(d) Letter dated 15 November 2010 from Mr Lodge to the Registrar in response to (c) above, attached:
- "Summary information on the different phases involved in the exploration and exploitation of polymetallic nodules and polymetallic sulphides in the Area", with annexes (annexes not reproduced)

INTERNATIONAL SEABED AUTHORITY

15 November 2010

Dear ~~Mr Gautier~~, Philippe,

I refer to your letter of 13 October 2010 relating to the case concerning Responsibilities and Obligations of States Sponsoring Persons and Entities with respect to Activities in the International Seabed Area (Request for Advisory Opinion Submitted to the Seabed Disputes Chamber).

As requested by the President of the Seabed Disputes Chamber I have the honour to enclose herewith a brief prepared by the Secretariat containing information on the different phases involved in the process of exploration and exploitation of resources in the Area. The brief contains a summary of information on the techniques and technologies used in exploration for and exploitation of polymetallic nodules and polymetallic sulphides and has been compiled from a number of different sources, including the reports of the proceedings of international scientific and technical workshops convened by the Authority. Copies of the workshop proceedings are also enclosed with the hard copy of this letter for reference purposes.

Yours sincerely,

Michael W. Lodge
Legal Counsel

Mr. Philippe Gautier
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International Tribunal for the Law of the Sea
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INTERNATIONAL TRIBUNAL FOR THE LAW OF THE SEA

(CASE NO. 17)

RESPONSIBILITIES AND OBLIGATIONS OF STATES SPONSORING PERSONS AND ENTITIES WITH RESPECT TO ACTIVITIES IN THE INTERNATIONAL SEABED AREA

SUMMARY INFORMATION ON THE DIFFERENT PHASES INVOLVED IN EXPLORATION AND EXPLOITATION OF POLYMETALLIC NODULES AND POLYMETALLIC SULPHIDES IN THE AREA

Information note prepared by the Secretariat of the International Seabed Authority in response to the request of the President of the Seabed Disputes Chamber

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SUMMARY INFORMATION ON THE DIFFERENT PHASES INVOLVED IN EXPLORATION AND EXPLOITATION OF POLYMETALLIC NODULES AND POLYMETALLIC SULPHIDES IN THE AREA

Information note prepared by the Secretariat of the International Seabed Authority in response to the request of the President of the Seabed Disputes Chamber

1. The present document has been prepared in response to a request by the President of the Seabed Disputes Chamber for "information on the different phases (such as collection of resources, transportation of the resources to the surface, initial treatment ...) involved in the process of exploration and exploitation of resources [polymetallic nodules as well as of polymetallic sulphides] in the Area"; said request having been conveyed to the Legal Counsel of the Authority by the Registrar of the Tribunal in a letter dated 13 October 2010. The document contains a summary of available information on the different phases involved in exploration and exploitation of polymetallic nodules and polymetallic sulphides, and has been compiled from a number of different sources, including the reports of the proceedings of international scientific and technical workshops convened by the Authority.

2. Three different phases of development of seabed minerals are identified in Part XI of the Convention and 1994 Agreement; "prospecting", "exploration" and "exploitation". Although these terms are not defined in the Convention or the 1994 Agreement, they are defined in the regulations on prospecting and exploration for polymetallic nodules and polymetallic sulphides adopted by the Authority in 2000 and 2010 respectively.[1] In each case, the definitions are the same and read as follows:

> "[P]rospecting" means the search for deposits of [polymetallic nodules] [polymetallic sulphides] in the Area, including estimation of the composition, sizes and distributions of deposits of [polymetallic nodules] [polymetallic sulphides] and their economic values, without any exclusive rights;
>
> "[E]xploration" means searching for deposits of [polymetallic nodules] [polymetallic sulphides] in the Area with exclusive rights, the analysis of such deposits, the use and testing of recovery systems and equipment, processing facilities and transportation systems, and the carrying out of studies of the environmental, technical, economic, commercial and other appropriate factors that must be taken into account in exploitation;
>
> "[E]xploitation" means the recovery for commercial purposes of [polymetallic nodules] [polymetallic sulphides] in the Area and the extraction of minerals therefrom, including the construction and operation of mining, processing and transportation systems, for the production and marketing of metals;

3. The present note has been prepared with these definitions in mind.

[1] Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area, ISBA/6/A/18 (2000); Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area, ISBA/16/A/12/Rev.1. (2010).

