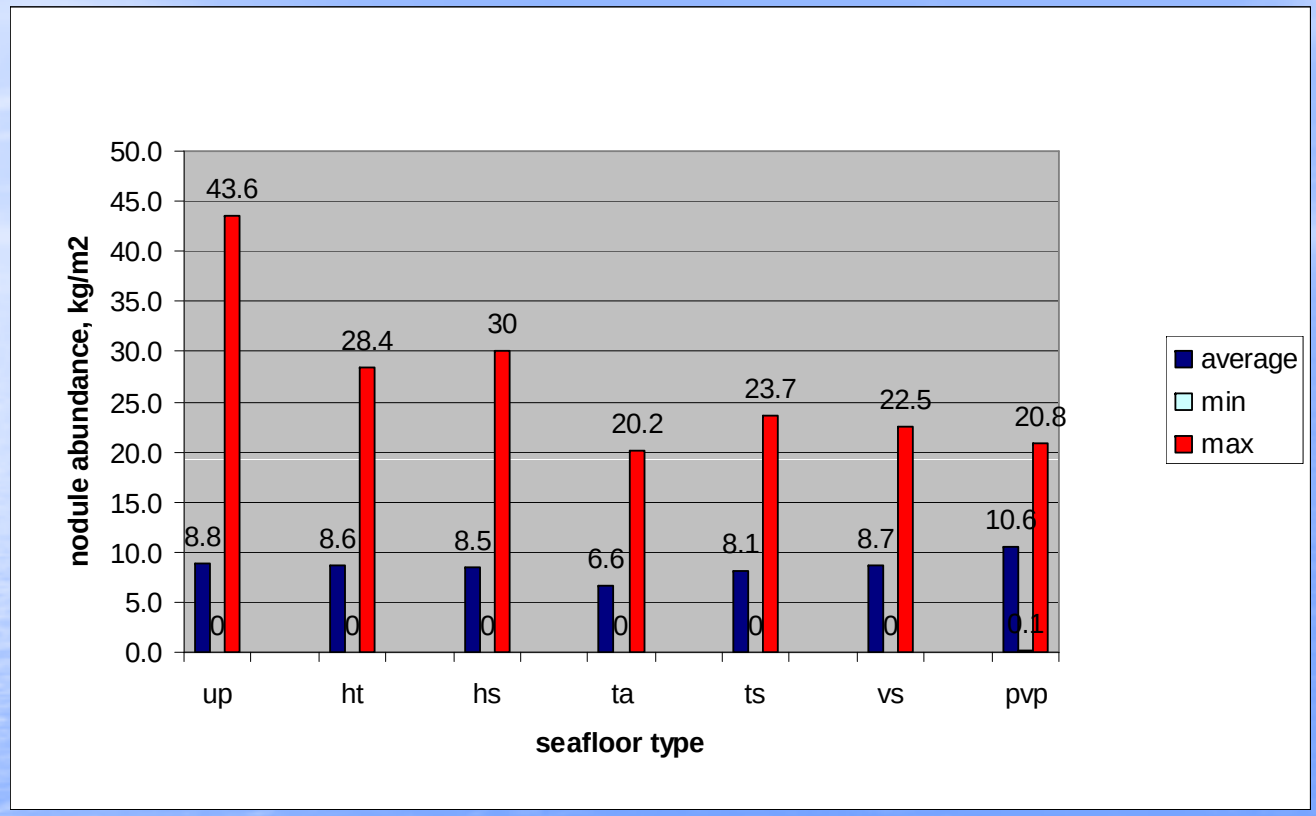
Buried nod. abundance - 9.9 kg/m^2;

Station 2292: Depth – 4,530 m;

Surface nod. abundance – 8.9 kg/m^2;

Buried nod. abundance - 11.3 kg/m^2

Nodule Abundance and Seafloor Morphology



In general, stations that yielded high nodule abundance were found on all types of seafloor morphology.

A total of 372 stations with nodule abundance > 10 kg/m^2:

- **151 (about 40%) occurred on undulating plains;**
- **89 (24%) on horst slope areas, and**
- **56 (15%) on trough slope areas.**

The remaining 96 stations were distributed among the other seafloor types.

Genetic Types of Nodules

H- hydrogenetically grown,

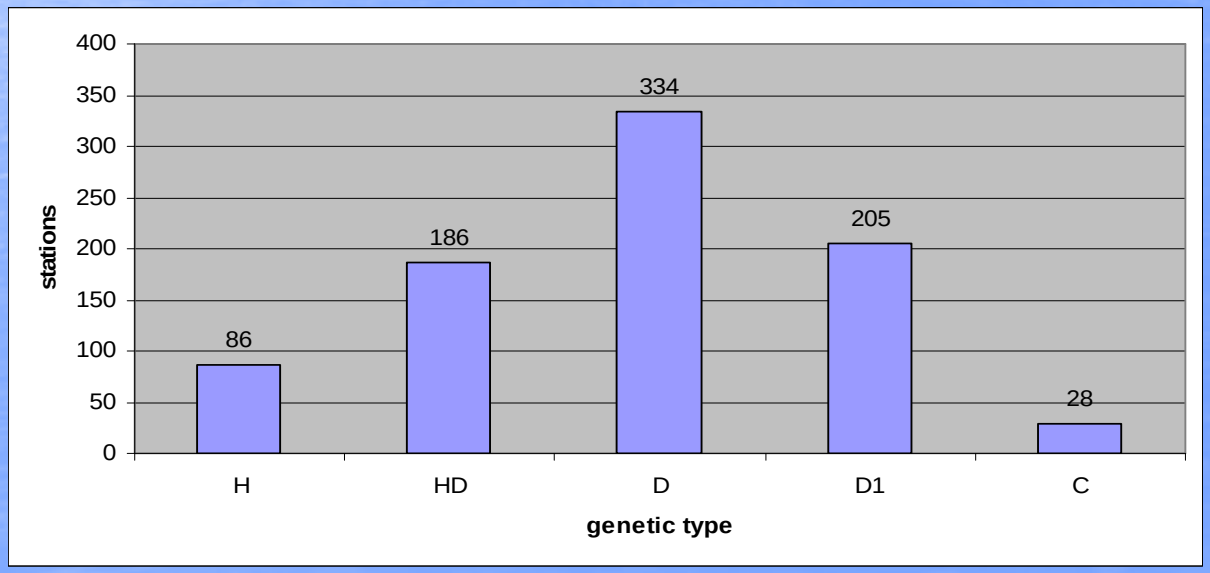
HD- hydrogenetic-diagenetically grown (Mixed Type),

