CPRM
Serviço Geológico do Brasil

RELATÓRIO DE VIAGEM AO EXTERIOR

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O presente relatório sintetiza as atividades, apresentações e recomendações feitas por seu autor, como participante do **"Workshop on the results of a Project to develop a Geological Model of polymetallic nodule deposits in the Clarion-Clipperton Zone"** (Workshop sobre os resultados do projeto de desenvolvimento do modelo geológico dos depósitos de nódulos polimetálicos da zona de Clarion-Clipperton) realizado entre 14 e 17 de dezembro de 2009, em Kingston, Jamaica. Os seguintes tópicos são apresentados no decorrer desse relatório:

Os documentos oficiais referentes ao workshop podem ser encontrados no site da Autoridade Internacional dos Fundos Marinhos (ISBA): www.isa.org.jm/en/scientific/workshops/2009.

1. INTRODUÇÃO

A "**Área**" corresponde aos fundos marinhos e oceânicos que se situam além dos limites da jurisdição nacional, tratada na Parte XI da Convenção das Nações Unidas pelo Direito do Mar (Convenção). A Convenção define a Área e seus recursos como patrimônio comum da humanidade. Os recursos da Área compreendem todos os minerais sólidos, líquidos ou gasosos in situ no leito do mar ou em seu subsolo.

A Convenção também estabelece uma organização internacional autônoma de caráter supranacional -a **Autoridade Internacional dos Fundos Marinhos** (Autoridade) -, através da qual os Estados-Parte organizam e controlam as atividades, visando o aproveitamento dos recursos minerais localizados na Área. A Autoridade tem, entre suas finalidades, garantir que a utilização dos fundos marinhos internacionais beneficie efetivamente toda a humanidade.

Um dos primeiros grandes resultados dos trabalhos desenvolvidos pelos órgãos da Autoridade foi o estabelecimento de regulamentos para a prospecção e a exploração de nódulos polimetálicos na Área.

O início das atividades de prospecção de nódulos polimetálicos de leito marinho foi marcado pelo envolvimento de mais de 40 empresas de mineração, provenientes de dezesseis países diferentes.

Quatro consórcios foram formados nos EUA entre 1974 e 1977:

- *Kennecott Consortium* (KCON) - criado em janeiro de 1974, incluindo uma empresa norte-americana, duas inglesas, uma japonesa e uma canadense;
- *Ocean Mining Associates* (OMA) - formado em 1974 por duas empresas norte-americanas, uma belga e cinco japonesas;
- *Ocean Management Incorporated* (OMI) - fundado em 1975 por uma empresa canadense, quatro alemãs e dezenove japonesas;
- *Ocean Minerals Company* (OMCO) – constituído em 1977 por duas empresas norte-americanas e uma holandesa.

Na França, a Sociedade *Le Nickel* e o Centro Nacional para a Explotação dos Oceanos (CNEXO) - posteriormente transformado em *Institut Français de Recherche pour l'Exploitation de la Mer* (IFREMER) - associaram-se em 1970 para conduzir as primeiras prospecções no sul do Oceano Pacífico. Em 1974, o Comissariado para Energia Atômica (CEA) e o Estaleiro *France Dunkerque* se associaram àqueles anteriormente mencionados para formar a Associação Francesa para o Estudo e a Prospecção de Nódulos (AFERNOD/IFREMER).

No início dos anos 80, os russos iniciaram uma prospecção sistemática no Oceano Pacífico utilizando navios de grande porte. Em 1985, constituíram uma empresa de mineração para nódulos polimetálicos (*Yuzhmorgeologiya*) que, contando com mais de 1.200 funcionários, desenvolveu equipamentos especialmente adaptados à prospecção dos nódulos.

Em 1982, o Japão criou uma empresa de mineração, denominada *Deep Ocean Research and Development* (DORD) que agrupava 49 organismos, incluindo alguns que já faziam parte dos consórcios formados nos Estados Unidos da América.

A Índia começou a prospecção do Oceano Índico no início dos anos 80 do século passado, contando com meios técnicos da Alemanha. Em seguida, desenvolveu sua própria competência para continuar os trabalhos por conta própria.

Em meados da mesma década, vários países socialistas, incluindo Polônia, Bulgária, Cuba, República Checa, República Eslovaca e Federação Russa, constituíram um consórcio internacional (*Interoceanmetal Joint Organization* – IOM), para prospectar nódulos no Oceano Pacífico Central. Nesta década, também a China e a Coréia constituíram suas empresas para exploração de nódulos polimetálicos.

À exceção da Índia, que desenvolveu suas atividades no Oceano Índico, todos os outros países concentraram suas ações de prospecção no Pacífico, onde os nódulos apresentam teor mais elevado de níquel e cobre.

No final dos anos 80, com exceção dos consórcios americanos, sete empresas de mineração submeteram à Autoridade, segundo os termos da Convenção, os seus planos de trabalho para a exploração de nódulos polimetálicos. Assim, essas empresas receberam o *status* especial de «Investidores Pioneiros» na exploração de nódulos polimetálicos, o que lhes conferiu alguns privilégios. Os Investidores Pioneiros são:

- *Department of Ocean Development* – DOD (Governo da Índia);
- *Institut Français de Recherche pour l'Exploitation de la Mer* e *Association Française pour l'Étude et la Recherche des Nodules* (França);
- *Yuzhmorgeologiya* (Federação Russa);
- *Deep Ocean Resources Development Co. Ltd.* (Japão);
- *China Ocean Mineral Resources Research and Development Association* – COMRA (China);
- *Korean Deep-sea Resources Research Center* - KORDI (Corea)
- *Interoceanmetal Joint Organization* (Polônia, Bulgária, República Checa, República Eslovaca, Cuba e Federação Russa).

Nos termos da Convenção (ONU, 1982), cada investidor pioneiro tem direito a uma área de exploração que não deve exceder 75.000km^2. Os pioneiros que até o momento da submissão de seu plano de trabalho não tiverem concluído a delimitação dessa área poderão reivindicar até 150.000km^2, mas deverão, no espaço de oito anos, restituir o excedente. A Convenção também determina que cada investidor pioneiro delimite uma outra área de mesmo tamanho e valor econômico, que passa a ser considerada como "área reservada" para atividades da Autoridade. Dessa forma, mais de 1.800.000km^2 dos leitos marinhos dos oceanos Pacífico e Índico foram atribuídos aos sete investidores pioneiros e à Autoridade.

Em 2005 a Alemanha, através do *Bundensanstalt für Geowissenschaften und Rohstoffe* (BGR - Instituto Federal de Geociências e Recursos Naturais), solicitou à Autoridade outro sítio de exploração no Oceano Pacifico.

Desta forma, até o presente momento a Autoridade Internacional dos fundos Marinhos estabeleceu contrato de trabalho com oito diferentes empresas, as quais são referidas como contratantes da Autoridade. A área total de trabalho atribuída aos contratantes é de mais 2.000.000 km^2, o equivalente a mais de 23% da superfície do território brasileiro, ou 11 vezes a área do Estado de São Paulo.

O projeto de desenvolvimento do modelo geológico dos depósitos de nódulos polimetálicos da zona de Clarion-Clipperton é uma iniciativa da Secretaria da Autoridade Internacional dos Fundos Marinhos e dos oito contratantes acima mencionados. O projeto, preparado por especialistas de vários países tem dois objetivos principais. O primeiro é de estabelecer parâmetros que permitam identificar áreas de ocorrência de nódulos polimetálicos onde poucos dados sobre esses recursos minerais foram coletados. Por exemplo, utilizando a batimetria, clorofila dissolvida na água do mar, as características sedimentares e biológicas para prever abundância de nódulos e seu teor em metais de valor econômico, tais como cobre, níquel, manganês e cobalto.

O segundo objetivo é de preparar um Guia de Prospecção de nódulos polimetálicos para facilitar o trabalho dos presentes e dos futuros contratantes da Autoridade. Esse guia traz significativas informações sobre a geologia, geofísica, oceanografia e biologia da Região de Clarion-Clipperton, fornece uma orientação geral sobre a origem dos depósitos de nódulos polimetálicos e indica como encontrar novos depósitos.

O projeto do modelo geológico foi elaborado em várias etapas, tendo sido iniciado com a elaboração de um workshop realizado em Fidji em 2004. Os dados utilizados são provenientes dos contratantes da Autoridade e de consórcios americanos.

2. OBJETIVOS DA VIAGEM

Participar, a convite da Autoridade Internacional dos Fundos Marinhos (ISBA), na qualidade de especialista em exploração de recursos minerais de mar profundo do último Workshop sobre os resultados do projeto de desenvolvimento do modelo geológico dos depósitos de nódulos polimetálicos da zona de Clarion-Clipperton.

Foto geral dos participantes do Workshop

O convite deve-se ao fato de que o autor do presente relatório foi o proponente do projeto e organizador dos workshop de Fidji quando trabalhou como Geólogo Marinho na Autoridade Internacional dos Fundos Marinhos.

3. PROGRAMA DE VIAGEM

O Workshop se desenrolou entre 14 e 17 de dezembro de 2009. A viagem teve início no dia 13 de dezembro e seu término no dia 18 de dezembro. A viagem aérea consistiu em ida e volta no trajeto Brasília/São Paulo/Miami/ Kingston – Kingston/Miami/São Paulo/Brasília. Passagens aéreas e despesas referentes ã essa viagem foram custeadas pela Autoridade Internacional dos Fundos Marinhos (ISBA).

4. DESCRIÇÃO E ANÁLISE DOS ASSUNTOS TRATADOS

O workshop foi iniciado com o pronunciamento do Secretário Geral da Autoridade, o Sr. Nii Odunton, que deu as boas vindas aos participantes e informou sobre os procedimentos dos trabalhos. Logo após, o chefe científico da Secretaria da Autoridade, o Sr. James MacFarlane, apresentou as linhas gerais do modelo geológico.

Em seguida várias apresentações foram feitas pelos especialistas que elaboraram as diferentes partes do Modelo Geológico da Região de Clarion-Clipperton e do seu Guia de Prospecção. As apresentações, seguidas de discussões foram feitas durante os dois primeiros dias de trabalho. Elas incluíram exposições sobre: implementação do projeto, dados e informações utilizados, batimetria, base cartográfica, vulcanismo, estrutura, sedimentação, bioquímica dos sedimentos, morfologia e distribuição teor dos nódulos polimetálicos.

Os dois seguintes dias do workshop foram dedicados à elaboração de recomendações feitas por quatro grupos de trabalho que desenvolveram os seguintes temas relacionados ao Modelo Geológico e ao seu Guia de Prospecção: (1) Extensão do modelo para outros oceanos; (2) Tecnologias e métodos de pesquisa e exploração; (3) Aplicação do modelo para reconhecimento de áreas de interesse ambiental; e (4) Métodos de divulgação do modelo e guia por parte da Autoridade Internacional dos Fundos Marinhos.

O autor do presente relatório atuou como coordenador do primeiro Grupo de Trabalho e foi responsável pela proposta de aplicação do modelo no Oceano Atlântico Sul. O objetivo dessa proposta foi de utilizar os conhecimentos do Modelo Geológico para enriquecer o projeto do Sistema de Informação Geográfica (SIG) do Atlântico Sul que esta sendo feito pela CPRM no contexto do Programa Brasileiro de Prospecção e de Exploração de Recursos Minerais da Área Internacional do Atlântico Sul (PROAREA).

Foto da reunião do Grupo de trabalho sobre a aplicação do modelo geológico em outros oceanos.

5.-ANÁLISES E RECOMENDAÇÕES DO WORKSHOP

Ao final das discussões e deliberações, os grupos de trabalho apresentaram suas análises e sugestões, as quais estão resumidas nos anexos 4ª, 4b, 4c e 4d.

Cabe destacar que os participantes do workshop reconheceram que existem muito pouco dados disponíveis sobre o Atlântico Sul para possibilitar uma aplicação do modelo geológico proposto para a região de Clarion-Clipperton. Por essa razão eles sugeriram que fosse realizado um projeto para o Atlântico Sul dividido duas fazes de trabalho. Na primeira a Autoridade poderia facilitar a coleta de todos os dados e informações existentes sobre essa região de forma a constituir uma base de dados. Na segunda faze seria feito a aplicação do modelo nas áreas mais apropriadas.

Os participantes também concordaram que o projeto para o Atlântico Sul seria uma ótima oportunidade de aplicação do Guia de Prospecção.

6-CONCLUSÕES

- O modelo geológico proposto para a região de Clarion-Clipperton e o Guia de Prospecção de Nódulos Polimetálicos constituem um trabalho de fôlego realizado em conjunto pela Secretaria da Autoridade Internacional dos Fundos Marinhos e por especialistas de vários países.

- Apesar do enorme esforço feito, o modelo ainda tem que ser aperfeiçoado com o aporte de novos dados geológicos e testados em outros oceanos para verificar a sua aplicabilidade global.

- Os princípios básicos do modelo e do guia de prospecção poderão ser utilizados pela CPRM na elaboração do SIG da Atlântico Sul e em projetos de prospecção de recursos minerais da plataforma continental brasileira e área oceânicas adjacentes.

7.- AGRADECIMENTOS

Agradeço ao Secretário-Geral da Autoridade Internacional dos Fundos marinhos pelo convite para a minha participação nesse evento, aos Dr. Agamenon Dantas, Presidente da CPRM e ao Dr. Manuel Barretto da Rocha Neto, Diretor de Geologia e Recursos Minerais da CPRM pelo apoio á minha participação nesse evento e a Dra. Maria pelo seu trabalho incansável e persistente na preparação dos documentos de viagem e interesse pelo assunto.