A. POLYMETALLIC NODULES

Characteristics

4. Polymetallic nodules occur on the floor of the ocean in a single layer. They vary in shape and size. An average nodule is slightly ellipsoidal with a diameter of 2.5 – 5 cm, but nodules vary from a few millimetres to many centimetres in diameter. They are porous, with water taking up one third to half of their weight. Their porosity means that they are crushed easily. Rather than digging up the soil to recover the ore, as is generally the case in land-based mining, nodules have to be swept or scooped up. In order to gather a large number of nodules, a wide area of the ocean floor needs to be covered.

5. The environment in which polymetallic nodules are found is characterized by ocean floor morphology, water depth, water column conditions, water surface conditions and distance from shore. The environment determines the operating conditions under which mining will take place. The ocean floor where nodules occur is not a featureless plain. Mountains, ridges, hills, scarps, troughs, basalt outcrops and boulders abound. Seamounts range in height from 800 to 1,500 m. The abyssal hills may be as high as 30 to 300 m, as long as 6 to 15 km and as wide as 2 to 5 km. Troughs can be 30 to 50 m deep, 250 m wide and 2 km long. The slopes of some of these troughs may be in excess of 30 degrees. The sediments on which nodules lie are fine-grained and of Bingham plastic type.[2] The bearing or shear strength of the sediments varies from area to area.

6. Polymetallic nodules contain various metals, among which nickel, copper, cobalt and manganese (and trace amounts of lanthanum, cerium, neodymium, yttrium, samarium and gadolinium) are considered to be of commercial interest. The grade of nodules (the content of the various metals of interest expressed as a percentage of their dry weight) and the abundance of nodules (the weight of wet nodules per unit area of ocean floor; usually expressed as kg/m^2) determine the amount of metals contained in nodules in a given area. Grades for potential economic deposits have been given in the general range of 1.1 to 1.6 per cent nickel, 0.9 to 1.2 per cent copper, 0.2 to 0.3 per cent cobalt and 25 to 30 per cent manganese. The range of abundance is indicated as 5 to 15 kg/m^2. Both grade and abundance vary considerably between different areas of the ocean floor and also within particular areas. Polymetallic nodules have been known to occur in relatively shallow water. However, nodule deposits of commercial interest with requisite grade and abundance are found only on the deep ocean floor at depths between 3,000 and 6,000 m.

7. For a nodule mining venture to be considered economical, it is commonly estimated that between 1.4 and 9 million metric tons of wet nodules have to be mined annually for a period of 20 to 30 years. The figure most often quoted is 3 million metric tonnes of dry nodules, which is equivalent to about 4.5 million metric tonnes of wet nodules. Assuming that an annual production rate of 4.5 million metric tons of wet nodules needs to be maintained for 20 years, the mineable areas should contain an amount of ore greater than 90 million metric tons of wet nodules, since not all the nodules can be recovered. Using a worst case recovery rate of 5 kg of nodules per square metre, this would require

[2] A Bingham plastic is a viscoplastic material that behaves as a rigid body at low stresses but flows as a viscous fluid at high stress. It is named after Eugene C. Bingham who proposed its mathematical form. [*E.C. Bingham,(1916) "U.S. Bureau of Standards Bulletin", 13, 309-353 "An Investigation of the Laws of Plastic Flow"*]. http://en.academic.ru/dic.nsf/enwiki/268641

mining of 900 square kilometres of seafloor per year, or 18,000 square kilometres of seafloor over a 20-year period.

8. There is currently no proven commercial scale technology for exploiting deep seabed polymetallic nodules. To date, developers have been pursuing integrated programmes designed to gradually reduce uncertainty about geological and technological factors. In the end, a decision can be taken about economic exploitation with acceptable risk that is informed by an assessment of economic and socio-political factors. The sequence of activities is commonly termed the "prospecting/exploration" sequence.

Prospecting

9. During the prospecting phase, the objective is to appraise existing data and information about mineral occurrence and the environment of the deposit in order to establish commercial viability. These data and information are obtained mainly from oceanographic cruises and other activities carried out by academic institutions and government agencies and include sea surface and water column characteristics such as wind, waves and swells. These data would, for example, allow general conclusions to be made regarding the geographical and temporal variability of storms and hurricane activity.

10. Data in the public domain can point to regions which are worth further investigation. For example, the public domain data available in the early 1970s indicated that the Clarion-Clipperton Zone in the north-east Pacific Ocean was the most promising region for polymetallic nodules and that indication has been reinforced by the fact that seven of the eight exploration contract areas with the Authority, as well as the corresponding reserved areas, are located in that region.