D- diagenetically grown

(Mn - 30±1%, Ni - 1.4±0.1%, Cu - 1.2±0.1%);

D_1- diagenetically sub-type *(Mn ≤ 33%, and Cu>Ni),*

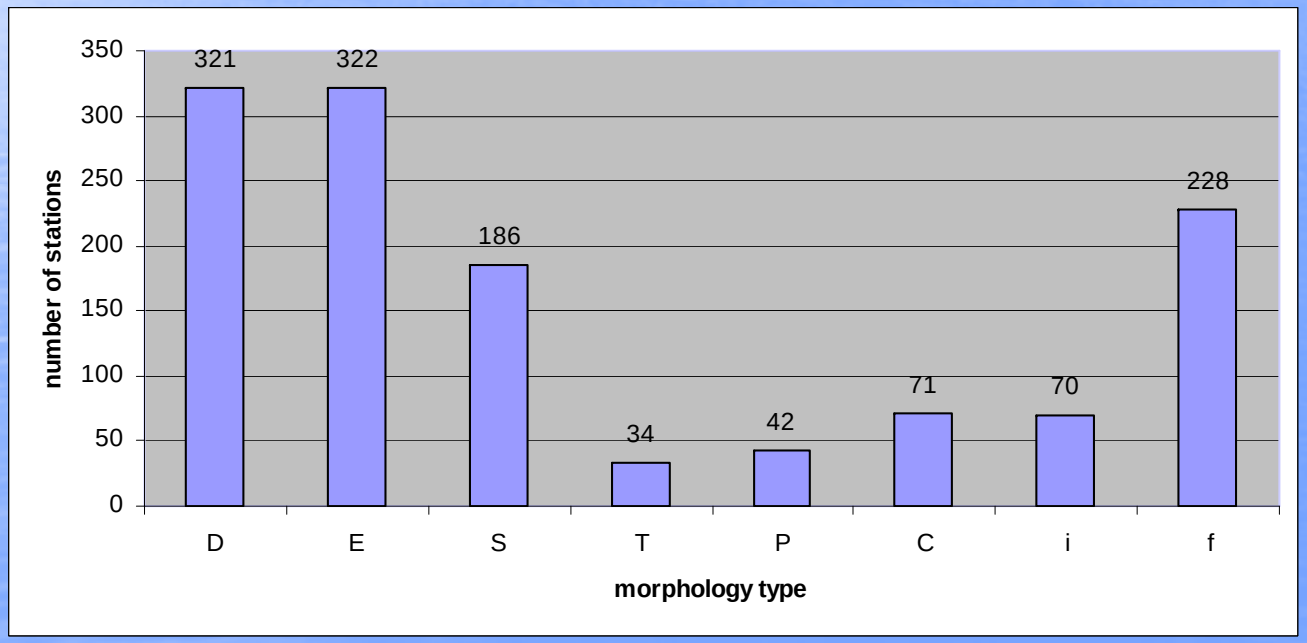
C- crusts, grown on hard substrates



Histogram of Genetic Nodule Types in the Eastern CCZ

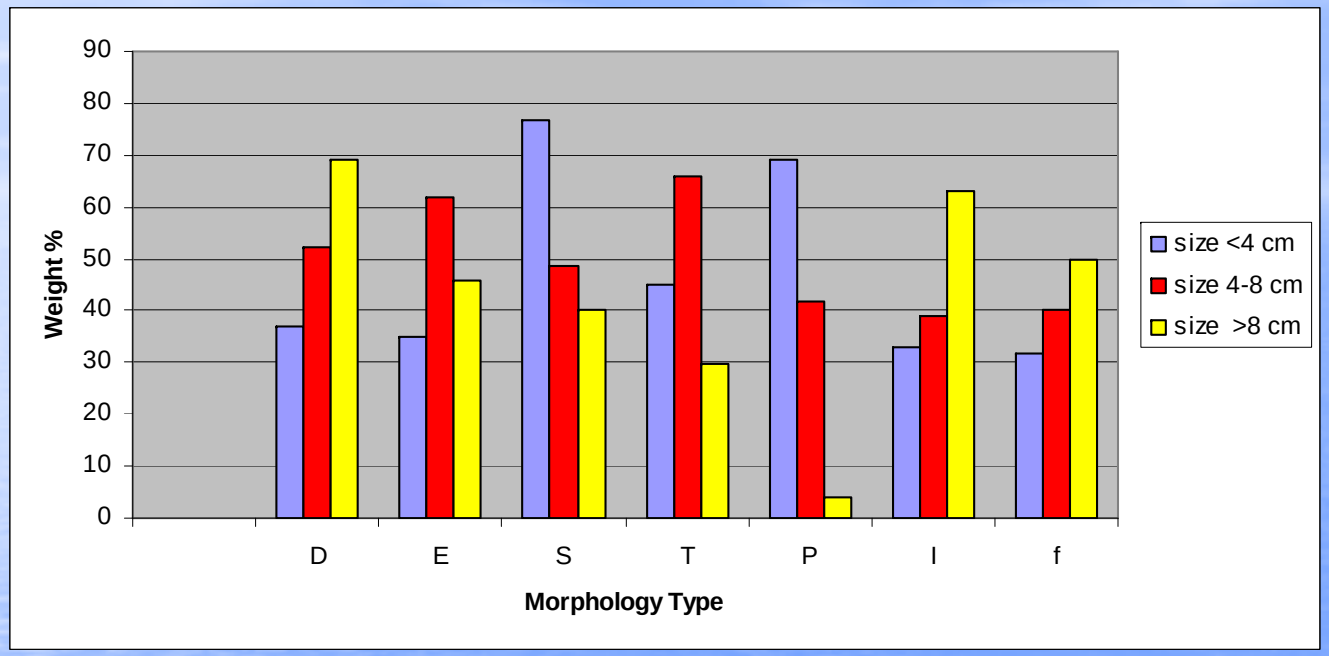
Morphological Types of Nodules

- D, discoidal,
- E, ellipsoidal,
- S , spheroidal,
- T , tabular,
- P, poly-nucleic aggregate,
- I, irregular shaped, and
- f , fragments.



