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Possible impact of the convention, with special reference to article 151, on developing countries which are producers and exporters of minerals to be extracted from the Area: report of the Secretary-General

Extract from the *Official Records of the Third United Nations Conference on the Law of the Sea, Volume XVI (Summary Records, Plenary, First and Second Committees, as well as Documents of the Conference, Eleventh Session)*

List of Documents

Noting that present efforts undertaken within the United Nations system in training, education and assistance in the field of marine science and technology and ocean services are far below current requirements and would be particularly inadequate to meet the demands generated through operation of the Convention on the Law of the Sea.

Welcoming recent initiatives within international organizations to promote and co-ordinate their major international assistance programmes aimed at strengthening marine science infrastructures in developing countries,

1. *Calls upon* all Member States to determine appropriate priorities in their development plans for the strengthening of their marine science, technology and ocean services;

2. *Calls upon* the developing countries to establish programmes for the promotion of technical co-operation among themselves in the field of marine science, technology and ocean service development;

3. *Urges* the industrialized countries to assist the developing countries in the preparation and implementation of their marine science, technology and ocean service development programmes;

4. *Recommends* that the World Bank, the regional banks, the United Nations Development Programme, the United Nations Financing System for Science and Technology for Development and other multilateral funding agencies augment and co-ordinate their operations for the provision of funds to developing countries for the preparation and implementation of major programmes of assistance in strengthening their marine science, technology and ocean services;

5. *Recommends* that all competent international organizations within the United Nations system expand programmes within their respective fields of competence for assistance to developing countries in the field of marine science technology and ocean services and co-ordinate their efforts on a system-wide basis in the implementation of such programmes, paying particular attention to the special needs of the developing countries, whether coastal, land-locked or geographically disadvantaged;

6. *Requests* the Secretary-General of the United Nations to transmit this resolution to the General Assembly at its thirty-seventh session.

DOCUMENTS A/CONF.62/L.84 AND ADD.1

Possible impact of the convention, with special reference to article 151, on developing countries which are producers and exporters of minerals to be extracted from the Area: report of the Secretary-General

DOCUMENT A/CONF.62/L.84

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SYNOPSIS

The Secretary-General was requested to prepare a preliminary study on what is essentially the question of the impact that sea-bed mining will have on the economies of developing countries which also produce and export the same metals as those which will be produced from the sea-bed (copper, nickel, cobalt and manganese). The following report covers work done in the preliminary study. It is divided into five sections and four annexes.

Section I of the report is an introduction and explains the structural form that has been used for the preliminary study. The directive to the Secretariat lends itself to quite a broad interpretation in establishing the purpose and scope of the preliminary study. At the same time, the fact that no specific guidance concerning parameters or data were provided by the Conference and included in the directive precludes the preliminary study from proceeding to any quantitative conclusions. Therefore a preparatory and planning role was assigned to the preliminary study, and the first section of the report further explains the reasoning which led to this decision. It then goes on to outline the plan for further investigation, which may take the form of a full-scale study.

Sections II, III and IV of the report explain the successive parts in the planned full-scale study which is outlined in Section I and define the data areas and the analytical techniques which have to be agreed upon before the full-scale study can proceed.

Section V summarizes the significant points that have emerged from the report and makes some concluding observations.

Annex I gives a very short description of the working of article 151 of the draft convention on the law of the sea. It then goes on to explain that the calculations in document A/CONF.62/L.66[1] of 24 February 1981 could be considered as a base for defining certain parameters which will be used in the full-scale study. However, the study in document A/CONF.62/L.66 covered a very wide range of assumptions, and it is pointed out that the range would have to be substantially narrowed if the results of further studies were to have any practical application. Annex II gives a list of documents previously published by the United Nations relating to the subject under study and includes a short résumé of several documents which are considered particularly relevant. It is pointed out in the report that a considerable amount of information on sea-bed mining, technical, economic and political, is available in the publications of various societies and institutions. Annex III is a brief outline of the role that the mineral industries play in the economies of several developing countries which, from *prima facie* evidence, could most likely be adversely affected. The subject matters of both annexes III and IV are of such wide and extensive character that the information given in these annexes must, of necessity, be very attenuated and is intended only to assist in explaining the purpose and procedure of the full-scale study.

SECTION I

1. At its 54th meeting, on 27 August 1981, the First Committee requested the Secretary-General to carry out a preliminary study on the possible impact of the convention on the economies of developing countries which are producers and exporters of the minerals to be extracted from the Area with special reference to the provisions of article 151.

2. It should be noted that the request stipulated a preliminary study, and this implied that further investigation in the

[1] See *Official Records of the Third United Nations Conference on the Law of the Sea*, vol. XV (United Nations publication, Sales No. E.83.V.4).

form of a full-scale study of the problems may be carried out at a later date.

3. Special reference has been made in the request to article 151, which specifies the policies regarding the production of metals produced from polymetallic nodules extracted from the Area. The study will therefore be directed specifically to considering the possible effect that the production of the metals from the international areas of the ocean in accordance with article 151 may have on the economies of those developing countries which also produce and export the metals.

4. Matters which had to be considered in determining the form that the preliminary study should take and the extent to which it should be carried were as follows. First, a full-scale study of this subject will require a substantial amount of data and information and would entail the use of complex analytical procedures, all of which must receive prior acceptance by parties concerned with the study. Secondly, if the study is to produce findings on which specific, and possibly far-reaching, action will be taken, these findings will have to receive a wide consensus of acceptance. This is only likely to be achieved if the study is detailed and comprehensively covers all aspects of the problems. Such a study will be a major research project and will require the commitment of considerable financial and technical resources over a relatively long period. The necessary resources could not be mobilized in the limited time between the end of the resumed tenth session in August 1981 and the pending session in March 1982. It was felt then that the preliminary study could be of most use to the Conference if it were viewed as a step in the planning process leading in a logical sequence to the full-scale study. Giving due consideration to the matters mentioned above, it appeared that the most useful purpose for the preliminary study would be to devise a plan of operations for the full-scale study and to examine the problems which may arise when implementing it. In the course of such examination, this study will define the necessary data and analytical information and will indicate possible analytical procedures needed for the full-scale study, on all of which guidance is required.

5. The mechanism through which the sea-bed mining will affect the economies of the developing countries which also produce and export the metals will be the supply-price-demand determination in the world metal markets. This will affect the production, sales and price received by the developing countries and consequently their export earnings and value of production, and this in turn has a direct relationship to the overall economy. The impact that the sea-bed mining will have on the economies of these countries can be evaluated only by a comparison between their economic situation as it would exist if sea-bed mining were operating in accordance with article 151 and their economic situation as it would be if no sea-bed mining were to take place.

6. A form for the full-scale study which seems to follow a logical sequence would be a process involving three parts. This scheme is briefly described in the subparagraphs below and the successive parts are further elaborated in the ensuing paragraphs of this report. At this point it should be emphasized that, for clarity of description, the parts are shown as three distinct operations, but they are very closely interrelated: each part will influence and be influenced by the other parts.

(*a*) Calculations would be made to show the production of all metals from polymetallic nodules extracted from the international area during some critical time-period to be covered by the study: it is assumed that the impact of sea-bed mining would not be a sudden event but would be spread over some period of time. The scale of production of the metals would be based on the nickel-production ceiling as calculated under provision of article 151;

(*b*) A comprehensive analysis of the functioning of the world metal markets would be made. The possible changes in the world metal markets in adapting to the new supply of metals from the sea-bed would be studied in depth. The possible changes in the volume and value of production and export of the developing country producers and exporters resulting from the changes in the world metal markets would be estimated;

(*c*) The effect that these changes in the volume and the value of export and production may have on the overall economies of the developing country producers and exporters of the metals would be determined by separate investigations.

As mentioned in paragraph 5, each part in the study will involve a parallel study of the situation in which no sea-bed mining occurs, and the comparison with this "base case" would be the measure of the effect of sea-bed mining. It will no doubt be understood, but it may be appropriate to mention, that the base case will not be a static situation but will also be the outcome of a dynamically developing mineral industry over the period to be covered by the study.

7. It should be pointed out that a considerable amount of research and study has been done on the subject of the impact of sea-bed mining on the mineral industry as a whole and on the export earnings of the existing land-based producer countries. A list of the United Nations and United Nations-associated documents is attached (annex II) together with a brief comment on several papers which have been quoted or referred to during the various sessions of the Conference. The greater part of this kind of work has been carried out by private organizations and technical societies, and comprehensive bibliographies will be found in their numerous publications.

SECTION II

8. The first part in the investigation will be to determine the quantity of metals that would be produced from the sea-bed by the application of the provisions of article 151 over some critical period of time. The critical period, when the impact of sea-bed mining is likely to be felt by the land-based producers which are also exporters, will be matter for decision, but it could be the 10 years after the commencement of the earliest commercial production or could even extend to the end of the interim period, and again some delegates may consider that the critical period would commence a few years before the commencement of the earliest commercial production, when the anticipation of metal surplus could affect the market. Agreement then will have to be reached both on the date of commencement of the earliest commercial production and on the critical time-period which the study has to span. One particular point in time when the impact of sea-bed mining could be very significant is at the commencement of the earliest commercial production, because, in accordance with the provision of article 151, quite a substantial tonnage of sea-bed minerals could be precipitated onto the market at that time. Previous estimates for this commencement tonnage vary from approximately 150,000 tons up to about 350,000 tons of nickel with a proportional amount of other metals. It is uncertain if sea-bed mining would be able to achieve this tonnage of production in such a short space of time that the possibility of seriously disrupting the markets would arise. Nevertheless, whatever the schedule for the buildup to production would be at the commencement date of the earliest production, it would be a critical factor in assessing the impact of sea-bed mining and also in anticipating possible means of market adjustments. It is essential, then, that a realistic time and production schedule for this commencement period be discussed and agreed upon.

9. Examples of the application of article 151 have been described in A/CONF.62/L.66 and a very brief summary is

given in annex I to this report. That study already shows the amount of nickel that will be produced from the international sea-bed sources over a number of different time-periods. These figures will be relevant to the new study provided that the commencement date and time-period to be agreed upon are within that covered by A/CONF.62/L.66 and provided that the statistical parameters to be agreed upon are within the range of those used in the previous study. It is relevant to note at this point, that, for the purpose of previous study, the maximum tonnages of nickel permitted under the provisions of article 151 were calculated, and it may be assumed that the tonnage would in fact be produced. Several published reports maintain, however, that the higher estimated production costs of sea-bed mining relative to that of some land-based producers raise doubts about this assumption and, in fact, there may be no initial rush to get into sea-bed mining. However, this matter would come up again at a later stage in the full-scale study when the feedback from the second part shows the changes in world demand, supply and price for the metals.

10. The formula in article 151 establishes a ceiling for the production of nickel from the sea-bed, but it does not directly establish the amount of production of any of the other metals which may be produced from the polymetallic nodules (copper, cobalt, manganese, molybdenum and others). To arrive at the production figures for these metals, a series of assumptions will have to be made. These are, first, the grade (percentage amount, on the average, of each of the metals contained in the nodules that will be mined) and, secondly, the recovery factors (the amount of each of these metals that will be recovered in the metallurgical process). From these figures it will be possible to calculate the tonnage of nodules that will be mined to produce the tonnage of nickel allowed in terms of article 151. From that tonnage of nodules, from the nodule grade and from the recovery factors, the tonnage of the other metals that will be produced from these nodules can then be calculated.

11. A considerable variation in the grade of the polymetallic nodules has been revealed in the sampling data that are available. In table 1 of document A/CONF.62/25 dated 22 May 1974,[2] the estimated metal content of the nodules was: nickel 1.6 per cent, copper 1.4 per cent, cobalt 0.21 per cent and manganese 24 per cent. However, later estimates are somewhat lower and document NG1/9 dated 3 May 1978,[3] containing the second progress report of the Sub-Group of Technical Experts, states in paragraph 6 (*b*): "Generally, the average nickel content is likely to be between 1.2 per cent and 1.4 per cent for mines operated with the 'first generation' of mining equipment". Some private feasibility studies have assumed a grade of 1.3 per cent to 1.5 per cent nickel, 1.0 per cent to 1.3 per cent copper, 0.25 per cent cobalt and 25 per cent to 29 per cent manganese. However, it should be possible to reach agreement on an average figure, within close limits, for the grade of the nodules which will be exploited during the initial and interim periods. Different estimates for the recovery factor have been given in several technical papers, particularly in the case of cobalt and manganese. Document A/CONF.62/25, paragraph 2 (*a*) (i) of section II, states: "Metal recovery depends on the metallurgical process adopted but it seems that the industry might obtain a 95 per cent yield on the recovered metals". A foot-note, however, states: "It is possible that some metallurgical processes will yield lower recovery rates than 95 per cent. These processes, requiring much lower total investments, are designed to optimize return on investment and not metal recovery." A widely quoted feasibility study used the following recovery figures: 95 per cent of the nickel, 95 per cent of the copper, 60 per cent of the cobalt and no recovery of manganese. Document NG1/11[4] dated 11 May 1978, containing the final report of the Sub-Group of Technical Experts, assumed a recovery factor for nickel of 90 per cent and went on to say in paragraphs 10 and 11: "The processing plant might be capable of recovering between 85 per cent and 95 per cent of the copper present in these nodules, between 55 per cent and 90 per cent of the cobalt and, perhaps, 50 per cent to 90 per cent of the manganese. It can be assumed that as much as possible of the nickel and copper will be produced from the nodules and that some, if not all, of the cobalt that can be recovered, will be produced. Initially, at least, manganese will be produced from only some operations." The metal recovery will also depend on the particular processing route used. A recovery of 90 per cent of the nickel seems to be widely used, but it is considered that copper recovery could drop to 80 per cent if a pyrometallurgical process is used. Most technical papers are somewhat reticent about the probable recovery of cobalt, but it seems that it could be 60 per cent or less. It should be understood that these are only estimates, because the development of nodule-processing routes has not yet advanced beyond the pilot-plant stage and there is quite a degree of uncertainty in extrapolating recovery efficiencies achieved during the research stage to that in a full-scale plant. Some of the differences in estimated recovery efficiency, however, are based on economic consideration; for instance, particularly in the case of manganese, technical opinions differ on whether, in fact, the cost of the processing plant and production justifies the recovery of this metal at all and, if so, on what scale. The assumptions referred to in this paragraph, particularly regarding the recovery factors in relation to manganese and cobalt, will have a significant effect on the outcome of this part of the study. Once again, the interrelationship of this part of the study with the second part, dealing with world metal markets, is evident.

