The International Seabed Authority

Data and information to administer the mineral resources of the Area: The International Seabed Authority’s Geological Model of Polymetallic Nodule Deposits in the Clarion Clipperton Zone and its CDR

SENSITIZATION SEMINAR ISA KINGSTON
28-30 MARCH 2011
Main Mineral Resources
Central Data Repository

Cobalt rich Crusts

Polymetallic Sulphides

Polymetallic Nodules
Objectives Of The CDR

Prior Situation: Large quantity of data collected and known to exist, but dispersed widely among various organizations and companies worldwide:
- in different formats, standards and supports
- not readily accessible to potential users.

The CDR aims to collect and centralize all public and private data and information on marine mineral resources:
- Should be accessible to all member states.
- Should display the acquired data and information.
- Display data in various forms: listing, graphs, maps…
- develop an integrated database system for use as a management and research tool
Central Data Repository

(a) NOAA – National Data Center, NGDC – (United States of America).
(b) U.S. Geological Survey (USGS) – (United States of America).
(c) Ministry of Natural Resources – (Russian Federation).
(d) COMRA – (China).
(e) Institute of Marine and Coastal Sciences, Rutgers University – (USA).
(f) Geological Survey of Finland – (Finland).
(g) Federal Institute of Geosciences and Natural Resources – (Germany).
(h) Bureau of Resource Sciences – (Australia).
(i) University of Toronto – (Canada).
(j) Geological Survey of Norway – (Norway).
(k) National Institute of Oceanography – (India).
(l) InterOceanMetal Joint Organization (IOM) – (Poland).
(m) IFREMER – (France).
(n) SOPAC – (Fiji).
(o) KORDI – (Republic of Korea).
(p) SCRIPPS Institution of Oceanography – (United States of America).
(q) DOALOS/United Nations.
Data Inventory

Polymetallic Nodules:

- **Sample Data Set**: Ancillary data describing samples and related information, such as cruise references etc... 2,753 samples

- **Geochemical Data Set**: data related to Location, Depth and results of geochemical analysis for over 60 elements including the method of analysis.

- **Major Elements Data Set**: Similar to the “Geochemical Data Set” set, but for the 9 elements that constitute 90% of the material on deep sea Polymetallic nodules (Al, Co, Cu, Fe, Mn, Ni, Pb, Si, Zn)
Polymetallic nodule locations in the CDR
Data Inventory - Cobalt rich ferromanganese crusts.

- **Sample Data Set**: Ancillary data describing samples and related information, etc... 3,533 samples
- **Geochemical Data Set**: data related to Location, Depth, thickness of crusts and results of geochemical analysis for over 60 elements including their analysis methods. – 3533 records
- **Major Elements Data Set**: Similar to the “Major Elements Set” of the Nodule Data – 3,533 records
Cobalt rich ferromanganese crust locations in the CDR
Seafloor Hydrothermal Vent Systems and Seafloor Polymetallic Sulphides

In 2001-2002, the Secretariat acquired a validated set of data on the worldwide distribution of seafloor polymetallic sulphides from the Geological Survey of Canada (GSC). During the first quarter of 2003, the Secretariat integrated that data set into the CDR. The related data is grouped into four functional sets:

**Deposit Information**: Location data, geological information and description of 327 sites of seafloor hydrothermal activity and mineral deposits.

- **Geochemical Data**: Geochemical analyses for 2,640 samples of seafloor polymetallic sulphides and hydrothermal precipitates from 69 different sites worldwide: Contains for each sample, geochemical analyses for up to 70 elements, together with their analyses method, sample type, mineralogical information, deposit location and references.
Locations of polymetallic sulphides occurrences in the CDR
Over the past couple of years, the Authority has been successful in assembling a biological data set which is now part of the CDR. Three types of biological data: abyssal plain biology; seamount biology; and vent biology, are available. The data streams contain information including the taxonomy of the species in given locations, collection and sampler details and depth information. The total amount of biological data available is listed in the consolidated Table 1, which also indicates the sources of the data. Each occurrence of a biological sample is noted as a separate record, and hence, a single location is listed several times. The number of records, therefore, exceeds the number of locations from which data was available.
Biological data locations represented in the CDR
### Summary of Data Inventory