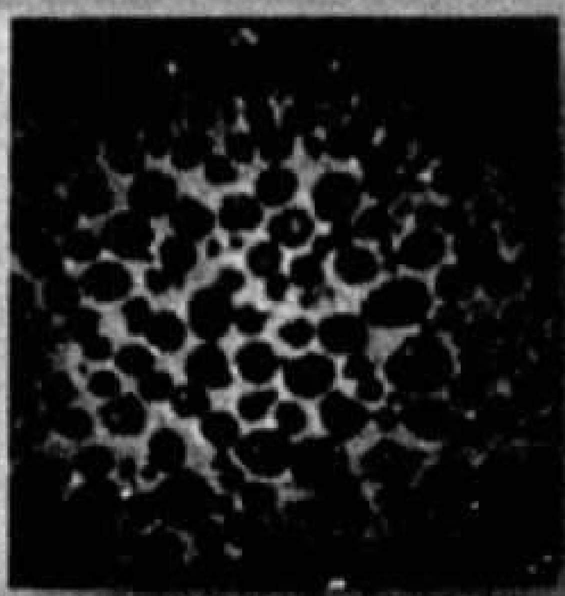
Gostaria também de agradecer ao Embaixador do Brasil na Jamaica, o Sr. Cesar Gueiros e ao Ministro Julio Matos pelo apoio durante a minha estada na Jamaica.

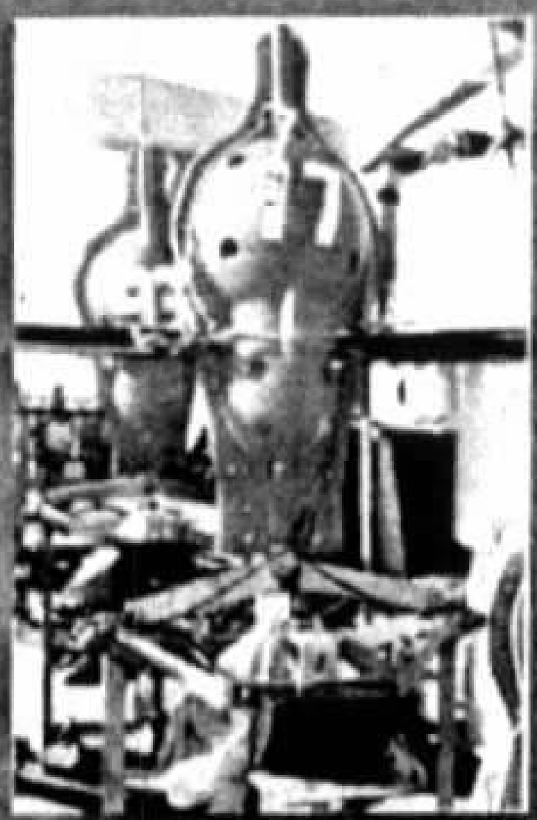
ANEXO 1

Agenda do Workshop.

Workshop on the Results of a Project to Develop a Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Zone Kingston, Jamaica

14-17 December, 2009

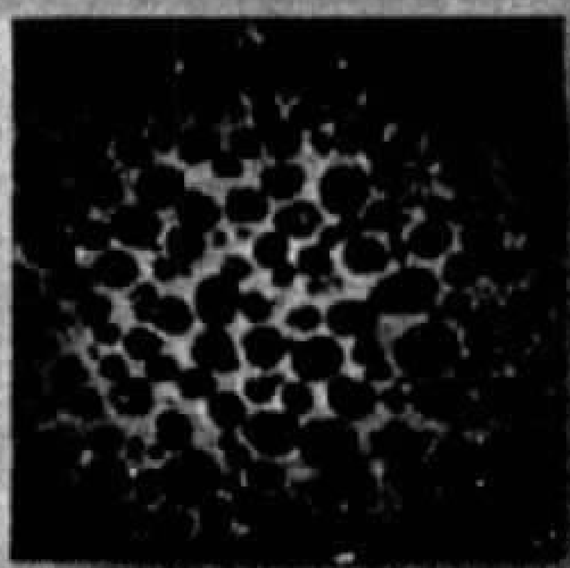


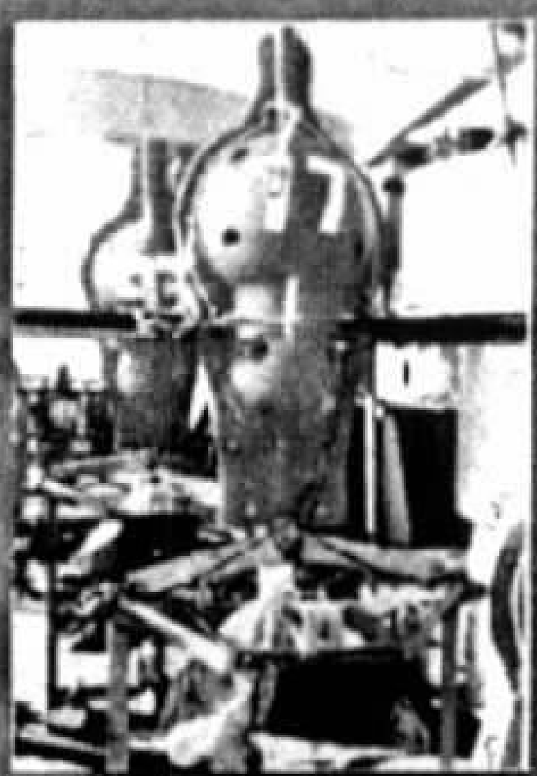


AGENDA

Monday, 14 December, 2009

09:30-10:30	**Registration of Participants**
10:30- 11:00	**Opening Session** - *Welcome & Opening remarks: H.E. Nii Allotey Odunton, Secretary-General, International Seabed Authority (ISA)* - *Outline of the workshop and objectives of the geological model project Mr. James A.R. McFarlane, Head, Office of Resource and Environmental Monitoring, ISA*
11:00-11:30	**Coffee Break**
Session:	**Model Development and Key Results**
11:30-12:15	**Project Implementation** - *Dr. Charles Morgan, Planning Solutions Inc., Hawaii USA*
12:15-13:30	**Review of Data used for the Model** - *Vijay Kodagali, Senior Scientific Affairs Officer, ISA*
13:30-14:30	**Lunch Break**
14:30-15:15	**Bathymetry and Base Map** - *Prof. Lindsay Parsons National Oceanography Centre, Southampton, UK*
15:15-16:00	**Analysis of Volcanic and Structural elements of Clarion-Clipperton Zone** - *Dr. Valery Yubko, Yuzhmorgeologiya, Russia to be presented by Ms. Valcana Stoyanova*



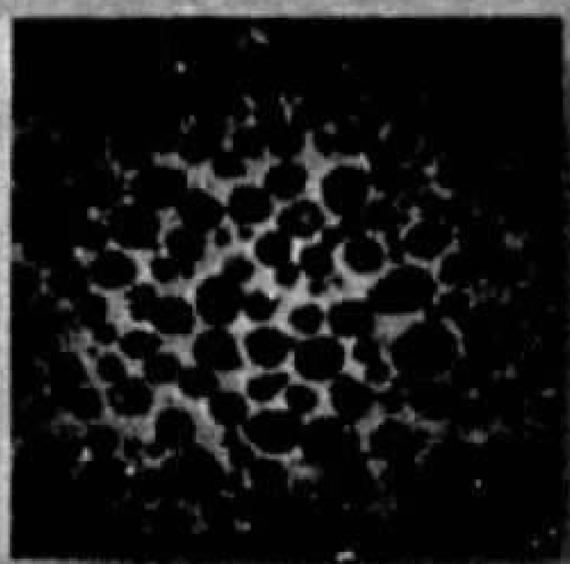


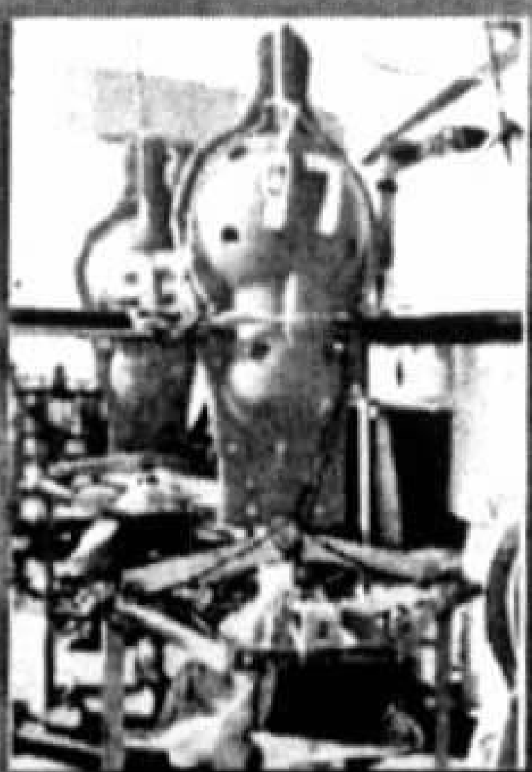
16:00-16:15 **COFFEE BREAK**

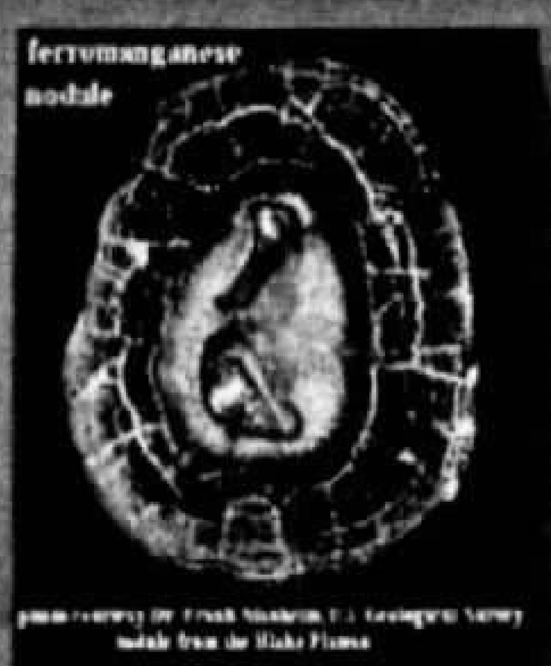
16:15-17:00	**REGIONAL EXAMINATION OF SEDIMENTS** - *Dr. Charles Morgan, Planning Solutions Inc, Hawaii USA*

TUESDAY, 15 DECEMBER, 2009

SESSION:	**MODEL DEVELOPMENT AND KEY RESULTS CONTINUED**
10:15-11:00	**BATHYMETRY AND SEDIMENTATION IN COMRA'S CONTRACT AREA** - *Prof. Huaiyang Zhou, School of Ocean and Earth Science Tongji University, Shanghai, PR China*
11:00-11:30	**COFFEE BREAK**
11:30-12:15	**RESULTS OF BIOGEOCHEMICAL MODELLING** - Dr. Charles Morgan, Planning Solutions Inc, Hawaii USA
12:15-13:00	**RELATION BETWEEN NODULE COVERAGE, MORPHOLOGY AND DISTRIBUTION** - *Ms. Valcana Stoyanova, Interoceanmetal Joint Organization, Poland*
13:00-14:00	**LUNCH BREAK**
14:00-14:45	**APPRAISAL OF NODULE RESOURCE POTENTIAL USING GIS AND GEOSTATISTICS** - *Dr. J.K Kang KORDI, Korea (to be presented by Dr Charles Morgan)*
14:45-15:30	**SPATIAL DECISION SUPPORT SYSTEM, FUZZY LOGIC MODELLING AND ILLUSTRATIVE MAPS OF POTENTIAL NODULE RESOURCES IN THE CCZ** - *Prof. Huaiyang Zhou, School of Ocean and Earth Science Tongji University, Shanghai, PR China*
15:30-16:00	**COFFEE BREAK**
SESSION:	REVIEW OF THE GEOLOGICAL MODEL AND PROSPECTOR'S GUIDE
16:00 -16:45	**REVIEW OF GEOLOGICAL MODEL AND PROSPECTOR'S GUIDE-2** - *Prof. Peter Halbach, Free University, Berlin., Germany*







WEDNESDAY, 16 DECEMBER, 2009

SESSION: **WORKSHOP RECOMMENDATIONS**

10:00- 13:00 **(WITH COFFEE BREAK)**

Participants will break in to 4 working groups. Working groups will meet in parallel sessions (Coffee Break 11:15-11:45). Each group will elect a chairman at the start of its deliberations.