12. A brief summary of the content of this part of the report is as follows: A schedule of production tonnages of all sea-bed metals (nickel, copper, cobalt, manganese etc.) will have to be calculated from the agreed date and over the agreed time-period on the basis of the tonnages of nickel allowable in terms of article 151. These calculations will themselves be based on an assumed date of commencement of the earliest commercial production and on assumptions concerning the future growth rate of world consumption of nickel, and this will be followed by calculations of tonnages of other metals based on assumptions of the average grade of polymetallic nodules to be mined and on the metallurgical recovery factors of each of the metals.

SECTION III

13. Having arrived at a schedule of production of metals from sea-bed mining, a prerequisite for analysing the possible changes in the markets in adapting to this production will be a clear understanding of how the world metal markets work. Most metals are dealt with in controlled and in open markets, and both of these systems have extremely complex structural organizations.[5] A detailed study will have to be made of the effects of the many factors and the behaviour of the many participants which are involved in establishing the supply and the demand functions.

14. Controlled metal markets usually operate through international ownership ties, long-term contracts and preferential trade blocs,[6] but little work, either theoretical or

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[2] *Ibid.*, vol. III (United Nations publication, Sales No. E.75.V.5).

[3] *Ibid.*, vol. X (United Nations publication, Sales No. E.79.V.4), document A/CONF.62/RONG/1, annex C.

[4] *Ibid.*, annex D.

[5] Louis Perlman and Michael Allingham, "Econometric Supply-Demand Models", *Mineral Materials Modeling: A State-of-the-Art-Review*, William A. Vogley, ed. (Washington D.C., Resources for the Future, 1975).

[6] John E. Tilton and André L. Dorr, "An Econometric Model of Metal Trade Patterns", *Mineral Materials Modeling: A State-of-the-Art-Review*, William A. Vogley, ed. (Washington D.C., Resources for the Future, 1975).

empirical, has been done on this type of market. Through arbitrage and other links, these markets may be connected with the open market system, but the determinants in the former type of market are often markedly different from those in the latter. In the case of metals contained in polymetallic nodules, there is evidence to suggest that controlled markets do exist. One crucial area of analysis will be to investigate how operations in the controlled market will change as a result of the sea-bed production of metals pursuant to article 151.

15. Some of the issues in this connection cannot be dealt with by strictly economical and financial analysis. These issues, such as the loss of markets caused by an adverse shift in trading patterns, may well be the response to completely different factors, e.g., ties between the sea-bed suppliers and major consumers, integrated financial interests between sea-bed and land-based mining groups, security of supply sources and other similar considerations. The effect of these factors on the economies of the developing countries which are producers and exporters will have to be studied in depth. It must be presumed, however, that at the time of the full-scale study, these matters will be the subject of a separate part of the study covering trade relations, commodity and industry agreements and such matters.

16. In the course of analysing the open markets, two significant areas have to be investigated: the underlying market structures and the behaviour of the participants in the market. Theoretically, two types of market structures can be distinguished, a purely competitive market and a market where some individual suppliers or demanders may have strong market influence. Each of the metals in question is characterized to some extent by a market structure of the latter type. The main participants in the metal markets are usually regarded as producers and consumers or suppliers and demanders (essentially, firms), but the role of the Governments on both the supply and the demand sides must be considered. Not only do Governments enter the demand side as stockpilers and the supply side as controllers of mining operations, but government policies on international trade, investment and economic development also have significant bearing on market processes.

17. On the supply side, the critical information necessary is the relative costs of production from the various mineral sources and the potential for expansion within the industry. One further complication is that cobalt is a co-product of a multi-product industry (copper-cobalt and nickel-cobalt) and, though sometimes classed as a by-product, this is an over-simplification of quite a complex internal costing structure. As a result, these industries do not necessarily follow similar supply-cost relationship to other metals.

18. The supply-cost relationship relevant to the mineral industry in developing countries *vis-à-vis* the supply-cost relationship of the mineral industry in developed countries as well as that in sea-bed production are pertinent for an overall view of the supply situation. This situation will change as new mines are opened up and will also be affected by new technological development within the mineral industry. In addition, the secondary supply from recycling of metals will have a significant effect. It is also conceivable that production may occur from nodules within the exclusive economic zone (which would not be subject to the provisions of article 151). Several interesting areas have been reported, and with the probable lower transport costs from near-shore sites, their inclusion in the supply situation cannot be ruled out.

19. On the demand side, the discussion usually centres around the responsiveness of demand to price changes (as measured by price elasticity of demand). Unfortunately, empirical investigation into price elasticity of demand is relatively scarce and whatever empirical information is available is inconclusive. As an example, a study on the cobalt industry, using one methodology, implies inelastic demand (long-run price elasticity of aggregate worldwide demand is −34); using a different methodology implies elastic demand (price elasticity of aggregate worldwide demand is −1.68, with price elasticity of demand facing Zaire as −2.51);[7] still another study distinguishes price elasticities of demand at high and low ranges of price.[8]

20. In addition to the price of the metal itself and the prices of substitutes, an activity variable (e.g., end-use, industrial production, income) is usually considered to affect demand. Changes in demand resulting from new substitution possibilities and possible new usages have also to be considered. Finally, to complete the picture on the demand side, desired changes in consumers' and producers' stocks have to be added.

21. The preceding discussion points out the salient factors in the investigation of the working of the world metal markets in order to arrive at the equilibrium quantities supplied (from various sources) and demanded (by various consumers) and the equilibrium prices. This determines the volume and value of production and exports of developing countries. It is evident that most of the factors involved and the outcomes are interrelated and there are numerous feedbacks within the system (see diagram). Notionally, the equilibrium values will be determined simultaneously, but in the real world, the adaptation process is a complex and involved one and may require a considerable amount of time. Expectations also play a key role in the metal markets, and supply-demand decisions are often made ahead of time on the basis of the expected future situation in the world metal markets.[9] This means that some aspects of market adaptation to sea-bed supply may be set in motion ahead of the time actual production from the sea-bed enters into the market.

22. This leads to further issues to be dealt with. Conceptually, a clear distinction can be made about the situation which would exist if no sea-bed mining occurred (base case), and the situation which would exist if sea-bed mining were operating, consistent with article 151 (in economic coinage, two equilibrium positions). Ways have to be devised, however, to deal with the real world situation, where the distinction may be blurred and the working of the adaptation process itself must be taken into consideration.

23. A pertinent point in the study is that while the volume of sea-bed production as calculated in the first part of the full-scale study (in accordance with article 151) will be used as an input into the second part of the study dealing with metal markets, the actual volume of sea-bed production as a result of the working out of the equilibriating adaptation process in the markets may be different. For instance, it is conceivable that a significant downward trend in prices will affect the investment climate in the mineral industry and this will lead to possible slowing down in sea-bed mining development and a reduction in volume of production from the sea-bed.

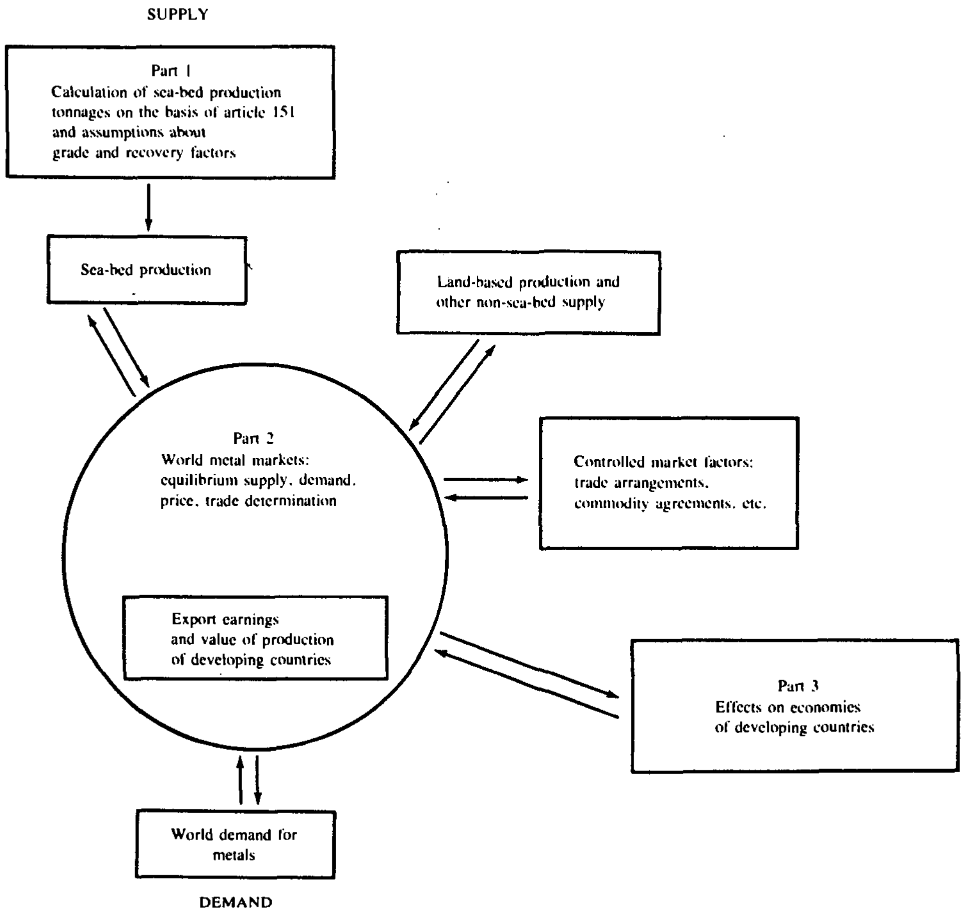
24. In summary, the preceding paragraphs in the report have endeavoured to explain that the extent of the impact of

[7]Charles River Associates, Incorporated, *Cartelization in the World Cobalt Market: Economic Analysis and Policy Implications* (Cambridge, Mass. 1976), pp. 19–22.

[8]F. Gerard Adams, *The Development of Manganese Nodules from the Ocean Floor: A Long-Term Econometric Analysis,* Discussion Paper No. 402 (Philadelphia, University of Pennsylvania, 1978), p. 17.

[9]For a theoretical exposition of the role of expectation in the metal markets, see Jere R. Behrman, "International commodity market structures and the theory underlying international commodity market models" in *Econometric Modeling of World Commodity Policy*, F. Gerard Adams and Jere R. Behrman, eds. (Lexington, Mass. and Toronto, Lexington Books, 1978), pp. 35–39. For an empirical application involving the role of expectation, see C. W. Smithson et. al., *World Mineral Markets: An Economic and Simulation Analysis*, Mineral Policy Background Paper No. 8 (Ministry of Natural Resources, Ontario, Canada, 1979).

Representation of proposed full-scale study



sea-bed mining on the economies of developing countries depends on various factors. Most of them are interrelated in crucial ways, and the whole problem will have to be studied by recourse to rigorous analytical methods. The extent of the impact is essentially a quantitative issue, and thus necessitates the use of quantitative methods, but even in order to arrive at qualitative conclusions, certain rigour is called for.

25. Several methodological approaches involving different degrees of simplification and abstraction are in vogue. "Many, or perhaps most, studies that seek to project future values of a particular quantity simply take past values of the quantity, determine the trend line that best fits these values, and project that line into the future in order to make forecasts about future values. While this technique has the advantage of simplicity, it does not allow analysis of the underlying market structure of the world market for a particular mineral. Neither does strict time series analysis allow one to examine the results of changes in any one of the important variables that affect that structure. In other words, such an analysis is too simplistic to give much insight into the functioning of the market or the impact of changes in important forces in the world."[10]

26. Econometric modelling, sometimes combined with simulation techniques, has been applied in analysing and forecasting interrelated phenomena. However, certain reservations on their usage have been expressed and, quoting from one authority on the subject, "models cannot usefully duplicate [the] complexity and detail [of international commodity markets]. Attempts to do so are doomed to failures because of the enormity of the task. Instead, good modeling requires simplifications and abstractions to represent the essential elements of the system under examination".[11] There is also the need for a balance between costs and complexity of the models and the results which will be achieved.

27. It is not intended to suggest, however, that suitable methodological approaches, including the use of econometric models, cannot be devised for the purpose of the full-scale study, but it is a prerequisite of the full-scale study that the interested parties agree to accept a particular approach or a combination of several approaches. Not all the approaches need necessarily be of a quantitative nature; in fact, some of the areas, especially the working of the controlled markets, may gainfully be explored by qualitative methodologies. The credibility of the conclusions from the full-scale study will depend on obtaining agreement on the simplifications and abstractions involved in the study and on the objectivity of the analysis, rather than on the possible limitations of methodologies. At the same time, an over-simplistic approach to this complex problem would be based on a considerable amount of subjective judgement, and the conclusions from such a study are unlikely to command the high degree of confidence required as a basis for future policy decisions.

