



SUMMARY OF THE AUTHORITY'S WORKSHOP ON PROSPECTS FOR MINING COBALT RICH FERROMANGANESE CRUSTS AND POLYMETALLIC SULPHIDES IN THE AREA- TECHNOLOGICAL AND ECONOMIC CONSIDERATIONS

At the ISA's 4th Session in August 1998, the Russian Federation delegation requested that the Authority adopt regulations for mineral resources other than polymetallic nodules, namely polymetallic sulphides and cobalt crusts. Up until 2000, the main focus of the work of the Authority was the completion of regulations for prospecting and exploration for polymetallic nodules in seabed areas beyond the limits of national jurisdiction (the Area).

At the Authority's tenth session, the Legal and Technical Commission submitted the "Draft regulations on prospecting and exploration for polymetallic sulphides and cobalt-rich ferromanganese crusts in the Area" to the Council for its consideration. The document ISBA/10/C/WP.1 comprises 43 regulations and includes four annexes. Annex 1 - "Notification of intention to engage in prospecting", Annex 2 - "Application for approval of a plan of work for exploration to obtain a contract", Annex 3 - "Contract for exploration", and Annex 4 containing standard clauses for exploration contracts.

At its eleventh session in August 2005, following the first reading of draft regulations, Council requested clarifications of some of the technical content by the Secretariat.

The aim of the Authority's workshop on *Prospects for Mining Cobalt Rich Ferromanganese Crusts and Polymetallic Sulphides in the Area- Technological and Economic Considerations* was to examine the prospects for the development of cobalt-rich ferromanganese crusts and polymetallic sulphides deposits in the Area, and to provide the members of the Authority with relevant and up-to-date data and information on, *inter alia*:

- a) The process through which occurrences of cobalt-rich ferromanganese crusts and polymetallic sulphides in the Area may be converted to commercially exploitable deposits;
- b) The geologic characteristics and geographic distribution of potential cobalt-rich ferromanganese crusts and polymetallic sulphide deposits/occurrences in the Area;
- c) Technological issues associated with commercializing cobalt-rich ferromanganese crusts and polymetallic sulphide deposits in the Area;
- d) Economic and financial issues associated with commercializing cobalt-rich ferromanganese crusts and polymetallic sulphide deposits in the Area;
- e) The market outlook for the base and precious metals to be found in these two potential ores;



- f) A comparison of the costs for environmental protection in land-based mining of the relevant base metals and for cobalt-rich ferromanganese crusts and polymetallic sulphides in the Area;
- g) A hypothetical cobalt-rich ferromanganese mining venture in the Area,
- h) A hypothetical polymetallic sulphides mining venture in the Area, and;
- i) To examine the effects of the proposed system of participation of the Authority in crusts and sulphides mines in the Area, using as a basis the hypothetical mining ventures for crusts and sulphides

These aims were achieved through a series of presentations by experts in their respective fields centering on two topics:

- Framework for prospecting and exploration for cobalt-rich ferromanganese crusts and polymetallic sulphides in the area;
- Market outlook for the metal commodities in cobalt-rich ferromanganese crusts and polymetallic sulphides

Following the 3-day presentations – working groups were formed and met to examine the draft regulations to ascertain the effects of the proposed system of participation by the Authority in the hypothetical mines of cobalt-rich crusts and polymetallic sulphides.

Presentation Summaries

Draft regulations on prospecting and exploration for polymetallic sulphides and cobalt-rich ferromanganese crusts in the Area (ISBA/10/C/WP.1) –

Mr. Baidy Diene, Legal and Technical Commission of the International Seabed Authority

Mr. Diene summarised the draft regulations that had been prepared by the Legal and Technical Commission and which was under review by the Council of the Authority. This was to ensure that all participants were aware of the regulatory framework that had resulted in the meeting. As part of the outline, he defined some of the terms from the regulations drawing the participants attention to the fact that the polymetallic sulphides and cobalt-rich crusts were potentially easier to exploit than manganese nodules and that there was interest in mining them in national waters, which whilst outside of the control of the Authority indicated the level of interest in the new resources and highlighted the importance of having regulations that ensured that these resources were treated as the “common heritage of mankind”.



Prospecting and exploration for polymetallic sulphides and cobalt-rich ferromanganese crusts in the Area – Framework established by the code –

Dr. Lindsay Parson, Legal and Technical Commission of the International Seabed Authority

Dr. Parson supplemented Mr Diene's presentation by describing the reasoning behind some of the provisions of the draft regulations. He stated that the draft regulations were still in development and would benefit from the discussions at the workshop. He added that the regulations needed to be written as such to take into account the various stakeholders including scientists, policymakers and potential contractors. Dr. Parson also noted that there were noticeable changes in the draft regulations for crusts and sulphides when compared to the regulations for prospecting and exploration of polymetallic nodules. He stated that this was as a result of there being more knowledge on polymetallic nodules than there currently is for cobalt-rich ferromanganese crusts and polymetallic sulphides. He advised that one of the changes was the inclusion of an environmental protection clause as part of prospecting in the current regulations which was not in the nodule regulations. This, he continued was important because it meant that a prospector had an environmental commitment without exclusive rights to the deposit.