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Polymetallic Nodules</th>
<th>Cobalt-rich Ferromanganese Crusts</th>
<th>Polymetallic Sulphides/Hydrothermal Vent Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geochemical elements</strong></td>
<td>2,753 records</td>
<td>3,533 records</td>
<td>6,000 records</td>
</tr>
<tr>
<td><strong>Sample data</strong></td>
<td>2,753 records</td>
<td>3,533 records</td>
<td></td>
</tr>
<tr>
<td><strong>Reduced data Set</strong></td>
<td>2,753 records</td>
<td>1,225 records</td>
<td></td>
</tr>
<tr>
<td><strong>Major elements</strong></td>
<td>2,753 records</td>
<td>3,533 records</td>
<td></td>
</tr>
<tr>
<td><strong>Actual data within the ‘Area’ Deposits</strong></td>
<td>1,944 records</td>
<td>627 records</td>
<td>232 sites</td>
</tr>
<tr>
<td><strong>Analysis methods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Main source of data</strong></td>
<td>US-NGDC</td>
<td>US-USGS</td>
<td></td>
</tr>
<tr>
<td><strong>Marine minerals bibliography</strong></td>
<td>~2,500 records</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biological data</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Abyssal Plain Biology</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vent biology</strong></td>
<td>666 (662)* records</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seamount biology</strong></td>
<td></td>
<td>7,318 (2,915)* records</td>
<td></td>
</tr>
<tr>
<td><strong>Main source of data</strong></td>
<td>Kaplan Project,</td>
<td>Seamounts Online</td>
<td>ChEss (Chemosynthetic Ecosystem Science)</td>
</tr>
<tr>
<td></td>
<td>Publications,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contractors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Numbers within brackets show records falling within the Area.
Dynamic On-line database queries

- More Flexibility

- Selection of subsets based on various parameters
  - Location (lat/Long. Or geographic zones)
  - Elements abundance
  - Cruise ID and Date

- Selection based on any user defined criteria
  - With the available forms, the end user may develop his own queries based on any field or combination of fields
WEBGIS

As an integral part of an online Atlas, a Web Geographical Information System (WebGIS) accommodates the Secretariat’s geographic information on the Area and regions of potential outer continental shelf. The map interface allows for interactive mapping by external users, and aims to enable the dissemination of available data on resource potentials as well as other physical, political and environmental information.

Objectives:

1. Map mineral resource distributions in the Area.
2. Integrate additional information from various sources and compile a holistic, multidisciplinary ‘Seabed GIS’ (including bathymetry, maritime boundaries, geological structures, biogeography, sediments and areas of particular interest).
3. Make the spatial information accessible through an interactive WWW interface.
5. Create visualization and analysis capabilities to support research and decision-making.
Presently, the following information can readily be mapped using the interactive WebGis tool:

- Deposit/occurrence locations from the CDR.
- Ocean floor features (such as seamounts, ridges, trenches and basins).
- EEZ limits.
- Biological data.
- World seas.
- Surficial sediments and sediment thickness.
- Bathymetric contours.
- Thematic maps, movies, 3D animations, etc.
A survey of international Patents to identify trends in the development of deep seabed mining technology (1960-1998)

- Related to Polymetallic nodule exploitation
- Survey Resulted in the identification of 352 patents in 12 patents systems
- Started in 1960, peak in 1983 with 34 patents for that year. Much reduced pace subsequently.
- 85% of the patents from USA, JAPAN, USSR
- 2 searchable CDROMS produced, containing patents grouped in 10 volumes and many sub-volumes according to Design Concepts
- Database fully implemented in the CDR, can be viewed with ADOBE READER
POLYDAT - data repository of the reserved areas submitted by contractors.