11. The availability and usefulness of public domain data about macro topography vary from region to region, but for particular regions, data about large topographical features, such as fracture zones, seamounts, ridges and troughs are considered sufficient. Public data about micro topography and obstacles are meagre; the use of high-resolution side-scan sonar systems and other bottom mapping technologies have the potential of augmenting public data about these factors. These systems can be towed behind ships or installed in Autonomous Underwater Vehicles (AUVs).[3] The advantage of AUVs for mapping operations is that the platform is more stable and results in maps of higher resolution

12. After an appraisal of existing data and identification of large regions worthy of investigation, prospecting proceeds with a higher resolution survey of the regions of most interest. The purpose is to select smaller target areas within the large regions. The target areas are surveyed in further detail to provide a large database, which allows decisions to be made at a higher level of confidence. The end results are target area refinements (some target areas are rejected, some are retained for future consideration and promising areas are selected for further investigation). It should be noted that during this stage indicative, rather than detailed data from a particular area are required concerning nodule characteristics and seafloor morphology. Precision depth recorders can generate data which allows

[3] Fully submersible AUVs are underwater vehicles which can operate below the sea surface without any physical connection or communication with a control station. They are pre-programmed to execute missions and have a small amount of "intelligence" or the ability to make simple decisions. They are appropriate for underwater missions such as seabed surveying where the vehicle must cover long distances at relatively slow speeds – between 1 and 2.5 meters per second

elimination of areas with macro topographical features. Survey operations are undertaken using towed bodies that can be equipped with still and video cameras to provide seafloor imagery at moderate speeds showing nodule coverage and density. Other sensor packages can be added to the towed body as required to expand system capabilities. The bottom sampling locations can be random and widely dispersed. The orientation of the ship track need not be planned carefully but the navigation data must be highly accurate and logged for future reference. The equipment and technology used during this stage are broadly comprised of bottom sampling, acoustic and visual devices. In general, these devices are used for the following activities:

(a) Gravity and magnetometric observation;

(b) Bottom and sub-bottom acoustic and electromagnetic profiling and imaging without the use of explosives;

(c) Limited mineral sampling using core, grab or basket samplers;

(d) Water and biotic sampling;

(e) Meteorological observation and measurement, including the setting of instruments;

(f) Oceanographic work, including hydrographic observation and measurement;

(g) Sampling by box core, small diameter core or grab sampler to determine geological or geotechnical seabed properties;

(h) Television and still photographic observation and measurement;

(i) Shipboard mineral assaying and analysis; and

(j) Positioning systems, including bottom transponders and surface and sub-surface buoys filed in Notices to Mariners.

Exploration

13. During exploration, additional surveying is performed in selected target areas to provide data sufficient to identify nodule deposits of probable economic interest. The evaluation of these data further refines the remaining target areas, allowing future exploration efforts to focus on deposits that have the most promising economic potential. In the next stage, these deposits are further investigated with the objective of delineating economically viable deposits. In the final stage of exploration, surveying provides sufficient data to allow evaluation of economically viable deposits, delineation of a mine site and preparation of a tentative mining plan for the initial period of commercial operation. Testing of mining systems will also be undertaken.

14. In order to arrive at the desired exploration objectives, large quantities of data must be collected systematically from vast areas of ocean floor and evaluated in an efficient manner. Since it is impossible to sample every square metre of a selected target area and because of variation in grade and abundance, exploration activities rely on statistical and, in particular, geostatistical methods of treating the data and decision-making on subsequent action is based on probability. The data that need to be collected comprise, inter alia, the following:

(a) Geologic

(b) Chemical

(c) Physical

(d) Biological

(e) Atmosphere and Climate

(f) Engineering

(g) Navigation

15. Targeted exploration proceeds from coarse grid surveying to increasingly finer grid surveys so that sufficient bottom sample data and data about seafloor morphology are generated for the delineation and evaluation of an economically viable deposit and, ultimately, the delineation of a mine site and preparation of a mining plan. In targeted exploration of areas of interest, the usual approach to sampling design, which follows land-based practice, involves gridding areas to be surveyed into square cells. Usually, 100 or more cells with 3 to 10 discrete samples in each cell are considered a reasonable number. However, the number of cells and the number of samples taken per cell must ultimately reflect judgments made concerning the variation in grade and abundance, and the accuracy expected to be achieved by the statistical methods. Statistical analysis of data collected within each cell is carried out on the assumption that the samples are representative of the given cell area at an assigned level of confidence. Further statistical treatment of all cells in an explored area is then used in immediate and future exploration activities.