Histogram of Nodule Morphology Types

Nodule Size Distribution vs Morphology



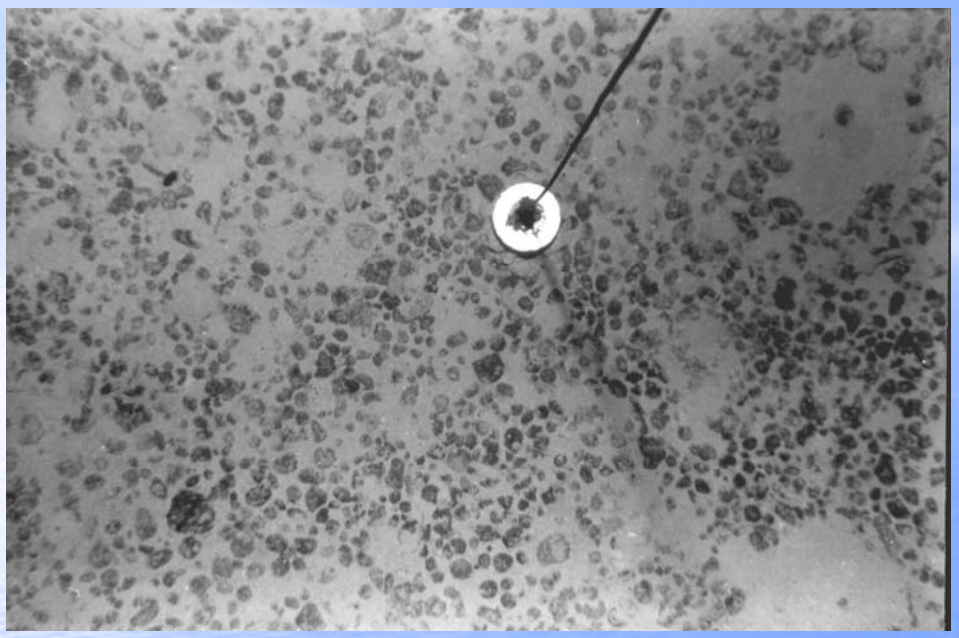
Size class of nodules < 4 cm is dominant for spheroidal and poly-nucleated aggregate;
Size class 4 – 8 cm is dominant for ellipsoidal and tabular;

The largest nodule size (>8 cm) is dominant for discoidal and irregular types and their regenerated fragments.

Hydrogenetically Grown Type (H)

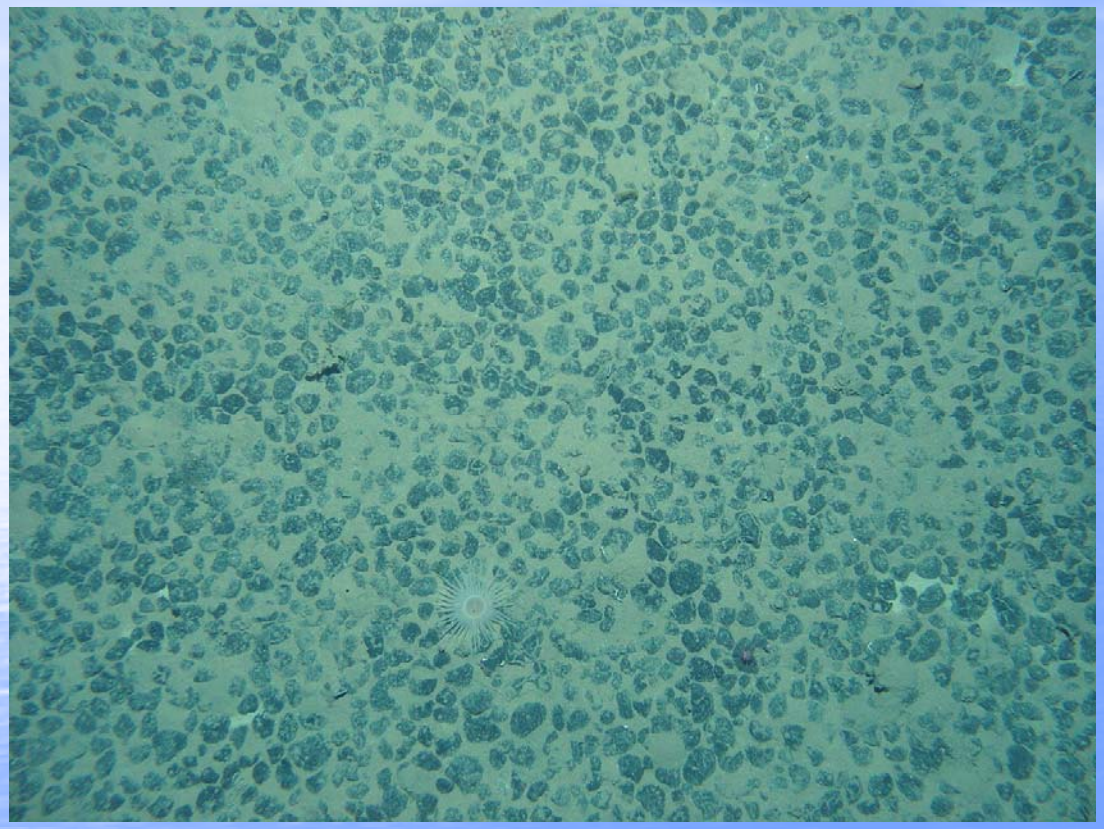
Small size - usually 2-4cm; smooth top and underside; spheroidal, poly-nucleic aggregate ; nucleus: multi type, volcanic clastic, bioclasts; Mn/Fe < 3.