28. It would be remiss if mention were not made of the considerable amount of work that has already been done in the construction of econometric models to predict the effects of sea-bed mining. This work has been reported in various publications of the United Nations Conference on Trade and Development (UNCTAD) referred to in annex II and based on studies carried out by Professor F. Gerard Adams, The Wharton School, University of Pennsylvania, at the

[10] C. W. Smithson et. al., *op. cit.*, p. 7.

[11] Jere R. Behrman, *op. cit.*, p. 9.

request of UNCTAD. The studies resulted in the construction of econometric models which predict the effect of sea-bed production on the copper, nickel, cobalt and manganese industries and on the overall export earnings of developing countries. The calculations were updated in 1978 but do not, of course, take into account the provision of article 151 and the most recent data and information, nor do the studies extend to investigating the effect on the economies of individual States. This previous work will undoubtedly be a matter for consideration when the full-scale study is initiated.

29. The results in the second part of the full-scale study would indicate how the international metal prices and trade would be affected by the new supply of metals coming from the sea-bed. The application of the prices to the export volumes of these metals from the land-based producer-exporters will then show how their export earnings will be affected. The evidence, on first consideration (based on existing studies, albeit with limitations) would suggest that the several metals produced from the sea-bed will have quite different impacts on their respective markets; in the case of copper, the sea-bed production will be a small proportion of the total world market and well within the increase in the world demand for that metal; for nickel, however, the sea-bed production will have quite a significant influence on international trade, and then the situation in the cobalt and the manganese industries could be such that the sea-bed production is a major supplier and well in excess of the increase in world demand.

30. Although the copper industry will be relatively unaffected in terms of percentage of sea-bed production in total market supply, of all the mineral industries which may be affected by sea-bed mining, the copper industry is by far the largest in terms of value of production, investment, employment and geographical spread. Therefore, the full-scale study could very usefully be extended to consider the possible long-term effects that sea-bed mining may have on this industry.

31. Considering the nickel sector, the provisions of article 151 are intended to ensure that production of this metal from the sea-bed is contained within the long-term increase in world consumption and thus the possibilities of long-term oversupply are limited. The new source of production will not necessarily generate new areas of demand, and the sea-bed mining industry will, no doubt, sell in the most convenient markets or to subsidiary consumers or financially associated organizations, and therefore some readjustment of trading patterns will occur. This may be only a temporary inconvenience or it may have longer-term adverse effects.

32. In the case of cobalt and manganese, the circumstances are different and an oversupply of these could well occur. In that event, the question is where and how the cut in production would be made to balance world consumption. In an ideal economic situation the high-cost producers would first cease production, and a study of the relative production costs would show where this would take place. It has already been mentioned, however, that cobalt is a co-product from a multi-product mining concern, and to calculate a real cost of production for each product would not be an easy matter. In any case, this in itself would not establish a metal price below which production would cease, because such a decision would undoubtedly have to take into account a number of other indirect economic factors such as investment cost, taxation position and social costs and benefits. Judging from past history of this sector of the mineral industry, it is unlikely that production and price trends would necessarily follow or could be predicted by generally applied economic theories. Nevertheless, a comprehensive cost study together with an understanding of the structure and working of the markets of all sectors of these industries will be an essential requirement of the full-scale study.

SECTION IV

33. Article 151, paragraph 4, provides for action to be taken when sea-bed production of the metals is likely to cause serious adverse effects on the export earnings or on economies resulting from a reduction in the price of an affected mineral or the volume of mineral exported. The second part in the full-scale study will have determined the effect that sea-bed mining may have on the export earnings of the developing countries which also produce and export these minerals. However, this study has been charged to also consider the possible impact that sea-bed mining may have on the economies of those countries, and this is the purpose of the third part in the full-scale study. It is evident that, at this point, the study project will become several joint affairs involving each of the countries concerned. In fact, when the findings of the full-scale study forecast a fall in the export earnings of any particular State, it would be a logical step for that State to take the initiative in further promoting an investigation into the overall effect on its economy. It is reasonable to accept that such action was implied in article 151, paragraph 4, which authorizes the State to request a study when it believes that it is likely to be affected.

34. It has been pointed out that the effect of sea-bed mining on the economy of the developing producer countries may be not just a sudden event but spread over a critical and possibly prolonged period. The study will therefore have to consider, as well as the contemporary economic situation, the future development plans of the mineral industries in those countries and the part that the mineral industries are expected to play in the overall economy. This reiterates the obvious need, at this stage, for the closest co-operation between the organization carrying out the full-scale study and the Governments of the developing countries concerned.

35. Some countries already have future development plans which are based on econometric model predictions, and, where these models exist, the effect on the economy of a fall in the value of the mineral exports can be demonstrated by the application of new variables in the model and the results compared with the base calculations. In other cases, the possible adverse effect on the economy caused by a certain fall in export earnings will have to be assessed by a direct study of the economy of the country affected.

36. From information that is now available, it is possible to identify some of the countries which are likely to be most adversely affected by sea-bed mining. It must be understood, however, that this is a situation which will be constantly changing and may be quite different at the time, and over the time span, of the full-scale study. The table below shows a situation based on the most recent statistics available and gives the total export earnings of a group of developing mineral producer-exporter countries and also the export value of the metals being considered in this study, i.e., copper, nickel, cobalt and manganese. The table illustrates the importance of these metals as export earners, but, for the purpose of assessing the vulnerability of the countries, account must of course be taken of just how sensitive the markets of each of these metals are to the impact of sea-bed mining. The preliminary study itself is not intended to make pronouncement on the effect of sea-bed mining, but previous studies seem agreed that, in the short- and medium-term, the copper market will be relatively unaffected; the nickel sector may be affected to some extent, but the cobalt and the manganese industries could be seriously affected. Taking these opinions merely as a guide in interpreting the figures in the table, it would suggest that the full-scale study may first be directed onto certain cobalt- and manganese-producing countries; in this particular instance, it could be Zaire, Zambia or Gabon. This is a preliminary observation based on the limited information in the table and intended only to illustrate the possible extent of the

TABLE. EXPORT REVENUES FROM METAL PRODUCTION
(*Millions of US dollars*)

	Total exports	*Copper exports*	*Percentage of total exports*	*Nickel exports*	*Percentage of total exports*	*Cobalt exports*	*Percentage of total exports*	*Manganese exports*	*Percentage of total exports*	*Cu+Ni+ Co+Mn Value of exports*	*Percentage of total exports*
Bolivia	942	3	–	–	–	–	–	–	–	3	< 1.0
Botswana	509	–	–	107[a]	21.0	–	–	–	–	107	21.0
Brazil	20 132	–	–	–	–	–	–	60	–	60	< 1.0
Chile	4 818	2 200	45.7	–	–	–	–	–	–	2 200	45.7
Cuba (1978)	4 487	2	–	228[b]	5.1	48	1.1	–	–	278	6.2
Cyprus	540	–	–	–	–	–	–	–	–	–	< 1.0
Dominican Republic	1 107	–	–	117	10.6	–	–	–	–	117	10.6
Gabon (1978)	1 152	–	–	–	–	–	–	109	9.5	109	9.5
Ghana (1978)	958	–	–	–	–	–	–	17	1.7	17	1.7
Guatemala	1 762	–	–	23	1.3	–	–	–	–	23	1.3
India	7 996	–	–	–	–	–	–	24	–	24	< 1.0
Indonesia	21 908	120	–	201	1.0	–	–	–	–	321	1.4
Mexico	15 480	56	–	–	–	–	–	8	–	64	< 1.0
Morocco	2 400	15	–	3	–	44	1.8	16	–	78	3.2
Papua New Guinea	1 150	476	41.4	–	–	–	–	–	–	476	41.4
Peru	3 400	661	19.4	–	–	–	–	–	–	661	19.4
Philippines	5 714	537	9.4	280	4.9	63	1.1	–	–	880	15.4
Zaire	1 570	678	43.2	–	–	332	21.1	–	–	1 010	64.3
Zambia	1 384	1 148	82.6	–	–	70	5.1	–	–	1 214	87.7
Zimbabwe	1 360	37	2.7	80	5.9	–	–	–	–	117	8.6

NOTE: This table is derived from several sources including IMF—*International Financial Statistics*, *United Nations Yearbook of International Trade Statistics* and several metal trade bulletins. Where available, 1980 figures have been used, but in some cases the latest available information was for 1979 and 1978. For the purpose of comparison, all currencies have been converted into United States dollars and, to this end, an average rate of exchange for the period was used. Where export values were not available, export volumes were valued at an average price for the period in some international market. It should be noted therefore that there could be some statistical imprecision in the table, but it is primarily intended to illustrate the discussion put forward in Section IV of the report and it is believed that it will adequately serve this purpose.

[a] Cu-Ni-Co matte.

[b] Concentrates and intermediate products of Ni and Co.

< Less than 1 per cent.

problems. However, the full-scale study may well reveal adverse situations in other countries which are not apparent by merely scanning the table. In fact, the figures in the table show only the relative importance of these metals as export earners, but this is not necessarily indicative of the importance that they play in the overall economy of the countries. Export earnings can affect a number of factors relevant to the economy of a country, such as the gross national product, the gross domestic product, the balance of payments, government revenue, investment and employment in the mining sector and in other unspecified and largely unquantifiable social areas. A fall in export earnings could affect different countries in different ways, probably having greater impact on one sector of the economy than another and varying from country to country. For instance, a recession in some particular industry which is a high employer of labour and consumer of local products would have more serious implication than a reduction in an industry which, though producing an export product, is also dependent on imported supplies and really shows a small net gain in foreign exchange. In drafting the terms of reference for the full-scale study, an understanding will have to be agreed upon in defining some measures of adverse effect, and guidance will be required concerning the focal points.

37. To summarize, the purpose of this part of the report is to explain the process by which the full-scale study will interpret a possible fall in export earnings of the developing countries which are producers of these metals, into a measure of the adverse effect on their overall economy. This stage of the study will, in fact, become a series of separate studies in conjunction with the countries which are likely to be affected. It is probable that, at this stage, other organizations which are engaged in economic investigation in developing countries may become involved.

SECTION V

38. The lack of any specific data and information and agreement on the analytical techniques to be used precludes the preliminary study from proceeding to quantitative conclusions. Under the circumstances, it was assumed that the purpose of the preliminary study was to develop a procedure for the full-scale study and to identify the data and information and the analytical methods which had to be agreed upon before the full-scale study could proceed.

39. The possible impact of deep-sea mining on the economies of land-based producer-exporter countries has already been the subject of several studies. The scope of these studies was usually limited to investigating the effect on their export earnings but did not extend to considering the effect on the overall economy of the different countries. In some cases, econometric models were used, but mainly they were based on opinion judgement and estimates and on the data that were available at the time. They were also carried out prior to the drafting of article 151 of the draft convention, so the provisions of this article were not taken into account. For these reasons, it was not considered practicable nor would it serve the purpose of the current study to try to revise and modify the previous studies.

40. The effectiveness of the full-scale study could be considerably reduced if the conclusions are not available well before the commencement of commercial sea-bed mining. On the other hand, the shorter the time prior to the commencement of the production that the full-scale study is carried out, the more accurate will be the information available and the more credible will be the findings that emerge from the study. Obviously, some compromise on the timing for the full-scale study must be found.

41. The data which have been used in previous studies covered a broad range of possible situations. This will have to be reviewed on a selective basis or, as mentioned above, a set of new and accurate data obtained. In any case, agreement will have to be reached on a comparatively narrow range of data and assumptions on which to base the full-scale study. Otherwise, the outcome will merely be another broad range of

findings, possibly conflicting. This would not provide a satisfactory basis for trying to reach agreement on further action. It may be concluded that, in fact, it would be premature and a questionable expenditure of money to embark on the full-scale study until such time as the data are sufficiently accurate and reliable and findings with a high degree of confidence and precision can be expected.

42. Some of the problems will not be amenable to purely financial and economic analysis, and reference is made particularly to the question of readjustment of metal trading patterns and the possible loss of markets by the present land-based producers. These problems will have to be discussed and resolved in appropriate international forums concerned with trading patterns and relationships.

43. The last stage of the study, which will evaluate the effect of possible fall in export earnings on the overall economy of the developing exporting countries, will entail joint investigations together with the countries concerned and possibly with other organizations engaged in economic studies. One of the problems that may arise is the question of the establishment of norms for such evaluation, and guidance on this matter may have to be sought.

ANNEX I

Article 151 establishes a ceiling for the tonnage of nickel that may be produced from the sea-bed in the international area. The ceiling tonnage is calculated from a formula which, based on long-term consumption trends, allows for sea-bed mining to produce a tonnage of nickel equivalent to the total increment in world demand for nickel over a five-year period starting six years prior to the commencement of the earliest commercial production and then increasing on a scale equivalent to 60 per cent of the increasing world demand for nickel with, however, certain limiting reservations. A more precise and detailed description of the working of this scheme is given in document A/CONF.62/L.66 dated 24 February 1981.

This document gives examples of the ceiling tonnages calculated according to the formula in article 151, over a range of assumed starting dates from 1985 to 1995 and assumed increments in world demand for nickel of 2 per cent up to 5 per cent. From the figures presented in table 1 of annex I of document A/CONF.62/L.66 it will be seen that the resulting range of ceiling tonnages for nickel are wide. For example, if the starting date were 1985, the ceiling tonnages could move up over a 20-year period from 174,900 tons to 480,100 tons if the increment rate were 2 per cent, or from 174,900 to 1,154,800 tons if the increment rate were 5 per cent; again, if the commencement date were 1995, the ceiling tonnages could move up over a 10-year period from 153,700 tons to 316,000 tons if the increment rate were 2 per cent, or from 348,500 tons to 818,200 tons if the increment rate were 5 per cent. It is obvious that, if this range of figures were used for the analytical exercise of the full-scale study, which itself will cover a range of possibilities, and the calculations further widened with a range of technical assumptions (grade, recovery factor etc.), the results would be too broad to give useful guidance for policy.