16. The technology required to complete the exploration phase of the potential mine site is similar to the equipment utilized during prospecting. Since this phase of the operation is focused on developing the highest resolution data set for the area under investigation advanced systems are required. Remotely Operated Vehicles (ROVs)[4] and Human Occupied Vehicles (HOVs)[5] augment the equipment already in use and provide the highest resolution data collected in the exploration phase.

Technology used for recovery and preliminary at-sea processing of polymetallic nodules

17. Research and development of polymetallic nodule mining technology starts with an examination of the pool of existing technologies and an assessment of the extent to which they can be adapted. A systems engineering approach is called for since modification of one sub-system or component has implications for other sub-systems and components and thus for the whole mining system. To minimize development costs, it is likely that the technology for deep seabed polymetallic nodule mining will be developed incrementally through modifying existing technologies in addition to using off-the-shelf sub-systems and components from the pool of existing technologies. Some new concepts, sub-systems and components will also have to be developed.

18. Of the range of available technologies, the most functionally similar to the collection of nodules is that used in offshore dredging. Currently, the deepest water in which dredging technology is utilized for the transportation of seabed materials is about 160 m. Nodule mining will be conducted at depths

[4] Remotely Operated Vehicles (ROVs) are unoccupied platforms that are basically a submersible robot tethered to the mother ship that is capable of supporting assorted subsystems required to complete the investigation tasks. The ROV is piloted by a person on the mother ship who is seated in a control room populated with monitors, computers, control panels, recording devices and power systems.

[5] Human Occupied Vehicles (HOVs) or submersibles are free swimming vehicles with no connection to the mother ship that allow direct human intervention to the site being explored. In addition to the subsystems that are common with an ROV an HOV must also have life support and acoustic communications capabilities.

which are more than an order of magnitude greater than this. Offshore drilling technology is another technology which provides lessons and scope for adaptability. Fixed platforms operate at depths of up to 535 m, and tension-leg platforms can operate at water depths of up to 2,000 m. These are still a long way from the depths at which deep seabed mining will occur. However, these existing technologies have relevance to deep seabed mining with respect to surface platforms, pipe handling, materials handling, structural design, and approaches to dealing with surface conditions, station keeping and logistics. Drill ships have operated at depths and with pipe lengths comparable to what would be required for deep seabed mining. The mining system has to be mobile, with the capability to withstand dynamic forces on the pipe and collector; the collector has to tackle much more varied bottom conditions; and the coordination between the mining ship and the transport ship needs to be maintained. Storms on the high seas are common and extreme storm conditions may occur occasionally.

19. After the assessment of the existing pool of technologies, gaps are identified which need to be filled by innovative technologies. The development of a new collector system composed of interrelated sub-systems and components, some of which are new, must first have an overall conceptual design. A wide array of design concepts for the whole system and for the new sub-systems or components is examined through preliminary engineering studies to select design concepts which look promising. Selected design concepts are then refined; a model or pilot scale component, sub-system or system is fabricated or integrated and tested. Depending on the evaluation of the design concepts, tests of components may be performed in a simulated ocean environment, in a laboratory, in shallow water or the deep ocean. Based on pilot scale test results, further phases of design refinement and testing are carried out. Large scale prototype testing in the deep ocean will be necessary in order to ultimately settle on the design and fabrication of the commercial scale system.

20. A crucial characteristic of the exploration stage is that the geological and technological activities are carried out in an interactive manner. Each stage of the technology research and development process identifies further data needs and the results of each geological activity are used in subsequent stages of the technology research and development process and vice versa. For example, the results of reconnaissance surveys throw light on the characteristics of the ore and the environment of deposition; design engineers use this information to refine their design concepts, which in turn influence the type of information to be collected during target area exploration activities. Using the information collected through target area exploration activities, engineering determinations are made of the techniques and equipment that can work on a potential economically viable deposit and processing routes that are most suitable for the ore.

21. Polymetallic nodule mining technology developers have to address the basic question of how to pick up the nodules from the ocean floor and bring them up to the surface facility (most likely a ship). Three basic design concepts for mining technology have been pursued: picking up nodules with a dredge-type collector and lifting them through a pipe; picking up nodules with a bucket-type collector and dragging the bucket up with a rope or cable; and picking up nodules with a dredge-type collector and having the collector ascend by the force of its own buoyancy. Based on these three alternative concepts, three alternative mining systems have been the subject of research and development. These are the hydraulic mining system, the continuous line bucket (CLB) mining system and the modular or shuttle mining system. Two of the basic design concepts – the continuous line bucket dredge and the shuttle system – have been abandoned or shelved. The hydraulic mining system and its various configurations is the technology currently being pursued most actively.