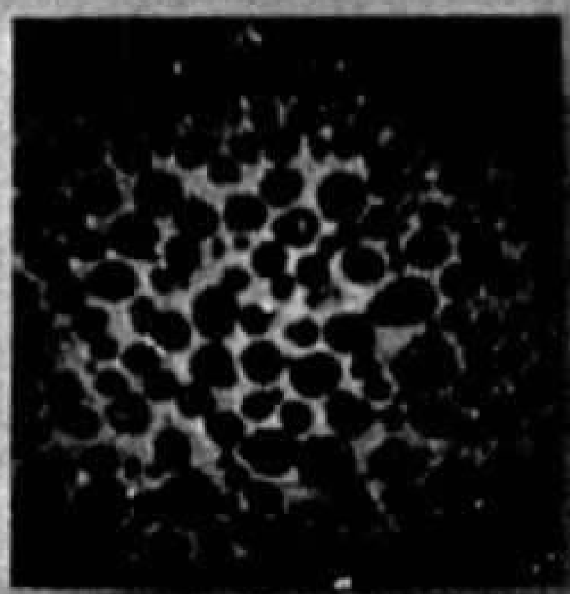
- Working Group 1- Extension of the model to other world oceans: Indian, Atlantic etc.
- Working Group 2- Exploration technology
  - Exploration, analytical methods, Mapping, visualization, ROV/AUV etc.
- Working Group 3- Environmental component
  - Research Plan, Time series, site plan and standardized data sets
- Working Group 4-Education and outreach of the results of the Model studies

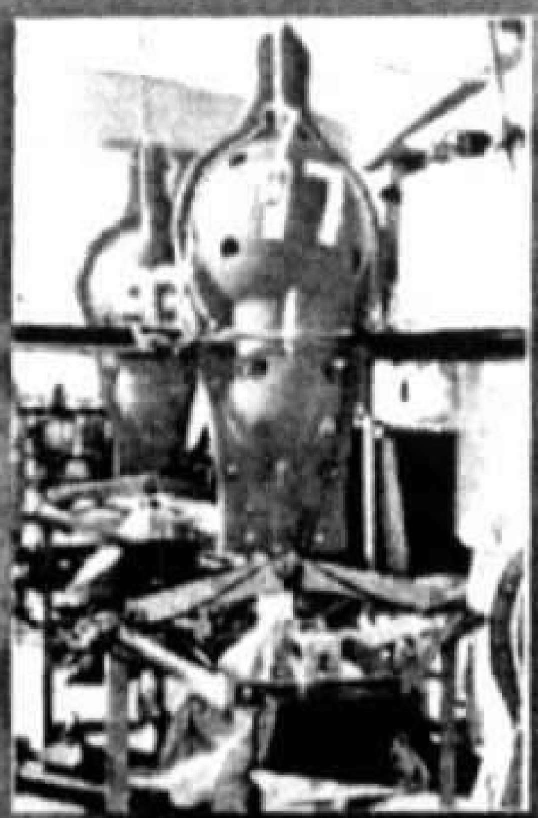
13:00- 14:00 **LUNCH BREAK**

14:00-17:00 **WORKING GROUP DELIBERATIONS CONTINUE WITH COFFEE BREAK FROM 15:00-15:30**

THURSDAY, 17 DECEMBER 2009

10:00- 11:30	**PLENARY SESSIONS ON DELIBERATIONS OF THE WORKING GROUPS**
11:30-11:45	**COFFEE BREAK**
11:45-13:00	Finalization of Working Group Reports
13:00-14:00	**LUNCH BREAK**
14:00- 15:00	**REPORT OF WORKING GROUPS**
15:00- 15:30	**COFFEE BREAK**





Concluding Session

15:30-17:00

- Remarks from LTC Members (Dr. Sudhakar, Dr. Sandor Muslow, Dr. Elva Escobar and Mr. Baïdy Deine)
- Remarks FROM CONTRACTOR REPRESENTATIVES
- Remarks from observers. Dr. Kaiser De Souza, Mr. Libbey and others
- Workshop recommendations
- Concluding Remarks of the Secretary-General.

ANEXO 2

Background paper
(informações gerais sobre o modelo geológico)

Workshop on the Results of a Project to Develop a Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Zone

14-17 December, 2009, ***Kingston, Jamaica***

Background Document

1. Polymetallic nodule resources contain nickel, cobalt, manganese and copper. While they occur in all oceans, deposits in the Clarion-Clipperton Zone (CCZ) are considered to be among the richest, containing high grade and high abundance nodules. Presently, seven of the eight exploration contractors with the International Seabed have exploration contracts in this area. As part of its mandate to conduct resource assessments of prospective mineral deposits in the Area, the Authority met with representatives of the seven contractors to discuss ways of improving the results of resource assessments of polymetallic nodule deposits in the CCZ. In the absence of sampling data across much of this vast geographic area, participants in the meeting suggested that if the suspected relationships between high nodule grade and abundance, and factors such as sediments, volcanism, topography and primary productivity etc. could be established, they could be used as proxies for grade and abundance in poorly sampled nodulized areas. They therefore recommended that the Authority should establish a geologic model of polymetallic nodule deposits for the CCZ. *Figure 1* shows the Clarion-Clipperton zone CCZ with the Contractor and the Authority's Reserved Areas. At the ninth session of the Authority, its Legal and Technical Commission, recognizing that such a model would be useful for prospectors, contractors and the Authority, endorsed this cause of action. Between 13 and 20 May 2003, the Authority convened a workshop in Nadi, Fiji to consider the data that could be taken into account to develop such a model. It identified candidate proxy variables and devised a programme for the development of the model and a Prospector's guide.

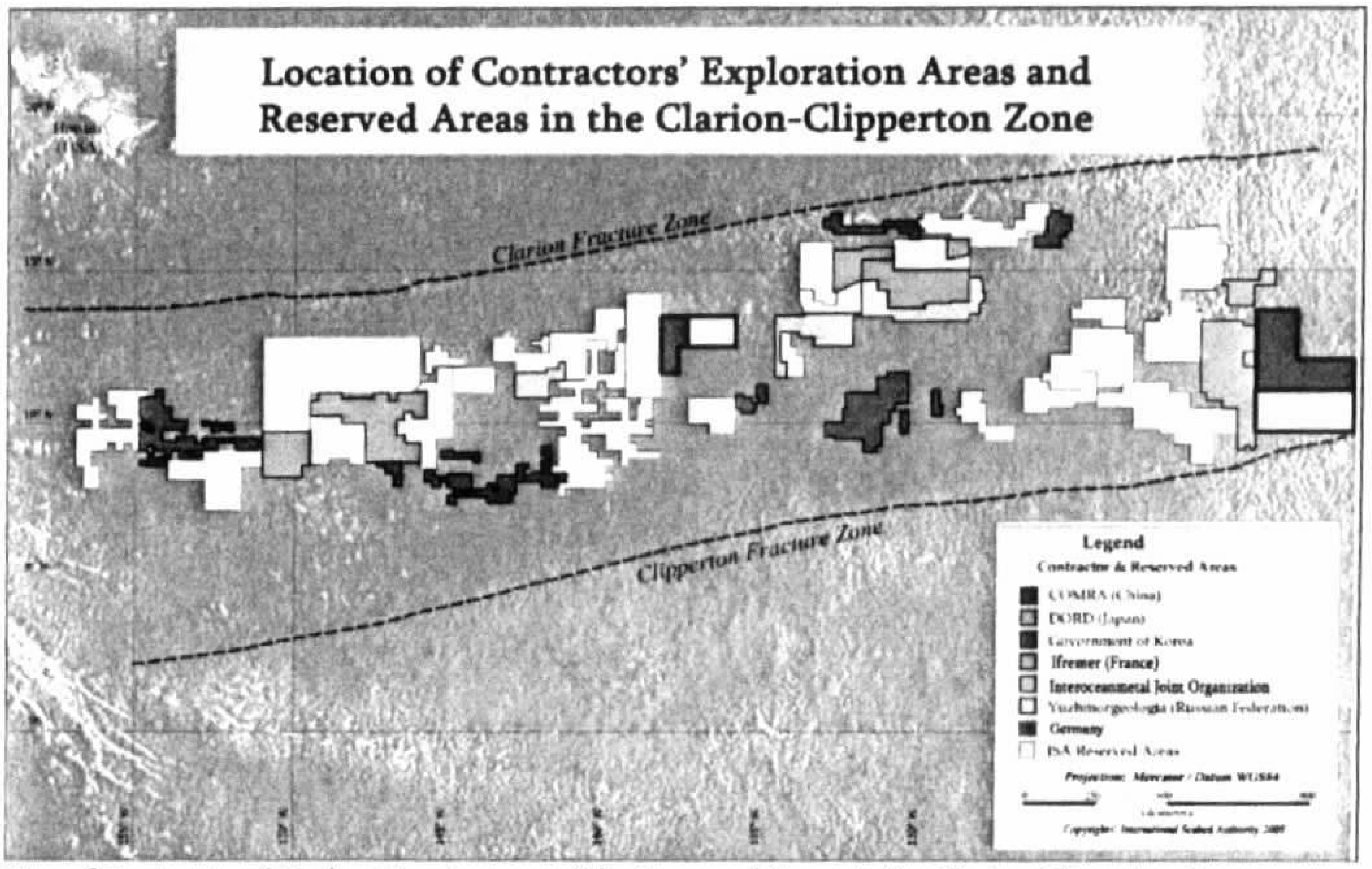


Figure-1: Location of Contractors' Exploration Areas and the Reserved Areas in the Clarion-Clipperton Zone.

2. Taking into account the results of the Fiji workshop, the seven member Group of Technical Experts identified the approach that it would use to generate the model, specified the proxy data that would be tested for use in predicting nodule grade and abundance, and devised a programme of work over a thirty month period to complete the work. The programme commenced in the 2005-2006 biennium. The area of interest for this study is 110° - 160° W Longitude and 0° - 20° North Latitude. Five different data sets of polymetallic nodule abundance and metal content are used in the modeling work, including both publicly available and proprietary data sets.

3. The Authority served as the link between the contractors, their scientists and the Group of Technical Experts for the development of the Geological Model of polymetallic nodule deposits in the CCZ and Prospector's Guide. It set up a closed ftp site for the use of the consultants and contractor scientists (project members). It also uploaded to the ftp site all the data, reports and other related notes concerning the project and made them accessible to all project members.

4. The Authority regularly monitored the progress of the project by evaluating the interim reports and facilitating the resolution of any matters that arose during project implementation. The Authority conducted a mid-course review of the programme at the East-west Centre, Hawaii during October 2006. At the mid-term review meeting, the consultants and the Secretariat discussed the progress of the work under the project and the future course of action to complete it. To facilitate the project's completion and undertake a final review of the model and prospector's guide the tasks were reassigned to the team members.

5. The primary products from the effort are (1) a ***Geological Model*** of polymetallic nodule deposits in the CCZ and (2) a ***Prospector's Guide*** containing a narrative description of the key factors relevant to exploration for polymetallic nodules in the CCZ, including data and available information on known deposits. The drafts of both the reports are ready and have gone through the preliminary process of review by the Authority and by the contributing consultants. The contents and main results from the reports are presented in the following paragraphs

The Prospectors Guide:

6. Included in this report are the results of nine independent studies that provide extensive geophysical, geological, oceanographic, and biological information related to the CCZ deposits and general guidance, based on many years of study of these deposits, of why these deposits occur where they do and criteria for seeking undiscovered deposits elsewhere. This report includes 23 tables and 92 figures.

i. GRIDDED BATHYMETRY OF THE CCZ

7. The seafloor lies mostly between 4,000 and 6,000 meters water depth. The seafloor is characterized by a number of seamounts, some of which reach depths of less than 3,000 meters. The wide-spread seafloor spreading fabric, oriented approximately orthogonal to the trend of the bounding fracture zones, provides a large number of flat floored valleys, separated by irregular, often discontinuous ridges a few hundred meters high. The study used the Smith and Sandwell data set as the base map and incorporated proprietary data and paper maps from ISA Contractors to derive a series of bathymetric grids of the CCZ at resolutions of 1, 0.5 and 0.1 minutes of latitude and longitude. These data files are available at the ISA's Central Data Repository. *Figure-2* shows the 1 minute resolution bathymetric map of the CCZ.

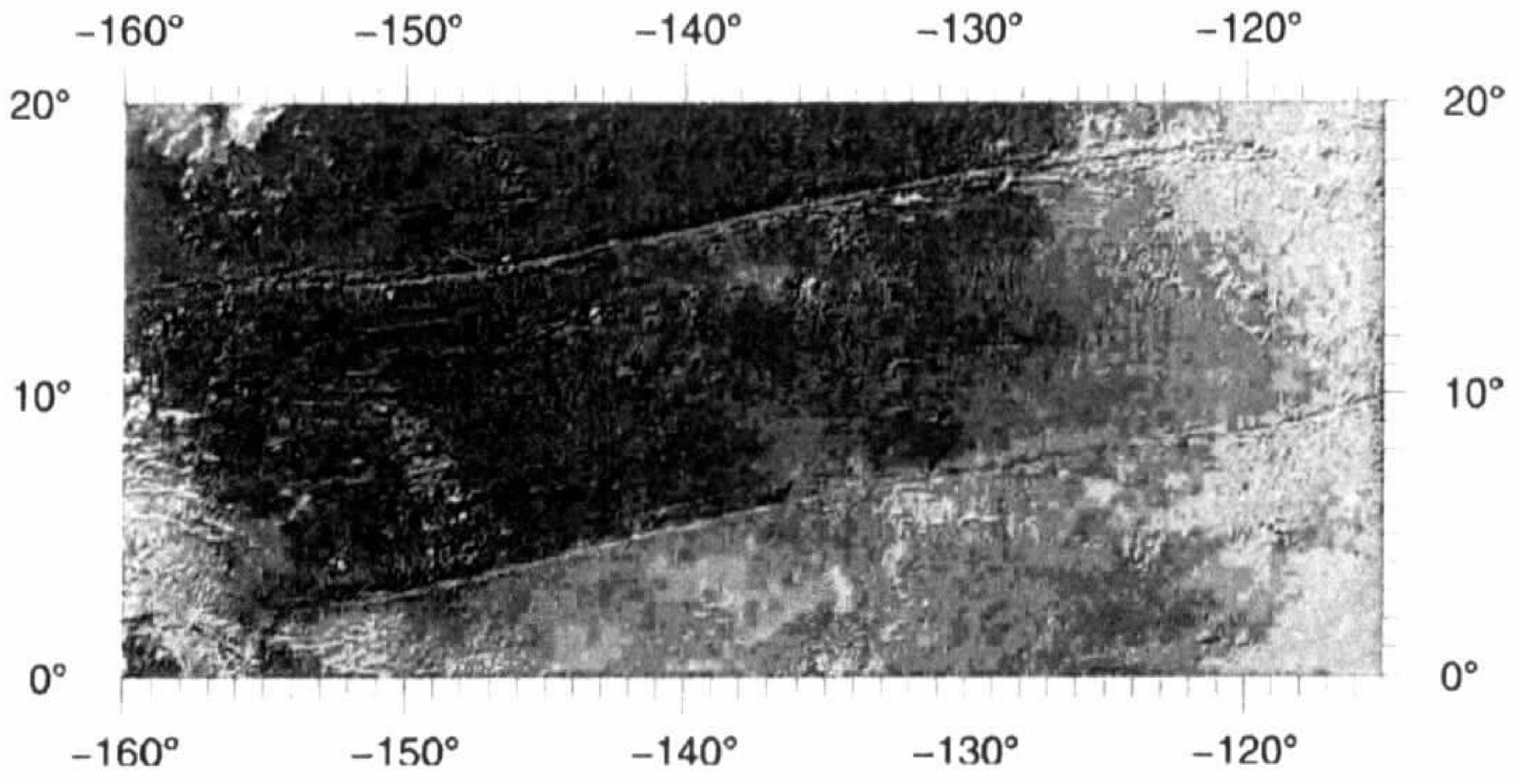


Figure-2: 1 min resolution bathymetry of the CCZ

ii. VOLCANIC, TECTONIC, AND SEDIMENTARY FACTORS

8. This study provides an analysis of the maps of volcanic and tectonic structural elements of the CCZ. The objective is to estimate the possible influences of static factors, (i.e. bathymetry, geomorphology, tectonic structure, and lithology), and dynamic factors (i.e. dynamic geological events such as tectonic movements and volcanogenic, hydrothermal, sedimentary, and erosive processes) on the growth of polymetallic nodules in the CCZ.