It may be noted that the calculations in the article 151 formula are based on the world consumption of nickel shown by the most recent 15 years' data that are available. Therefore the later that the full-scale study can be made prior to the commencement of commercial production, the less error is likely to arise from inaccurate estimation. This is some justification for leaving the full-scale study as long as possible but, at the same time, it is realized that, to be of any practical use, the findings from the study need to be available well before commercial production starts.

ANNEX II

A series of documents on the subject of mineral production from the oceans was produced under the auspices of the Committee on the Peaceful Uses of the Sea-Bed and the Ocean Floor beyond the Limits of National Jurisdiction, between the years 1968 and 1973. Brief comments on the papers most relevant to the study follow:

Document A/AC.138/36 dated 28 May 1971[12] covers a broad overview of the potentialities of ocean mineral production including hydrocarbons. The report includes reference to the usage, production, trade and future supply-demand situation of the metals manganese, copper, nickel and cobalt. Several paragraphs are devoted to the future development of sea-bed mining for production of these metals, to the economics of such an industry and to the possible impact on the economies of developing countries which also produce and export the metals. A considerable amount of statistical information has been included, but only up to the year 1968.

The above document was followed by another report, A/AC.138/73 dated 12 May 1972,[13] which covers much the same material as document A/AC.138/36 but excludes consideration of hydrocarbons. It discusses, in general terms, the future issues that would arise and the possible solutions when considering the formulation of policies for production of metals from the sea-bed.

Document A/CONF.62/25 dated 22 May 1974[14] was a follow-up document to the above (A/AC.138/36 and A/AC.138/73). It is a broad and comprehensive report covering all aspects of sea-bed mining in the light of the information available and the circumstances prior to 1974. It discussed the many long-term issues that would arise.

The three documents mentioned above served a useful purpose in disseminating information about sea-bed mining, the problems that were likely to arise and possible avenues for solution. The statistics and the information in these papers are, however, now rather dated and many of the matters raised have been subsumed by discussions within the Conference.

Document A/AC.138/87 was published on 4 June 1973. It provided a considerable amount of additional information on sea-bed mining but mostly dealt with the physical characteristics of the ocean mineral resources and made some references to possible economic values.

A later document, A/CONF.62/37 dated 18 February 1975,[15] was a resumé and updated discussion on the impact that sea-bed mining would have on the land-based producers of the metals. Mention was made of possible policy areas for resolving the problems. The conclusions were non-quantitative.

The United Nations Conference on Trade and Development (UNCTAD) issued a series of documents in 1973 and 1974 on the economic impact of the production of metals from the sea-bed on the land-based producer-exporters of the same metals. Those reports were based on investigations carried out by Professor F. Gerard Adams (The Wharton School, University of Pennsylvania) using econometric models and thereby obtaining quantitative conclusions. The documents were: TD/B/449/Add.1 dated 26 June 1973 (cobalt), TD/B/483 dated 23 April 1974 (manganese), TD/B/484 dated 28 May 1974 (copper), TD/B/C.1/172 dated 4 December 1974 (nickel). Two other documents, TD/B(XIII)/Misc.3 dated 31 July 1973 and UNCTAD/CD/Misc.59 dated 20 November 1974, gave more detailed information about the actual model procedure used.

The findings and the conclusions from the four econometric studies on the impact of sea-bed mining on the cobalt, manganese, copper and nickel industries were summarized in document TD/B/C.1/170 and Corr.1 dated 8 January 1975. This document also lists the previous UNCTAD reports.

Document TD/B/C.1/170 and Corr.1 was updated and the results published in document TD/B/721/Add.1 dated 10 August 1978, entitled "Impact of manganese nodule production from the ocean floor: long-term econometric estimates—Report prepared by Prof. F. Gerard Adams, The Wharton School, University of Pennsylvania". It has been mentioned elsewhere in the report that these studies, though quantitative in their conclusions, did not take account of the provisions of article 151 and therefore the results are not directly related to the present study. It is, however, an example of the application of econometric models to the problem.

Following is a list of the United Nations and UNCTAD documents relating to the subject under study. However, it must be pointed out that as a result of activities carried out within the United Nations system on sea-bed minerals, metal markets etc., a considerable amount of information and analysis pertinent to the subject under study is available. Also, a great amount of information that has been published and is currently being published on these topics will be found in the journals and documents of technical and other societies and in those of research and educational institutions.

[12] Summary contained in *Official Records of the General Assembly, Twenty-sixth Session, Supplement No. 21* (A/8421).

[13] *Ibid., Twenty-seventh Session, Supplement No. 21* (A/8721 and Corr.1).

[14] See *Official Records of the Third United Nations Conference on the Law of the Sea*, vol. III (United Nations publication, Sales No. E.75.V.5).

[15] *Ibid.*, vol. IV (United Nations publication, Sales No. E.75.V.10).

List of Documents

LIST OF REPORTS PREPARED BY THE UNITED NATIONS AND THE UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT ON THE SUBJECT OF THE EXPLOITATION OF THE MINERAL RESOURCES OF THE SEA-BED BEYOND THE LIMITS OF NATIONAL JURISDICTION

Economic implications of the exploitation of mineral resources on and underlying the sea-bed and ocean floor and its subsoil, with particular reference to world trade and prices: note by the Secretariat (dated 11 June 1968)	A/AC.135/14	
Economic considerations conducive to promoting the development of the resources of the sea-bed and ocean floor beyond the limits of national jurisdiction in the interest of mankind: preliminary note by the Secretariat (dated 4 March 1969)	A/AC.138/6	
Possible impact of sea-bed mineral production in the area beyond national jurisdiction on world markets, with special reference to the problems of developing countries: a preliminary assessment. Report of the Secretary-General (dated 28 May 1971)	A/AC.138/36	
Additional notes on the possible economic implications of mineral production from the international sea-bed area: report of the Secretary-General (dated 12 May 1972)	A/AC.138/73	
Request for a study on the different economic implications of the various problems for limits of the international sea-bed area: submitted by Afghanistan, Austria, Belgium, Bolivia, Czechoslovakia, Hungary, Nepal, Netherlands, Singapore, Zaire and Zambia (dated 9 August 1972)	A/AC.138/81	
Economic significance, in terms of sea-bed mineral resources, of the various limits proposed for national jurisdiction: report of the Secretary-General (dated 4 June 1973)	A/AC.138/87 and Corr.1	
Economic implications of sea-bed mineral development in the international area: report of the Secretary-General (dated 22 May 1974)	A/CONF.62/25	
Economic implications of sea-bed mining in the international area: report of the Secretary-General (dated 18 February 1975)	A/CONF.62/37	
Commodity problems and policies: mineral production from the area of the sea-bed beyond national jurisdiction: issues of international commodity policy: report by the UNCTAD secretariat	TD/113/Supp.4	March 1972
Exploitation of the mineral resources of the sea-bed beyond national jurisdiction: issues of international commodity policy	TD/B/449	June 1973
Exploitation of the mineral resources of the sea-bed beyond national jurisdiction: issues of international commodity policy: case study of cobalt	TD/B/449/Add.1	June 1973
The impact of cobalt production from the sea-bed: a review of present empirical knowledge and preliminary appraisal (by Professor F. Gerard Adams, Consultant)	TD/B/(XIII)/Misc.3 (English only)	July 1973
The effects of production of manganese from the sea-bed, with particular reference to effects on developing country producers of manganese ore: report by the UNCTAD secretariat	TD/B/483	April 1974
An econometric model of the manganese ore industry	TD/B/483/Add.1	April 1974
The effects of possible exploitation of the sea-bed on the earnings of developing countries from copper exports: report by the UNCTAD secretariat	TD/B/484	May 1974

Exploitation of the mineral resources of the sea-bed beyond national jurisdiction: examination of the economic implications for developing countries and of possible measures to avoid adverse economic effects: note by the UNCTAD secretariat	TD/B/492 and Corr.1	July 1974
The effects of the production of nickel from the sea-bed, with particular reference to the impact on the export earnings of developing country producers of nickel: report by the UNCTAD secretariat	TD/B/C.1/172	December 1974
The impact of nickel production from the ocean floor: an econometric appraisal (by Professor F. Gerard Adams, Consultant)	UNCTAD/CD/Misc.59 (English only)	November 1974
Implications of the exploitation of the mineral resources of the international area of the sea-bed: issues of international commodity policy	TD/B/C.1/170 and Corr.1	January 1975
Implications of the exploitation of the mineral resources of the international area of the sea-bed: issues of international commodity policy: note by the UNCTAD secretariat	TD/B/721	August 1978
Impact of manganese nodule production from the ocean floor: long-term econometric estimates: report prepared by Professor F. Gerard Adams, The Wharton School, University of Pennsylvania	TD/B/721/Add.1	August 1978

ANNEX III

A. Copper

Copper was the first industrial metal used by mankind, and, today, the consumption of copper is exceeded in metal usage only by iron and aluminium. The estimated world consumption of copper in 1980 was 9,577,500 metric tons, of which 7,815,000 metric tons was new production. Differences between new production and consumption figures are accounted for mostly by recycled metal (scrap copper), which is an important factor in the industry and supplies more than 20 per cent of the copper used.

The electrical and electronic industries are the principal users of copper (over 50 per cent), and the remainder goes to building construction, transport and miscellaneous industries; a certain amount (less than 10 per cent) goes into chemical (non-recoverable) end products. The substitution of aluminium in the electrical industry and of stainless steel and plastic in other sectors of industry has reduced the expansion potential for copper. However, the developing countries still have a *per capita* energy usage of less than half of that in the industrialized countries (which is one measure of demand for copper); so, as development progresses, the demand within the developing countries will increase. The overall world demand for copper has been estimated by the United States Bureau of Mines to show a probable increase at the rate of 3.7 per cent, but other studies place it at between 2 per cent and 3 per cent up to the year 2000.

The occurrence of copper mineralization and the principal production centres are geographically widespread, and the trading pattern of the metal in its several forms is quite extensive and complex. However, the predominant fact in the pattern is that the two largest consumers of copper (the United States and the Soviet Union) are also the major producers and are, to a large extent, self-sufficient in supply, whereas the other two major industrialized groups (European Economic Community and Japan) are almost entirely dependent on imported copper. This demand, and also the shortfall in the other industrialized groups, is met by imports from Canada, Australia and South Africa but mainly from several developing countries which are major producers and exporters of copper. These are Chile and Peru in the American region, Zambia and Zaire in Africa and the Philippines and Papua New Guinea in the Pacific area.

The trade in copper is usually in one of three forms, either as a copper concentrate, which is the first product from the metallurgical concentration process and contains about 30 per cent copper; or as a blister copper, which is the smelted concentrate and contains about 98 per cent copper; or as a refined copper, which is 99.9 per cent pure and suitable for fabricating into industrial products (wires, tubes, plates etc.). The degree of vertical integration in the exporting countries varies, and whereas Canada and several other developed countries still export copper concentrates, Zambia exports only refined copper. No developing countries have seriously proceeded beyond the refining stage and set up local fabricating plants to produce wires, tubes, sections, plates etc., mainly because of finance, transport, marketing and tariff problems.

The world reserves of copper as estimated by various authorities are between 400 and 500 million tons of metal, excluding sea-bed resources. However, this is a figure which is constantly changing as new discoveries are made and advances in mining and metallurgical technology enable tonnages which are now considered only as resources to be considered as viable ore reserves.

The selling of copper is usually by annual or longer-term contracts, with a certain amount being sold as immediate sales. Pricing in the United States is mainly based on a scale set by the large producers, though an open Commodities Exchange also exists. Export contracts are more often related to the prices quoted on the London Metal Exchange, which is also an open market. These pricing systems have been subject to much criticism, but they have been defended on the grounds that the price in the United States is competitive among a number of producers and the London Metal Exchange price, although only a small amount of actual metal is sold on the Exchange, does represent the marginal price. The volatility of this pricing system has been one of the major problems facing the copper industry, both producers and consumers, and although some efforts have been made to establish some stability in the pricing system, they have, as yet, been unsuccessful.

Because copper is produced in so many different countries and under so many different conditions and types of management, it would be quite impossible to calculate an economic price for copper with any precision. A complicating factor is that copper is very often a co-product with other metals—cobalt, molybdenum, gold, silver, lead, zinc, nickel—and although it is possible to calculate the separate cost of each metal on a purely notional basis, the real costs are those of the project as a whole. Once the capital cost of a multi-product operation has been committed, the circumstances rarely arise which justify reducing or stopping production of one metal; one possible reason may be to influence a temporary market situation. On the basis of an integrated (multi-product) industry, it has been calculated that the operating costs of producing copper fell by 3 per cent during the years 1976 and 1979, but the real reason behind this apparent fall was a rise in the prices and revenues from the co-products—cobalt, molybdenum, gold and silver. In a way, it can be said, these metals subsidized the copper industry: the return from these metals covered over 30 per cent of the cost of production of the copper, but the situation has now changed and the return from these metals is down to about 15 per cent. Under these circumstances, it is estimated that a price of between $1.15 and $1.45 per pound of copper is needed to justify starting a new large-scale copper mine (present prices are about $0.80 per pound).

B. Nickel

Though identified as a metal as long ago as 1751, nickel does not seem to have been produced on a commercial scale until the extensive deposits were located in New Caledonia in 1860. However, it was the discovery of the sulphide deposits in Canada in the 1880s and the development of an effective copper-nickel separation process that enabled nickel to reach its present level as an industrial metal.

The most important usage of nickel is in the steel industry, mainly for stainless steel and other steel and iron alloys, and this accounts for 75 per cent of the total consumption. Electroplating, chemical and other industrial uses account for the remaining 25 per cent.