Dr Parson also reviewed the draft regulations, and in particular the process of submission of a plan of work for exploration by a contractor that is to be prepared in the form of a contract between the Authority and the applicant. He noted that the application would need to include a statement by a competent authority certifying that the applicant had the necessary financial resources and the technical capability to carry out the proposed plan of work. The area allocated would be 100 blocks and contiguous. He also described deep seabed polymetallic sulphides mine sites, in particular two that had been quantified (estimates of their in situ resource potential made) – the TAG hydrothermal field and the Middle Valley field. He said that their bulk tonnages were 2.7 and 10-15 million tonnes respectively whereas the the "Cyprus" type ophiolite hosted polymetallic sulphides on land on average contained 1.6 million tonnes.

Dr. Parson said that discussions of the draft regulations at the Authority's 12th session would cover, among others, the number and size of the exploitation area, block size and the geometry of exploration areas. He added that the Council would consider the provisions on relinquishment, the joint venture options and the protection of the marine environment as it related to the two mineral resources at the Authority's twelfth session.

Geologic characteristics and geographic distribution of potential cobalt-rich ferromanganese crusts deposits in the Area

Dr. James R. Hein, U.S. Geological Survey, Menlo Park, CA, USA

Dr Hein presented an overview of what was known about cobalt-rich ferromanganese crusts including their distribution and properties. He stated that crusts occurred in all oceanic basins because of their physical properties which allowed them to absorb and concentrate metals from



the surrounding seawater and that virtually all elements from the periodic table were enriched in them as compared to other natural material. The greatest number of samples, he said, had been collected from the Pacific Ocean where the thickest crusts occurred between water depths of 1,500-2500 metres. He informed participants that the most important properties of cobalt-rich crusts were their high porosity, extremely high specific surface area and extremely slow rate of growth. He added that these properties were instrumental in allowing for surface absorption of large quantities of metals from seawater.

With regard to the economic potential of crusts deposits, Dr Hein pointed out that the metals of commercial interest in a metric ton of ferromanganese cobalt-rich crusts from the Central Equatorial Pacific Ocean were:

- Cobalt – mean price (2006 \$/kg) \$32.41; mean content in crusts 6899 (g/ton), value per metric ton \$223.60;
- Nickel – mean price (2006 \$/kg) \$17.36, mean content in crusts 4125 (g/ton), value per metric ton \$71.61, and
- Copper -- mean price (2006 \$/kg) \$5.93, mean content in crusts 896 (g/ton), value per metric ton \$5.31.

His presentation included figures that showed how metal prices and consumption had changed in recent years, suggesting that mining could become economically viable in the foreseeable future

Dr Hein also pointed out that the main elements in crusts by wet weight were manganese (~21%) and iron (~17%) and when providing a brief overview of seamount biology, he said that the ecology of seamounts was affected by their physical setting.

Noting that the most significant impediment to exploration was real time measurement of crust thicknesses with deep-towed instrument, Dr Hein made the following suggestions for future research:

- There should be detailed mapping of selected seamounts, including analysis of small-scale topography;
- Better dating techniques for crusts should be developed;
- The oceanographic and geologic conditions that produce very thick crusts must be ascertained;
- The processes that control the concentration of platinum-group elements and other rare earth elements in crusts must be determined:



- Remote sensing techniques should be developed to measure crust thickness.
- New mining technologies, especially new, innovative processes of extractive metallurgy should be developed.

Technological issues associated with commercializing cobalt-rich ferromanganese crusts deposits in the Area

Mr. Tetsuo Yamazaki, President, Japan Federation of Ocean Engineering Societies and National Institute of Advanced Industrial Science and Technology, Japan,

Mr. Yamazaki's presentation noted that since cobalt-rich ferromanganese crusts and polymetallic nodules were ferromanganese oxides, metallurgical processing methods for their beneficiation were expected to be similar. He listed some of the significant feasibility studies that had been carried out for polymetallic nodule mining and summarized their results and described a possible mining system for crusts, stating that the mining subsystem would comprise a seafloor collector or a miner, a pipe string with submersible hydraulic pumps, and a mining vessel. He also described a self-propelled miner with mechanical slicing and crushing capabilities, along with hydraulic pick-up devices which had been designed for mining crusts and showed crusts processing models, citing a smelting and chlorine leach method for 3-metal recovery. He said that such a metallurgical plant had been built and was located near Tokyo, Japan.

Mr. Yamazaki said that it was estimated that the total investment costs for nodule mining would be \$1171.0 million, whereas the figure for cobalt-rich manganese crusts was estimated at \$639.9 million (2004).

Mr. Yamazaki also presented a comparison between nodules and crusts including their depth, location and metal composition. He noted that whilst the concentrations of metals in the two types of mineral resources were different, their metal compositions were similar and as such they would be competing for investment funds. He continued by outlining how different factors (such as crusts metal content, location of the processing facility and type of processing used etc.) would affect the profitability of a crusts mining system. Therefore, Mr Yamazaki said that a more advanced validation analysis of crusts mining was required. Mr. Yamazaki concluded his presentation by stating that as a result of microtopographic undulations, excess substrate rock would often be collected and 70-80% of potential crust mining sites would be less profitable than nodule mining scenarios.



