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INTERNATIONAL CONTROL OF DEEP SEA MINERAL RESOURCES

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Introduction. The United States is committed as a matter of national policy to enter into negotiations with all countries in the United Nations in a serious attempt to bring the law of the sea in line with "... the needs of modern technology and the concerns of the international community."[1] These needs and concerns are numerous and often conflicting, and their resolution is complicated by the fact that even the preliminary negotiations are being conducted in the political forum of the United Nations rather than on a quieter technical level as in the case of the 1958 conventions.[2] If a general codification of principles for the law of the sea is to be agreed upon, then common interests and elements upon which agreement can be based must be found, and found in relatively short order or the Law of the Sea Conference scheduled for the summer of 1973 will surely founder on its own rhetoric. The place for agreement to start is in the area in which the affected interests are least entrenched. Using this criterion one can quickly eliminate the issues of territorial seas and the right of free transit since national security interests are involved. Likewise legal clarification of the seaward limit of the Continental Shelf can be eliminated because strong interests in oil, fisheries, et cetera, are intimately connected with this question. The highly emotional question of pollution in the oceans is recognized to be a part of the larger question of the total environment and as such is being dealt with in a separate conference. Further away from land, the so-called high seas are again connected with national security interests, and the water column beneath them is the concern of strongly entrenched fishing interests. The deep seabed is another matter, and it is here that interests appear least entrenched. There are two reasons for saying this. First, commercial recovery of any deep seabed resource has not started. Second, on a national and international political scale there appears to be general agreement that the deep seabed and its resources should be reserved for all of mankind. The "property of mankind concept" appears then to serve a useful purpose as a starting point from which more general agreement can commence. Indeed, the disagreement that exists on the deep seabeds is not to whom do they belong, but rather on the form of an international regime to oversee them.

Resources of the Deep Seabed. If there were nothing of interest to nations, industries, or individuals upon or under the seabed, then agreement on an international regime would be a relatively easy matter.[3] Indeed, a simple scientific coordination agency such as the existing International Oceanographic Commission would suffice. Such is not the case, however, and a summary of the known mineral wealth of the oceans which is important to the problem of international agreement is given by Wang.[4] In the deep oceans, recovery of metal-rich oozes is speculated about, as is the existence of oil and vein mineral deposits, but the only resource which has been identified beyond the speculation stage are manganese nodules. These deposits are of particular interest in this paper since their occurrence in grades of commercial interest occurs in depths generally in excess of 3,000 meters, in geographical areas far from even the most liberal interpretations of the boundary of the Continental Shelf, and well within the area considered the property of all mankind.

Manganese Nodules as a Resource. That interest in the nodules as a resource has passed beyond the speculation stage or that of oceanographic curiosity is amply demonstrated by the fact that today no less than 33 major companies have active programs of exploration and development. These include Deep Sea Ventures (Tenneco), Kennecott Exploration (Kennecott Copper), Hughes Tool, Lockheed and Global Marine, Ocean Resources, Metallgesellschaft, Kaiser, International Nickel, Nippon Steel, Sumimoto, Mitsubishi, Mitsui, Societe le Nickel, et cetera.[5] If one is to deal with the problem of policy formation concerning the resources of the deep seabed, then the place to start is with the least abstract resource, the manganese nodules.

In focusing on the manganese nodules one is immediately confronted with the question of why major companies from the United States, Japan, Germany, and France are interested in these as a resource.

The answer to this essentially lies in the composition of the nodules, the location of analogous land deposits, and the location of the companies involved. The major elements composing manganese nodules are silica, manganese, copper, iron, nickel, cobalt, lead, and aluminum. Of particular interest are cobalt, copper, nickel, and manganese. Over 80 percent of the world's supply of cobalt comes from the Congo. The United States produces only slight amounts as byproducts of the copper industry. Germany, France, and Japan produce none. The principal use of cobalt is as a high-temperature alloying agent in steel. Russia produces over 60 percent of the world's manganese. Manganese is vital to the steelmaking process. Nickel is also used, principally as an alloying agent in steel. In many instances nickel and cobalt are interchangeable. Japan, the United States, Germany, and France rank in the top five as producers of steel, but none have major land-based deposits of com-

TABLE I

Metal	% Drywgt Content of Nodules[a]		Principal Land-based Producers[b]
	Low	High	
Cobalt	0.2	0.5	Congo, Zambia
Copper	1.2	1.6	United States, U.S.S.R., Zambia, Chile
Nickel	1.2	1.6	Canada, New Caledonia, U.S.S.R., Cuba
Manganese	20.0	25.0	U.S.S.R., Brazil, Republic of South Africa, India, Ghana

Source: [a]These are generally accepted values obtained by personal contact with geologists at Woods Hole and various companies.