World consumption of nickel in 1980 was 725,200 metric tons. For the 25 years prior to 1970, the increase in the rate of consumption had been over 6 per cent, but this has slowed down in recent years. Some observers consider that the reason for this trend is the saturation of the initial high demand for stainless steels, because nickel products have an estimated life of 20 years and now because an increasing supply of scrap material is coming back on to the market. Forecasts for future consumption vary; some industry spokesmen have quoted a growth rate between 3.2 per cent and 4 per cent; the United States Bureau of Mines has quoted a probable growth rate of 3.4 per cent between 1975 and 2000. In the present economic climate, lower growth rates are being openly discussed.

Nickel ore deposits are geographically widespread, occurring mainly as sulphide minerals and in oxidized material known as laterites. The laterites are the result of surface weathering and are mostly in tropical areas or where tropical conditions have existed, and these projects are worked by surface open-pit operations. The sulphide ore bodies are deep-seated and are more often, though not always, worked as underground mines. The principal known commercial sulphide ore-bodies are in Canada, the Soviet Union, Australia, Zimbabwe, Botswana and Finland, though sulphide mineralization has been reported in other areas. The laterite deposits are wider in occurrence and are being worked in New Caledonia, Cuba, the Dominican Republic, Colombia, Guatemala, the Philippines, Indonesia and Australia. (See table reproduced from United Nations, *The Nickel Industry and the Developing Countries*, New York, 1980, document ST/ESA/100.)

The estimated world reserves of nickel are quoted as 64,200 thousand tons in exploitable deposits and an additional 125,150 thousand tons in additional resources exclusive of sea-bed resources. Of the reserves, 30 per cent are sulphides and 70 per cent are in laterite deposits, and, of the additional resources, 18 per cent are sulphides and 82 per cent in laterites. At the present and foreseeable rate of consumption, the reserves would seem to be adequate to carry well into the next century and the "resources" would provide for a considerable period beyond that. However, it should be noted that over 70 per cent of the future reserves and resources are in laterite deposits, whereas nearly 60 per cent of present production comes from sulphide deposits. It is obvious, then, that the future supply of nickel must depend more on the laterite deposits, and it would be prudent to consider what this may entail for the industry.

The difference between the two types of ore, from the industry point of view, is in the relative cost of production. On the average, the laterite deposits have grade (metal content) comparable with that of sulphide deposits, but, being worked by surface open pits rather than underground mines, the mining costs tend to be lower. However, this is more than offset by the much higher energy requirements in the complex metal recovery process from the laterites compared with that of the sulphide ores (two to three times as much), and, as a generalization, it can be said that the cost of production from laterites will be considerably higher than from sulphide ores. This point is well illustrated in the United Nations publication *The Nickel Industry and the Developing Countries*.

A new factor will enter into the nickel industry with the advent of production from the sea-bed. This has not yet commenced on a commercial scale and we can only make an estimate of the cost of production. Weight of opinion would suggest that the cost may be somewhere between that of production from sulphide ores and that from laterites. This is, however, based only on estimates and the confidence to be placed in these estimates is a matter of individual judgment. It would seem that, at present, nickel prices are more controlled by the lower-cost sulphide production, but the higher-cost laterite must have an increasing influence on price and supply as production inevitably moves towards these sources. The question will be asked: what will be the pattern for the future development of the nickel industry? In the short term, it would seem that the answer lies in the possibility of further discoveries of sulphide ore deposits of a grade comparable with those now being worked. In the long term, however, the ore reserve position would suggest that the more abundant laterites and sea-bed sources will have to supply the shortfall. Which of these two sources is likely to be the main additional supplier, the laterites in which many developing countries have interest, or the sea-bed resources which will probably mainly be financed from industrialized countries, will depend on several factors, including the comparative cost advantages.

The nickel market has, for many years, been dominated by the major Canadian producers, who have established the prices for the metal. In recent years, the supply base has broadened, and nickel metal is now quoted on the London Metal Exchange. However, it is reasonable to believe that the price of nickel is closely related to the cost of production from sulphide ores, and, in the current economic recession, when the industry is operating on approximately 70 per cent of capacity, it is the laterite operations which are being curtailed.

C. Cobalt

Cobalt has graduated from being just a nuisance metal in the recovery of copper and nickel (hence the name, from kobold, a miners' goblin) to become a highly valued industrial metal. The present world consumption of cobalt is in the order of 30,000 tons per year, of which Zaire supplies about 60 per cent.

Cobalt has a number of specialized usages, in heat- and corrosion-resistant steels and in tool steels, in hard facing material for drilling equipment, in the manufacture of permanent magnets and in the chemical industry. The considerable increase in the price of cobalt in 1979 has led to the substitution of ceramics in permanent magnets, and there are other areas where substitution can occur. However, with the return to a more stable price for cobalt, it is possible that an increasing demand will develop. Taking into account the comparatively small total production and usage of cobalt, even minor developments in new fields could have a significant effect on the market. The United States Bureau of Mines has estimated that the future demand for cobalt will increase at a rate of about 3.2 per cent.

Cobalt occurs in several different mineral forms, occasionally on its own but usually in association with copper and nickel ores. The amount of cobalt in these minerals is small, varying from less than 0.1 per cent up to more than 0.5 per cent, and the physical association with the other metals is very close, with the result that the separation process is complex and costly. Cobalt is considered as a co-product or a by-product, and the processing plants are primarily designed to obtain the highest possible recovery of the main metals, copper and nickel. In pursuing this objective, it is not always economically sound or even technically practicable to aim for an equally high recovery of the cobalt. It would be very difficult to obtain reliable statistical information on the matter of overall cobalt recovery, but, as an estimate, it could be said that, of the cobalt-bearing ore presently being treated, at least 90 per cent of the copper and the nickel reaches the markets but probably much less than 50 per cent of the cobalt.

The factors which control the amount of cobalt that is produced, in the short term, are the type of the copper- and nickel-processing plant in use and the capacity of the cobalt recovery sector of the plant; it is not necessarily a direct function of the amount of copper or nickel produced. In the case of some cobalt-bearing copper and nickel ores, no processing plant has been installed to recover the cobalt and it is discarded, mainly in the smelter slag.

The definition of cobalt as a by-product is not strictly correct. Certainly a cobalt-bearing material emerges from the copper and nickel recovery plants, but the further processing to a saleable product entails an additional highly capital-intensive recovery plant. The decision then that faces the producers (land-based and sea-bed) is whether the market demand and price justifies the use of a mineral-processing route which allows for recovery of cobalt (and this could entail a lower

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TABLE. WORLD NICKEL RESOURCES
(*Thousands of tons metal content*)

	Economically exploitable resources				*Additional resources*			
	Total	*Percentage*	*Sulphide ores*	*Laterite ores*	*Total*	*Percentage*	*Sulphide ores*	*Laterite ores*
Canada	7 600	11.8	7 600	–	7 500	6.0	7 500	–
United States of America	200	0.3	–	200	300	0.2	–	300
Dominican Republic	1 000	1.6	–	1 000	700	0.6	–	700
Brazil	1 950	3.0	–	1 950	900	0.7	–	900
Colombia	1 400	2.2	–	1 400	200	0.2	–	200
Venezuela	600	0.9	–	600	450	0.4	–	450
Guatemala	500	0.8	–	500	1 000	0.8	–	1 000
Puerto Rico	–	–	–	–	1 000	0.8	–	1 000
Cuba	3 400	5.3	–	3 400	16 000	13.3	–	16 600
North and South America	16 650	25.9	7 600	9 050	28 650	22.9	7 500	21 150
South Africa	800	1.2	800	–	3 450	2.8	3 450	–
Rhodesia	600	0.9	600	–	5 150	4.1	3 750	1 400
Botswana	500	0.8	500	–	–	–	–	–
Other Africa[a]	300	0.5	–	300	4 800	3.8	–	4 800
Africa	2 200	3.4	1 900	300	13 400	10.7	7 200	6 200
Australia	2 500	3.9	1 900	600	6 500	5.2	4 000	2 500
New Caledonia	13 500	21.0	–	13 500	30 000	24.0	–	30 000
Indonesia	8 800	13.7	–	8 800	5 000	4.0	–	5 000
Philippines	6 500	10.1	–	6 500	30 000	24.0	–	30 000
Other	500	0.8	–	500	3 400	2.7	–	3 400
Asia and Oceania[b]	31 800	49.5	1 900	29 900	74 900	59.8	4 000	70 900
Greece	2 000	3.1	–	2 000	2 300	1.8	–	2 300
Yugoslavia	800	1.2	–	800	600	0.5	–	600
Finland	800	1.2	800	–	–	–	–	–
Western Europe	3 600	5.6	800	2 800	2 900	2.3	–	2 900
Union of Soviet Socialist Republics	9 000	14.0	7 200	1 800	5 000	4.0	4 000	1 000
China	750	1.2	–	750	–	–	–	–
Albania	200	0.3	–	200	300	0.2	–	300
Centrally planned economies	9 950	15.5	7 200	2 750	5 300	4.2	4 000	1 300
WORLD[c]	64 200	100.0	19 400 (30.2)	44 800 (69.8)	125 150	100.0	22 700 (18.1)	102 450 (81.9)

Sources: BGR report; United States Department of the Interior, Bureau of Mines; and files at the Division of Natural Resources and Energy of the United Nations Secretariat.

[a] Mainly Burundi and Madagascar.
[b] Excluding centrally planned economies.
[c] Figures in parentheses refer to percentages.

recovery of the other metals) and the extra capital cost of the cobalt recovery section. The costing structure of these multi-product industries is complicated and it would not be possible in this study to try to detail a comparison of relative costs between different land-based plants and the likely cost of sea-bed production. However, it is conceivable that, by the time sea-bed production of cobalt affects the market, the land-based cobalt plants will be financially written off and will therefore have a cost advantage over sea-bed production, particularly in the early years while depreciation is still a charge (the sea-bed plants will also have to face those inevitable teething troubles that beset any new metallurgical plant). Then, taking into account the fact that the revenue from cobalt sales may be more significant in the overall return from the sea-bed mining projects than the land-based projects, with a possible exception in the case of Zaire, it will be mainly in the interest of the sea-bed mining industry to establish a fair and stable market for cobalt.[16]

Cobalt is usually sold as a metal, though the export from the producing country may take the form of a cobalt matte or a copper or nickel concentrate for recovery and refining elsewhere. The price has been controlled by the major supplier from Zaire (Gecamines-Sozacom) and had shown a fairly consistent pattern of price range between $1.50 and $4.50 per pound for a number of years until the disruption of supplies from Zaire in 1978. This pushed the price up to $50 per pound in 1979, but that crisis has been resolved and the official price has fallen to $17.50, with some sales at much lower prices.

The world reserves of cobalt in identified resources are estimated by the United States Geological Survey to be in the order of 9,400 million pounds of cobalt metal. This is contained mainly in the copper ores in Zambia and Zaire, in the nickel sulphide ores in Canada and Australia and in the very extensive nickel laterite ores. These figures must be viewed as very approximate estimates, because many cobalt-bearing copper and nickel ore-bodies are not accurately sampled for cobalt, nor is the estimated cobalt content recorded as reserves. Likewise, the cobalt content of many large cobalt-bearing tailings dams (waste dumps) and smelter slag dumps at operating copper and nickel mines is unrecorded.

[16] Assuming that a sea-bed project will produce from 3 million tons of nodules per year, 38,000 tons of nickel, 30,000 tons of copper and 3,500 tons of cobalt and that prices are, nickel $3.00 per pound, copper $0.80 per pound and cobalt $17.50 per pound, the revenue represents about 31 per cent of the total revenue. Taking the 1979 production figures for copper and cobalt of the two largest producers and the same prices as above, in Zaire the revenue from cobalt would represent 41 per cent of the total mineral revenue and in Zambia it would represent 11 per cent. This situation depends on the relative prices of the metals and would of course change if copper and nickel increase in price.

D. MANGANESE

Manganese has been used from ancient times as a pigment in glass and in ceramics, but it was the rapid advance in the technology of steel-making during the nineteenth century which developed the present demand. Approximately 97 per cent of manganese now being used goes into the steel industry, both as a processing agent (a scavenger to remove unwanted oxygen and sulphur) and for making impact-and-wear-resisting manganese alloy steels (10 per cent to 14 per cent manganese). There are no practical substitutes for these purposes, and manganese is considered as a strategic metal in most industrialized countries. It is also used as an alloy with other metals (aluminium, copper) and in the manufacture of dry-cell electric batteries and in the chemical industry in various ways, such as glass-making, food processing etc.

World production of manganese ore has been in the order of 27 million tons per year, with a manganese content of 9 to 10 million tons (9,574,000 tons in 1977). These figures must be viewed with some reservation, because an unrecorded amount of manganiferous iron ore (with too low a manganese content to be classed as manganese ore) is probably being fed directly into iron blast furnaces. The consumption of manganese is so closely linked with that of iron and steel that the future demand can be considered to run parallel. This relationship will, however, change as new steel processing methods evolve, and there has already been a drop from an average consumption of 6.6 kilogrammes per ton of steel to 6.1 kilogrammes per ton in recent years as the use of electric steel furnaces has increased. One observer considers that this may fall to 4.4 kilogrammes by 1990. In a United States Department of Commerce study, it is estimated that the world demand for manganese between 1975 and 2000 will probably increase at the rate of 2.9 per cent.