Framework

– Available Data
  ▪ Co-Ordinates
    – Sampling Station

Topography

2335 station data
  Water depth, abundance, Mn, Ni, Cu, Co
Acknowledgement

The Secretariat has so far received data from the following institutions:

- NOAA
- USGS
- InterOceanMetal Joint Organization (IOM)
- GSC – Geological Survey of Canada
- COMRA, China
- IFREMER France
- The Republic of Korea
- DORD Japan
- Inter Ridge
- other public domains

We wish to express our gratitude to these institutions/sites.
We will strive to excel

- Continuously update the CDR database with new data sourced from the public domain, institutions, contractors and published literature. Try to integrate gravity data, seafloor age and other data into the CDR-WebGIS by 2011.
- Request the Contractors and other member States to provide any non-proprietary data for addition to the CDR.
- More biological data to be collected from different sources and through collaboration with marine scientific institutions and organizations. Also, increase the database with all environmental, physical meteorological data.
- Continue to develop a more robust CDR with better graphic interfaces, a searchable database (for example, SQL-based query forms) and more user-friendly options.
- Link CDR to Google Earth.
- Continuously update the bibliographic database
- Refine the patent searchable database and update the patent database to include all recent patents.
- Extend the CDR to include map, photograph and video galleries.
- Update the CDR with the data and results of the Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Fracture Zone project.
- Strive to establish a museum of marine mineral resources.
Part II
DEVELOPMENT OF GEOLOGICAL MODEL AND PROSPECTOR'S GUIDE FOR POLYMETALLIC NODULE DEPOSITS IN THE CLARION CLIPPERTON ZONE
1. IMPROVE CLARION-CLIPPERTON RESOURCE ASSESSMENT

2. INTEGRATE AVAILABLE RESOURCE AND RELATED ENVIRONMENTAL DATA

3. PROVIDE USEFUL GUIDELINES FOR PROSPECTING AND EXPLORATION
AREA OF INTEREST:
110° – 160° W; 0° – 20° N
Location of Contractors’ Exploration Areas and Reserved Areas in the Clarion-Clipperton Zone
<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>COMPLETION DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DRAFT REPORTS</td>
<td>JULY 2006</td>
</tr>
<tr>
<td>2. MID-COURSE MTG.</td>
<td>SEPTEMBER 2006</td>
</tr>
<tr>
<td>3. Interim REPORTS</td>
<td>2007-2008</td>
</tr>
<tr>
<td>4. Final reports</td>
<td>Early 2009</td>
</tr>
<tr>
<td>5. External Review of documents</td>
<td>June 2009</td>
</tr>
<tr>
<td>6. FINAL WORKSHOP</td>
<td>December 2009</td>
</tr>
<tr>
<td>7. Publication of results</td>
<td>2010-2011</td>
</tr>
</tbody>
</table>
ISA’s secured FTP/VPN site

- Bathymetry data from the public domain.
- Additional data acquired from contractors for GeoModel Program.
- Data/reports submitted by consultants.
- Digitization and geo-referencing of bathymetric maps provided by Pioneer Investors.
DATA COLLECTION

PROXY DATA
- BATHYMETRY
- TECTONIC/VOLCANIC DATA
- SEDIMENT DATA
- NODULE MORPHOLOGY
- WATER COLUMN DATA
- BIOLOGICAL DATA

RESOURCE DATA
- ABUNDANCE
- MANGANESE
- NICKEL
- COPPER
- COBALT
### Geological model Programme- additional data provided by contractors

<table>
<thead>
<tr>
<th>Content</th>
<th>COMRA</th>
<th>KORDI</th>
<th>IOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymetallic nodules data</td>
<td>241+536 station 50000 data points</td>
<td>232 stations outside the area</td>
<td>230 +69 +561 (abundance and chemistry)</td>
</tr>
<tr>
<td>MFES abundance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravity and Magnetic data</td>
<td>6610 points</td>
<td>Figures for free-air anomaly and magnetic intensity and magnetic anomaly provided</td>
<td></td>
</tr>
<tr>
<td>Meteorology</td>
<td>3396 points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTD</td>
<td>7 Profiles</td>
<td>Have provided multibeam data in 12 sectors in xyz format</td>
<td>15 profiles</td>
</tr>
<tr>
<td>Bathymetric data</td>
<td>xyz and grd data around 250000 xyz points additional around 8300 xyz points single beam echosounding</td>
<td></td>
<td>2 blocks Block-1 22 ascii files Block-2 55 ascii files</td>
</tr>
<tr>
<td>Sediment type</td>
<td>Around 1500</td>
<td></td>
<td>4 sediment cores</td>
</tr>
<tr>
<td>Particle size of sediment</td>
<td>Around 200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep tow photography</td>
<td>4 profiles data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Other contractor data**

DORD JAPAN 1450 data points Mn/Fe ratios only

IFREMER- 500 stations nodule abundance, grade data for validation and sediment data
Prospector’s Guide Proxies