[b]*Commodity Yearbook 1971.* For a complete listing of the more than 50 manganese producing countries, see U.S. Dept. of Interior, Bureau of Mines, "Manganese in 1963, *Mineral Industry Surveys.*

mercially minable manganese, cobalt, or nickel. Known world reserves of high and good grade manganese ores, cobalt ores, and nickel ores appear to be adequate to supply all known and forecast needs well into the 21st century.[6] None of these strategic mineral deposits exist in the major non-Communist countries. On the other hand, the principal producing countries are, with the exception of Canada, countries which either have relatively unstable governments or are not particularly friendly with this country or the other major free world steel producers. It would seem desirable from a national security point of view to develop an independent source of these ores.

Indeed, this point seems to have been recognized for some time. In particular regard to the sea, the 1966 Marine Resources and Engineering Development Act declares that "The marine science activities of the United States should be conducted so as to contribute to the following objectives": and lists as the first objective "The accelerated development of the resources of the marine environment."[7] The 1968 Report of the President to the Congress on Marine Resources and Engineering Development notes the national need for "continuous access to an adequate, dependable, and economic supply of raw materials to meet the demands of an expanding population with a rising standard of living." It further sets the criteria for Federal policy designed to implement this. The policies should contribute to economic development and national security by assisting the Nation in:

- developing adequate and dependable supplies of needed mineral raw materials;
- acquiring mineral supplies at lowest costs consistent with the satisfaction of other national objectives;
- emphasizing domestic supplies of mineral resources to assist in maintaining favorable balance of payments;
- providing a climate for American industry to produce efficiently under competitive conditions, the minerals required for the domestic economy and foreign trade;
- conserving the Nation's mineral resources by using them wisely and efficiently;
- preserving the quality of the environment while obtaining needed minerals.

These criteria are repeated in subsequent reports made by the International

Oceanographic Commission throughout its entire existence.

The Bureau of Mines has a long history of having supported development and exploitation of low-grade domestic deposits of manganese. Nevertheless, there is no such project currently in existence. David B. Brooks in his 1966 book *Low Grade and Non-Conventional Sources of Manganese*[8] clearly sets forth that, of the possible alternate sources of manganese not residing in foreign territory, the deep sea manganese nodules were the most attractive and the most likely to be economically feasible. The only domestic sources of cobalt are closely tied to copper because the production of cobalt in this country is strictly as a byproduct of the smelting and refining processes of the domestic copper industry.[9]

In the preceding few paragraphs the first of the pressures upon any international convention becomes clear. It is the highly developed nations which are interested in exploiting the sea. It is in their national interests to do so. In the United States, to do so is clearly stated national objective and policy. Hence, any international agreement which must be submitted for ratification to the U.S. Senate clearly must foster the exploitation of the deep sea resources. On the other hand, the nations which have major land-based deposits with which the minerals from manganese nodules must compete all belong to the group called the emerging or developing nations, and their interests would be to protect their own production. Hence, any international regime from their point of view should be, in general, repressive of deep sea mining.[10] Any agreement or convention which hopes to be useful must provide for a reconciliation of these views.

Less disagreement exists concerning the copper contained in the nodules. The United States is a major producer with only Chile and the Congo having substantial deposits among the developing nations. The static reserve index of the Bureau of Mines indicates a 40-year world reserve of copper at current usage. However, this index is based on a linear usage prediction while, in fact, both domestic and world consumption of copper has been increasing exponentially. In the case of copper this increase has been about 3 percent per year even with the considerable material substitution and scrap recovery efforts that currently exist. Calculations using this more realistic exponential usage curve show a world reserve of only 26 years. In other words, we are possibly coming toward a period of resource deficiency.[11] A good illustration of the advanced degree of depletion of copper reserves lies in the fact that some 60 years ago the raw ore extracted from the earth contained an average of 1.88 percent copper. Today it contains about 0.7 percent.[12] When one considers that the analysis of copper in manganese nodules has produced results ranging from 0.3 percent to over 3 percent with an average in many areas of over 1 percent,[13] the potential importance of the source can be seen.