Manganese is usually recovered as an oxide ore, though large deposits of lower-grade carbonate ores exist and projects are already afoot to upgrade these ores to a commercial quality by calcining. Chemically, an oxide could contain up to 72 per cent of manganese, but the naturally occurring deposits are usually classified as commercial ore if the manganese content exceeds 35 per cent. However, most ores are still beneficiated in some way to obtain a more commercially acceptable and transportable ore of 48 per cent to 50 per cent manganese. Chemical and battery grade manganese is of higher quality (70 per cent to 80 per cent manganese) and is usually selectively mined from certain areas of the ore-body, or produced synthetically from lower-grade ores. The steel industry itself does not now use very much manganese ore but finds it more convenient to use an intermediate product, a high manganese-iron alloy (ferro-manganese, containing about 80 per cent manganese and carbon and iron, and silico-manganese, containing about 70 per cent manganese and silicon and iron). Several of the large producers of manganese ore have now vertically integrated their projects and supply ferro-manganese and silico-manganese direct to the steel industry.

Geologically, manganese, like most mineral occurrences, is quite widespread but the number of areas where the ore can be exploited as a viable operation are limited. The supply base for manganese is, however, now being mainly concentrated in South Africa, the Union of Soviet Socialist Republics, Gabon, India and Australia, and they supply a very wide group of customers. This situation is not likely to change in the immediate future, as no deposits of manganese ore have been discovered in recent years which would be exploitable under present conditions. It also illustrates that, though there need be little concern about the quantity of available reserves, it is fairly clear that the influence of consumers over their supply base and their ability to assure themselves of uninterrupted supplies are limited.

The practical possibilities and the economic viability of the production of manganese from the sea-bed and the likely effect on the land-based industry are matters which have probably had less exposure in publication and discussion than most of the other matters concerned with sea-bed mining.

The questions of mineral reserves and trade patterns were referred to in a previous paragraph. The additional reserves that could be available from sea-bed resources are, at present, inestimable. However, to get some perspective on the situation, it should be noted that the average manganese content of the nodules which, it is believed, will be the first targets for exploitation is between 25 per cent and 29 per cent. Therefore, theoretically, the manganese output from one sea-bed mining project processing 3 million tons of nodules per year could be some 800,000 tons, or over 8 per cent of the total world consumption. Experts associated directly with the planning of sea-bed mining projects, however, agree that these figures bear little relationship to the realities of the situation and that the commercial production of manganese from the sea-bed will be controlled by other factors than the manganese content of the nodules. These factors are the technical problems of producing a saleable product, and the economics of production, but also, of course, the high strategic importance of the metal.

Some of the industry groups now involved in planning sea-bed mining projects say that the cost of setting up and operating a plant to produce manganese would not make it competitive in world markets. The steel industry is very large and is geared to the usage of certain types of commercially produced manganese products (manganese oxide ore, ferro-manganese and silico-manganese). The actual consumption of manganese is, however, only approximately 6 kilogrammes of manganese per ton of steel, and, at current prices, this represents less than 1 per cent of the cost of the steel. Therefore, to break into this market, the sea-bed mining industry will have to produce the same types of material, or material that can be used in the existing steel-making processes at a lower cost (changes in plant procedure are usually costly and can be justified only by significant savings in the material input costs). The type of manganese material that emerges from the nodule processing plants depends on the plant (hydrometallurgical or pyrometallurgical), but, from the rather meagre information that is now available, it is apparent that these materials would need further processing to be acceptable as the main source of manganese for the steel-makers. The evidence suggests that manganese produced from nodules may not seriously compete with the land-based production of these materials in the immediate future. In the long term, however, a massive industry like the steel industry can and has to adapt to changing circumstances, and in the long term the role of sea-bed manganese may be more assured. In the meantime, some technical observers believe that the area where sea-bed manganese may well be competitive is in the production of pure manganese metal for alloying the other metals, copper, aluminium etc.

The above appreciation of the potentials of sea-bed production of manganese is based entirely on the economic factors, but other considerations may have to be taken into account. The facts are that the sea-bed mining industry will have large quantities of manganese-bearing material to dispose of. Whether, then, any country feels that the environmental problems, the cost of alternative disposal and the strategic value still justify commercial treatment of the material, or whether it feels that the mere existence of dumps of manganese-bearing material is, in itself, a strategic insurance, are matters which the States concerned will, no doubt, carefully consider.

ANNEX IV

A. Zaire

The economy of Zaire is highly dependent on the export of a diversity of minerals (copper, cobalt, diamond, tin, zinc, gold and others), but, of these, the most important are copper and cobalt, which account for approximately 70 per cent of the total value of exports, though in 1979 the high price of cobalt raised it to over 80 per cent.

Table 1 shows the relative importance of the minerals since 1974 and also a comparison with one of the major agricultural exports, coffee. A significant fact which is apparent from the table is the increasing importance of cobalt as an export earner. The records available (up to 1979) indicate that, though the volume of export of cobalt has not substantially changed, the increasing price (at the same time as a depressed real price for copper) has pushed the relative position of cobalt as an export earner to a peak in 1979 and ahead of copper. The situation now (1980 figures), with the price of cobalt receding, seems to be changing again, and copper is the predominant export earner.

The mining and metal processing has been the largest contributing sector to the gross domestic product. In current terms, it has varied since 1972 from a low of 11.4 per cent up to 23.4 per cent, but, in constant 1970 figures, it has been remarkably consistent between 20 per cent and 23 per cent.

The copper reserves of Zaire have been quoted at approximately 40 million tons of copper in ores of 4 per cent average grade. The estimated reserves of cobalt have been stated to be in the vicinity of 1,000 million pounds, but this must be viewed with a certain degree of reservation and could well be higher.

The copper-cobalt-bearing ores in Zaire occur in the same Katanga rock series as those in Zambia. On the whole, they are of higher metal content than in Zambia, but they also include some refractory ores which present more difficult processing problems with lower recoveries. The very high cobalt content of the ore has made Zaire the world's leading producer and exporter of cobalt, and it now provides approximately 53 per cent of world consumption. Some of the higher-grade cobalt resources have not yet been exploited.

The expansion of other sectors of the Zaire economy—agriculture, manufacturing, services etc.—will probably reduce the proportion of the gross domestic product due to the mineral industry over a period of time, but it will undoubtedly be the principal export earner for the foreseeable future. In the normal course of events, copper would be considered the predominant metal, but events in recent years have shown that cobalt must also be considered as an important contributor.

TABLE 1. ZAIRE

	1975	1976	1977	1978	1979	1980
Total value of exports (million zaires)	432.4	747.3	846.9	778.2	2 342.2	4 553.8
Volume of copper exports (thousand metric tons)	456	444	482	424	400	496
Value of copper exports (million zaires)	216.5	316.5	344.3	322.7	853.6	1 966.1
Volume of cobalt exports (thousand metric tons)	11.9	12.8	10.2	13.1	14.1	
Value of cobalt exports (million zaires)	48.4	98.6	93.0	180.7	1 067.0	962.6
Value of diamond exports (million zaires)	26.7	47.4	55.2	103.2	171.2	191.6
Value of coffee exports (million zaires)	27.1	103.1	165.5	138.2	243.4	458.5
Value of copper as percentage of total exports	50.0	42.4	40.7	41.5	36.4	43.2
Value of cobalt as percentage of total exports	11.2	13.2	11.0	23.2	45.6	21.1
Gross domestic product (current price, million zaires)	1 989	2 909	4 058	5 515	10 654	
Gross domestic product (mineral sector)	293	363	546	628	1 704	
GDP of mineral sector as percentage of total GDP	14.7	12.5	13.5	11.4	16.0	

Sources: IMF, *International Financial Statistics* and Bank of Zaire.

B. ZAMBIA

Minerals are the most important exports of Zambia and have consistently been responsible for about 98 per cent of the total export earnings. Copper usually represents 93 per cent of export earnings, with other metals such as lead and zinc representing about 3 per cent to 4 per cent and cobalt about 1 per cent. However, since 1976 there has been an increasing trend in cobalt prices, with quite a dramatic rise in 1978-1979, and at the same time copper and other base metal prices have remained static or even been recessional. The result of these changes is that in 1979 copper represented 85.1 per cent of total export earnings and cobalt represented 11 per cent. More recent trends in cobalt prices, however, show that cobalt will be returning to a lower position (1980 provisional figures).

The mineral industry is directly attuned to the international copper supply-demand pricing system, which has been relatively static for some years, whereas other sectors of the economy related to the local situations have expanded. The result is that the mineral industry, which was responsible for 41 per cent of the gross domestic product in the past, contributed only 18 per cent to the gross domestic product in 1979. The industry employs over 65,000 people in a total national work force of 370,000, i.e. 18 per cent.

Zambia is primarily a copper-producing country, and the reserves are quoted in various journals at about 860 million tons of ore grading 3.06 per cent copper (26 millions tons of contained copper). This does not, however, take account of considerable tonnages of protore which will eventually be mineable when certain technical mining and metallurgical problems are overcome.

Cobalt occurs in practically all of the Zambian copper ores, but it is only in some mines that the grade and physical characteristics enable recovery to be economic. If the demand arose, and the capital cost of the recovery plants could be justified, Zambia could considerably increase the supply, not only from the new ore but from tailing dumps and smelter slag heaps.

Other sectors of the Zambian economy are expanding, but the mineral industry will be the main export earner for a long future.

C. GABON

Gabon is dependent for its foreign exchange to a large extent on the export of mineral products. This is mainly in the form of petroleum products, but manganese ore also plays an important part. In 1977, the total value of exports was $1,218 million, of which $988 million (81 per cent) was from petroleum products and $109 million (9 per cent) was from manganese.

Gabon has shown a higher than average economic growth rate during the last 20 years, averaging 16.9 per cent between 1950 and 1979. The average for African developing countries over this period has been 10.3 per cent, but for other mineral-producing countries has been somewhat lower (e.g., Zimbabwe 8.70 per cent, Zambia 7.0 per cent, Zaire 4.2 per cent). This high increase has been due to the development of the petroleum industry. The result is that Gabon also has a high gross domestic product (in 1977 GDP was $2,588 million; per capita GDP was $4,865, which compares with the average for African developing countries of $482). The mineral industry accounts for 65 per cent of the gross national product and employs 7,000 people in a work force of 220,000.

Gabon is the third largest producer of manganese ore and the world's largest exporter. Exports in 1980 amounted to 2.2 million tons, but exports are planned to expand to 3.6 million tons when the Trans Gabon Railway is completed (now estimated to be in 1986). The reserves are estimated to be in the order of 210 million tons of high-grade (48 per cent) manganese ore.

TABLE 2. ZAMBIA

	1975	1976	1977	1978	1979	1980
Total value of exports (million kwacha)	518	749	685	685	1 088	1 004
Volume of copper exports (thousand metric tons)	495	709	656	643	588	596
Value of copper exports (million kwacha)	471	689	646	598	901	
Volume of cobalt exports (metric tons)	2 626	2 430	2 500	2 500	3 176	3 309
Value of cobalt exports (million kwacha)	7.1	15.9	15.3	30.6	130.0	69.5
Total value of copper and cobalt (million kwacha)	479	705	661	634	926	960
Copper and cobalt as per cent of total exports	92.5	94	96.5	92.6	85.1	95.6
Copper as per cent of total exports	90.9	92	94.3	87.3		
Cobalt as per cent of total exports	1.4	2	2.2	4.5	11.9	6.9
Gross domestic product (GDP)	1 583	1 872	1 952	2 201	2 623	3 038
GDP of mineral sector as percentage of total GDP	13	18	11	12	18	17

Sources: *Zambia Year Book* and IMF, *International Financial Statistics*. The 1979 and 1980 figures are provisional.

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[*Original: English*]
[*16 March 1982*]

Calculations of production ceilings under assumptions provided by the delegation of Zambia

1. At its 55th meeting held on 9 March 1982, the First Committee requested the Secretary-General to prepare an addendum to this preliminary report.

2. The purpose of the addendum is to show the tonnages of nickel, cobalt and manganese corresponding to the production ceilings, under certain assumptions provided by the delegation of Zambia. These assumptions are:

"A. Projected land-based cobalt production from Zambia and Zaire is 33,000 tonnes;

"B. Single start-up date for sea-bed mining to be 1987;

"C. Market growth rates for the consumption of cobalt to be 2.3 per cent, 3.5 per cent, and 4.5 per cent per annum;

"D. For each of the above growth rates assume metallurgical recovery factors for cobalt of 65 and 85 per cent. The recovery factors for manganese to be assumed as 80 per cent and 90 per cent. The recovery factor for nickel and for copper to be assumed as 90 per cent;

"E. Assume the following mineral grades in the manganese nodules for each case of the above market growth rates in consumption of cobalt:

nickel:	1.24 per cent
cobalt:	0.20 per cent
copper:	1.01 per cent
manganese:	27.5 per cent

"F. Use production limitation formula contained in article 151 of the draft convention to derive figures for cobalt, manganese, etc.;

"G. World consumption figures for nickel used in the previous 1981 Secretariat study contained in document A/CONF.62/L.66[17] but only three annual growth rates of 3.0, 3.5 and 4.5 per cent to be used to obtain substitute data;

"H. Informal proposal by Gabon, Zaire, Zambia and Zimbabwe to be used to provide a basis for comparative studies;

"I. For brevity, computation of estimates and results of the study to be tabulated for 6 of the 20 years, viz.

1987 (start-up year)
1991
1995
1999
2003 and
2007."

3. The production ceilings are calculated first, according to article 151 paragraph 2 (*b*) of the draft convention and, secondly, according to an informal proposal by the delegations of Gabon, Zaire, Zambia and Zimbabwe, dated 6 April 1981. The scheme, based on that proposal, operates as follows:

(*a*) A nickel tonnage is calculated in the same way as the nickel production ceiling in accordance with article 151;

(*b*) A cobalt tonnage is calculated in accordance with the same basic principles as those by which the nickel production ceiling is calculated in article 151, except that a 15-year trend line of world consumption of cobalt is used instead of nickel;

(*c*) A nickel tonnage is then calculated which would be produced from the same volume of nodules as that which would produce the cobalt tonnage calculated in step (*b*) above;

(*d*) The production ceiling for nickel will be the mean of the nickel tonnage calculated in step (*a*) and the nickel tonnage calculated in step (*c*).