9. The bathymetric characteristics within the CCZ follow a pronounced order, most commonly consisting of trends that line up with the overall movement of the Pacific Plate and trends perpendicular to this direction. Generally, water depths and crustal age increase with distance from the East Pacific Rise. Recent seismic activity in the region has been also aligned with or perpendicular to the plate motion, suggesting that it is caused by strike-slip and normal faulting associated with the relief of stress caused by the rifting of the Pacific Plate to the northwest

10. The sediment facies exhibit a unidirectional gradient perpendicular to the fracture zones, trending from predominant carbonate sediments in the southeastern extreme to predominant siliceous red clay in the west-northwest. There are also regional-scale non-conformities, including latitudinal zonation of a variety of young (Pleistocene-Holocene) sediment facies; and a pronounced surface unconformity of Middle Miocene age, denoting an interruption of the sediment accumulation, dislocation and erosion of the earlier cumulated sediments

11. The analysis of the spatial distribution of nodule abundance and metal concentration suggests an axial line of maximum abundance that is approximately parallel to and midway between the bounding fracture zones. The spatial distribution of metal content is different. The Mn/Fe ratio clearly increases from north-south, while, less distinct, decreases from east to west. These observations suggest that volcanogenic-hydrothermal activity of the EPR is one of the main sources of the ore components, which, finally, are included in manganese nodules composition as the result of complicated processes of dispersion and transportation to the bottom in dissolved and organic-fixed forms.

iii. GROWTH MODEL FOR POLYMETALLIC NODULES

12. Polymetallic nodules are composed of both nuclei and concentric layers of iron and manganese hydroxides. Generally, according to their morphology, size and texture etc., polymetallic nodules are classified into three types: S-type (Smooth type), R-type (Rough type) and S-R-type (Smooth-Rough mixed type). They generally grow very slowly, at rates of 1-10 mm per 10^6 yr. Six factors are believed to be important to nodule formation These factors are;

a. Supply of metals to growing surface;
b. Presence of nucleus

c. The corrosive and erosive forces caused by benthic currents of Antarctic Bottom water
d. Occurrence of semi-liquid surface layer on the seafloor (sediment water interface)
e. Bioturbation and
f. Internal Stratigraphy of individual nodules.

iv. NODULE COVERAGE, MORPHOLOGY, AND DISTRIBUTION IN THE EASTERN CCZ

13. In order to understand the nodule distribution within this study area, an analysis was made to determine the correlations among such nodule parameters as coverage, abundance, morphology, size, genetic type, and the water depth, bottom morphology, and geographic region. A classification system for nodule morphology and formation mechanism separates hydrogenetic from diagenetic nodules, and isolates different morphological types (discoidal, spheroidal, etc.).

14. Throughout the eastern part of the CCZ diagenetic, discoidal and ellipsoidal nodules are the dominant types. In the areas of highest nodule abundance, nodules with multiple nuclei are the most common morphology. The highest percentages of seafloor covered by nodules are found in water depths between 4,100 – 4,200 m, and the highest abundance values are found between 12° to 16° N latitude.

v. SEDIMENTS IN THE EASTERN CCZ

15. Detailed examination of bathymetry and sediment distributions and compositions in the eastern CC has been carried out. The topography of the area is characterized by NW-SE to NNWSSE trending elongated seabed structures. Two predominant acoustic reflectors delineate Miocene and Oligocene unconformities. The surface sediments consist of Pleistocene-Holocene siliceous silty clay and ooze underlain by Miocene to Pliocene pelagic clay, zeolitic clay and zeolitic crust and hiatuses of Plio-Pleistocene and Late Miocene ages. The ocean floor is a hilly plain - plateau, crossed by a strictly north-south system of horst and graben structures. The surface relief of this hilly plain is generally less than 100 m in extent, with hills and ridges exceeding 100 m in plains.

16. The most common sediment types in this region include Reddish Brown clay and zeolitic clay (less than 5% amorphous silica content), slightly siliceous (with 5-10% amorphous silica content) and siliceous (10-30% amorphous silica content) silty clay as well as slightly calcareous (5-10% $CaCO_3$ content) and calcareous (10-30% $CaCO_3$ content) silty clay. The uppermost part of the sediment profile features predominantly siliceous, silty clay, which, down core grades into slightly siliceous, silty clay. Calcareous, silty clay and calcareous oozes are observed only in the southern part of the study area. Metal contents in these sediments generally follow the following trend of decreasing concentrations- Fe > Mn > Cu > Ni > Zn > Co

vi. NODULE GENESIS & SEDIMENT DISTRIBUTION IN THE KOREA ALLOCATED AREA

17. Nodule genesis and growth are affected by many environmental factors, especially (1) supply of biogenic, terrigenous and hydrogenetic material to the sediment and to the nodules; (2) deposition and reworking of sediments due to seafloor morphology; (3) bottom water composition and movement; and (4) bioturbation. Morphological and textural characteristics of manganese nodules in the study area are summarized as follows. The northern block (KR2) is characterized by relatively high nodule abundances, low Mn/Fe ratios, low Cu and Ni contents, and high Fe and Co contents. In morphologies, poly-nucleated and irregular-shaped nodules are dominant. In texture, smooth types and transitional types between smooth and rough are abundant. All these characteristics indicate that hydrogenetic process has been dominant over diagenetic one in the northern block. Taking account of the relatively slow growth rate of hydrogenetic nodules, the presence of smaller nodules in the northern block is consistent with other chemical, morphological, and textural characteristics of nodules.

18. On the contrary, the southern block (KR5) is characterized by relatively low nodule abundances, high Mn/Fe ratio, Cu, and Ni, and low Fe and Co contents. Figure 1 shows the abundance ranges in areas KR5 and KR2. Different from the northern blocks, rough-surface and dimorphic (rough on one side, smooth on the other) discoidal and ellipsoidal nodules are the dominant morphological and textural nodule types in the southern block. All these characteristics indicate that digenetic process have dominated over hydrogenetic ones in the southern block

19. The sediments in the study area consist of three major lithological units: Units 1, 2, and 3, which are distinctive in color and textures. Unit 1 comprises the topmost layer and shows dark grayish brown to dark brown colors. It is homogenous mud and characterized by very high water content with dominant occurrence of quartz and illite. Unit 2 lies below or alternates with Unit 1 in most cores. It consists of yellowish brown to brown colored mud and includes lots of burrows filled with overlying Unit 1 sediments. Burrow densities decrease downward. Unit 3 is overlain by Unit 2 in most cores where it occurs and shows very dark brown to black color. Both Units 2 and 3 contain abundant smectite minerals. Sedimentation rates for all units are estimated to be near 0.1 mm/1,000 yr.

20. The distribution of different nodule genetic types in the northern and southern blocks can be explained with topography and sedimentation rate. It is known that hydrogenetic nodules are formed preferentially in areas with high topographic variation and low sedimentation rates, consistent with dominant nodule types and geological settings found in the northern block. Diagenetic nodules are known to be formed preferentially in flat abyssal areas with high sedimentation rates. The southern block has a geological setting more preferable to diagenetic nodule formation than the northern block.

vii. BATHYMETRY AND SEDIMENTATION IN THE COMRA CONTRACT AREA.

21. The area explored includes two non-contiguous portions, an East Area and a West Area. Water depth in the East Area ranges from 3,901.8 m to 5,590.7 m. The West Area ranges in depth from 2,969.1 m to 5,986.6 m. The area deeper than 5,300 m in water depth covers about 8.5% of the East Area and about 11% of the West Area. Water depth in the COMRA area, in both portions of the area, is mostly between 5,000 m to 5,300 m. There are generally four types of sediment in surface layer of seafloor of the COMRA area, including siliceous clay, siliceous ooze, siliceous-calcareous ooze and calcareous ooze. Siliceous sediments are the most abundant sedimentary types in the East Area. Siliceous clay covers 72% of the area and siliceous ooze 22%. Siliceous clay is mainly distributed in abyssal hills and plains with an average water depth of 5,096 m. Siliceous ooze is mostly distributed in transitional areas between siliceous clay and calcareous ooze in the southeastern part of the East Area. Calcareous sediment is limited to seamounts in southeastern and western parts of the East Area. In general, calcareous sediments confined to the tops of seamounts, while the siliceous sediments cover the lower regions.

viii. REGIONAL EXAMINATION OF SEDIMENTS.

22. Data sets were provided to the study by three Contractors in the Area, including the French- IFREMER, Chinese contractor COMRA, and the multi-national consortium IOM. In addition, publically available sediment data within the CCZ study area were downloaded from the U.S. National Geophysical Data Center (NGDC). In order to investigate the relationships between the sediment type and nodule abundance and metal content, we interpolated a sediment type for each of the 0.1° grid points where nodule data are available. We then calculated the average metal content and abundance for each sediment type represented in the data set. The results generally confirm the qualitative conclusions noted by scientists for many years, i.e. that the highest abundances of nodules occur in the siliceous sediments and not in the calcareous sediments. However, somewhat surprisingly, siliceous, calcareous mud host the highest abundances, and the siliceous oozes have surprisingly low abundances.

ix. BENTHIC BIOLOGICAL DATA FROM THE CCZ

23. A number of research programs have sampled the abyssal North Pacific seafloor, many of which collected data for multiple parameters of interest to biogeochemical modeling efforts. Overall, meiofaunal (63-300 μm) and macrofaunal (300 μm-3 mm) abundances and/or biomass represent the most widely sampled biological parameters in this region, and these data sets also exhibit the greatest consistency in collection methods across field programs. Preliminary examination of the data indicates that, in general, the abundance of these benthic fauna is roughly proportional to the flux of nutrients available in particles settling from the surface.

Geological Model of polymetallic nodule deposits in the CCZ

24. In this report, the results of three independent approaches to establish the Geological Model for the CCZ deposits are presented. No undisclosed or proprietary algorithms are used so that the Model can be subject to peer review in the short term and available for updating as better data or better algorithms become available. Report includes over 23 tables and 58 figures.

x. PRIMARY RESOURCE DATA SET

25. The area of interest for this study is 110° - 160° W Longitude and 0° - 20° North Latitude. Five different data sets of polymetallic nodule abundance and metal content are used in the modeling work, including both publicly available and proprietary data sets. The additional data sets were generously provided by the Contractors (COMRA, Korea, IOM, France) and by the consortia Ocean Minerals Company (OMCO). These contributions of additional data increased the Nodule abundance data base to over 61000 data points (as against ~ 300 available with Authority's Central Data Repository-CDR) and the metal grade values to nearly 8000 data points (as against ~850 available with CDR). The methods used to produce this integrated data set and its basic characteristics are described in the report.

26. In order to preserve the spatial information inherent in these data while accommodating the proprietary concerns of the data owners, the above data were assembled into groups representing all data collected within a defined grid with dimensions of one-tenth of a degree of both longitude and latitude. For each grid block where data are available, the data values are averaged. For each resource parameter (abundance and metal content), the number of stations within the grid bounds, mean, minimum, and maximum values, and, where at least three stations are present, the standard deviation of the values are reported. The report presents the interpolated maps generated for the abundance and the metal values. The *Figures 3, 4* and *5* respectively show the original data, the gridded data and the interpolated contours for the abundance values.