Economic Aspects of Nodule Mining and Production. It would seem to be in the international interest to develop a new source of copper. The nodules present such a new source. The difficulty in this approach of using copper as a common meeting ground lies in the economics of mining and extraction of the minerals from the nodules. The nodules which are minerally enriched generally lie at depths of 3-5 km., thus requiring development of new technology to gather or mine them. Further, the copper and other minerals contained in them are imbedded in a silica matrix unlike any mineral deposits found on land. Thus, in general, land-based methods which are well developed will not work on the deep sea nodules.[14] Mining of any mineral deposit, be it land- or sea-based, requires very high levels of capital investment. In the case of the sea-based mines the new technology required adds a high risk factor onto the high capitalization. Alvin Kauffman of the Bureau of Mines gathered together many estimates.[15] Independent investigation has revealed that, in general, the higher estimates of Kauffman for production costs are those in use today. The cost of operation can be said to be relatively low. When one considers the cost of capital in with the cost of operation, then the total cost presents a different picture.

Table III assumes in all cases an output of 1 million tons per year, taxes at 50 percent of return on invested capital. Kauffman assumed a 12 percent return on $100 million before taxes. This paper uses 30 percent return on an investment of $200 million before taxes.[16] The total costs of a manganese nodule mining and refining company can be seen to be somewhat higher than previously thought, and the dominant factor in the operation is clearly the

TABLE II—ESTIMATED COSTS OF PRODUCING METALS FROM THE DEEP SEA MANGANESE NODULES ($/TON)

Cost Item	Kauffman	This Paper[a]
Exploration	$ .70	$ .70
Lease Acquisition	2.50	------
Mining Cost	5.00	4.00
Transportation to Shore	1.00	1.00
Unloading	1.00	1.00
Benefication	2.00	2.00
Processing	20.00	20.00
Waste Disposal (Environmental Protection)	5.00	5.00
Overhead	4.00	4.00
Cost of Operation	$41.20	$37.70

Source: [a]No lease acquisition costs are included because they in part depend on the regime under which rights are granted. Mining costs are based on those of John L. Mero, Offshore Technology Conference 1971, Paper No. OTC 1410. Processing costs are based on a process such as reported by Deep Sea Ventures in D.M. Taylor, "Worthless Nodules Become Valuable," *Ocean Industry*, June 1971, p. 27-28. All other costs are those of Kauffman in lieu of better figures.

TABLE III—TOTAL COSTS OF PRODUCING MANGANESE NODULES ($/TON)

Cost Item	Kauffman	This Paper		
		4 year Writeoff	6 year Writeoff	8 year Writeoff
Return on Capital Investment	$ 6.00	$ 30.00	$ 30.00	$ 30.00
Taxes	6.00	30.00	30.00	30.00
Depreciation	------	50.00	33.33	25.00
Cost of Capital	$12.00	$110.00	$ 93.33	$ 85.00
Cost of Operation (From Table II)	41.20	37.70	37.70	37.70
Total Cost of Production	$53.20	$147.70	$131.03	$122.70

capital involved. The viability of the industry can be examined by comparing the recoverable value to the total cost. No single answer is apparent here. Using 1970 average market prices,[17] assuming an optimistic 100 percent recovery of the metals from the nodule, and using the metal content range from table I, the recoverable value of a million tons of nodules would be as shown in table IV.

What is immediately apparent from comparing these figures with the costs involved is that the whole operation is somewhat marginal. If one is interested only in the copper, nickel, and cobalt content, then the capital investment required had better be less than $100 million. Considering that projected capital costs for the recovery of the same tonnage of nickel from lateritic ores as from a million-ton nodule operation, according to Le Que, is over $200 million,[18] serious doubt is cast on the credibility of the $100 million capital investment figures. It is obvious that if $200 million is required for a million ton nodule operation, it will be profitable only if the manganese is recovered and used in competition with the existing ferromanganese market. Even in this case the operation, while definitely viable, leaves little margin for error in cost estimation or for market fluctuations.

The Problem of Market Impact. If the nodules are to be mined then for their total mineral content, they will be in competition with land-based sources of many countries and will have an effect on and be affected by the manganese, copper, nickel, and cobalt markets. The question then is to what degree is the concern of the developing countries justified? To put this in perspective, assume the same million ton per year operation presented in table I. Bertrand de Jouvenil has estimated that such an operation would yield the following as shown in table V.