Prospecting and exploration for cobalt-rich ferromanganese crusts in the Area - Dr. James R. Hein, U.S. Geological Survey, Menlo Park, CA, USA

In his second presentation, Dr Hein spoke on the parameters that could be used to define the sizes of exploration and mine site areas for cobalt-rich ferromanganese crusts in the Area. He presented a paper that he had prepared for the Authority - ISBA/12/C3/Part I – *Exploration and Mine Site Model Applied to Block Selection for Cobalt-Rich Ferromanganese Crusts and Polymetallic Sulphides. Part I Cobalt-rich ferromanganese crusts* which examines how the Authority's draft regulations can be applied to the known global distribution of cobalt-rich ferromanganese crusts in the Area. At the outset, Dr Hein said that the parameters that would ultimately be used to define a cobalt-rich ferromanganese crusts exploration area and mine were unknown. He said that he had used reasonable assumptions to identify the likely characteristics of exploration and mining areas. He pointed out that the set of conditions he had selected was based on the present state of knowledge of seamount morphology and size, and the distribution of cobalt-rich crusts on seamounts. Dr Hein continued that mining operations for crusts would take place around the summit regions of guyots on flat or shallowly inclined surfaces in the central Pacific Ocean region. He described the average seamount noting that the actual surface area to be mined would be limited by crust exposure/sediment cover which varied from nearly 0% to nearly 100%. Other impediments to mining included prohibitive small-scale topography and biological corridors.

Based on his data set of 34 measured seamounts, he said that 1.1 to 2.6 large guyots or 2.8 to 6.7 average size seamounts were needed for a 20-year mining project. He also said that a single large seamount could sustain a 20-year mining operation under favourable conditions. With regard to the most likely areas to be mined, Dr Hein said that these would be large guyots with little sediment cover, subdued topography and average crusts thickness of 2.5 cm. He recommended an exploration lease-block size of 100 sq. kms which should be contiguous where relinquishment of unwanted territory could proceed using the 20 sq km sub-blocks. These, therefore, could be relinquished in several phases; he added that 25 sub-blocks of 20 sq kms would define the final 20-year mine site of 500 km.

Comments and suggestions on the Draft Regulation on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts

Mr. Yang Shengxiong, Guangzhou Marine Geological Survey, People's Republic of China

Mr. Yang Shengxiong presented alternative calculations to Dr Hein suggesting that as 75% of seamount summits would be covered by sediment, 2,800 sq km was a more appropriate final mining area than the 500 sq km proposed by Dr Hein. Mr. Shengxiong said that the 2,800 sq km mining area would be able to sustain a mining operation of 2 million wet tonnes of crusts ore per year for 20 years with a mining efficiency of 0.3 %. He further stated that a total exploration area of 10,000 square kilometers was a good choice for a contractor before further scientific



identification and technology for the exploration and mining of crusts. He noted that even though the blocks/ clusters might not be contiguous, contiguity was needed to limit the number of seamounts. He added that this would be in conformity with the common heritage principle. He suggested the following definitions:

- (i) a sub-block should be a cell of a grid as provided by the Authority, no greater than 20 square kilometers;
- (ii) Blocks should comprise five contiguous sub-blocks, no greater than 100 square kilometers;
- (iii) A cluster should comprise of several continuous sub-blocks, and
- (iv) An exploration area would comprise of several clusters, no more than 100 blocks and no greater than 10,000 square kilometers.

With regard to the total area covered by the application (Regulation 12), he said that the exploration area for cobalt-rich crusts should not be greater than 10,000 square kilometers, and should comprise not more than 100 blocks (500 sub-blocks). He also said that the exploration area might comprise several clusters and that two clusters that touched at any point should be considered contiguous. He pointed out that clusters need not be contiguous, but should be proximate and located within the same geographic area. With regard to the size of an exploration area and relinquishment, he said that assuming an initial allocation of 500 sub-blocks; the contractor would relinquish areas as follows:

- (i) 40% or 200 sub-blocks at year 5;
- (ii) 65% or a further 125 sub-blocks at year 10;
- (iii) 72% or a further 35 sub-blocks at year 15; leaving the contractor with 140 sub-blocks for exploitation.