Hydrogenetic-diagenetically Grown Type (HD)



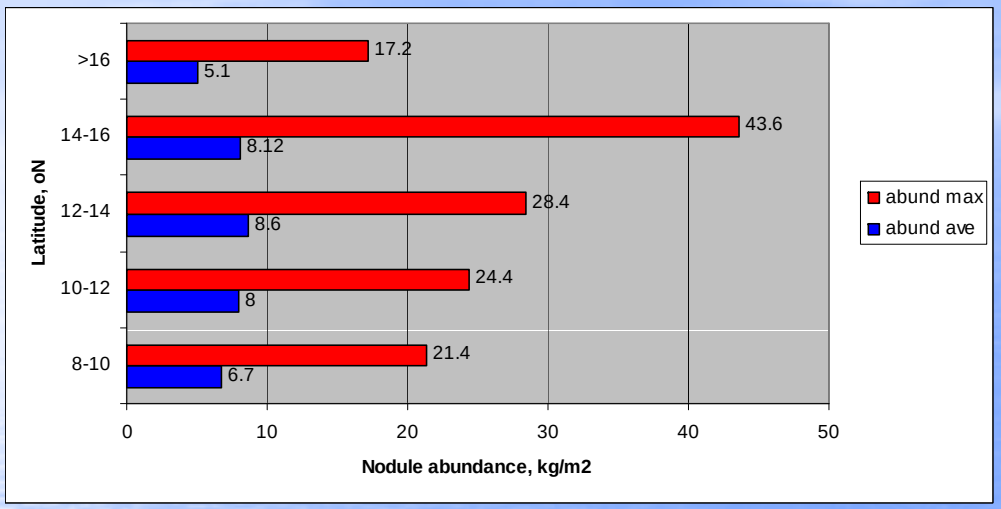
Usually medium size – 4-8 cm; smooth topics and a rough underside; ellipsoidal, discoidal, tabular types; nucleus – lithified sediments (clayey-zeolitic), bioclasts; Mn/Fe >3<5.

Diagenetically Growth Type (D)

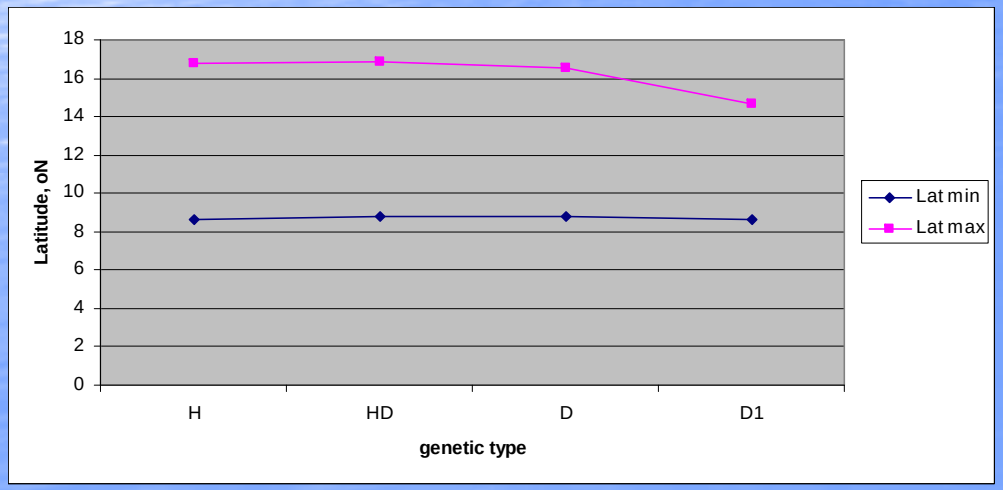


Size from 6 up to 12 cm and more; topside is rough or botryoidally, underside is rough; discoidal, ellipsoidal, irregular morphotypes are dominant; nucleus – fragments of older nodules, micronodules; Mn/Fe>5