While these figures would tend to indicate that the impact of a million tons of nodules per year would be minimal, this is not necessarily so. The true impact of the metals from the nodules derives

TABLE IV—RECOVERABLE VALUE OF METALS FROM DEEP SEA MANGANESE NODULES ($/TON)

Metal	High Content Value	Low Content Value
Nickel	$ 41.00	$30.50
Copper	19.30	14.40
Cobalt	18.50	7.40
Total Recoverable Value Without Manganese	$ 78.80	$52.30
Managanese Considered As a 50% Mn. Content Ore Equivalent	$ 13.25	$10.60
Recoverable Value of Other Metals	78.80	52.30
Total Recoverable Value	$ 92.05	$62.90
Manganese Considered As a Ferromanganese Equivalent	$ 47.50	$38.00
Recoverable Value of Other Minerals	78.80	52.30
Total Recoverable Value	$126.30	$90.30

TABLE V

Metal	Production Yield	% of 1968 World Production
Nickel	12,600 tons	2.5
Copper	10,000 tons	0.15
Cobalt	2,400 tons	12.5
Manganese Ore (Equivalent)	800,000 tons	5.0

Source: Bertrand de Jouvenil, "The Economic Potential of the Oceans," Paper prepared for Pacem in Maribus working group meeting, October 1971.

from the fact that they act and are classed as commodities. A commodity exhibits the following characteristics:

- It is indifferentiable. Thus no producer can obtain a higher price or better trading terms through advertising or product modification. He must accept the open market price which prevails at the time of the sale.
- Its marginal production costs, labor and material, are a very small fraction of total production costs. Thus there is little short-term response to price changes by producers.
- Its cost is generally a small fraction of the total cost of the products in which it is used. Thus consumption is relatively price inelastic.
- Price and production rates of commodities are quite unstable, generally varying from 1 year to the next by 5 to 25 percent.[19]

It is in the instability of the price and production rates that the true effect is exhibited. Examination of production and price data for manganese reveals many instances where a production increase of 10 percent resulted in a price decrease of 20 percent and production increases of 5 percent resulting in price decreases of 10 percent. In general, such a 2 to 1 (price change to production change) ratio is also apparent in the cobalt cycle. While this is a very simplistic view of a highly complicated process, the point is that the effect of the relatively sudden placement of the metals from the manganese nodules on the market will be out of proportion to the fraction of the market which they represent.[20] Since, in general, commodities account for some 90 percent of the foreign exchange of the developing countries,[21] it would seem their concern is justified. For example, a change of only 1 percent in the price of copper means $6 million a year in foreign exchange to the Government of Chile. Further, if the mining companies survive the price dip caused by their entry, it can be expected that their presence will have a continuing destabilizing effect upon the commodity market which will affect them as well as the land-based producers. These market fluctuations thus would appear to be a common element linking the land- and sea-based producers. It would be in the interests of both to preclude a market dip when the sea-based metals come onto the market and to stabilize the market in the long run, that is, to rid the market of the major year-to-year fluctuations in price.

Conclusions. Thus we may contend that market impact is a common key to the problem of deep sea resources. No matter what the difference in technology required or special legal considerations or even the difference of humanist philosophies behind the mining and extraction of land- and sea-based mineral resources, they face common problems in the world market place. The central issue in defining a policy for exploitation is *not* how to mine the nodules or how to define a tract of sea bottom or even who should own the sea bottom. It is rather how these minerals are to be used after they have been extracted from the nodules which is critical. A policy defining the desired impact that the deep sea minerals have upon the international mineral market is the one against which all other policy considerations should be placed in perspective. The choice is simply whether the minerals originating from the seabed should be used to stabilize an unstable commodities market or not. The choice is relatively clear. To opt for a free market means that, if an international regime is to be brought into being, each of the subsidiary questions—such as who owns the seabeds—must be dealt with as generally separate, standing on its own merit. This could be expected to lead to a long and acrimonious series of negotiations, which in turn would severely decrease the chances of any international settlement. On the other hand, once agreement is reached on the principle and means of using the deep sea minerals to help stabilize the world metals market prices, then one would expect resolution of all subsidiary questions in a logical and more rapid manner. Since the unstable market affects both developed and developing nations, it is in the interests of both to adopt the premise of stabilization, provided the strategy of stabilization appears to be a feasible one.

Even if one adopts the long-term view, as did the U.N. in its Secretary General's Report on the Economic Effects of the Deep Sea Minerals,[22] the shorter term commodity fluctuations are important. It is the purpose of the Law of the Sea Conference to provide legal principles and machinery with some enduring qualities. The performance of the international regime must be such that it can deal effectively with the initial shorter term economic problems as well as the long-term issues or a crisis of confidence in the usefulness of the regime will result. The attention span of the lesser developed countries is too short to wait for long-term market expansion. If the international regime is to succeed and be supported in the long run, considerably more attention must be paid to the impact of the deep sea minerals on the commodity cycles.