22. A lift or riser pipe, attached to the ship, extends close to the bottom of the ocean. A collector mechanism is linked to the end of the pipe by a flexible hose interface to isolate the motion imparted by surface conditions. The collector picks up the nodules and feeds them into the pipe. Depending on the size of the nodules they may require a rough crushing before being introduced into the pipe. The nodules are then pumped up through the pipe with hydraulic pumps fixed to the pipe; or they are sucked up through the pipe by means of compressed air injected into the pipe.

Collector sub-system

23. The collector is the most unique and complex sub-system of the mining sub-systems. Over the years, more than 60 patents have been issued on collectors and several alternatives have been developed and tested with varying degrees of success. The essential task of the collector is to collect nodules from the seabed, concentrate them and feed them into the vertical lift. In accomplishing this task, it has to be able to perform three groups of functions:

(a) Collection and material processing;

(b) Movement on the seabed; and

(c) Monitor its position and operation.

24. Since nodules vary in size and shape the collecting mechanism needs to be designed in such a way as to retrieve an average nodule and discard objects that do not fall within a chosen size range. The collecting mechanism must also be designed to have a sediment-nodule separation capability. In terms of the materials processing task, two basic design concepts have been developed: a "mechanical collector" collects nodules mechanically, crushes them and injects the mixture into the lift sub-system; a "hydraulic collector" can be likened to a sledge that moves over the seabed and, by means of a metal plate mounted beneath the sledge, forces the mixture of sediment and nodules up a raised duct. Jets of water separate the sediment and nodules, the nodules are then injected into the duct and are then fed into the lift sub-system. Again, depending on the size of the nodules crushing may be required before transport to the surface.

25. Tests have been conducted on both self-propelled and towed collectors. In either case, account must be taken of the bearing, or shear strength, of the sediment. The collector has also to be designed to handle some degree of slope as well as some of the smaller obstacles. Various types of navigation, sensing and observation devices are integrated in the collector sub-system much like on an ROV. This equipment is used to: measure the rates at which nodules are collected and fed into the lift sub-system; show visual reports of the operation of the collector; provide acoustic information about the topography ahead and to the sides of the collector and its forward velocity; and provide information for position fixing of the collector relative to the mining ship and relative to previously mined tracks.

Lift sub-system

26. The lift sub-system performs the basic task of lifting the nodules fed into the lift or riser pipe from the collector to the surface ship. Two alternative lifting methods have been developed; the hydraulic pump lift and the airlift. In the hydraulic pump lift, nodules are mixed with seawater to form a slurry, which is forced upwards with hydraulic pumps mounted in or on the pipe in a line at various depths. In the air lift method, compressed air is injected into the pipe at various depths; the air-water mixture produces a density differential in the pipe. The mixture then moves upward under the influence of the hydrostatic head. This upward movement causes suction at the bottom of the pipe and the nodule slurry is sucked upward. Overall the lift sub-system should have the capability to:

(a) Pump or suck up the slurry;

(b) Control slurry flow;

(c) Work as a conduit for the slurry;

(d) Provide a mechanical connection to the collector;

(e) Provide propulsion for the collector, if it is towed;

(f) Serve as a structural support for power cable and communications link to the collector;

(g) Withstand excitation caused by ship oscillation and movement through the water column;

(h) Withstand excitation of the pipe propagated through the collector encountering topographic variation;

(i) Avoid clogging in the pipe, particularly in case the slurry flow is shut down unexpectedly; and

(j) Support its own weight along with the equipment and instrumentation attached to it.

27. In view of the porosity and fragility of the nodules, the pumping function has to take into account slippage associated with the flow of the slurry in the pipe and friction associated with the impacts among solid particles and between solid particles and the pipe wall. Pipe pressure gradients and pump power requirements are determined by the need for these two factors to be at acceptable levels, and the need for sufficient power to lift the nodules, sediment and water from the seafloor to the surface. The diameter of the pipe will have to be geared for the optimum transport of slurry. The link between the pipe string and the collector has to withstand bending without significant stresses, because it is subject to high curvature. The link also has to accommodate variation in local water depth and bottom topography.