Regional Variability of Nodule Abundance and Genetic Type

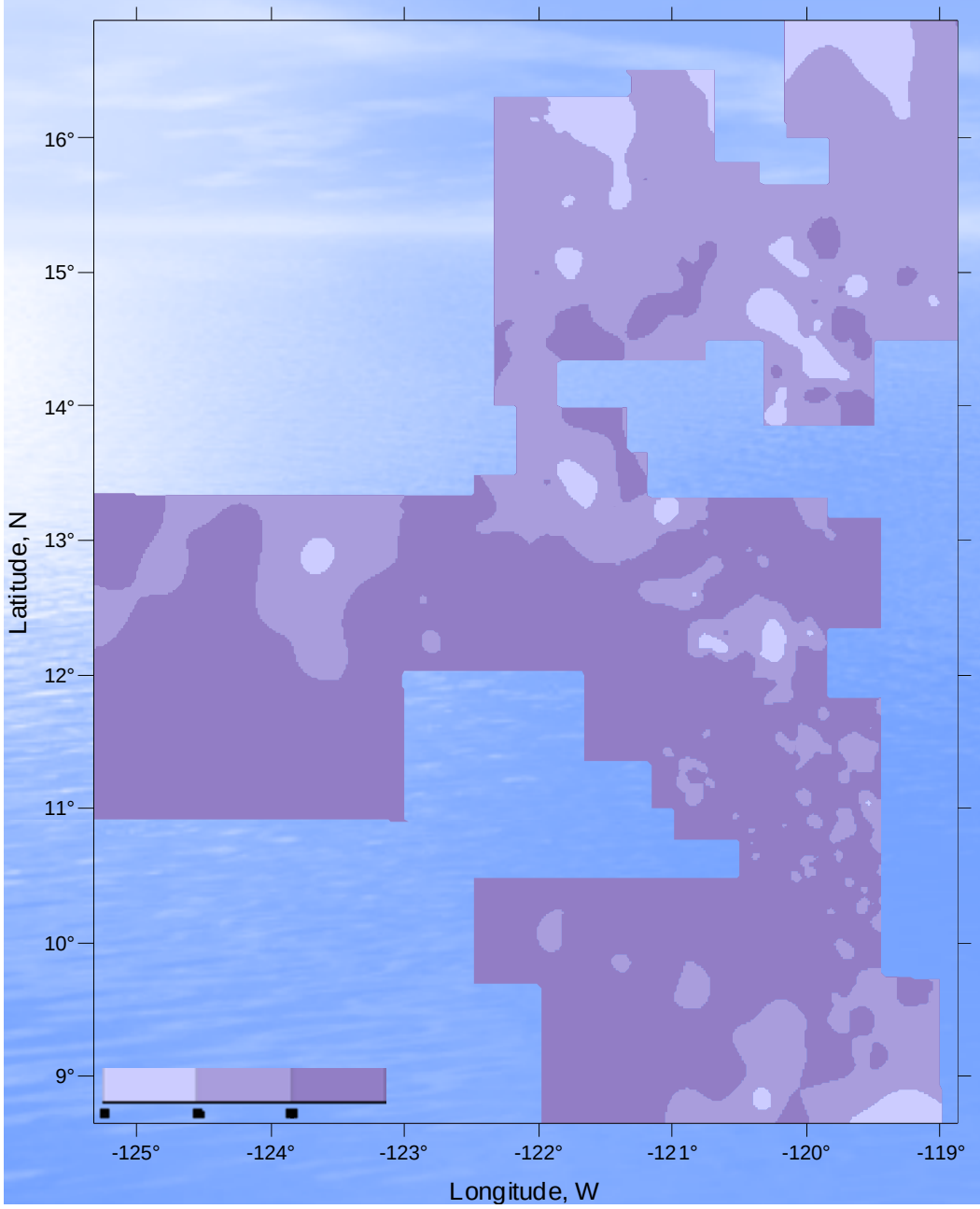


The most productive stations (with the highest mean abundance and with the highest maximum value) were situated between 12 – 16^0 N



Types H, HD, D were most uniformly distributed within the latitude range of 8.66 – 16.88^0 N, while the diagenetically grown sub-type D_1 decrease range of occurrence to 8.65 - 14.63^{0}N.

Mn / Fe Ratios



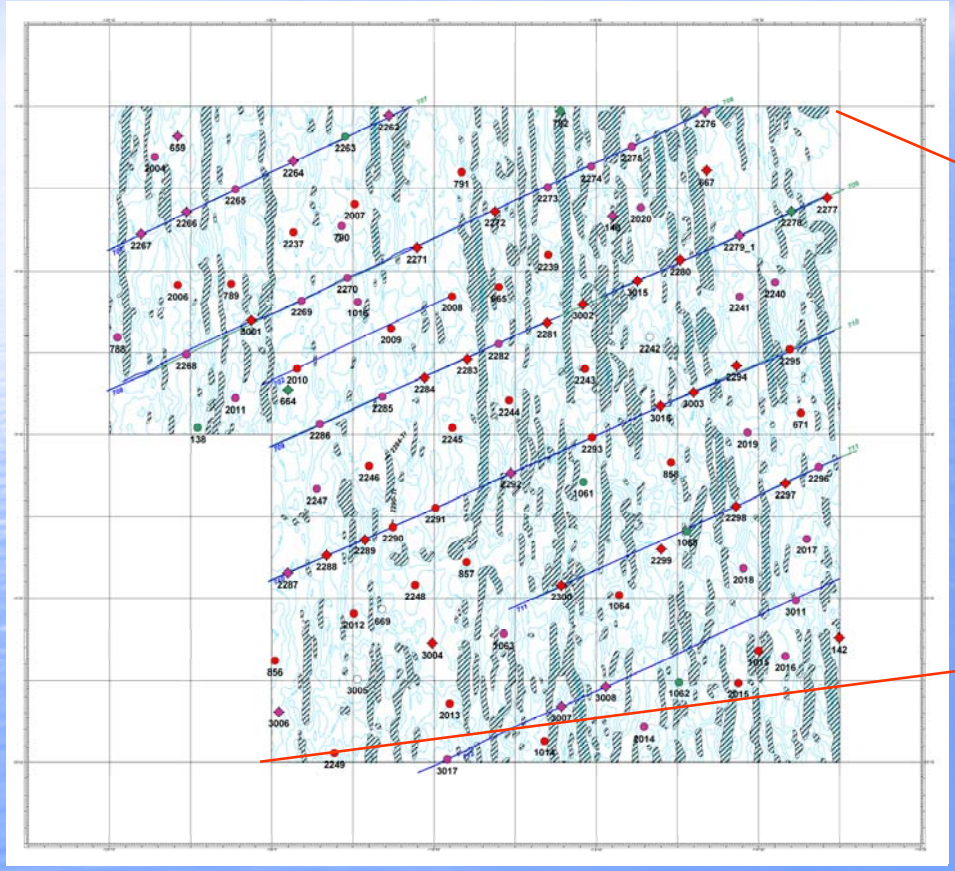
Mn/Fe (around 3) in the most northern part of the study area, and in general increases toward southern part.