- Gridded Bathymetry
- Volcanic, tectonic and sediment factors
- Growth model for Polymetallic nodules
- Nodule coverage, Morphology and distribution in eastern CCZ
- Sediments in eastern CCZ
- Nodule genesis and sediment distribution in Korean Allocated area
- Bathymetry and sediments in COMRA area
- Regional examination of sediments
- Benthic Biological data from CCZ
Bathymetric map of CCZ
(from etopo- 1’ depth data)
Coverage of ISA Datasets
Tectonic sketch of the CCZ
Sediment facies and nodule abundance

1 - Northern facies; 2 - Central facies; 3 - Southern facies; 4 - Mahi-Mahi Fracture Zone; 5 - Hydrothermal deposits;
Thick black dashed line - Axial line of maximum nodule abundance
Paleo-reconstruction of CCZ-20 MYA

1. Siliceous-Argillaceous Sediments; 2. Calcareous Sediments; 3. Hawaiian Ash Fall
PROXY DATA:
odule morphology

IOM- report on nodule coverage, Morphology, and distribution in eastern Part of the CCZ.
- Based on 926 station data
- Discoid type nodules dominate
- Distribution of nodule types shows zonality
<table>
<thead>
<tr>
<th>Classification</th>
<th>Surface shape</th>
<th>Morphology</th>
<th>Mineralogy</th>
<th>Chemical Make-up</th>
<th>Occurrence</th>
<th>Genesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-type</td>
<td>Smooth</td>
<td>Spherical, aggregate with poly-nucleus, irregular</td>
<td>Vernadite</td>
<td>Rich in Fe, Co, poor in Mn, Cu, Ni, ratio of Mn/Fe is less than 2</td>
<td>Exposure on surface layer</td>
<td>Hydrogenous: Source of ore-forming materials is sea water</td>
</tr>
<tr>
<td>R-type</td>
<td>Rough, grainy, papillate shape</td>
<td>Spherical, waxberry, kidney</td>
<td>Todorokite and vernadite</td>
<td>Rich in Mn, Cu, Ni, ratio of Mn/Fe is larger than 5</td>
<td>Buried or mostly buried in surface layer</td>
<td>Diagenetic, ore-forming materials are from pore water in surface sediments</td>
</tr>
<tr>
<td>S-R type</td>
<td>Smooth on the top side surface, rough on the lower side surface</td>
<td>Generally asymmetric elliptical, some tabular or irregular</td>
<td>Difference between top side and lower side, the top is similar to S-type and the lower side similar to R-type</td>
<td>Difference between top side and lower side, the top is similar to S-type but the lower side is similar to R-type</td>
<td>Semi-buried in surface layer</td>
<td>Mixed Genesis: hydrogenous for the top side and diagenetic for the lower side</td>
</tr>
</tbody>
</table>
Six factors necessary for nodule growth

- Supply of metals
- Presence of Nuclei
- Antarctic Bottom Water (AABW)
- Semi-liquid surface layer
- Bioturbation
- Internal Stratigraphy
# Abundance and Coverage Vs. Water depth

<table>
<thead>
<tr>
<th>Depth Range (m)</th>
<th>No. Stations</th>
<th>Nodule Coverage, %</th>
<th>Nodule Abundance, kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Min.</td>
</tr>
<tr>
<td>3,470 - 4,100</td>
<td>51</td>
<td>31.7</td>
<td>3</td>
</tr>
<tr>
<td>4,101 - 4,200</td>
<td>63</td>
<td>33.0</td>
<td>0</td>
</tr>
<tr>
<td>4,201 - 4,300</td>
<td>154</td>
<td>29.9</td>
<td>0</td>
</tr>
<tr>
<td>4,301 - 4,400</td>
<td>348</td>
<td>29.6</td>
<td>0</td>
</tr>
<tr>
<td>4,401 - 4,500</td>
<td>196</td>
<td>30.0</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 4,500</td>
<td>112</td>
<td>23.8</td>
<td>0</td>
</tr>
</tbody>
</table>
Bathymetry and sediments-
COMRA east area
COMRA West area
Sediment distribution - COMRA east