4. The following tables numbered 1 to 6 give the results of the calculations.

Tables 1 and 2 present the quantities of cobalt and manganese corresponding to the production ceilings calculated according to article 151 of the draft convention and according to the informal proposal by Gabon, Zaire, Zambia and Zimbabwe.

Tables 3 and 4 present the production ceilings (nickel) calculated according to article 151 of the draft convention and according to the informal proposal by Gabon, Zaire, Zambia and Zimbabwe, as well as the quantities of polymetallic nodules corresponding to these two sets of production ceilings.

Tables 5 and 6 show the world consumption statistics for nickel and cobalt and the substitute data which have been used in the calculations.

Figures have been rounded to one decimal place in the calculations.

[17] See *United Nations Conference on the Law of the Sea*, vol. XV (United Nations publication, Sales No. E.83.V.4).

Table 1. Quantities of cobalt and manganese corresponding to the production ceilings calculated according to article 151, and the projected land-based cobalt production from Zaire and Zambia

	Year					
	1987	*1991*	*1995*	*1999*	*2003*	*2007*
A. Quantity of cobalt (*thousands of metric tons*)						
A1. Nickel growth rate 3.0 per cent Cobalt recovery 65 per cent	20.9	27.6	37.6	45.0	56.8	70.1
A2. Nickel growth rate 3.0 per cent Cobalt recovery 85 per cent	27.4	36.0	49.1	58.8	74.3	91.6
A3. Nickel growth rate 3.5 per cent Cobalt recovery 65 per cent	21.1	29.4	43.2	54.9	70.5	88.1
A4. Nickel growth rate 3.5 per cent Cobalt recovery 85 per cent	27.5	38.4	56.4	71.7	92.1	115.3
A5. Nickel growth rate 4.5 per cent Cobalt recovery 65 per cent	21.3	33.0	55.2	77.7	102.8	131.8
A6. Nickel growth rate 4.5 per cent Cobalt recovery 85 per cent	27.9	43.2	72.2	101.7	134.5	172.4

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TABLE 1 (*continued*)

	Year 1987	1991	1995	1999	2003	2007
B. PROJECTED COBALT PRODUCTION FROM ZAIRE AND ZAMBIA (*thousands of metric tons*)	33.0	33.0	33.0	33.0	33.0	33.0
C. QUANTITY OF MANGANESE (*thousands of metric tons*)						
C1. Nickel growth rate 3.0 per cent Manganese recovery 80 per cent	3.5	4.7	6.4	7.6	9.6	11.9
C2. Nickel growth rate 3.0 per cent Manganese recovery 90 per cent	4.0	5.2	7.2	8.6	10.8	13.3
C3. Nickel growth rate 3.5 per cent Manganese recovery 80 per cent	3.6	5.0	7.3	9.3	11.9	14.9
C4. Nickel growth rate 3.5 per cent Manganese recovery 90 per cent	4.0	6.0	8.2	10.4	13.4	16.8
C5. Nickel growth rate 4.5 per cent Manganese recovery 80 per cent	3.6	5.6	9.4	13.2	17.4	22.3
C6. Nickel growth rate 4.5 per cent Manganese recovery 90 per cent	4.1	6.3	10.5	14.8	19.6	25.1

NOTES: Rows A1-A6: Quantities of cobalt corresponding to the production ceilings calculated according to article 151 of the draft convention have been obtained by multiplying the quantities of nodules by the cobalt content in the nodules and the metallurgical recovery factor for cobalt; in this table, Row A = Row B in table 3 × (0.0020 × 0.65 or 0.85).

Rows C1-C6: Quantities of manganese corresponding to the production ceilings calculated according to article 151 of the draft convention have been obtained by multiplying the quantities of nodules by the manganese content in the nodules and the metallurgical recovery factor for manganese; in this table, Row C = Row B in table 3 × (0.275 × 0.80 or 0.90).

TABLE 2. QUANTITIES OF COBALT AND MANGANESE CORRESPONDING TO THE PRODUCTION CEILINGS CALCULATED ACCORDING TO THE INFORMAL PROPOSAL BY GABON, ZAIRE, ZAMBIA AND ZIMBABWE AND THE PROJECTED LAND-BASED COBALT PRODUCTION FROM ZAIRE AND ZAMBIA

	Year 1987	1991	1995	1999	2003	2007
A. QUANTITY OF COBALT (*thousands of metric tons*)						
Cobalt growth rate 2.3 per cent, Cobalt recovery 65 per cent						
A1. Nickel growth rate 3.0 per cent	12.9	17.2	24.8	30.4	38.6	47.7
A2. Nickel growth rate 3.5 per cent	12.9	18.1	27.6	35.4	45.5	56.7
A3. Nickel growth rate 4.5 per cent	13.0	19.8	33.7	46.8	61.6	78.5
Cobalt growth rate 2.3 per cent, Cobalt recovery 85 per cent						
A4. Nickel growth rate 3.0 per cent	16.0	21.4	30.6	37.2	47.4	58.5
A5. Nickel growth rate 3.5 per cent	16.2	22.6	34.2	43.7	56.4	70.2
A6. Nickel growth rate 4.5 per cent	16.3	25.0	42.2	58.6	77.5	98.8
Cobalt growth rate 3.5 per cent, Cobalt recovery 65 per cent						
A7. Nickel growth rate 3.0 per cent	12.9	18.1	25.4	33.2	40.2	50.6
A8. Nickel growth rate 3.5 per cent	12.9	19.0	28.2	38.2	47.1	59.5
A9. Nickel growth rate 4.5 per cent	13.0	20.8	34.2	49.7	63.2	81.4
Cobalt growth rate 3.5 per cent, Cobalt recovery 85 per cent						
A10. Nickel growth rate 3.0 per cent	16.0	22.3	31.3	40.1	49.0	61.4
A11. Nickel growth rate 3.5 per cent	16.2	23.5	34.8	46.6	58.0	73.1
A12. Nickel growth rate 4.5 per cent	16.3	25.8	42.7	61.5	79.0	101.7
Cobalt growth rate 4.5 per cent, Cobalt recovery 65 per cent						
A13. Nickel growth rate 3.0 per cent	12.9	18.6	27.3	37.4	46.0	58.6
A14. Nickel growth rate 3.5 per cent	12.9	19.5	30.2	42.4	52.9	67.6
A15. Nickel growth rate 4.5 per cent	13.0	21.3	36.1	53.8	69.0	89.3
Cobalt growth rate 4.5 per cent, Cobalt recovery 85 per cent						
A16. Nickel growth rate 3.0 per cent	16.2	23.0	33.2	44.4	54.7	69.4
A17. Nickel growth rate 3.5 per cent	16.2	24.0	36.7	50.8	63.8	81.1
A18. Nickel growth rate 4.5 per cent	16.3	26.4	44.7	65.8	84.8	109.6
B. PROJECTED COBALT PRODUCTION FROM ZAIRE AND ZAMBIA (*thousands of metric tons*)	33.0	33.0	33.0	33.0	33.0	33.0
C. QUANTITY OF MANGANESE (*millions of metric tons*)						
Manganese recovery 80 per cent; Cobalt growth rate 2.3 per cent, Cobalt recovery 65 per cent						
C1. Nickel growth rate 3.0 per cent	2.2	2.9	4.2	5.1	6.5	8.1

TABLE 2 (*continued*)

	Year					
	1987	*1991*	*1995*	*1999*	*2003*	*2007*
C. QUANTITY OF MANGANESE (*continued*) (*millions of metric tons*)						
C2. Nickel growth rate 3.5 per cent	2.2	3.1	4.7	6.0	7.7	9.6
C3. Nickel growth rate 4.5 per cent	2.2	3.3	5.7	7.9	10.4	13.3
Cobalt growth rate 2.3 per cent, Cobalt recovery 85 per cent						
C4. Nickel growth rate 3.0 per cent	2.1	2.8	4.0	4.8	6.1	7.6
C5. Nickel growth rate 3.5 per cent	2.1	2.9	4.4	5.7	7.3	9.1
C6. Nickel growth rate 4.5 per cent	2.1	3.2	5.5	7.6	10.0	12.8
Cobalt growth rate 3.5 per cent, Cobalt recovery 65 per cent						
C7. Nickel growth rate 3.0 per cent	2.2	3.1	4.3	5.6	6.8	8.6
C8. Nickel growth rate 3.5 per cent	2.2	3.2	4.8	6.5	8.0	10.1
C9. Nickel growth rate 4.5 per cent	2.2	3.5	5.8	8.4	10.7	13.8
Cobalt growth rate 3.5 per cent, Cobalt recovery 85 per cent						
C10. Nickel growth rate 3.0 per cent	2.1	2.9	4.0	5.2	6.3	7.9
C11. Nickel growth rate 3.5 per cent	2.1	3.0	4.5	6.0	7.5	9.5
C12. Nickel growth rate 4.5 per cent	2.1	3.3	5.5	8.0	10.2	13.2
Cobalt growth rate 4.5 per cent, Cobalt recovery 65 per cent						
C13. Nickel growth rate 3.0 per cent	2.2	3.1	4.6	6.3	7.8	9.9
C14. Nickel growth rate 3.5 per cent	2.2	3.3	5.1	7.2	9.0	11.4
C15. Nickel growth rate 4.5 per cent	2.2	3.6	6.1	9.1	11.7	15.1
Cobalt growth rate 4.5 per cent, Cobalt recovery 85 per cent						
C16. Nickel growth rate 3.0 per cent	2.1	3.0	4.3	5.7	7.1	9.0
C17. Nickel growth rate 3.5 per cent	2.1	3.1	4.8	6.6	8.2	10.5
C18. Nickel growth rate 4.5 per cent	2.1	3.4	5.8	8.5	11.0	14.2
Manganese recovery 90 per cent						
Cobalt growth rate 2.3 per cent, Cobalt recovery 65 per cent						
C19. Nickel growth rate 3.0 per cent	2.5	3.3	4.7	5.8	7.4	9.1
C20. Nickel growth rate 3.5 per cent	2.5	3.4	5.2	6.7	8.7	10.8
C21. Nickel growth rate 4.5 per cent	2.5	3.8	6.4	8.9	11.7	14.9
Cobalt growth rate 2.3 per cent, Cobalt recovery 85 per cent						
C22. Nickel growth rate 3.0 per cent	2.3	3.1	4.5	5.4	6.9	8.5
C23. Nickel growth rate 3.5 per cent	2.4	3.3	5.0	6.4	8.2	10.2
C24. Nickel growth rate 4.5 per cent	2.4	3.6	6.1	8.5	11.3	14.4
Cobalt growth rate 3.5 per cent, Cobalt recovery 65 per cent						
C25. Nickel growth rate 3.0 per cent	2.5	3.4	4.8	6.3	7.6	9.6
C26. Nickel growth rate 3.5 per cent	2.5	3.6	5.4	7.3	9.0	11.3
C27. Nickel growth rate 4.5 per cent	2.5	4.0	6.5	9.5	12.0	15.5
Cobalt growth rate 3.5 per cent, Cobalt recovery 85 per cent						
C28. Nickel growth rate 3.0 per cent	2.3	3.2	4.6	5.8	7.1	8.9
C29. Nickel growth rate 3.5 per cent	2.4	3.4	5.1	6.8	8.4	10.6
C30. Nickel growth rate 4.5 per cent	2.4	3.8	6.2	9.0	11.5	14.8
Cobalt growth rate 4.5 per cent, Cobalt recovery 65 per cent						
C31. Nickel growth rate 3.0 per cent	2.5	3.5	5.2	7.1	8.8	11.2
C32. Nickel growth rate 3.5 per cent	2.5	3.7	5.7	8.1	10.1	12.9
C33. Nickel growth rate 4.5 per cent	2.5	4.1	6.9	10.2	13.1	17.0
Cobalt growth rate 4.5 per cent, Cobalt recovery 85 per cent						
C34. Nickel growth rate 3.0 per cent	2.4	3.3	4.8	6.5	8.0	10.1
C35. Nickel growth rate 3.5 per cent	2.4	3.5	5.3	7.4	9.3	11.8
C36. Nickel growth rate 4.5 per cent	2.4	3.8	6.5	9.6	12.4	16.0

NOTES: Rows A1-A18: Quantities of cobalt corresponding to the production ceilings calculated according to the informal proposal by Gabon, Zaire, Zambia and Zimbabwe have been obtained by multiplying the production ceilings by the cobalt content of the nodules and the metallurgical recovery factor for cobalt. In this table, Row A = Row E of table 4 × (0.0020 × 0.65 or 0.85, as appropriate).

Rows C1-C36: Quantities of manganese corresponding to the production ceilings calculated according to the informal proposal by Gabon, Zaire, Zambia and Zimbabwe have been obtained by multiplying the production ceilings by the manganese content of the nodules and the metallurgical recovery factor for manganese. In this table, Row C = Row E of table 4 × (0.275 × 0.80 or 0.90).