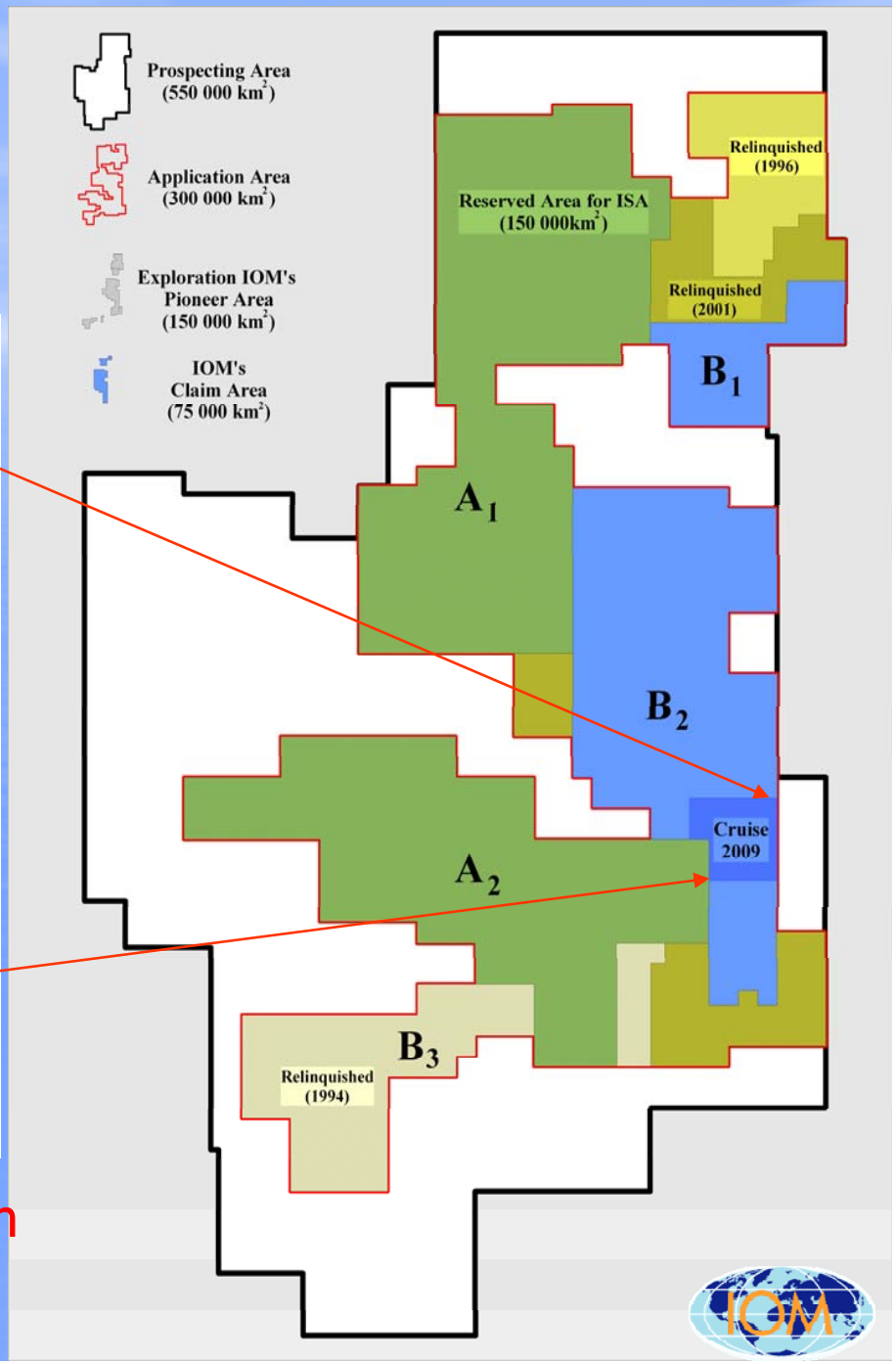
Mn/Fe	No stations	Nodule Abundance (kg/m^2)		
		Mean	Min	Max
< 3	61	8.5	0.1	21.4
3 - 5	283	8.2	0.06	43.6
> 5	509	10.9	0.1	30

The highest Mn/Fe ratio corresponds with the highest mean nodule abundance.

IOM '2009 cruise

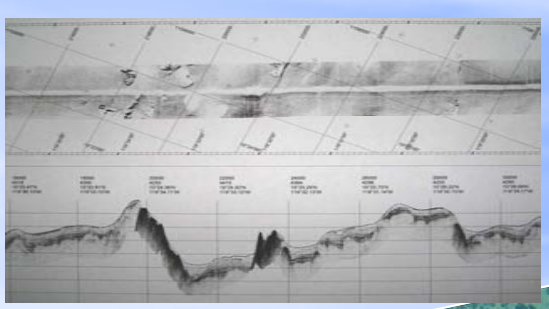
IOM exploration area in the eastern part of Clarion-Clipperton Zone (75 000 km$^{2)}$.

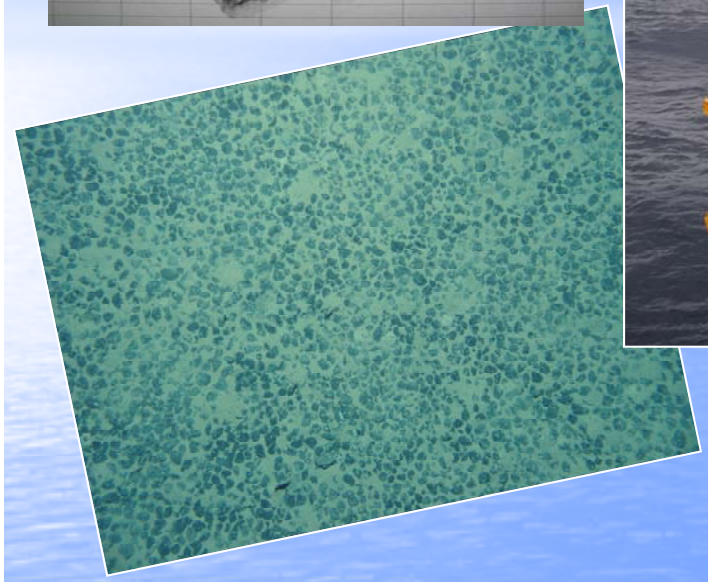




Selected prime site for detailed exploration (IOM'2009) covers about 4000 km^2

IOM'2009 geological exploration





- bathymetric survey (multi-beam echo-sounder system);
- deep-tow photography survey (digital format);
- bottom sampling and analysis of physical, mechanical and chemical properties of sediments and nodules.