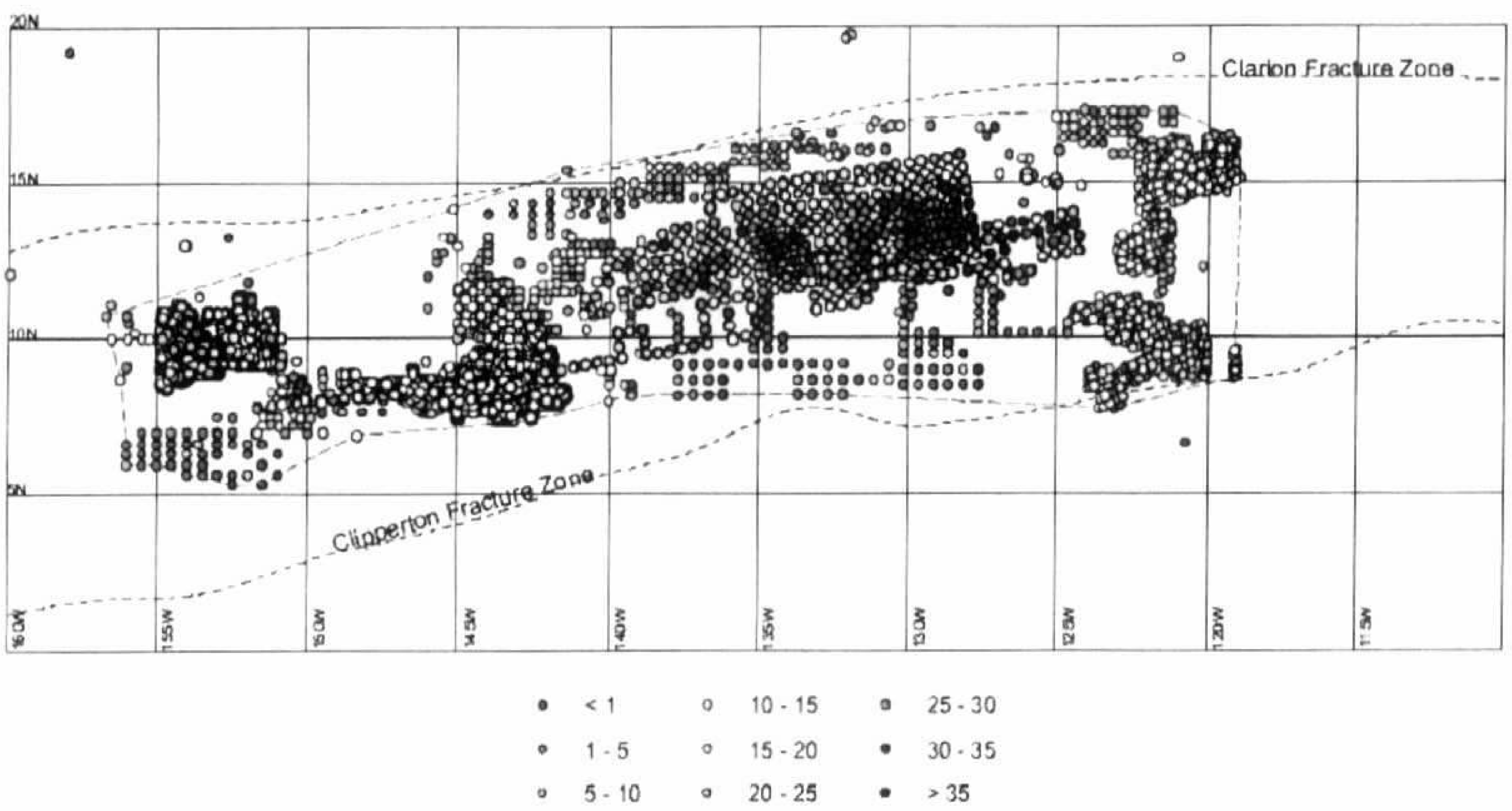


Figure 3: Abundance (Kg/m²) Original Data locations and values

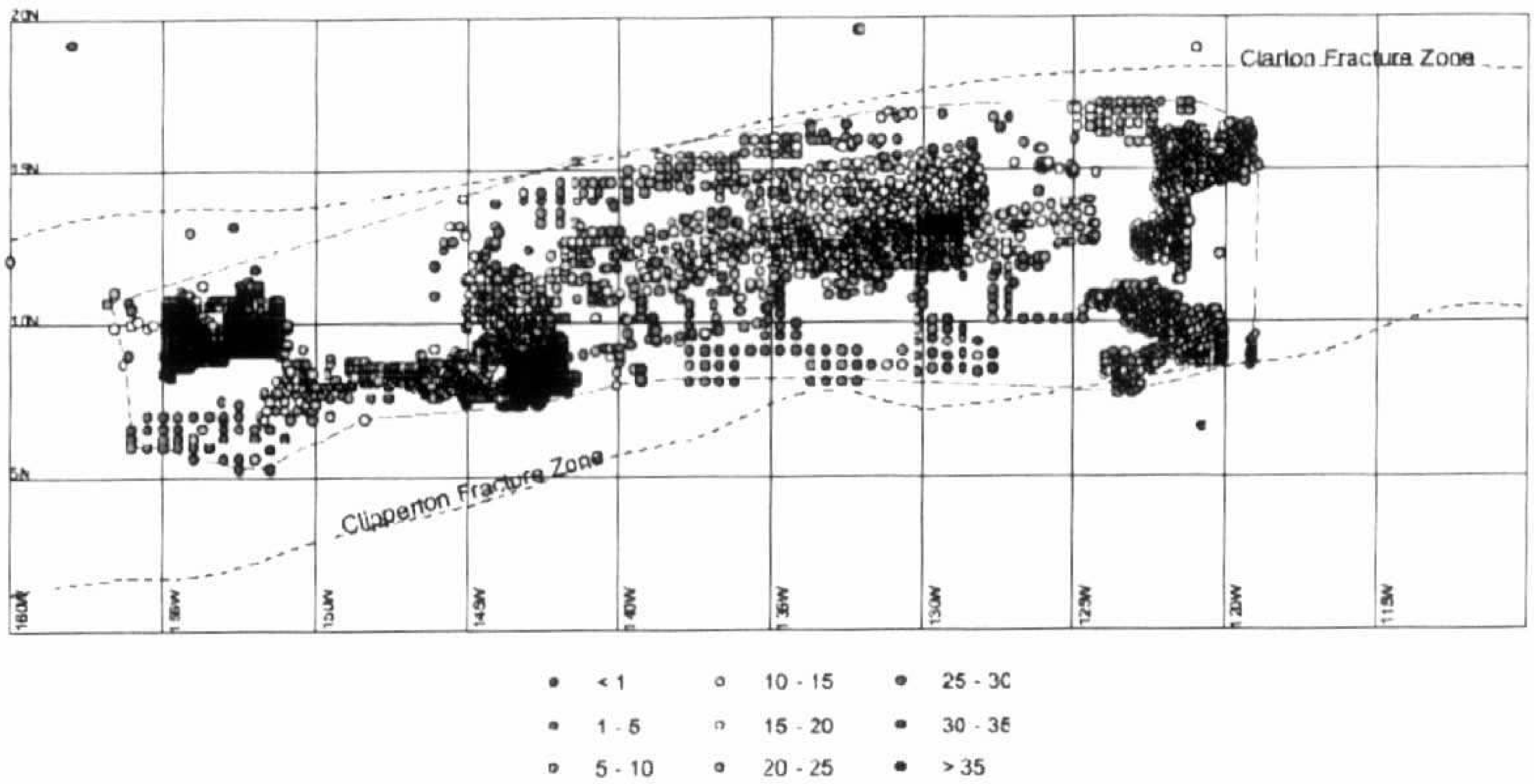


Figure 4: *Grid block data locations and values of Abundance (kg/m^2)*

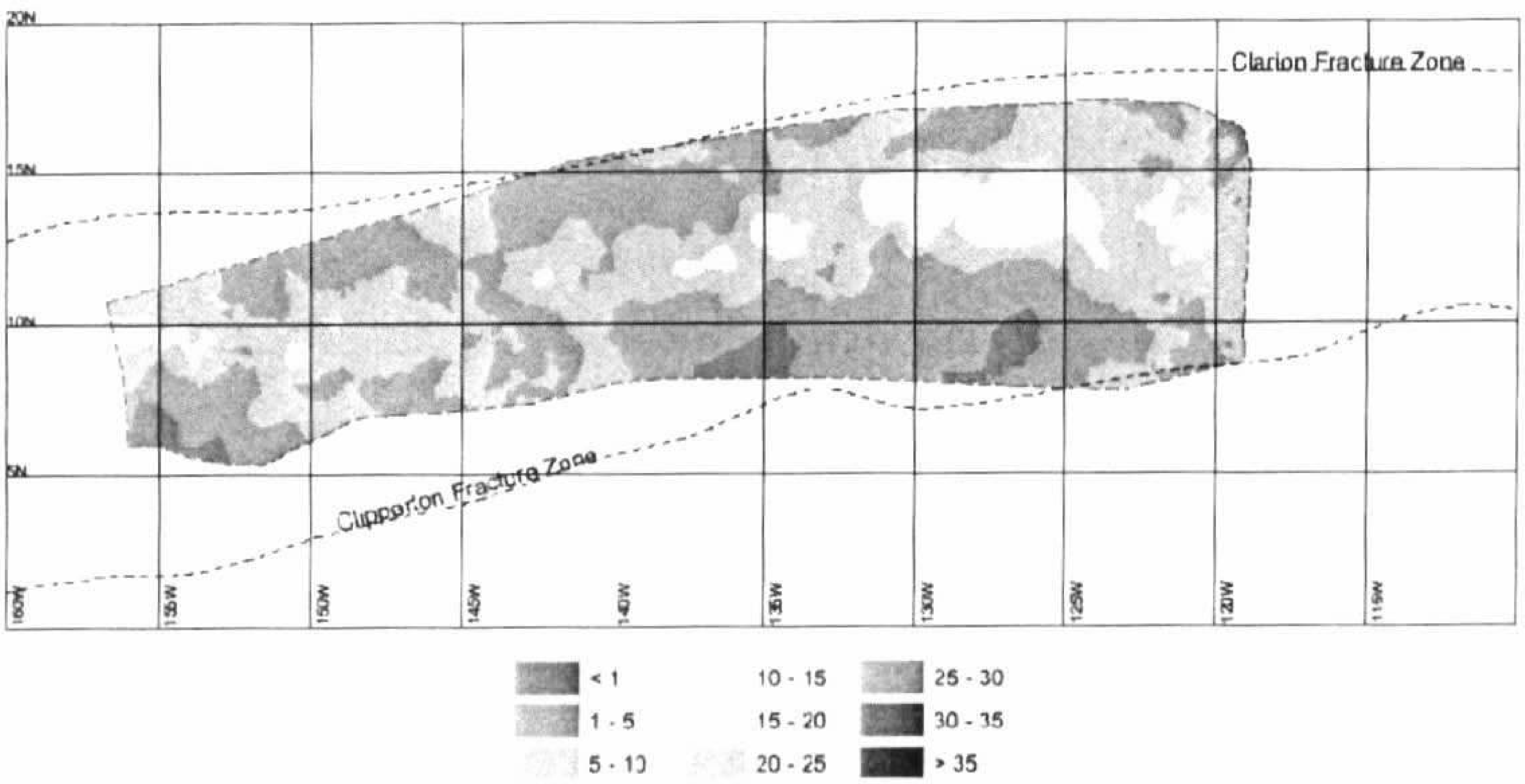


Figure 5: *Abundance- grid block data interpolated contours.*

xi. INFERRED RESOURCES

27. Several methods of estimating the quantities of polymetallic nodules and contained metals within portions of the study area. These methods range from interpolations made using standard kriging methods to extrapolations from the existing data to predict quantities outside of the areas covered by the available data. Table 1 lists representative values of these estimates. The first three rows of this table are derived from different interpolation schemes, while the last row uses extrapolations based on predictions from a linear regression model that uses specific proxy variables to predict metal content in the CCZ where no data are available.

Table-1: Estimated resources.

Source	Included Area (km2 X 106)	Nodules	Estimated Tons (metric tons X 10^6) Mn	Co	Ni	Cu
Reduced area	3.83	21,100	5,950*	46.4*	270*	234*
Total study area	4.19	30,700	8,657*	67.5*	393*	341*
Biogeochemical model	4.85	27,100	7,300	58.0	340	290
Potential resources of nodules	12.57	62,000	17,500	134.0	761	669

*Estimated using mean metal content values

xii. BIOGEOCHEMICAL MODELING

28. 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).

29. The general model of formation of the Clarion-Clipperton Zone (CCZ) polymetallic nodule deposits is illustrated in *Figure 6*. The primary sources of metals for these deposits are from terrigenous or volcanogenic sources on the North & Central America and the East Pacific Rise. The metals are adsorbed to the surfaces of fine-grained sediments and carried with them westward along the North Pacific Current. The sediments are consumed by filter-feeding zooplankton en route and converted into silt-and sand-sized fecal matter that is large enough to sink to the seafloor in the deep tropical Pacific waters. These fecal pellets can then be metabolized by benthic animal communities and bacterial processes after they reach the sea floor, processes that will remove the organic materials that bind the metals and will reduce them to cationic species that are readily absorbed by the anionic manganese oxide matrix that constitutes the bulk of these deposits.

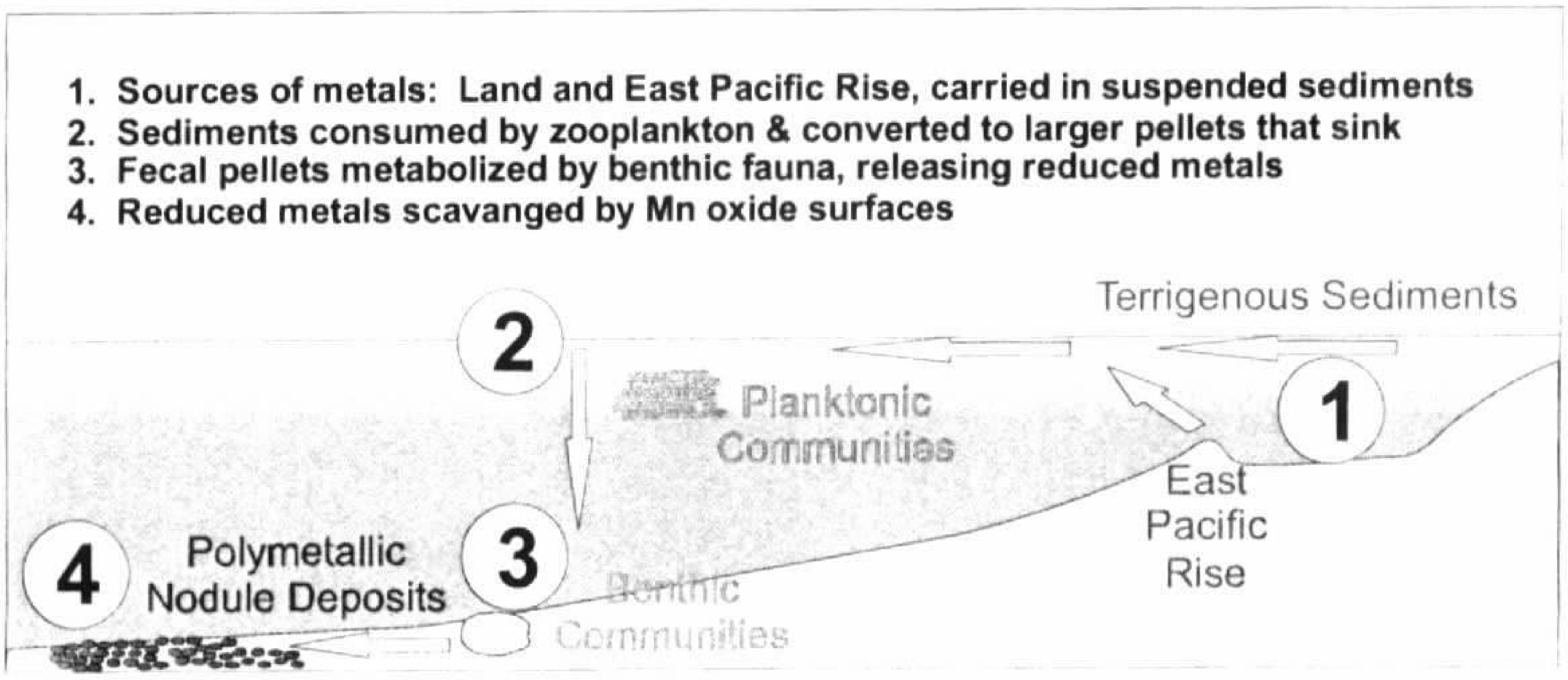


Figure 6: General Nodule formation model for CCZ.