Technological issues associated with commercializing polymetallic sulphide deposits in the Area

Mr. Tetsuo Yamazaki, President, Japan Federation of Ocean Engineering Societies, Japan

Mr. Yamazaki stated that since there was no information on the resource potential of polymetallic sulphides deposits in the Area, for his presentation, he had used data from an assessment of such deposits in the Japanese EEZ. He stated that a feasibility study for the extraction of sulphide-rich muds in the Red Sea had been undertaken in the past but that the extraction of these deposits was not found to be attractive. Mr. Yamazaki described the Sunrise deposit in the Japanese EEZ and showed the results of proposed processing techniques, a technical model and an economic evaluation of the deposit. He noted that the mining system would be the same as that proposed for polymetallic nodules and cobalt-rich ferromanganese



crust mining. Mr. Yamazaki stated that in order to improve technical models and economic evaluations, it would be necessary to know the vertical extent and the distribution of metal concentrations within the deposit. This could be achieved with a combination of geophysical surveys and taking cores of the polymetallic sulphides deposits. He believed that the trial being carried out by Nautilus Minerals in Papua New Guinea would be very useful in addressing these questions. Mr. Yamazaki concluded his presentation pointing that of the three mineral resources being considered by the Authority, the mining technology for polymetallic sulphides mining would be the easiest of the three (sulphides, crusts and nodules) to develop.

Review of metal markets

Ms. Caitlyn L. Antrim, Director, Center for Leadership in Global Diplomacy, USA

Ms Antrim made presentations on the markets for nickel, cobalt and manganese metals, the copper, lead and zinc markets, and the gold and silver markets.

Outlook for the nickel, cobalt and manganese metal markets.

Ms Antrim pointed out that metal demand was subject to unpredictable factors, both transient and transformational. In this regard, she informed participants that fluctuations in cobalt prices in the recent past were due to a conflict situation in the Democratic Republic of the Congo, a leading producer. She pointed out that more recently; an increase in the price of cobalt was due to an increase in the production of batteries and electronic goods. She said that the price of nickel, a metal of interest because of polymetallic nodules, was “moving up nicely”. She continued that the price of manganese was also steady because of the increase in steel production. She also noted that the price of copper was on the upturn as well.

Ms Antrim informed participants that global production of **nickel** was rising and was estimated to have been 1.5 million metric tons in 2005. Global reserves of nickel were estimated at 62 million metric tons in 2005. She pointed out that the Russian Federation was the largest producer of nickel followed by Australia which had the largest reserves. With regard to end use, she said that nickel was a component in most stainless steels; an element in some steel alloys, and was also used for plating and in batteries.

In relation to **cobalt**, Ms Antrim said that it was an essential metal for advanced economies, particularly in the production of superalloys, carbides, batteries, tool bits and surface treatments. She said that cobalt is generally a by-product of nickel and copper production, and that nickel metal could substitute for cobalt metal in some applications (uses). With regard to production, Ms. Antrim said that 2005 mine production of cobalt was 52,400 tonnes (leading producers - Congo, Zambia, Australia and Canada), and that global reserves of cobalt at year end 2005 were estimated at 7 million metric tons (leading countries – Congo, Australia and Cuba).



Ms. Antrim said that the primary use of **manganese** was in steel production, including specialty steels and aluminium alloys, and in the production of conventional alkaline and advanced lithium-ion batteries. She said that production in 2005 was 9,790 thousand metric tons (Leading producers – South Africa, Australia, Gabon and Brazil) with reserves estimated at 430,000 thousand metric tons (Leading countries – Ukraine, India, Australia, China and South Africa).

With regard to the major factors affecting the supply of nickel, cobalt and manganese, Ms. Antrim said that these included the stability of cobalt exports from the Democratic Republic of Congo; Russian exports versus its domestic consumption of nickel; the development and expansion of major nickel deposits such as Voisey's Bay (Labrador, Canada) and Goro (New Caledonia); and improved application of pressure acid leaching technology to nickel laterites.

In relation to global demand for nickel, cobalt and manganese, Ms Antrim pointed to the economic growth of China, India, Russia and Brazil, the use of the 200 series of stainless steel in place of nickel-based stainless steels, and the adoption of hybrid and electric automobiles with high-capacity batteries as factors that could increase demand for these metals. With regard to potential major demand changes, Ms Antrim spoke about the impact of rising fuel costs in promoting innovation in automobile design. She indicated that the major competing technologies are advanced diesel engines and hybrid and electric vehicles. She pointed out that current and projected designs of hybrid and electric vehicles will use batteries based on metals from crusts and nodules, thus providing a potential boost for these nascent industries. She said that annual world production of batteries for automobiles exceeds 55 million. She further said that a 10 per cent penetration of hybrid vehicles would require 66,000 tonnes of nickel or 16,500 tonnes of cobalt, representing 4.5 and 31 per cent of the current world production of these metals respectively.

Ms Antrim stated that since land-based reserves of these metals were more than adequate to meet the projected increases in global demand, seabed operations will have to compete for a share of the metal markets. She also said that the by-product relationships found in nodules and crusts would be advantageous for seabed production of those minerals.

Demand Outlook for Copper, Lead and Zinc

In a second presentation on the outlook for copper, lead and zinc Ms. Antrim gave a short description of the price history of these metals, commenting that since the early eighties there had been a decline in the prices of these metals in real terms.

She informed the workshop that the largest producer of copper was Chile, accounting for over 35 per cent of world mine production of copper in 2004 (5.4 million of the 14.6 million metric tons produced in 2004), followed by the United States, Peru, Australia, Indonesia and China. She said that world reserves of copper are estimated to be about 470 million metric tons, of which Chile had the largest reserves of 140 million metric tons followed by the United States and Indonesia (35 million metric tons) and Peru and Poland (30 million metric tons).