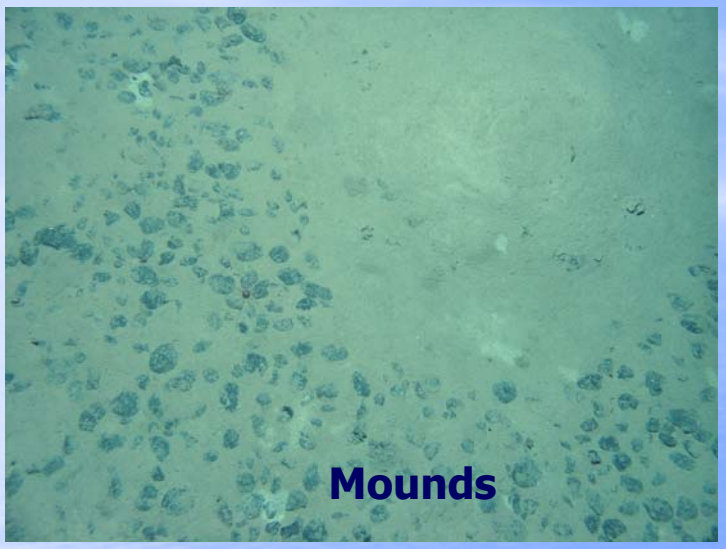
IOM'2009 environmental research

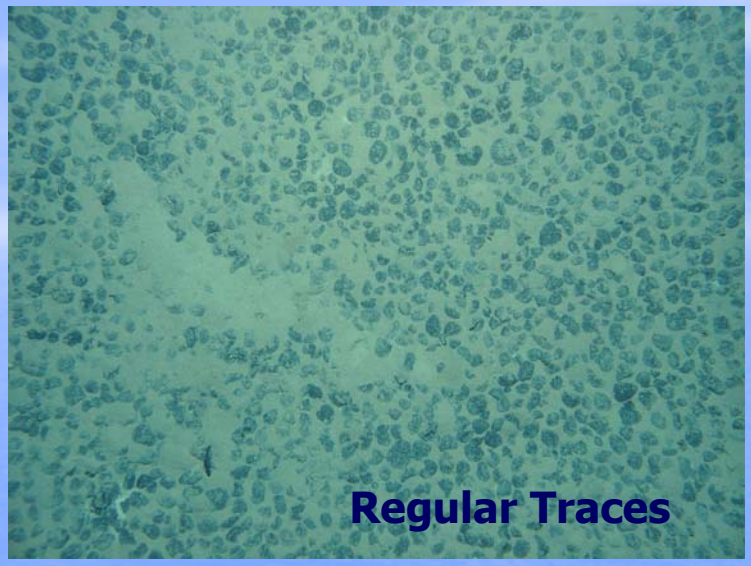
- establishment of baseline in the exploration area
- development of monitoring program

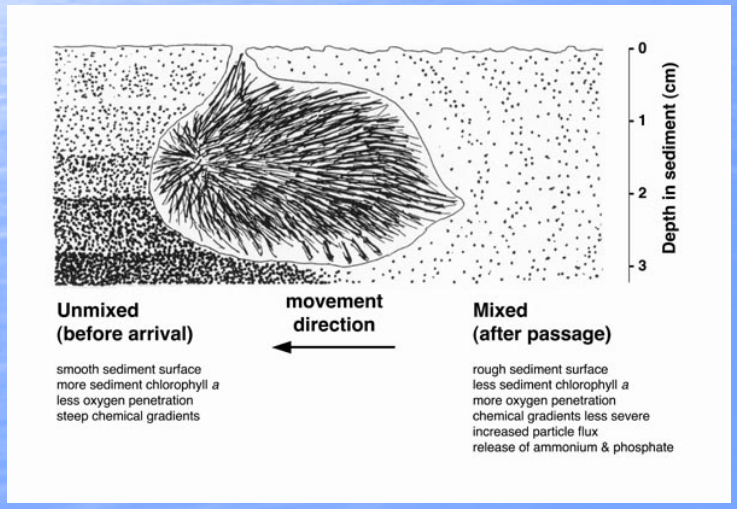
Mineability of nodules in the IOM area

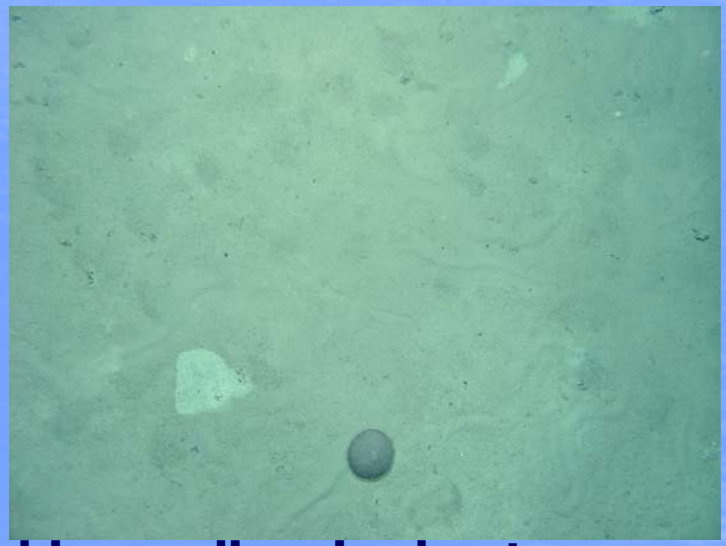
- The estimation of nodule resources, as well as a basic metals tonnage and their contents of Ni, Cu, Co, Zn, Mo, and Fe within the IOM's area was accomplished by Ordinary Kriging method.
- The ore is assumed to contain Mn – 31.3%, Ni – 1.31%, Cu – 1.18%, and Co - 0.18%; also: Mo – 0.056%, and Zn – 0.141%.
- The key parameter for assigning a station to standard category was nodule productivity as assessed with the nickel equivalent content ($\geq$0.35 kg/m^2).
- The monetary value of products of mining and processing the commercial ore within the contoured indicated nodule resources of the IOM exploration area was calculated for different indices of ore-bearing (1.0, 0.7, 0.6, 0.5), exhaustion (5, 10, and 15%), and losses on mining and transport (20, 30, and 40%).
- As shown by the calculations, the supply of commercial ore for a future mining enterprise processing 3 million tonnes dry nodules, at the worst-case scenario of geological and mining conditions, should support the enterprise's operation for more than 30 years.