COMRA-West
Increasing Biological Productivity

CCD vs WATER DEPTH

CCD < WATER DEPTH

CCD > WATER DEPTH

Nodule Deposits
(DEPTH – CCD) vs Abundance

![Graph showing the relationship between abundance and depth-ccd in kg/m².](image)
BIOLOGICAL DATA:
BENTHIC FAUNAL ABUNDANCE
TREND SURFACE PLANES
Nitrogen export flux

Carbon export flux
Geological Model

- Primary data source
- Inferred resources
- SDSS (Spatial decision support system) Modeling
Data Sets-

- KORDI models using Geostatistical and GIS techniques.
- Biogeochemical approach to modeling examines the use of specific proxy variables to predict deposit characteristics where data are lacking.
- Spatial Decision Support System (SDSS) approach to the modeling, which employs Weights of Evidence Modeling, Fuzzy Logic, Logistic Regression and Artificial Neural Network (ANN) techniques based on the some of proxy variables
SAMPLE STATIONS IN
RESOURCE ASSESSMENT
<table>
<thead>
<tr>
<th>Data Source</th>
<th>CDR</th>
<th>KOREA</th>
<th>OMC0</th>
<th>COMRA</th>
<th>IOM</th>
<th>Totals After Screening</th>
</tr>
</thead>
<tbody>
<tr>
<td># Stations: Abundance</td>
<td>253</td>
<td>329</td>
<td>7,738</td>
<td>52,473</td>
<td>790</td>
<td>61,583</td>
</tr>
<tr>
<td># Stations: Manganese</td>
<td>879</td>
<td>258</td>
<td>5,875</td>
<td>716</td>
<td>664</td>
<td>8,392</td>
</tr>
<tr>
<td>#Stations: Cobalt</td>
<td>711</td>
<td>258</td>
<td>5,900</td>
<td>716</td>
<td>664</td>
<td>8,249</td>
</tr>
<tr>
<td>#Stations: Nickel</td>
<td>799</td>
<td>258</td>
<td>5,923</td>
<td>716</td>
<td>664</td>
<td>8,360</td>
</tr>
<tr>
<td># Stations: Copper</td>
<td>882</td>
<td>258</td>
<td>5,924</td>
<td>714</td>
<td>664</td>
<td>8,442</td>
</tr>
</tbody>
</table>
### Summary resources

<table>
<thead>
<tr>
<th></th>
<th>Abundance</th>
<th>Manganese</th>
<th>Cobalt</th>
<th>Nickel</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean (kg/m²)</strong></td>
<td>5.58</td>
<td>1.51</td>
<td>0.012</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Median (kg/m²)</strong></td>
<td>5.06</td>
<td>1.33</td>
<td>0.011</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Maximum (kg/m²)</strong></td>
<td>24.22</td>
<td>7.71</td>
<td>0.059</td>
<td>0.36</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>Minimum (kg/m²)</strong></td>
<td>0.01</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Mean Std. Error (kg/m²)</strong></td>
<td>5.38</td>
<td>2.61</td>
<td>0.036</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Tonnage (10⁶-metric)</strong></td>
<td>27,063</td>
<td>7,300</td>
<td>58</td>
<td>340</td>
<td>290</td>
</tr>
<tr>
<td>Source</td>
<td>Included Area (km² × 10⁶)</td>
<td>Estimated Tons (metric tons × 10⁶)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------</td>
<td>----------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nodules</td>
<td>Mn</td>
<td>Co</td>
<td>Ni</td>
</tr>
<tr>
<td>Reduced area</td>
<td>3.83</td>
<td>21,100</td>
<td>5,950*</td>
<td>46.4*</td>
<td>270*</td>
</tr>
<tr>
<td>Total study area</td>
<td>4.19</td>
<td>30,700</td>
<td>8,657*</td>
<td>67.5*</td>
<td>393*</td>
</tr>
<tr>
<td>Biogeochemical model</td>
<td>4.85</td>
<td>27,100</td>
<td>7,300</td>
<td>58.0</td>
<td>340</td>
</tr>
<tr>
<td>Potential resources of nodules</td>
<td>12.57</td>
<td>62,000</td>
<td>17,500</td>
<td>134.0</td>
<td>761</td>
</tr>
</tbody>
</table>