Ms Antrim said that as a very efficient conductor of electricity, copper had many uses ranging from heating, air conditioning, plumbing, adapters, roofing, computers, cars, wiring, electrical leads, motors and transformers.

With respect to lead, Ms Antrim said that world mine production in 2004 was about 3.15 million metric tons with the top six producers accounting for about 82 per cent of the world's total production. The largest producers were China (30%), Australia (22%), the USA (14 %), Peru (10 %), Mexico (4 %) and Canada (2%)>. She informed participants that world reserves of lead were about 67 million tons, and that Australia, China and the United States had 15, 11 and 8.1 million tons of lead reserves.

Ms Antrim said that while lead is essential to the production of many highly technical products ranging from fetal monitors, soldering, lead-solders, and lead glass to fibre optics, almost 80 per cent of all lead is for the production of lead-acid batteries. With regard to market outlook, Ms Antrim said that it is anticipated that in China, further increases in the vehicle fleet, increased exports of automotive batteries, and ongoing investments in the telecommunications and information technology sectors were expected to result in increased demand for lead.

Ms Antrim said that the leading producers of zinc in 2004 were China (about 2.3 million metric tons, Australia (about 1.3 million metric tons), Peru (1.2 million metric tons) and Canada (about 0.8 million metric tons). World mine production for 2004 was 9.6 million metric tons. She also said that world reserves of zinc were about 220 million tons, with Australia, China, the United States, Kazakhstan and Peru containing 33 million, 33 million, 30 million, 30 million and 19 million metric tons of reserves respectively. She pointed out that factors affecting demand for zinc were growth of developing country economies, by-product relationships in ore deposits and future automobile electrical system design.

Outlook for the silver and gold markets:

In a third presentation on the market outlook for silver and gold, Ms. Antrim said that gold and silver were potential by-products in polymetallic sulphides. She noted that precious metals often contributed significantly to the profitability of sulphide ores, while gold and silver were major incentives for exploration on land and on the seabed. Gold applications were in dental, industrial/investment, jewellery, and electronics. She informed participants that gold production in 2005 was 2450 metric tons, while reserves were estimated at 42,000 metric tons. The leading producers of gold in 2005 were: South Africa (300 tons), Australia (254 metric tons), the United States (250 metric tons), and China (225 metric tons). In respect of reserves, as at year end 2005, South Africa had the largest reserves (6,000 metric tons), followed by Australia (5,000 metric tons), Peru (3,500 metric tons), Russia (3,000 metric tons) and Indonesia (1,800 metric tons).



Ms Antrim said that silver applications were in jewellery, photography, chemical/Industry and coins. She informed participants that world production of silver in 2005 was 20,300 tons, while reserves stood at 270,000 tons. The leading producers of gold that year were: Peru (3,060 metric tons), China (2,800 metric tons), Mexico (2,700 metric tons), and Australia (2,250 metric tons). At year end 2005, the countries with the largest reserves of silver were: Poland (51,000 metric tons), Mexico (37,000 metric tons), Peru (36,000 metric tons), Australia (31,000 metric tons), China (26,000 metric tons), and the United States (25,000 metric tons).

Overall outlook for the metals to be found in Cobalt-rich ferromanganese crusts, Polymetallic Sulphides and Polymetallic Nodules

Discussing the future of the concerned base and precious metals, Ms Antrim said there could be strong growth in demand and continuing price increases in response to the development of advanced developing countries. She also said that reduction of Russian exports of metals as its economy improved should also be taken into account. She pointed to other factors including the development of advanced auto batteries as major new markets for nickel, cobalt and manganese. Industry-wide, Ms Antrim stated that the most important risk factors were uncertainty of demand projections and market changes due to end user technology or preferences. For land-based minerals, she cited political uncertainty of some mineral regions such as the Pakistan-Iran region and the Democratic Republic of the Congo as significant risk factors. For seabed minerals, she referred to the technical uncertainty of seabed mining technology and the untested International Seabed Authority regime.

Mineral Resources in China

Mr. Haiqi Zhang, China Geological Survey, Beijing, People's Republic of China

Mr. Haiqi Zhang of the Geological Survey of the People's Republic of China outlined the geological work that has been carried out by China. He said the 171 minerals had been discovered in China and that reserves of 158 of them had been established. He said that more than 10,000 large and medium-scale mining enterprises had been established in China in addition to 240,000 small-scale enterprises. and that 92% of energy requirements and over 80% of China's industrial raw materials were from mineral resources.

Mr. Zhang said that while there were significant resources of iron, manganese aluminium and copper in China, they were low grade, associated with other minerals, and difficult to process.

He said that the mineral resources situation in China was serious, because by 2010, reserves of minerals such as iron, manganese, copper, lead, zinc, cobalt, tin and gold would have been exhausted. He further noted that consumption of these metals was rising rapidly. Mr Zhang said that the measures being taken by the Government to halt the decline of its mining industry included strengthening management, increasing mineral recovery rates and by introducing comprehensive new technology. He also said that more investment was being made in mineral



exploration in Western China. He stated that international cooperation was being extended and multi-channel imports of resources were being established.