xiii. SDSS (SPATIAL DECISION SUPPORT SYSTEM) MODELING

30. Spatial Decision Support System (SDSS) modeling was employed to estimate the mineralization potential in selected areas of the CCZ where nodule abundance and metal content data are not available. The study is based on data sets 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. The results of this work provide differing assessments of the spatial distribution of areas within the study area where the occurrence of nodule deposits is likely. The results consistently indicate that the better prospects can be found in the center and northern parts of the CCZ, while the southern, southwestern and eastern parts of the CCZ are likely to be unfavorable for nodule deposit occurrence. Likely prospects of nodule occurrence in CCZ from Weights of Evidence Modeling, Logistic Regression and from Fuzzy Logic are listed in the following figures. (*Figures 7, 8 and 9*). The future explorers might expect to get better results from exploration efforts that focus on the center and northern areas of the CCZ than the southern, southwesters, or eastern areas

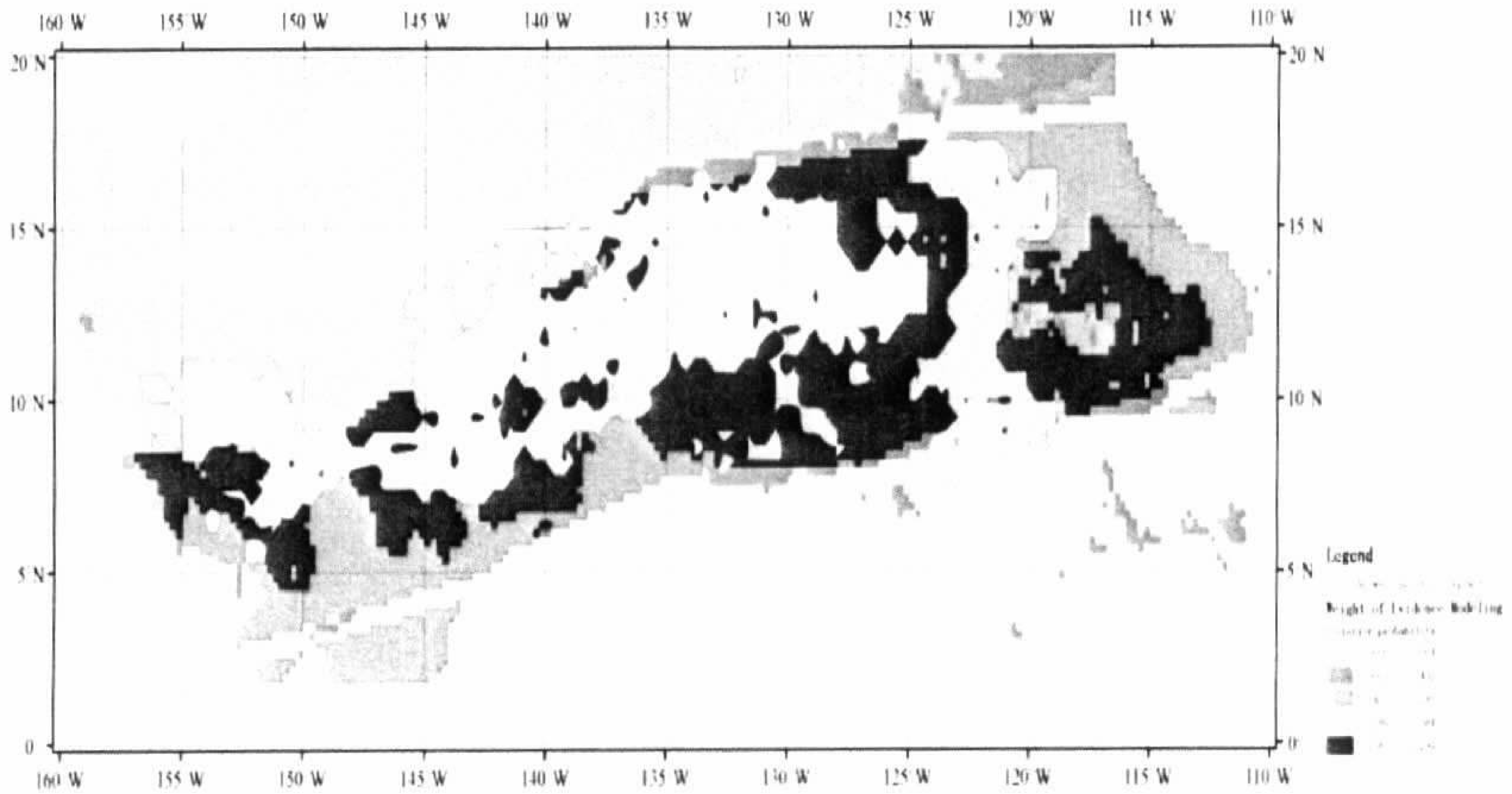


Figure 7: Likely Prospects for Nodule Occurrence, Weights of Evidence Modeling

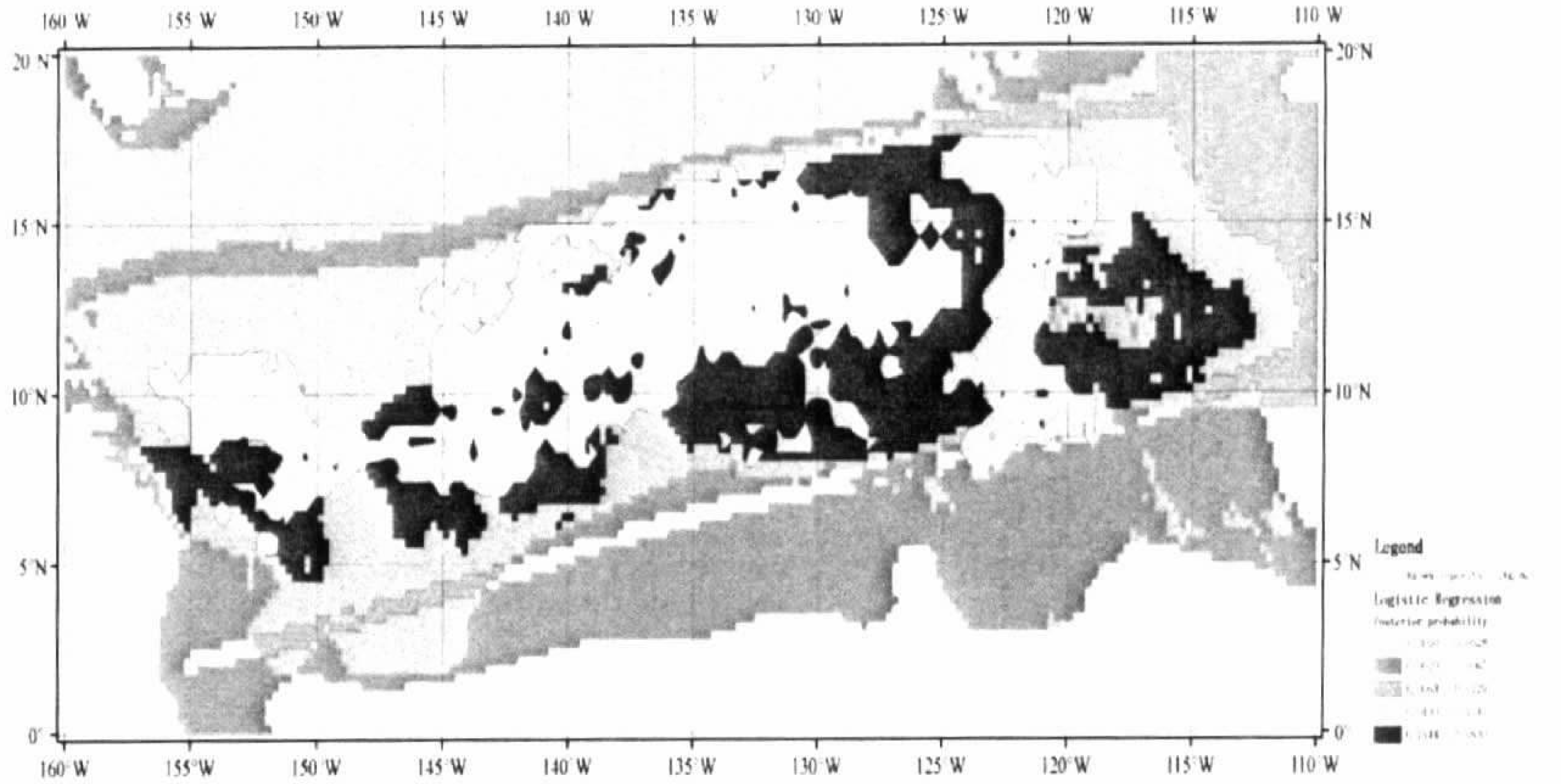


Figure 8: Likely prospects of nodule occurrence- Logistic Regression.

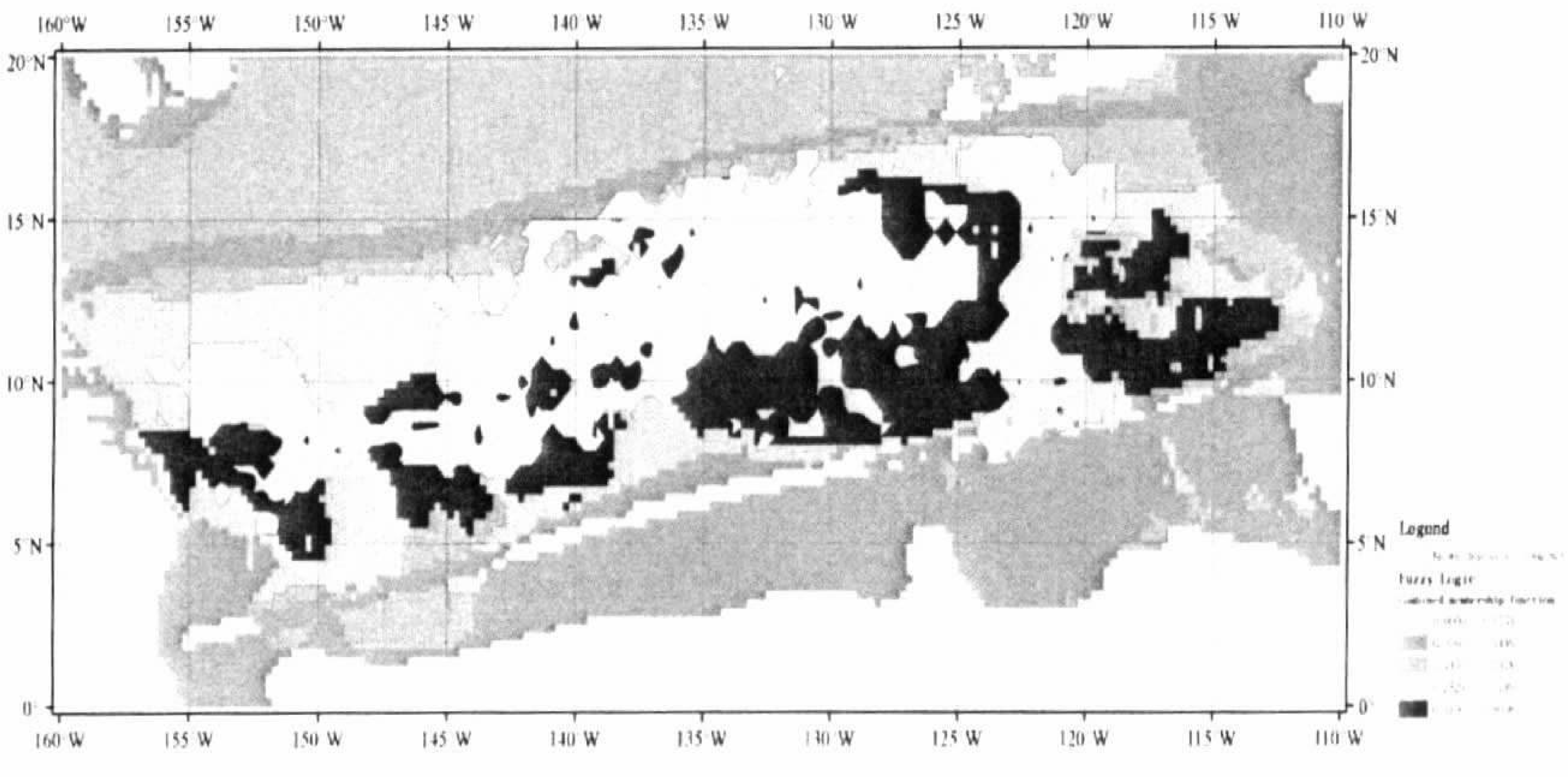


Figure 9: Likely prospects of nodule occurrence- Fuzzy Logic

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ANEXO 3
Lista de participantes

WORKSHOP ON THE RESULTS OF A PROJECT TO DEVELOP A GEOLOGICAL MODEL OF POLYMETALLIC NODULE DEPOSITS IN THE CLARION-CLIPPERTON ZONE

Convened by the

INTERNATIONAL SEABED AUTHORITY
KINGSTON, JAMAICA

14-17 DECEMBER, 2009

List of Participants

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2.	Dr. Huaiyang Zhou zhouhy@tongji.edu.cn	State Key Laboratory of Marine Geology School of Ocean and Earth Science Tongji University Siping Rd. 1239, Shanghai, 200092, P.R.China	"Bathymetry and Sedimentation in COMRA Contract Area" and "Spatial Decision Support System, Fuzzy Logic Modelling and Illustrative Maps of Potential Nodule Resources in the CCZ"
3.	Prof. Lindsay Parson lmp@soc.soton.ac.uk	Southampton Oceanographic Centre University of Southampton Waterfront Campus European Way Southampton SO14 3ZH United Kingdom	"Bathymetry and Basemap for the CCZ"
4.	Prof. Peter Halbach, hbrumgeo@zedat.fu-berlin.de	Institute of Geosciences Free University, Malteserstr. 74-100 12249 Berlin, Germany Tel: 030-8387-0675	"Review of the Geological Model and Prospector's Guide"
5.	Dr. Valcana Stoyanova v.stoyanova@iom.gov.pl	Inter Ocean Metal Joint Organization (IOM) Szczecin, Poland	"Relation between Nodule Coverage, Morphology and Distribution" and "Analysis of Volcanic and Structural Elements of Clarion-Clipperton Fracture Zone (contribution of Dr. Kotlinski and Dr. Yubko)"

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ANEXO 4a
Recomendações dos grupos de trabalho (WG1)

Workshop on the Results of a Project to Develop a Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Zone

Working Group 1

Participants:

1. Kaiser de Souza- Chairman
2. Lindsay Parson – Reporter
3. Walter R. Roest – Reporter
4. Jose Luis Medenos
5. Sudhakar Maruthadu
6. Eusebio Lopera Caballero
7. Peter Halbach
8. Baïdy Diène
9. Huaiyang Zhou
10. Elba G. Escobar-Briones
11. Sandor Mulsow
12. Vijay Kodagali

Introduction

Working Group 1 was given the task of:

- developing recommendations on how to take the geological model of Clarion-Clipperton Zone forward to Indian Ocean, Atlantic Ocean, Peru Basin, Mexico Basin and elsewhere,
- identifying shortfalls, deficiencies and limitations of the model on application to other areas
- suggesting how to improve the Model and the Prospectors Guide

Indian Ocean

This presentation introduced a brief history of exploration in the Indian Ocean. Several distinct basins exist and these all have some potential for polymetallic nodules, for example Somali, Crozet, Wharton, South Australia Basins. The density of data is large in Central Indian Ocean Basin (CIOB) and remains poor in the other basins.