Mining ship sub-system

28. The essential function of the mining ship sub-system is to receive nodules from the lift sub-system and transfer them to the transport sub-system. It must:

(a) Provide structural support for the sub-surface sub-systems (the collector and the lift sub-systems);

(b) Provide the means to assemble, deploy, operate, monitor and recover the sub-surface sub-systems;

(c) Supply power to the sub-surface sub-systems;

(d) Propel the whole mining system over the mine site if the system is a towed collector, possibly according to a pre-determined mining plan;

(e) Transfer the ore to the transport system;

(f) Provide buffer storage for accumulated ore and also storage for sub-surface sub-systems when not in use;

(g) Control the whole mining and transfer operation; and

(h) Serve as a hotel, storehouse and repair shop.

29. The decision to transfer nodule ore, personnel, spares, and consumables at sea is based on an assessment that it is an economic requirement to run the mining ship on site continuously for profitable operations. The alternative of merging the transportation and mining functions into one large ship or to process nodules at the mine site (beyond immediate at-sea processing as described above) is not economically viable. In this case, the transport vessels could be viewed as essentially conventional bulk carriers which can be leased to reduce capital requirements. These requirements define many of the parameters of the mining ship sub-system which include, inter alia, ore de-watering, bulk storage, Dynamic Positioning (DP)[6], propulsion, ore transfer sub-system and queuing facilities.

30. A key operational parameter is the availability of the mining ship and the availability of the transfer system to the mining ship. The mining ship must have high availability at the mine site because its availability and the required production are inversely related; the higher the availability of the mining system, the smaller its production capacity requirement. Based on the generally accepted production requirement of approximately 3 million dmt (dry metric tonnes) per year, the mining ship will have to produce about 10,000 dmt of nodules per day. High availability also involves the mining ship and transport vessels being able to operate in most, if not all, sea states. The availability of the ore transfer system must be high or both the buffer storage and ore transfer capacity requirements will be high.

Processing and refining of ore from polymetallic nodules

31. Polymetallic nodules differ in physical form and chemical composition from all terrestrial ores now being mined. Therefore a processing sequence uniquely designed to extract metals from nodules must be developed. Processing must meet technological feasibility, production requirements and environmental standards. Processing is a significant part of nodule exploitation, since the associated costs are likely to be greater than those incurred during mining operations. It is possible that the processing plant could be decoupled from the mining operation.

32. Processing is expected to occur on land. No onboard processing of nodule ore is expected to occur either on the mining ship sub-system or on the transport ships. So far none of the early consortia or the current contractors has suggested processing in the high seas or aboard their mining ships. This is driven by available space as the actual mining operation requires a considerable amount of equipment to complete the operation: the riser, collectors, spares; and nodule storage. Additionally, the high cost of capitalization of a floating processing system, coupled with the high operational costs, do not provide an economical business model.

33. It should be noted that mining sites and shore off-loading facilities may be large distances apart (more than 3,000 nautical miles in the case of the Clarion-Clipperton Zone). Nodules can be shipped to shore in three main forms: slurry; whole; or dried/ground. Nodules at the mine site will have a moisture content of 70 per cent. When slurry water is removed this is reduced to 40 per cent. It is expected that special facilities for the receipt of inbound nodules would be needed at any processing plant.

34. A number of processing alternatives exist. Metals can be extracted from nodules using various combinations of pyrometallurgical operations (including smelting and roasting) and/or

[6] Dynamic positioning (DP) is a computer controlled system to automatically maintain a vessel's position and heading by using its own propellers and thrusters. Position reference sensors, combined with wind sensors, motion sensors and gyro compasses, provide information to the computer pertaining to the vessel's position and the magnitude and direction of environmental forces affecting its position.

hydrometallurgical (leaching) operations. The choice of a process depends partly on what metals are deemed economically viable. Ultimately, the choice of a process will reflect the need to balance metal recovery efficiency and volume against the amount of capital investment in the processing plant.

35. There are presently five promising process options: three-metal plants that recover nickel, copper and cobalt utilizing high temperature sulphuric acid leach, reduction/ammonia leach or cuprion/ammonia leach; and four-metal plants that recover nickel, copper, cobalt and manganese utilizing either smelting or reduction/hydrochloric acid leach.