Mr Zhang noted that since 1990 consumption had increased faster than domestic production, and that only 24 of the 45 minerals mined in China would be sufficient to meet domestic demand after 2010. Of the 24 minerals mined in China, he noted that only 6 would meet domestic demand until 2020. Mr. Zhang further stated that between 60% and 95% of the demand for certain metals (iron, copper, chromium and manganese) were met through imports by China and that it was planned to obtain some of these minerals from deep seabed mining.

Global exploration models for polymetallic sulphide deposits in the Area

Dr. James R. Hein, U.S. Geological Survey, Menlo Park, CA, USA

Dr. Hein presented a paper that had been prepared for the Authority by Mark Hannington and Thomas Monecke (ISBA/12/C3/Part II) – **Exploration and mine site model applied to block selection for polymetallic sulphides** which examines how the Authority's draft regulations can be applied to the known global distribution of polymetallic sulphides in the Area. Dr Hein noted that 40% of the known hydrothermal venting activity in the Oceans was to be found in the Area and that 331/3% of hydrothermal venting sites had associated with them polymetallic sulphides deposits. Of these, he said that only 2 were known to contain deposits in excess of one million tonnes although 5 others may be of this order of magnitude. He stated that individual occurrences covered less than 1km in diameter with the median tonnage of the deposits in most 100km² blocks not being greater than 50,000 tonnes. The report presented two models: one that followed the draft regulations where all blocks had to be contiguous but which was not considered practicable; and a second option proposed by the authors wherein an exploration area comprised 100 blocks split into 4 clusters. Under the second option, the blocks within each cluster would be contiguous but clusters did not need to be contiguous. To emphasise this point the report showed that the grid system as proposed in the draft regulations would not have been profitable in cases where leases had been granted in national waters.

Environmental aspects of cobalt-rich ferromanganese crusts and polymetallic sulphides development – framework established by the code

Dr. Lindsey Parson, Legal and Technical Commission of the International Seabed Authority

Dr. Parson highlighted the various components of the draft regulations that were of relevance to the environment, highlighting changes that had been introduced compared to the regulations for prospecting and exploration for polymetallic nodules. He made comments about the significant workshops that had been held by the Authority and noted that the current workshop was going to be very useful to the Legal and Technical Commission during its discussions at the twelfth session.



He described the physical differences between manganese nodules, cobalt-rich ferromanganese crusts and polymetallic sulphides.

He also described the process of a submission of a plan of work by an applicant prepared in the form of a contract between the Authority and the applicant. He said that the application had to include a statement by a competent authority certifying that the applicant had the necessary financial resources and the technical capability to carry out the proposed plan of work. The area allocated to the contractor on the seabed would be 100 blocks which would be contiguous.

Dr Parson described potential polymetallic sulphides mine sites in the Area, focussing on two which had been quantified, the TAG and Middle Valley fields. Dr Parson said that the bulk tonnages of these deposits were 2.7 m and 10-15 m respectively. He said the “Cyprus” type ophiolite hosted polymetallic sulphides averaged 1.6 m.

Dr. Parson said discussions of the draft regulations at the Authority’s 12th session would cover, among others, the number and size of the exploitation area, block size, the geometry of exploration areas and the contiguity of clusters. There would also be consideration of relinquishment provisions, joint venture options, the marine environment and the speed and development of the draft regulations.

A cost comparison of implementing environmental regulations for land-based mining and polymetallic sulphides mining

Mr. Mike Johnston, Vice President, Corporate Development, Nautilus Minerals, Australia

Mr. Johnston noted that with land-based mining ventures an expected level of environmental impact from activities was agreed upon before exploration commenced. He said that in general, this was a low cost activity. However, once a company believed a project was economic, further investigations needed to be carried out, an Environmental Impact Statement (EIS) was required which was a much more costly venture. Mr Johnston said that the EIS stage took up to 2 years to complete and could cost in excess of US\$10 million. He also said that for land-based mining ventures, there were three types of activities, low impact (not ground disturbing, agreed in advance), higher impact (e.g. drill sampling, predicted impact graded and accepted levels agreed upon) and high impact (e.g. bulk sampling or test mining, some form of EIS required).

Mr. Johnston suggested that the ISA should adopt a similar approach, particularly as work at sea would have less impact during the early stages than the comparable stage in a land based venture. He noted that the key advantages of a seafloor mine compared to a land-based mine were that the grades selected would be high, meaning that a small volume would be required resulting in a smaller footprint, there would be no waste dumps required (75% of the material mined on land was waste) and there would be no land-use conflicts.



According to Mr. Johnston, during the prospecting and exploration stages, the impacts from activities would be similar to marine scientific research. He felt that it was not reasonable to get a full impact assessment and baseline survey for non-impacting work. He was of the opinion that the first marine mines were likely to be in territorial waters or EEZs following codes modified from land-based regulations. He suggested that the ISA should follow this example. Mr. Johnston concluded by stating that the ISA should manage all data and make such data available to all interested parties to improve environmental compliance and monitoring.