In 1981, two areas were identified as Siliceous ooze area in the North and Red clay area in the South of the basin. Strikingly, the geological model of CCZ reports the potential deposit of nodules between 12-16 N compared to the similar report from CIOB being situated between 12-16 S. The spatial setting of the CIOB is also similar with respect to the chlorophyll distribution in the CCZ. Biomass values 100-150 g/m^2 x yr here (cf 50 g/m^2 x yr in CCZ) Biomass values 100-150 g/m^2 x yr here (cf 50 g/m^2 x yr in CCZ). The age of the oceanic crust ranges from 49-59 Ma, chrons 21-25.

Terrigenous sediments to the north of the CIOB are derived from the input of rivers like Ganges and Brahmaputra originating from the Himalayas that include illites and kaolinites. Regular sediment sampling shows calcareous sediments to the west, siliceous sediments in the central part of the CIOB changing to pelagic (red) clays to the South. Nodules occur in water depths ranging from 4600-5400 m

Nodules are of generally mixed type and abundance and grade both increase towards the south (average Co+Cu+Ni 2%, abundance 5-7 kg/sq m). Nodule nuclei are dominantly volcanic, both basaltic and pumiceous and fragments of older nodules compare to the Pacific, where they are mixture of biological (shark teeth etc), volcanic and oxidic nodule fragments .

After the discussion, the participants conclude that the CCZ model may be applicable to CIOB, and recommend that the model be tested in this region.

This recommendation is based on the strong similarities of several factors, including, water depth situated below the CCD, sediment type, recent volcanism and the structural and tectonic setting in particular the chains of seamounts. There are large seamounts raising from the seafloor up to a height of 2000 m (water depth 3200 m). There is a strong tectonic frame work in the CIOB, where 73 E, 75 45 E and 79 E fracture zones are reported similar to Clarion and Clipperton fracture zones in the Pacific.

Discussion showed that other factors may be different, such as patterns of primary production and different nucleus composition, which are probably due to proximity to volcanic island arcs (e.g. Indonesia) to the East.

In order to increase the knowledge of the area it was strongly recommended that contractors make data available to develop a model of the CIOB.

Participants felt that the CCZ model needs to be tested in the CIOB, before it can be considered as a global model for polymetallic nodules.

Atlantic Ocean

A presentation on a Collaborative project proposal by countries bordering the South Atlantic Ocean was presented with the aim to identify how this project could provide a framework for the applicability of the geological model and the prospect guide of the CCZ in the South Atlantic Ocean.

The aim of the project is to collect, integrate and make available in a single geo-referenced environment all the available data and information on the geology and mineral resources of the South Atlantic Ocean. Such a dataset would allow the identification of new areas for future projects on specific mineral resources and would facilitate the applicability of the CCZ model in the South Atlantic Ocean.

The results of the project could be used as a geological reference and a guide for the technical and scientific activities to be carried out in the South Atlantic Ocean by contractors, potential applicants and others.

Participants expressed their views on the various parameter of the South Atlantic Ocean comparing them to CCZ. These parameters included the strong continental control of sedimentation due to the presence of major rivers from both sides, presence of Antarctic currents, lack of siliceous sediments (except diatom ooze in the far South), deep calcite compensation depth, etc. Participants felt that these parameters could constrain the applicability of the CCZ model to this region. However, the project could benefit from the Prospectors Guide.

Participants were informed that, comparing to other regions, there are limited data available in the South Atlantic Ocean, and would be insufficient to make a full test of CCZ model in this region. Therefore, it is proposed consider the project in two phases.

The first phase would be an ISA-led initiative facilitating the collection of all available data (and analyses) for the South Atlantic, from coastal and other States, to be consolidated and create an integrated database. Participants agreed that this phase could be completed in a two years programme.

The second phase would be a test of the CCZ model on the suitable areas of the South Atlantic Ocean.

The participants suggested that the proposal for the South Atlantic Ocean project could be a good opportunity for the application of the prospector Guide in this region. The participants also felt that the proposed project could provide the necessary framework to search for areas where factors/conditions that control CCZ nodule formation also exist in the South Atlantic Ocean.

Mexico Basin

The presentation on the area off the Mexican margin, characterized by a very narrow shelf followed by an extended abyssal plain, showed that the metal content of nodules in this area is strongly related to a direct terrestrial contribution.

In terms of primary producers Mexico Basin is in a high condition inshore (like upwelling) to a nutrient limited conditions offshore. Silica export and aggregate particles that sink, which contribute to the nodule generation. This particular export setting can only occur near the coast, or near upwelling regions like Peru and Ecuador, but not offshore where stable oligotrophoc conditions pertain.

Another important factor is the regional dissolved oxygen distribution in the East Pacific. Nodules in Mexican EEZ occurs under MOZ hydrographic conditions. Using water density of ca 27 gm/cc (equivalent of approximately 3000-3500m water depth) Oxygen dissolved is controlled by slumping of sediments to the seabed from the shore.

For the Mexican case, this is a major factor (which is not included in the CCZ model). Dissolved oxygen can also be delivered by the deep Antarctic water controlling CCD in the CCZ area. For example, the Indian results confirm importance of AABW – so are these two mechanisms incompatible?

Several studies of the beaches and river input (metal content). Metal content in solid sediment compositions, depositional rates, (isotopic dating very accurate). Verification of metal inputs by numerous samples/analyses. The Mexican situation indicates that continental input is very significant. Another factor identified is the hydrothermal input from sections of the EPR associated with Clarion and Clipperton zone.

So, two factors (terrigenous and hydrothermal input) which were largely discounted during the development of the CCZ seem to be significant factors off the Mexican coast, and need to be considered in the GM as is the viability of export of POC to deep in offshore areas.

We recommend that the CCZ model be revisited taking into account the results presented regarding the Mexico Basin, and particularly the importance of hydrothemal input and the lateral transport of sediments and dissolved metals of terrigenous origin.

Peru Basin.

A presentation on the geology and nodules resources of the Peru Basin was given by one of the participants. Some of the differences between this area and the CCZ were exposed, including the presence of mud closer to the shelf and the high concentration of micro nodules. Another critical issue exposed was the pattern of the bioproductivity isolines. The Peru Basin has three times more than CCZ (up to 150 g/sq m x yr). Peculiar cauliflower nods here. The nodules of the Peru Basin have very fast growth (cms/million year) an its abundance is higher, up to 45 kg/sqm. Peru Basin has also high organic flux from surface with much higher diagenetic conditions that in the CCZ. Reducing conditions are more prevalent in Peru Basin than in CCZ. Mn/Fe ratios (up to 20) are very high compared to CCZ and Mn/Fe versus Cu, shows strong divergence (Mn/Fe vs Ni not so much).

Therefore, the working group recommends that the analyses and results from the Peru Basin, and particularly the high Mn/Fe ratios representing the type of end member composition of the digenetic nodules observed, also be considered in the CCZ model.

Other recommendations

Participants also discussed and took note of the following points:

a) there was a potential for the applicability of the CCZ model in the North Atlantic Ocean;

b) contractors could test the model in their areas, and the ISA could test the model in the reserved areas;

c) trace metals might be of high future importance considering the growing market trends. For example, molybdenum, zinc, titanium, REE and others should also be used in the model to check its applicability to define their resource potential;

d) the geological model and the prospector's guide have dealt with the nodule morphology, size and shape and also the sediments. However, during the discussions following the presentations, it was observed that, there is no uniformity in the classification schemes for all these parameters. Contractors are using their own method of classification. This working group, therefore, recommends a standard classification scheme to be developed. It is suggested that the Authority convenes a workshop/meeting of experts on this issue and that the standard scheme be made applicable to all future publications and reports.

ANEXO 4b
Recomendações dos grupos de trabalho (WG2)

Working group-II
Exploration Technology

Although several experts believe that many of the individual technologies needed for the basic functions needed to collect CCZ nodules are accounted for by capabilities commercially available today, others more recently attracted to analyzing the attractiveness of nodule harvesting call for the ISA to aid in the analysis by helping to provide:

- Current status of technology developed or the state of technology in development for exploiting and readiness for exploration and ultimately harvesting nodules at depth (4-6000m), and especially those that would minimize or avoid environmental disturbance;
- Set of reference models for estimated costs because without knowing the cost, the techno-economic viability study can not be done which is the primary step before going after the large investment need for actual nodules harvesting;
- Provide the state of process technology (extractive metallurgy); and,
- Means to evaluate the additional economic value of the nodules provided by such other elements as Titanium and the Rare Earths (both in terms of percent content and any commentary on processing methods/costs. Since any chance to increase the value of recovery or any technology to reduce recovery or processing costs is crucial to nodule harvesting frequent such analysis should help existing contractors and attract new interest. It is recommended that the ISA commission a market-oriented study to help the community more correctly assess the economic benefits of nodule harvesting including projections for Rare Earths and other economically significant components.

Even where component technologies are mature there are no openly available operational integrated system tailored to CCZ operations either at scale or sub-scale. Thus a significant confidence-building milestone would be an open demonstration with today's technology a sub-scale, in water at depth, trial nodule collection operation. Such a set of such activities would give capital markets, potential contractors, and technology providers increased urgency to focus on ISA and contractor activates. One approach to attain such a demonstration is envisioned in the latter sections of this workshop report by using such a system to provide environmental data and validated procedures to eventually provide a reference document that would fulfill claimants' environmental contractual requirements as far as possible.

With the relative maturity of components explorations technology is suggested to focus more on the gaps that need to be filled for the contractors. Two needs seem to rise to high importance: environmental data and nodule data for specific contractor fields. Environmental data and plans are needed to fulfill the contractual obligations (particularly with respect to the CCZ contractor areas). These needs appear to be so similar to all the contractors that some collective effort should be considered to reach a common or reference contract answer more speedily. Additionally, data detailed enough to make decisions on the order of importance of nodules fields (and perhaps suggesting if tailored collection techniques might be required) to harvest within claims is needed.

Biota and environmental data
Additional scientific research to fulfill the requirements of the contracts to include specific focus on CCZ Biota is needed. Biology census to develop baseline and provide a common understanding should be a high priority.

Specifically, new sensors (e.g., are there electrical, acoustic or chemical means for stand off detection of biota?) should be considered to determine if there are more rapid capabilities to increase spatial awareness of biota for environmental planning or even to modulate mining behavior during harvesting operations to avoid areas of biotic concentrations.

Micro Exploration
To date, Technology has yielded data for the macro (CCZ-wide) that is generally quite satisfactory for the contractor baseline use. However, for their particular use in their fields for planning harvest operations more data is needed and may suggest that a common/baseline vehicle be investigated based on open architecture standards discussed below) to, *inter alia*:

- Increase data commonality;
- Decrease unit and maintenance costs;
- Allow new technologies (e.g., sensors like gamma rays, lasers; batteries; communications; *et al*) to be inserted more easily;
- Allow multiple vendors to compete;
- Allow collaboration between vehicles;
- Enable easier and more complete data fusion; and,
- Standardize data and communications to reduce cost.

Such a micro data collector would provide fine-grained data needed to assess in detail anticipated actual harvesting operations, and would likely be useful in monitoring or post harvest environmental assessments with confidence building standardized sensors and data.

Funding
Funding for at least the Biota/environmental exploration technology (above) and perhaps data collection and operational validation should be assessed against the missions of such organizations as the USA National Institutes of Health, the philanthropic Howard Hughes Medical Institute, the Chilean Servicio Nacional de Salud, and other similar national and charitable organizations. These groups and institutions should be excited to be able to fund early benthic biotic research firsthand under the ISA scientific research authority and perhaps realize some of the potential step functional increases in unique medical and genetic knowledge leading to dramatic improvements in human health.

From the ISA point of view the primary goal would be to have such research fund most if not all of the requirements of the needs for the contractors' environmental section, having the additional benefit that data would be provided from a common disinterested third party.