B. POLYMETALLIC SULPHIDES

Characteristics

36. Polymetallic massive sulphides (PMS) deposits were first discovered in 1979 at high-temperature black smoker hydrothermal vent sites. Since that time the mapping of these formations has been a major effort of scientific institutions worldwide and sites have been located in water depths of up to 3,700 metres. PMS deposits are typically associated with high-temperature (ca. 350°C) black smoker vents that occur in areas of active or recently active volcanism (e.g., deep-sea mid-ocean ridges, sedimented ridges, mid-plate seamounts, arc volcanoes, back-arc rift environments). When these sites are active circulate seawater that is mineral rich and superheated is discharged at the vent and the resulting plume precipitates metal sulphides onto the seafloor. Over time these mineral deposits become substantial and are not covered by any overburden and are therefore readily exploitable.

37. More than 300 sites of submarine hydrothermal venting and associated mineralization are known on the ocean floor. About 100 of these are host to PMS deposits. Known deposits range in size from a few thousand metric tonnes to a maximum of about 10 million metric tonnes. However, accurate sizes have been determined in only a few cases where drilling information is available (e.g., Middle Valley, Juan de Fuca Ridge; TAG Mound, Mid-Atlantic Ridge). The deposits consist of massive accumulations of sulphide minerals, including mainly pyrite, pyrrhotite, chalcopyrite and sphalerite. A number of different types of seafloor hydrothermal systems and associated seafloor mineral deposits are recognized. These may be grouped into six categories according to deposit type or the nature of the associated hydrothermal venting: polymetallic massive sulphide deposits (PMS); low-temperature hydrothermal vents and associated mineral deposits; near-field metalliferous sediments; distal metalliferous sediments; vein and breccia deposits; and known occurrences of hydrothermal plumes (i.e., remotely-detected but unconfirmed high-temperature vent sites).

38. The state of knowledge of the distribution and fundamental characteristics of PMS deposits can be summarized as follows: There are more than 300 known hydrothermal sites. About 40 per cent of those are in the Area. Most parts of mid-ocean spreading centres fall within the Area. In contrast, large parts of volcanic arcs that have sulphide formations are within the exclusive economic zones of island nations. Sixty-five per cent of the sites are at mid-ocean ridges; 22 per cent at back-arc basins; 12 per cent at volcanic arcs and 1 per cent at mid-plate volcanoes. 100 of those hydrothermal sites are host to polymetallic sulphides. However, individual occurrences cover no more than 1 km diameter, commonly tens to hundreds of metres. Hydrothermal vents and associated sulphide deposits may also occur spatially clustered within smaller distances; an example is the Endeavour segment of the Juan de Fuca Ridge which consists of about 30 different sulphide complexes distributed among eight vent fields along

a 10 km segment of axial valley. In total, there is 55,000 km of oceanic spreading centres as well as 22,000 km of volcanic arc and back-arc spreading ridges. The average spacing along the ridge is about 98 km between one vent site and the next; 167 km for slow-spreading ridges and 46 km for fast-spreading ridges. The median tonnage in most 100 km² blocks will not be greater than 50,000 tonnes. The TAG vent system in the Atlantic Ocean is probably the best known of all polymetallic sulphide deposits in the ocean basins. It has been drilled seventeen times and measures about 200 m by 60 m.

Prospecting

39. The processes and techniques used for prospecting for PMS deposits would be the same as used for prospecting for polymetallic nodules.

Exploration

40. The general objectives of the exploration phase are the same as for polymetallic nodules – to carry out more detailed site exploration in order to quantify the size and mineral composition of the deposit. There are differences of approach, however, having regard to the different nature of the deposits.

41. Seafloor surface imagery provides only limited information about this type of deposit and to assess the commercial viability of a prospective mine site more data is required. This can be accomplished by first utilizing a marine gravimeter allowing a sub-bottom 3-D image of the mineral formation to be obtained. Once this has been accomplished a benthic rock-coring programme would be undertaken to quantify the mineral percentages to allow assessment of the value of the deposit. Rock coring systems are either a stand-alone benthic drilling system or ROV deployed concurrently. Other environmental research must also be performed during this phase of the programme to understand the composition of the marine biota in the site area. Active hydrothermal vents provide a chemosynthetic source of energy that in turn sustains a very rich and diverse community of marine biota. Dormant vent sites do not sustain these communities and therefore the environmental impact to marine biota is drastically reduced. It is of note that it should be only dormant sulphides deposits that should be considered for mining operations. The mining of an active vent site would be technically problematic also because of the superheated water that would cause problems for the mining system.

42. The evaluation of data further refines the remaining target areas, allowing future exploration efforts to focus on deposits that have the most promising economic potential. In the next stage, these deposits are further investigated with the objective of delineating an economic deposit. Polymetallic sulphides are found in localized areas and once these deposits have been identified the targeted exploration is very specific and detailed. In the final stage, the activities provide sufficient data to allow evaluation of the economic deposit, delineation of a mine site and preparation of a tentative mining plan for the initial period of commercial operation.