*Estimated using mean metal content values

Inferred resources
Station map and blocks used in the study
<table>
<thead>
<tr>
<th>Block</th>
<th>Area (km²)</th>
<th>ArcGIS OK (10^6 ton)</th>
<th>GSILB OK</th>
<th>SIS Realizations (10^6 ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA-1</td>
<td>1,056,593.908</td>
<td>6,850.134</td>
<td>6,658.146</td>
<td>8,869.857, 7,906.983, 8,271.747</td>
</tr>
<tr>
<td>ISA-2</td>
<td>1,405,484.041</td>
<td>7,568.250</td>
<td>7,625.559</td>
<td>9,442.066, 9,160.971, 9,324.734</td>
</tr>
<tr>
<td>ISA-3</td>
<td>966,323.969</td>
<td>5,304.177</td>
<td>5,097.307</td>
<td>7,397.636, 4,811.399, 6,045.043</td>
</tr>
<tr>
<td>ISA-4</td>
<td>764,320.813</td>
<td>3,660.990</td>
<td>3,690.781</td>
<td>4,969.960, 4,731.932, 5,309.745</td>
</tr>
<tr>
<td>Total</td>
<td>4,192,722.731</td>
<td>23,383.551</td>
<td>23,071.793</td>
<td>30,679.520, 26,611.285, 28,951.269</td>
</tr>
</tbody>
</table>

OK- Ordinary Kriging
SIS-Sequential Indicator simulation
Biogeochemical modeling

The model presented here predicts the geographical distributions of nodule metal content (Mn, Co, Ni, Cu, and Ni concentrations) and abundance (kilograms of ore deposits per square meter of seafloor) using as model components the values of other, known variables, including chlorophyll concentrations in surface waters, distance from the East Pacific Rise, and Carbonate Compensation Depth (CCD).
Summary of resource estimation-
Estimation from biogeochemical modeling

<table>
<thead>
<tr>
<th></th>
<th>Abundance (kg/m²)</th>
<th>Manganese</th>
<th>Cobalt</th>
<th>Nickel</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.58</td>
<td>1.51</td>
<td>0.012</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>Median</td>
<td>5.06</td>
<td>1.33</td>
<td>0.011</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Maximum</td>
<td>24.22</td>
<td>7.71</td>
<td>0.059</td>
<td>0.36</td>
<td>0.33</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.01</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Mean Std. (kg/m²) Error</td>
<td>5.38</td>
<td>2.61</td>
<td>0.036</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Tonnage (10⁶-metric)</td>
<td>27,063</td>
<td>7,300</td>
<td>58</td>
<td>340</td>
<td>290</td>
</tr>
</tbody>
</table>
1. Sources of metals: Land and East Pacific Rise, carried in suspended sediments
2. Sediments consumed by zooplankton & converted to larger pellets that sink
3. Fecal pellets metabolized by benthic fauna, releasing reduced metals
4. Reduced metals scavanged by Mn oxide surfaces
Proxy variables used

- Distance from EPR
  - Chlorophyll content in surface waters: The chlorophyll content in surface waters is closely related to the level of biological activity taking place and also to the export productivity at the site, (i.e. the flux rate of biogenic material out of surface waters). In this study we use the estimates of chlorophyll content that were determined by blending historical archives of in situ (National Oceanographic Data Center) and satellite (Coastal Zone Color Scanner) chlorophyll data, which were combined using the blended analysis method of Reynolds (1988) in an attempt to construct an improved climatological seasonal representation of global chlorophyll distributions (Gregg, W.W. and M.E. Conkright, 2000). These data are available as seasonal and annual averages.

- Distance from CCD
Chlorophyll in surface waters
Figure 5.5  Water Depth minus CCD (del) in the Clarion-Clipperton Zone
The study is based on data sets compiled by other experts that include bathymetry, topography, sediment type, CCD, and surface chlorophyll. Specific techniques employed in the study include Weights of Evidence Modeling, Fuzzy Logic, Logistic Regression and Artificial Neural Network (ANN) techniques.
Workshop on the results of a project to develop a geological model of polymetallic nodules in the Clarion Clipperton Zone

- ISA 14-17 December 2009
- The workshop was attended by a total of 24 participants, including some members of the Legal and Technical Commission of the Authority, representatives of contractors, representatives of member States, industry representatives and the experts who contributed to the development of the Model.
Thank You