Standards

A great service to contractors would be for the ISA to lead in the construct of common or reference models to fulfill contractual needs common to all claimants, especially as new data is collected. In the instance of environmental issues, a fresh effort should be lead by the ISA to review existing data against new discoveries and technologies and to point out inconsistencies in data formulation or metrics and lead the workshops needed to establish a consistent and achievable set of data standards going forward, perhaps reviewable on the order of every 5 years.

In those technical portions of anticipated contractual submissions, the ISA should develop and validate model process and methods.

Where possible these standards should recognize and collaborate with ongoing international efforts like the OOI (Ocean Observatory Initiative) to reduce costs and ensure well-established international standards. Indeed, ISA may be able to simply validate some environmental methods or sensors to speed development of a reference model. For instance, permanent mooring activities and associated communication schemes might be adapted to standardize environmental monitoring of nodule post-harvesting operations.

Environmental and Pilot Harvest Efforts

The Technical working group acknowledges that a successful pilot project showing the technical feasibility of nodule exploitation will be of utmost importance for any possible investor. The results of that project shall be published and serve as a calibration for cost/benefit calculations and technical assessments.

The Technical working group encourages deliberations to determine if the Enterprise of the Authority could be used to without full activation ("pre-activation ad interim tests") to initiate and coordinate a project using an appropriate reserved area.

Based on receiving some significant degree of funding mentioned above ("Funding") one concept would have, under ISA leadership, a set of demonstrations to determine the sets of data necessary to answer in full the environmental impacts assessments, and post-harvest implications necessary to form a reference document that meets all critical contract needs. In this manner the joint contractor/ISA efforts will greatly reduce risk, promote uniformity, and be backed by common data and validated procedures for measurement. Any such ISA/contractor/funding party team should have the broadest possible set of technology subject matter experts represented to cope with the many unexpected likely to be encountered.

An additional question to be discussed would be if some set of Developing Nations be invited to invited to participate in the trials to assess such factors as:

- Better understanding of issues of Enterprise startup;
- Costs associated with efforts;
- Operational capability transfer; and,
- Technology transfer opportunities, issues and interest

Open Architecture

Commonality in many of the technologies needed across harvesting nodules worldwide, crusts, and methane hydrates drives rough equipment similarity. Yet mere similarity is not sufficient to drive out cost in either initial acquisition, operational or in lifetime maintenance costs. Furthermore, as sensors, batteries and other components improve backwards integration is rarely graceful or inexpensive.

Alternatively it is recommended that the ISA consider chairing a contractor committee to promote an open discussion of standards (e.g., voltages, bus, communication, connectors) protocols that would be openly publish agreed issues. Proven detailed methodologies can readily be adapted to ISA needs and will:

- Drives down cost to get to COTS (commercial off the shelf), and
- Forces commonality and increase possibility multiple vendor competition.

Other Technology Observations

Without regard to order other observations were made to improve technology environment in CCZ exploration and operations.

- Visualizing capability; Exploratory research combined with increased sophistication and volume of sensor data suggests that an important baseline technology will be data fusion that is able to be presented by ever better visualization techniques.
- Technical /Program management: the ISA should consider that as harvesting operations are closer to reality that individual contractor advocacy within the ISA might be well served by program mangers able to work issues with a more robust technical staff to minimize loosing lessons learned from previous research/operations.

ANEXO 4c
Recomendações dos grupos de trabalho (WG3)

INTERNATIONAL SEABED AUTHORITY

14-20 Port Royal Street, Kingston, Jamaica • Tel: (876) 922-9105 to 9 Fax: (876) 967-0801

The Results of a project to develop a Geological Model of Polymetallic nodule deposits in the Clarion-Clipperton Zone Workshop

Environmental component: Research Plan, Time series, Site plan, Standardized data sets

Working Group 3

Kingston, Jamaica

December 14-17, 2009

The Results of a project to develop a Geological Model of Polymetallic nodule deposits in the Clarion-Clipperton Zone Workshop

Environmental component: Research Plan, Time series, Site plan, Standardized data sets Working Group 3

PARTICIPANTS:

- Adam Cook, ISA
- Elva Escobar Briones UNAM Mexico- Working Group Chair
- Valcana Stoyanova, IOM, Poland
- Huaiyang Zhou, Tongji University, China

INTRODUCTION:

Working group 3 was given the task of recognizing how to help contractors to recognize zones of environmental interest, guide contractors to improve the environmental assessment and reports from accomplishments in the Geological Model (GM); that its resources help in the identification/definition of abyssal habitats in the CCZ and help identify data required to accomplish environmental assessments and the relevance in the environmental protection of the seabed for the future.

This narrative is provided as supporting documentation for the issues that were discussed within the group in which the contribution of the GM to future environmental monitoring and assessment was recognized, how the GM can provide an insight for defining habitats, the gaps and omissions that were recorded in the environmental aspect and the recommendations made for future action and evolution of the GM. This document is not intended to get into detailed design or methodologies but guide on the usefulness of the GM to improve the environmental evaluation in the CCZ through the knowledge provided by contractors and the one that can be provided in the future activities.

The contribution of the GM recognized to future environmental monitoring and assessment activities were that the model recognized a depth trend, characterized the CCZ topographically, by localizing and evaluating area coverage of seamounts, hills, the abyssal basin, grabens and other topographic features. It recognized heterogeneity of the abyssal environment characterized by sediment changes and a local variability in the scale of several 100s of metres that define the patchy nature of the nodules. It is clear that the GM provides a guide for environmental studies in the future providing baseline knowledge to describe regional hydrographic regimes, trends of biota distribution and criteria for different scales of occurrence.

Available information on community structure and function is limited and is required to help evaluate and to anticipate, avoid, minimize, or offset adverse effects on the environment. This because data can be used to evaluate the affected environment and to identify measures necessary to monitor and investigate residual effects.

In aspects of environment for the CCZ the following gaps and omissions mere recognized in the GM: The resolution of data are low, there should be a better knowledge provided on the biological factors and their participation in understanding the current distribution and potential origin of the nodules, changes in the biotic associations of the seafloor should be recorded with better resolution, description of habitat types.

During the group discussion the following considerations were made: Formats that are uniform for scientists and contractors are required that can help in data gathering in a similar level of resolution. In addition common key parameters require to be identified that describe the scale of the environmental factors that give a robustness to the GM. The questions being asked will require different sets of data and it is important to keep this in mind for the environmental tasks required in the future; the impact analysis and the experiments that evaluate the recovery of the seafloor conditions.

The group tried to answer a set of questions on the usefulness of the GM in the improvement of the environmental evaluation in the CCZ through the existing knowledge and that provided by contractors in the future. These are listed below.

What areas should be considered for environmental monitoring and assessment? The group recognized the need to encourage sampling in the zones recognized in the GM. At a first stage the sampling should be limited to the CCZ and as new areas are explored and models evolve sampling and studies expanded to these new areas.

Are there factors that need to be considered in the GM? The evaluation of the export hypothesis of fotoautotrophic POC needs to be revised and reevaluate the importance of the extension of the minimum oxygen zone. The possibility of lateral transport should be considered. In new areas the proposed future models may encounter new factors related to different geographical settings in the seafloor conditions, hydrography and topography. The GM can help identify the biological settings, habitats. Time scales for nodules and for environment are different. It is difficult to define environmental factors that can describe the presence and nature of currently existing nodule occurrences.

What priority features or factors allow recognizing habitat types based on the GM? Among the factors that were identified are depth, slope, sediment type, the geochemical gradients and the biological ecotones. It will be important to establish cutting points for these factors that can allow recognizing the thresholds of impact on the environment i. e. % nodule coverage, and others. The standard study strategies will require establishing inter-comparisons among areas, the factors to evaluate, the levels of resolution that contractors can carry out in the future.

What criteria should be used to define types of potential habitats? Among the criteria that were recognized and discussed are: the type of substrate (being this hard vs soft); with and without nodules and within this the abundance of nodules, the chemical composition of nodules, to consider the patchy nature of the nodule covered area, its patchy nature and relation or effect to the biota on the seafloor and the scales of resolution (from micro to megabiota). Accompanying these criteria it was recognized that standardized methodologies are required when evaluating the environment

How can the GM contribute to environment studies in the future? It was recognized that there are many data available from the contractors from the topography, the sediments, the chemical components, the environment, and only a few of the biota. These gaps in knowledge will need to be improved to better understand the relation to trace metals and major elements, the diagenetic processes of nodules and help define time series recovery experiments. This information will be of utmost importance to refine the recognition of habitats within the zones recognized by GM.

Recommendations

The recommendations that group 3 can contribute of the GM for future environmental monitoring and assessment include:

- Improve understanding the biological participation of distribution and origin of the nodules

- Standardize methods, factors, resolution and others

- Encourage habitats scale studies and data gathering for future impact analysis and recovery experiments

- Encourage contact with appropriate scientific research institutes.

- Continue promoting interactions between mining companies and relevant international scientific programs that might exist. The benefit of cooperating with the scientific community to the GM would be by benefiting of the interactions with multiple oceanographic disciplines and multiple institutions. The above will help facilitate the establishment of baselines of natural variability from geologic and other environmental records in the selected areas.

Cooperative programs may be synergistic, bringing together the expertise, research facilities, logistic capability and common interests of the mining companies and cooperative institutions and agencies. In this way, the contractors may make the best use of expensive research facilities such as vessels, and the extensive expertise in different disciplines of academic colleagues to develop full potential of the GM and its predictive capabilities in relation of extraction and the effect of these activities to environment.

- Develop a training and preparation program for environmental assessment that help standardize the resolution and information delivered.

- Integrate unpublished data that may add to the baseline understanding of the environment

Desired activities that are advised for improving the GM to have better prediction capabilities related to the environmental factors include:

- Environmental long term monitoring and assessment with the development and design of a monitoring network, ensuring storage and access to information across and among sites providing time series of basic information. The GM can benefit by strengthening its knowledge and recognizing variations between geographical zones recognized in the GM. Take benefit or emerging technology.

- Identify and evaluate with use of the GM areas with original environmental conditions, native biological diversity and typical nodule coverage that can be available primarily for scientific research and/or environmental monitoring excluding exploitation or extraction and or environmental protection.

ANEXO 4d
Recomendações dos grupos de trabalho (WG4)

14-20 Port Royal Street, Kingston, Jamaica • Tel: (876) 922-9105 to 9 Fax: (876) 967-0801

INTERNATIONAL SEABED AUTHORITY

Polymetallic Nodule Mining Technology Workshop

Educational and Outreach Strategies

Working Group 4

Kingston, Jamaica

December 14-17, 2009

Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Zone

Workshop 14-17 December, 2009

Working Group 4
Educational and Outreach Strategies.

PARTICIPANTS:

Sandor Mulsow (Chair)
Cary Reid
Chen Wang

INTRODUCTION:

Working Group 4 was given the task of generating recommendations to address educational and outreach strategies. Members of this working group actively participated in the meetings carried out for the other three working groups. This operational approach was considered more efficient given the cross-cutting nature of the tasks of the Working Group 4.

The Working Group's main suggestion, after two days of deliberation is that the International Seabed Authority (ISA) must be charged with the responsibility of communicating the results of, and progress made on scientific, cultural, and environmental work done in the deep seabed to all parties that would be affected by or benefit from this work. The Authority is mandated with the management of the mineral wealth of the deep seabed, which is the common heritage of mankind, As stewards of this common heritage, mankind, in common, must be made aware of the work being done in the Area. In this regard, the Working Group proposed the following recommendations.

The Working Group 4 on Educational and Outreach Strategies recommends:

1. The ISA should carefully evaluate to which target groups the activities of the Authority must be communicated. These groups must include

    a. municipal law and policy makers;

    b. international organizations, including NGOs;

    c. the university community; and

    d. children.

    The member parties to the ISA are states and state law and policy makers must be made aware of the work of the ISA so that this work will have a greater impact in the creation of national policies, as well as permit states to contribute more effectively to the activities of the Authority. While the ISA is the only organization charged with the management of the resources of the deep seabed, it is not the only international organization responsible for oceanographic research, the management of marine life, or mineral extraction and exploitation. The information gathered and disseminated by the ISA is of direct and immediate interest to both faculty and students at universities. The final target audience must be children as the Authority acts, in essence, as a steward of the steward of their resources.

2. The evaluation mentioned in Recommendation # 1 must generate communication strategies which address the cultural and intellectual differences that exist among these different groups of people. The communication strategies must identify tools that will enable information to be communicated at the appropriate level of complexity (in terms of language and content) to the various target groups. This translation must not vulgarize the scientific knowledge on which is based; it must reflect this knowledge to the fullest extent of its scientific meaning. It is important to note that other international organizations, namely the United Nations, have developed platforms through which to address these issues.

   The work of the ISA affects everybody on the planet and the Authority must be able to convey its findings to anybody who wishes to learn. As outlined in Recommendation # 1, the level of appreciation of the work of the ISA required by a student in high school, a doctoral candidate in marine geology, and a legislator will be quite different. However these differences should not be a barrier, preventing each of these persons understanding the work of the Authority, but should be accounted for, in order to ensure that information is communicated at a level appropriate to their intellectual background and representative of their culture.

3. The imperative communication and educational objectives to be achieved include the development of the following tools/exhibits aimed at expressing certain specific information:

   a. Visual Road Map of the history of the Deep Sea mining (exploration, prospecting) technology;

   b. Visual Road Map of the achievements of the ISA's important milestones (including the Geological Model for Nodules);

   c. Visual Road Map of regulation/policy creation and formulation process of the ISA;

   d. Visual Road Map of the environmental concerns surrounding the activities of the ISA;

   e. Environmental Awareness of the Deep Sea, including a historical perspective and state-of-the-art examples; and

   f. Deep Sea Techno-garden mining activities and technologies.

4. These displays should be produced professionally in all six UN languages for use at all international conferences. The presentations should also be produced in the language of the host country of the conference at which they are used. The ISA should participate in at least three major ocean sciences scientific meetings each year.

5. Increase the number of webpage applets already employed by the ISA to include the Model presented at this Workshop.

6. **Promoting and sharing deep Sea data (side scan sonar data) stored at ISA/contractors, that could be display under Google Earth with the authoring of ISA.**