Technology

43. The technology required to exploit polymetallic sulphides has been the focus of serious research and development efforts for companies who are on the verge of commercial operations. These efforts have ranged from advanced imagery systems to scaled mining systems and have leveraged existing technology from diverse and mature subsea user groups.

44. To date planned commercial operations for PMS exploitation are all in areas under national jurisdiction with mine site water depths of approximately 1,500 metres. The technology required for mining operations will include a subsea mining unit, riser or lift pipe for the ore, surface support ship, materials handling and ore transportation from the mine site. The mining unit cutter head is an area where continuous research and development will be ongoing during the life of the programme. The surface support vessel currently under consideration is an enlarged version of a Diving Support Vessel (DSV) or Multi-Support Vessel (MSV) used to support undersea operations in the offshore oil and gas industry. These vessels are mature in their design and technological capability with integrated saturation diving systems, ROV systems, heavy lift capability, moon pools and large accommodations packages to support the personnel requirements. Additionally DSVs and MSVs have advanced navigational and station keeping capabilities even in very harsh and demanding conditions. This vessel design is capable of operating in any location on the oceans but the distance from the mine site to the materials depot on shore can greatly impact the final size of the vessel. The distance to the materials depot will also influence the size and type of ore transport vessel so the mining system can continue mining operations uninterrupted.

45. The deepest PMS deposits currently identified in the Area are in water depths of up to 3,700 metres. Of the available existing technology the ocean diamond mining industry has the most functionally similar equipment as that which will be required for the exploitation of sulphides. There are operational depth differentials for sulphide versus diamond mining efforts but that will not limit the development or deployment of the technology. The primary difference in a sulphide mining unit will be the cutter head and there have been development efforts for both land and marine based systems in this regard.

46. The first commercial-scale PMS mining system has been in development for a number of years but the system is yet to be manufactured because of economic considerations. The preliminary design shows a system that is lowered from the surface support vessel to the mine site. Sulphides deposits consist of solid high-grade ore that requires large amounts of force and energy to crush into a transportable material. The mining system required to perform this task is very large and heavy to allow the mining cutter head to deliver the required force to break up the rock face. The cutter head will also provide the collection point for the minerals. It is not clear as yet if additional in-situ processing will be required to get the ore into a transportable condition. The present design proposal plans to perform .another level of processing on-board ship before the ore is transported to shore for further refining. This processing would produce tailings that would be returned to the seafloor using return conduits in the riser system. The grain size of the returned materials will impact the size of the subsea plume.

47. The preliminary mining unit design is currently targeting an average production of 100 m^3 per hour with peak production rates of 6,000 metric tonnes per day. The mining unit currently under consideration is designed to be operated on adjustable legs to deal with the rough terrain that will be encountered during the initial development of the mine. Once the initial phase of the mine development has been completed and there are areas of flat seafloor that can be used, the mining unit will be converted to a tracked drive system allowing greater ease of navigation around the site. A lift sub-system will perform the basic task of lifting sulphide ore fed into the lift or riser pipe from the collector to the surface ship and is likely to be similar to the technology deployed for polymetallic nodules.

Processing of ore from polymetallic sulphides

48. Polymetallic sulphides are similar in chemical composition to terrestrial sulphide ores now being mined. Therefore a processing sequence can be leveraged from existing processing processes to extract metals from sulphide ore. Processing must meet technological feasibility, production requirements and environmental standards. Processing is a significant part of sulphide exploitation, since the associated costs are likely to be greater than those incurred during mining operations. A number of processing alternatives exist. Metals can be extracted from sulphide ore using various combinations of pyrometallurgical operations (including smelting and roasting) and/or hydrometallurgical (leaching) operations. The choice of a process depends partly on what metals are deemed economically viable. Ultimately, the choice of a process will reflect the need to balance metal recovery efficiency and volume against the amount of capital investment in the processing plant.

49. As with polymetallic nodules, there are a number of process options: three-metal plants that recover nickel, copper and cobalt utilizing high temperature sulphuric acid leach, reduction/ammonia leach or cuprion/ammonia leach; and four-metal plants that recover nickel, copper, cobalt and manganese utilizing either smelting or reduction/hydrochloric acid leach. It is not expected that processing will take place on the high seas or aboard the mining ship as to do so would not be economically feasible.

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