Biological Activity & Nodule Distribution









Volume of the sediments displayed by Echinocardium is about 20,000cm^3/m^2/day (Lohrer et al.,2004; www.niwascience.co.nz)

Conclusion Remarks:

- The eastern part of the CCZ area features all the genetic and morphological type of nodules known in the entire region;
- Diagenetically grown type D (and D_1 sub-type) are dominant;
- Size class 4 – 8 cm is dominant for ellipsoidal and tabular, while the largest nodule size (>8 cm) is dominant for discoidal and irregular types and their regenerated fragments;
- Analyse show that highest nodule coverage were observed within 4,300-4,400 m;
- The highest nodule abundance were observed in the seafloor depth range of 4,400-4,500 m;
- The most productive stations (with the highest mean abundance and with the highest maximum value) were situated between 12 – 16^0 N;

Conclusion Remarks (cont.)

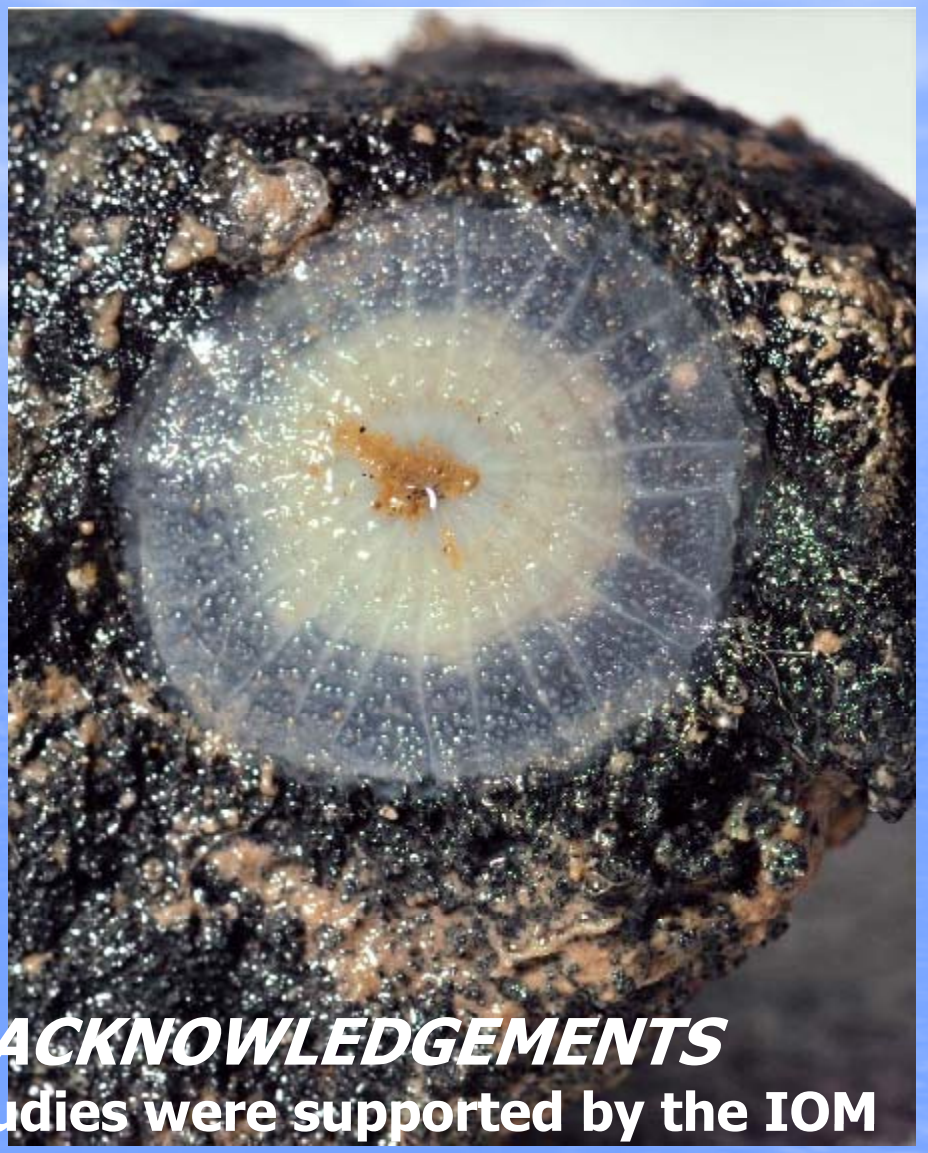
- Topography plays an important role in distribution of nodule deposits; stations that yielded high nodule abundance were found on all types of seafloor morphology;

- Mn/Fe ratio of nodules was lower (around 3) in the most northern part of the study area and steady increases toward southern part.

- The highest Mn/Fe ratio corresponds with the highest mean nodule abundance - counted to 10.9 kg/m^2 (in range 0.1 – 30 kg/m^2).

- Alongside geological, bathymetric, geographical, e. a. conditions and factors responsible for the modern pattern of the nodule occurrence on the seafloor, the role of the benthic activity (bioturbation, lifting, burial, re-worked, burrowing, e. a.) have to be also considered in understanding of the distribution of nodule types and facies.

- The practice of the IOM in evaluating of the nodule deposit within its exploration area is a prove that the potential mining of nodule deposit is feasible.



ACKNOWLEDGEMENTS

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Thank you