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TABLE 3. PRODUCTION CEILINGS CALCULATED ACCORDING TO ARTICLE 151 AND QUANTITIES OF POLYMETALLIC NODULES CORRESPONDING TO THESE PRODUCTION CEILINGS

	Year 1987	1991	1995	1999	2003	2007
A. PRODUCTION CEILINGS (QUANTITY OF NICKEL) (*thousands of metric tons*)						
A1. Nickel growth rate 3.0 per cent	179.9	236.7	322.8	385.7[a]	487.2	601.8
A2. Nickel growth rate 3.5 per cent	180.9	251.8	370.2	470.8	604.9	756.4
A3. Nickel growth rate 4.5 per cent	182.6	283.3	474.0	667.2	882.3	1 131.1
B. QUANTITY OF NODULES (*millions of metric tons*)						
B1. Nickel growth rate 3.0 per cent	16.1	21.2	28.9	34.6	43.7	53.9
B2. Nickel growth rate 3.5 per cent	16.2	22.6	33.2	42.2	54.2	67.8
B3. Nickel growth rate 4.5 per cent	16.4	25.4	42.5	59.8	79.1	101.4

NOTES: Rows A1-A3: The method of calculating production ceilings according to article 151 of the draft convention has been described in document A/CONF.62/L.66.

Rows B1-B3: Quantities of polymetallic nodules corresponding to the production ceilings have been obtained by dividing the production ceilings by the nickel content in the nodules and the metallurgical recovery factor for nickel; in this table, Row B = Row A ÷ (0.0124 × 0.90).

[a] In this case, the so-called "floor" provision applies.

TABLE 4. PRODUCTION CEILINGS CALCULATED ACCORDING TO THE INFORMAL PROPOSAL BY GABON, ZAIRE AND ZIMBABWE, AND QUANTITIES OF POLYMETALLIC NODULES CORRESPONDING TO THESE PRODUCTION CEILINGS

	Year 1987	1991	1995	1999	2003	2007
A. LIMITING QUANTITIES OF COBALT FROM COBALT CONSUMPTION (*thousands of metric tons*)						
A1. Cobalt growth rate 2.3 per cent	4.7[b]	6.8[b]	12.1[b]	15.8[a]	20.5[a]	25.3[a]
A2. Cobalt growth rate 3.5 per cent	4.7[b]	8.6[b]	13.2	21.5	23.7	31.0
A3. Cobalt growth rate 4.5 per cent	4.8[b]	9.7[a]	17.1	29.9	35.3	47.1
B. LIMITING QUANTITES OF NICKEL FROM COBALT CONSUMPTION (*thousands of metric tons*)						
B1. Cobalt growth rate 2.3 per cent Cobalt recovery 65 per cent	40.3	58.4	103.9	135.6	176.0	217.2
B2. Cobalt growth rate 2.3 per cent Cobalt recovery 85 per cent	30.9	44.6	79.4	103.7	134.6	166.1
B3. Cobalt growth rate 3.5 per cent Cobalt recovery 65 per cent	40.3	73.8	113.3	184.6	203.5	266.1
B4. Cobalt growth rate 3.5 per cent Cobalt recovery 85 per cent	30.9	56.5	86.7	141.1	155.6	203.5
B5. Cobalt growth rate 4.5 per cent Cobalt recovery 65 per cent	41.2	83.2	146.8	256.7	303.0	404.3
B6. Cobalt growth rate 4.5 per cent Cobalt recovery 85 per cent	31.5	63.7	112.3	196.3	231.7	309.2
C. LIMITING QUANTITIES OF NICKEL FROM NICKEL CONSUMPTION (*thousands of metric tons*) (same as Row A in table 3)						
C1. Nickel growth rate 3.0 per cent	179.9	236.7	322.8	385.7[a]	487.2	601.8
C2. Nickel growth rate 3.5 per cent	180.9	251.8	370.2	470.8	604.9	756.4
C3. Nickel growth rate 4.5 per cent	182.6	283.3	474.0	667.2	882.3	1 131.1
D. PRODUCTION CEILINGS (QUANTITY OF NICKEL) (*thousands of metric tons*)						
Cobalt growth rate 2.3 per cent Cobalt recovery 65 per cent						
D1. Nickel growth rate 3.0 per cent	110.1	147.6	213.4	260.6	331.6	409.5
D2. Nickel growth rate 3.5 per cent	110.6	155.1	237.0	303.2	390.4	486.8
D3. Nickel growth rate 4.5 per cent	111.4	170.0	289.0	401.4	529.2	674.2
Cobalt growth rate 2.3 per cent Cobalt recovery 85 per cent						
D4. Nickel growth rate 3.0 per cent	105.4	140.6	201.1	244.7	310.9	384.0
D5. Nickel growth rate 3.5 per cent	105.9	148.2	224.8	287.2	370.0	461.2
D6. Nickel growth rate 4.5 per cent	106.8	164.0	276.7	385.4	508.4	648.6
Cobalt growth rate 3.5 per cent Cobalt recovery 65 per cent						
D7. Nickel growth rate 3.0 per cent	110.1	155.2	218.0	285.2	345.4	434.0
D8. Nickel growth rate 3.5 per cent	110.6	162.8	241.8	327.7	404.2	511.2
D9. Nickel growth rate 4.5 per cent	111.4	178.6	293.6	425.9	542.9	698.6
Cobalt growth rate 3.5 per cent Cobalt recovery 85 per cent						

TABLE 4 (*continued*)

	Year 1987	1991	1995	1999	2003	2007
D. PRODUCTION CEILINGS (QUANTITY OF NICKEL) (*continued*) (*thousands of metric tons*)						
D10. Nickel growth rate 3.0 per cent	105.4	146.6	204.8	263.4	321.4	402.6
D11. Nickel growth rate 3.5 per cent	105.9	154.2	228.4	306.0	380.2	480.0
D12. Nickel growth rate 4.5 per cent	106.8	169.9	280.4	404.2	519.0	667.3
Cobalt growth rate 4.5 per cent Cobalt recovery 65 per cent						
D13. Nickel growth rate 3.0 per cent	110.6	160.0	234.8	321.2	395.1	503.0
D14. Nickel growth rate 3.5 per cent	111.0	167.5	258.5	363.8	454.0	580.4
D15. Nickel growth rate 4.5 per cent	111.9	183.2	310.4	462.0	592.6	767.7
Cobalt growth rate 4.5 per cent Cobalt recovery 85 per cent						
D16. Nickel growth rate 3.0 per cent	105.7	150.2	217.6	291.0	359.4	455.5
D17. Nickel growth rate 3.5 per cent	106.2	157.8	241.2	333.6	418.3	532.8
D18. Nickel growth rate 4.5 per cent	107.0	173.5	293.2	431.8	557.0	720.2
E. QUANTITY OF NODULES (*millions of metric tons*)						
Cobalt growth rate 2.3 per cent Cobalt recovery 65 per cent						
E1. Nickel growth rate 3.0 per cent	9.9	13.2	19.1	23.4	29.7	36.7
E2. Nickel growth rate 3.5 per cent	9.9	13.9	21.2	27.2	35.0	43.6
E3. Nickel growth rate 4.5 per cent	10.0	15.2	25.9	36.0	47.4	60.4
Cobalt growth rate 2.3 per cent Cobalt recovery 85 per cent						
E4. Nickel growth rate 3.0 per cent	9.4	12.6	18.0	21.9	27.9	34.4
E5. Nickel growth rate 3.5 per cent	9.5	13.3	20.1	25.7	33.2	41.3
E6. Nickel growth rate 4.5 per cent	9.6	14.7	24.8	34.5	45.6	58.1
Cobalt growth rate 3.5 per cent Cobalt recovery 65 per cent						
E7. Nickel growth rate 3.0 per cent	9.9	13.9	19.5	25.6	30.9	38.9
E8. Nickel growth rate 3.5 per cent	9.9	14.6	21.7	29.4	36.2	45.8
E9. Nickel growth rate 4.5 per cent	10.0	16.0	26.3	38.2	48.6	62.6
Cobalt growth rate 3.5 per cent Cobalt recovery 85 per cent						
E10. Nickel growth rate 3.0 per cent	9.4	13.1	18.4	23.6	28.8	36.1
E11. Nickel growth rate 3.5 per cent	9.5	13.8	20.5	27.4	34.1	43.0
E12. Nickel growth rate 4.5 per cent	9.6	15.2	25.1	36.2	46.5	59.8
Cobalt growth rate 4.5 per cent Cobalt recovery 65 per cent						
E13. Nickel growth rate 3.0 per cent	9.9	14.3	21.0	28.8	35.4	45.1
E14. Nickel growth rate 3.5 per cent	9.9	15.0	23.2	32.6	40.7	52.0
E15. Nickel growth rate 4.5 per cent	10.0	16.4	27.8	41.4	53.1	68.7
Cobalt growth rate 4.5 per cent Cobalt recovery 85 per cent						
E16. Nickel growth rate 3.0 per cent	9.5	13.5	19.5	26.1	32.2	40.8
E17. Nickel growth rate 3.5 per cent	9.5	14.1	21.6	29.9	37.5	47.7
E18. Nickel growth rate 4.5 per cent	9.6	15.5	26.3	38.7	49.9	64.5

NOTES: Rows A1-A3: The method of calculating limiting quantities of cobalt from cobalt consumption is the same as that used in calculating production ceilings according to article 151 of the draft convention, except that world cobalt consumption is used in place of world nickel consumption.

Rows B1-B6: Limiting quantities of nickel from cobalt consumption have been obtained by first dividing the limiting quantities of cobalt from cobalt consumption by the cobalt content in the nodules and by the metallurgical recovery factor for cobalt and then multiplying the resultant quantity by the nickel content in the nodules and the metallurgical recovery factor for nickel; in this table, Row B = Row A ÷ (0.0020 × 0.65 or 0.85) × (0.0124 × 0.90).

Rows D1-D18: Production ceilings are the arithmetic means of the limiting quantities of nickel from nickel consumption and nickel from cobalt consumption; in this table, Row D = 1/2 (Row C + Row B).

Rows E1-E18: Quantities of polymetallic nodules corresponding to the production ceilings have been obtained by dividing the production ceilings by the nickel content in the nodules and the metallurgical recovery factor for nickel; in this table Row E = Row D ÷ (0.0124 × 0.90).

[a] In these cases, the so-called "floor" provision applies.

[b] In these cases, the so-called "safeguard" provision applies.

TABLE 5. WORLD CONSUMPTION OF NICKEL AND COBALT: 1965-1979
(*Thousands of metric tons*)

Year	*World consumption of nickel*	*World consumption of cobalt*
1965	431.0	19.4
1966	467.5	22.2
1967	472.9	21.0
1968	490.2	21.9
1969	502.8	26.6
1970	576.6	27.3
1971	526.6	23.4
1972	580.1	25.6
1973	657.5	30.8
1974	710.7	32.8
1975	577.2	24.7
1976	666.3	28.2
1977	643.0	29.0
1978	701.3	27.0
1979	782.6	29.8

Sources: Nickel—A/CONF.62/L.66, annex II, table 1. Cobalt—1965: Leonard L. Fischman, *World Mineral Trends and U.S. Supply Problems* (Research paper R-20), Resources for the Future (Washington, D.C., 1980), table 2-5; adjusted. 1966-1976: Bundesanstalt für Geowissenschaften und Rohstoffe and Deutsches Institut für Wirtschaftsforschung, *Untersuchungen über Angebot und Nachfrage Mineralischer Rohstoffe, XI. Kobalt* (E. Schweizerbartische Verlagsbuchhandlung, Stuttgart, October 1978), table 44. 1977-1979: Communications from the delegation of Zambia; estimates.

TABLE 6. SUBSTITUTE DATA FOR WORLD CONSUMPTION OF NICKEL AND COBALT: 1980-2005
(*Thousands of metric tons*)

Year	*Obtained by applying an annual growth rate of the following percentages on the trend line value for 1979*					
	Nickel			*Cobalt*		
	3.0 per cent	*3.5 per cent*	*4.5 per cent*	*2.3 per cent*	*3.5 per cent*	*4.5 per cent*
1980	771.5	775.2	782.7	31.5	31.9	32.2
1981	794.6	802.1	817.9	32.2	33.0	33.6
1982	818.4	830.4	854.7	32.9	34.2	35.1
1983	843.0	859.5	893.2	33.7	35.4	36.7
1984	868.3	889.6	933.4	34.5	36.6	38.4
1985	894.3	920.7	975.4	35.3	37.9	40.1
1986	921.1	952.9	1 019.3	36.1	39.2	41.9
1987	948.7	986.2	1 065.2	36.9	40.6	43.8
1988	977.2	1 020.7	1 113.1	37.7	42.0	45.8
1989	1 006.5	1 056.4	1 163.2	38.6	43.5	47.9
1990	1 036.7	1 093.4	1 215.5	39.5	45.0	50.1
1991	1 067.8	1 131.7	1 270.2	40.4	46.6	52.4
1992	1 099.8	1 171.3	1 327.4	41.3	48.2	54.8
1993	1 132.8	1 212.3	1 387.1	42.2	49.9	57.3
1994	1 166.8	1 254.7	1 449.5	43.2	51.6	59.9
1995	1 201.8	1 298.6	1 514.7	44.2	53.4	62.6
1996	1 237.9	1 344.1	1 582.9	45.2	55.3	65.4
1997	1 275.0	1 391.1	1 654.1	46.2	57.2	68.3
1998	1 313.2	1 439.8	1 728.5	47.3	59.2	71.4
1999	1 352.6	1 490.2	1 806.3	48.4	61.3	74.6
2000	1 393.2	1 542.4	1 887.6	49.5	63.4	78.0
2001	1 435.0	1 596.4	1 972.5	50.6	65.6	81.5
2002	1 478.0	1 652.3	2 061.3	51.8	67.9	85.2
2003	1 522.3	1 710.1	2 154.1	53.0	70.3	89.0
2004	1 568.0	1 770.0	2 251.0	54.2	72.8	93.0
2005	1 615.0	1 832.0	2 352.3	55.4	75.3	97.2

Sources: Nickel—A/CONF.62/L.66, annex II, table 2. Cobalt—Obtained by applying the growth rates to 30.8 thousand metric tons (the value for 1979) on the trend line derived from a linear regression of logarithms of actual cobalt consumption for 1965-1979, presented in table 5.