FOOTNOTES

1. See "United States Policy for the Sea Bed," Statement by President Nixon, *Department of State Bulletin,* 15 June 1970, p. 737-738.
2. For a history of the 1958 conventions, see B.F. Oxman, "The Preparation of Article 1 of the Convention on the Continental Shelf."
3. An example of this is the treaty to prohibit emplacement of weapons of mass destruction on seabed and ocean floor. U.N. Resolution 2749 (XXV) (A/C.1/544). This was adopted 108 to 0 with 14 abstentions. No nation had emplaced such weapons prior to adoption. Only the United States had both the technology and the strategic need to do so. The domestic political support to do so was lacking, hence it was not viable. Thus no nation had an interest in emplacing such weapons, and agreement was relatively quickly reached.
4. F. Wang, "Mineral Resources of the Sea," U.N. Report ST/ECA/125, dated April 1970.
5. There are several sources on this, including *Ocean Science News,* 15 October 1971.
6. David B. Brooks and Barbara S. Lloyd, "Mineral Economics and the Oceans," *Proceedings of a Symposium on the Mineral Resources of the World Ocean,* University of Rhode Island Occasional Publication No. 4, Kingston, R.I., 1968.
7. U.S. Laws, Statutes, etc., *Marine Resources and Engineering Act,* Public Law 89-454, 89th Congress, 2d sess. (Washington: U.S. Govt. Print. Off., 1967), p. 204.
8. David B. Brooks, *Low Grade and Non-Conventional Sources of Manganese* (Baltimore: Johns Hopkins Press, 1966).
9. J.C. Burrows, *Cobalt: an Industry Analysis* (Lexington, Mass.: Heath, 1971).
10. For an analysis of this trend of thinking as exhibited in the voting patterns of developing countries, see almost any paper by Robert L. Freidheim, including "Ocean Science in the United Nations Political Arena," Professional Paper No. 50, Center for Naval Analysis, June 1971.

11. For an excellent exposition of the Dynamic Reserve Index see William W. Behrens, "The Dynamics of Natural Resource Utilization," Club of Rome *Project on the Predicament of Mankind,* May 1971.

12. J.W. Shuster, "Copper Price Behavior in the Short Run 1949-1966," M.S. Thesis, Massachusetts Institute of Technology, Cambridge, 1967.

13. Clifford E. Schatz, "Observations of Sampling and Occurrence of Manganese Nodules," Offshore Technology Conference 1971 Paper No. OTC 1364; also personal contact with C.E. Hollister, Woods Hole Oceanographic Institution.

14. For a current assessment of the technology for solving these problems see E.J. Lecourt, Jr., and D.W. Williams, "Deep Ocean Mining–New Application Oil Field and Marine Equipment," Offshore Technology Conference 1971, Paper No. OTC 1412; Yoshig Masuda, et al., "Continuous Bucket-Line Dredging at 12,000 Feet," Offshore Technology Conference 1971, Paper No. OTC 1410; A. Blake Caldwell, "Deep Sea Ventures Readying Its Attack on Pacific Nodules," *Mining Engineering* (Reprint volume number and date not available).

15. Alvin Kauffman, "The Economics of Mining," *MTS Journal,* v. 4, no. 4.

16. Thirty percent is a generally accepted figure for return on high-risk investments whose costs are not proven. Two hundred million dollars capital investment requirements have been announced by Deep Sea Ventures in "Ocean Firm Launches $100-200 Million Mining Venture," *Ocean Industry,* March 1969, p. 66-72. It is not uncommon for such announced values to be underestimated by 25 percent, hence this figure is considered conservative.

17. *Commodity Yearbook 1971;* U.S. Dept. of Interior.

18. F.L. Le Que Panel Statement; Draft Report of Pacem in Maribus 2.

19. Classnotes Course 15, 872 MIT, Assoc. Prof. D.L. Meadows.

20. This view differs from the generally used supply/demand elasticity of 1:1. Further, while cobalt and nickel markets are oligopolistic now, it is highly doubtful they would remain so in the face of an influx of deep sea minerals. The history of transition from dominated to free market is often one of violent oscillations (see footnote 12).

21. Classnotes Course 15.

22. U.N. Doc. A/AC.138/36.