A hypothetical polymetallic sulphides mine in the Area

Mr. Mike Johnston, Vice President, Corporate Development, Nautilus Minerals, Australia

In his second presentation, Mr. Johnston advised that Nautilus had carried out test mining and that the “genetic models” for predicting grade and abundance held up well. He said that Nautilus had found that there were high metal grades in their sulphides deposits and that it was possible to “cut the material”. However, he noted that topographic variation would present engineering challenges. From test mining, he said that values of 15g/tonne of gold and 12-13% copper had been found. Mr. Johnston suggested that a continuous mining system should be used with pumping or airlifting to transport material to the surface and that the technology was available to carry out seabed mining. From Nautilus’ test, he said that it had been estimated that it would cost US\$260 million to mine a deposit and that 2-3g/tonne of gold would be needed to recover costs.

Mr. Johnston also stated that the further a venture was from land the harder it would be for a profitable venture as a result of increased costs and legislation being formulated by more than one government. Therefore, work in the EEZs was likely to occur first and this should be used by the ISA as case studies. Mr. Johnston noted that a question that needed answering was whether there was a desire to mine the resources or whether it was a last resort when all other resources had been exhausted as this would affect the regime. If there was a desire to mine the resources then the regulations needed to be competitive with land mining. He noted that profit sharing was not a desirable model for companies as they would be taking a lot of risk for little profit. He felt that an equity split model would be preferred, and hence more likely to become a reality, as it would be less risky but would result in less return for the ISA.

A hypothetical cobalt-rich ferromanganese crusts mine in the Area

Dr. Charles Morgan, Environmental Planner, Planning Solutions, Inc., Mililani HI, USA

Dr Morgan said that a method for mining cobalt-rich crusts had been proposed in a report in 1987 but noted that there had been little development in the years following the report. The report referred to by Dr Morgan was “Mining development scenario for cobalt-rich manganese crusts in the exclusive economic zones of the Hawaiian archipelago and Johnston Island”. Issued in January 1987, the report was the result of a joint study by the United States



Department of the Interior Minerals Management Service and the Department of Planning and Economic Development of Hawaii. The report provides a complete development scenario, including the definition of possible options, selection criteria, rationale and conclusions.

Dr. Morgan stated that the development scenario had identified key issues and provided baseline for policy development and determining what needed to be measured for impact assessment. However, he noted that a lot had changed since the publication and that the values that were used in the scenario were within the range predicted by modern analysis. He pointed out that as part of the scenario, the report's authors had predicted the use of a self-powered system with a cutting head and collection system. The authors assumed that there would be system downtime as a result of maintenance, repair and unfavourable conditions, resulting in 206 working days each year. They also analysed the impact that small scale topographic variation would have on the efficiency of the system, noting that depending on various factors, cutting efficiency would be 56-76% with a crust purity of 32-72%. Dr Morgan said that the report indicates that ideal recovery would occur where there were thick crusts found on a smooth topography with hard substrate. In conclusion, Dr Morgan noted that whilst crusts mining could be a significant component of world production of the target minerals, the operation would impact a small area. However, incorporation of substrate with the crust would be an issue that needed to be addressed.

Working Groups

Following the presentations, participants divided themselves into two working groups to examine the effects of the proposed system of participation of the Authority as contained in the draft regulations, in Crusts and Sulphides mines in the Area, using the hypothetical mines in the Area as described in the two presentations earlier.

The cobalt-rich crusts working group was led by Dr James Hein and the polymetallic sulphides group led by Dr Charles Morgan. The working groups spent a day deliberating before presenting their conclusions in plenary. The reports of the working groups are summarised below.

Report of the polymetallic sulphides working group

The polymetallic sulphides working group suggested that there was a need for a preamble to the regulations that emphasized the fact that the intent of the Authority was to promote utilization of deep seabed minerals whilst ensuring protection of the marine environment, within the context that the resources were the common heritage of mankind. The working group generally agreed with the contents of the draft regulations except the provision on the application fee and the final configuration of the proposed mining area.



Application Fee

With regard to the application fee, the group suggested a second option for its payment. The group suggested that if a contractor wished, rather than paying US\$250,000 as an initial investment, a contractor could elect to pay a lower initial application fee and then pay annual fees based on the number of blocks that it retained. The Authority would increase the cost per block over time to take into account the relinquishment of blocks as required by the draft regulations. The initial payment suggested by the group was US\$25,000 which would be supplemented by a charge for each block retained by the contractor. This option would result in more money being paid to the Authority in the long term. Figures were presented by the working group showing that using the second option the Authority would obtain US\$50,000 per year throughout the exploration contract and the process would encourage involvement by contractors as less investment would be required at the early stages when risks were high. The increase in cost per block would also encourage early relinquishment.

Relinquishment

The working group proposed a slight deviation to the regulations following the reduction of the exploration area to 25 blocks. The group suggested that the remaining 25 blocks should be subdivided as appropriate by the Authority. It was argued that breaking the blocks into smaller portions would lead to more efficient exploration as well as providing more flexibility and efficiency in the use of the seabed. The provision on relinquishment would be as follows:

- Contiguity of blocks is not required after relinquishment
- After a maximum of 5 years, the area shall be reduced to 50% of original
- After a maximum of 10 years, the area shall be reduced to 25% of original
- After a maximum of 15 years, the area shall be reduced to the equivalent of 25 blocks

Recommendations in relation to the system of participation by the Authority in a polymetallic sulphides venture.

The working group did not specifically address this issue and suggested that the Secretariat should work with a group of specialized consultants to develop recommendations in this respect.

Report of the cobalt-rich crust working group

The working group did not come to a consensus on some essential questions regarding the size of application and mining areas. Basically, two different approaches were introduced; one by Dr. Hein (USA) and the other by the Chinese delegation, based on different research data and assumptions.



Recommendations on the size of exploration areas

Consensus was reached on the following points

- Exploration blocks should be 100 km², consisting of five 20 km² contiguous sub-blocks
- Exploration blocks need not be contiguous but should cluster within a local geographic area
- Relinquishment should be based on the 20 km² sub-blocks and should occur during two stages
- The final set of 20 km² sub-blocks that define the mine site need not be contiguous

The sizes of exploration areas and mine sites for crusts were contentious. Dr. Hein suggested an exploration area of 2,500 km² and a mining area of 500 km². The Chinese delegation suggested a larger exploration area of 10,000 km² as per the draft regulations and a mining area of 2,800 km². Another point of view was that the size of the exploration area is not that important because it could be compensated for by more detailed prospecting, but that the mining area should be 1000 km².

Since there was no compromise among the members of the working group, it was decided to incorporate both suggestions and all points of view in the group's report. During group discussions, the issue of what would happen if suitable areas were very small. It was suggested that in the case of smaller areas, an applicant should be allowed to apply for two or more areas. In this context the question of the applicable provisions to restrain one applicant claiming too many suitable areas in the region of interest was raised.

The matter of the application fee of 250,000 USD to be paid at the time of submission of the application (Regulation 21) was not considered as an obstacle to resource development. Regarding the application fees and/or rental fee system the working group supported the introduction of the second option as suggested by the Polymetallic Sulphides working group.

Effects of the proposed system of participation by the Authority on a crusts mine in the Area.

In order to examine the effects of the proposed system of participation by the Authority in Cobalt-rich ferromanganese crusts mines in the Area, the group started with a discussion of the mining operation being sought by a potential investor in a cobalt-rich ferromanganese crusts mine in the Area (metal content, thickness of crusts, annual throughput of ore, life of the mine, and associated costs), how a deposit/deposits meeting the parameters needed to satisfy the potential investors would be identified during exploration, and the ability of the cobalt market to accommodate a new source of cobalt.

The working group agreed on the following assumptions:



- The mine would have enough in situ resources to operate for 20 years based on the efficiency of mining technology.
- Annual ore production would be 1 million wet tons of (670,000 dry tons)
- Mean crust thickness would be 6 cm
- Ore grade would be 0.6 % cobalt (Co) and 0.5 % nickel (Ni)
- 78 kg/ m²
- Approximately 4,020 tons of cobalt would be mined annually¹
- An area of approximately 12.82 km² would be mined each year
- The exploration area would be 2,500 km²
- The cost of early exploration to reduce this area to a mine site(s) meeting the twenty-year production requirements would amount to approximately US\$4.5 million dollars. (60 days at US\$75,000 per day).²
- A 20% IRR is required to satisfy investors..

Using the assumptions noted above, a preliminary draft of an economic model of a crusts venture was presented by Ms Antrim. A test of this preliminary model showed that it was very sensitive in terms of IRR. Slight changes in conditions (e.g. Co grade from 0.6 to 0.5 %) could significantly affect profitability. In addition to the proposals involving equity interest joint venture and production sharing participation as contained in Regulation 19, other elements of the cost structure for ventures, including the recovery of development costs (exploration) have to be incorporated in the model.

The working group agreed that the following steps need to be taken to get an appropriate output from the model:

- Prepare narrative descriptions of representative development activities for deep seabed cobalt-rich ferromanganese crusts mining;
- Estimate ranges of values for individual variables;
- Create a range of scenarios and evaluate them in a discounted cash flow model;
- Incorporate provisions for taking into account development costs (Article 13 of Annex III, article 13 of the Convention and the Implementation Agreement, Annex, section 8)

¹ A maximum of 10% market penetration for Co from the seabed is assumed

² The cost of early stage exploration for an area of 10,000 square metres will increase proportionately.



- Add the equity participation scheme to the analysis and estimate benefits to the Authority and the commercial viability of the venture.
- Invite experts to assess the model and the scenarios and to develop and enhance the schemes for participation of the Authority in the seabed mineral development activities

Recommendations on relinquishment procedures

- No requirement for contiguity after relinquishments
- After maximum of 5 years, reduce area to 50% of original
- After maximum of 10 years, reduce area to 25% of original
- After maximum of 15 years, reduce area to 25 sub-blocks