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The concepts "ocean" and "law" do not mix easily. We prefer to think of the sea, like the wilderness, as the domain of rugged pioneers, whose opportunistic exploitation of natural resources we mask in romantic notions of daring and the spread of civilization. For centuries, "freedom of the sea" has governed the development of ocean law, but only the great maritime powers were able to make use of this "freedom." Ideals of communication and exchange between cultures were used to justify the creation of colonial empires. To the subject peoples, freedom of the sea was the equivalent of freedom of contract to the workers of industrial Europe and America: a doctrine of submission.

The developing nations of the world, including many former colonies, seek to scrap a "freedom" reminiscent of colonial times and, by means of a solid majority in the United Nations, to institute an allocation of ocean resources which favors their own development. These Third World demands coincide with increased dependence on ocean resources by all nations. In the past, the sea's economic significance was primarily as a medium for military and political rivalry, but technology has expanded the uses of the sea and the exploitation of its wealth, so that the seabed itself may be the object of a new wave of colonization.¹

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1. While this paper is concerned with seabed minerals, similar observations can be made with regard to the ocean fisheries. These historically have had great economic significance, but the former state of technology limited exploitation to local fisheries supplying the local population. Advancing technology has drastically altered this pattern:

[F]irst, the fishing fleets of the developed countries of the north have moved south, aided by the development of the long range, self-contained freezing trawlers, and of the integrated fleets of fishing and support vessels; second, the poorer countries are developing their own industrial fisheries, especially those countries which have an advancing technology but still have fishermen prepared to work for long hours under difficult conditions for low wages. For example, Korean longline tuna vessels fish all over the world, Ghana has an increasingly efficient fleet of large factory trawlers operating as far afield as Morocco, while Peru has a fish-meal industry capable of catching and pro-
Developing states have met the threat of seabed colonization by advocacy of two principles which, at least in methodology, are diametrically opposed. Coastal states among developing countries have tended to extend their territory by appropriating adjacent maritime zones at distances from shore hardly entertained until recently, thus forestalling colonization by preemptive claims. There is also virtually universal support for the proposition that a limit must be established beyond which national or private appropriation is to be prohibited altogether. This part of the seabed would become “The Common Heritage of Mankind.” The developing countries demand that exploitation of this public international domain be controlled by an international authority, with primary consideration given to their own needs.

Study should begin with an analysis of the seabed resources involved, since the size and nature of the stake will also shape policy concerning the property regime to be adopted. The various interest blocs are then described, with special attention to the United States and the developing countries. The eventual regime must be responsive to the environmental and economic impact of seabed mining; examination of these issues demonstrates the feasibility of a relatively independent international seabed resource authority. The concluding section of the Comment outlines basic policy choices in structuring that authority.

I

MINERAL RESOURCES OF THE SEABED

Valuation of the seabed’s non-living resources is a game played with very large numbers: consider, for example, the placer deposits of cessing in three weeks a weight of fish equal to the entire annual United States catch. Gulland, *Fishery Management and the Needs of Developing Countries*, in *WORLD FISHERIES POLICY* 175, 176 (B. Rothschild ed. 1972).

2. Ironically, an industrialized coastal nation, the United States, was one of the first to extend its jurisdiction, while stopping short of an outright appropriation of the seabed. The Truman Proclamation laid claim to “the natural resources of the subsoil and seabed of the continental shelf . . . contiguous to the coasts of the United States.” Presidential Proclamation No. 2667, Sept. 28, 1945, 3 C.F.R. 67 (1943-1948 Comp.). Several Latin American states quickly followed suit, many with much broader claims. For a discussion of these and subsequent claims, see K. Hjertonsson, *The New Law of the Sea* (1973).

3. This term as applied to the seabed is the contribution of Ambassador Arvid Pardo of Malta, used initially in his memorandum supplementing a note verbale addressed to the Secretary-General of the United Nations. U.N. Doc. A/6695 (1967). The “Common Heritage” formula has become the starting point of all subsequent discussion, but its content remains nebulous, as apparently was its originator’s design. See Pardo, *Some Considerations on the Need for and the Requirements of an International Regime for the Sea-Bed and the Ocean Floor*, in *SYMPOSIUM ON THE INTERNATIONAL REGIME OF THE SEA-BED* 363, 378-79 (J. Sztucki ed. 1970).
gold, estimated at about five million tons, or a value at current prices running to trillions of dollars.4 The resources also take surprising forms, such as the enormous quantities of fresh water trapped in continental shelf sediments5 and the mineral-rich brines and muds discovered in a depression of the floor of the Red Sea.6 But the cost of recovery for most of these resources still prohibits their exploitation. The present race to the seabed was initiated chiefly through concern for one class of deposits, the hydrocarbons.7 However, the history of offshore exploitation of hydrocarbons reveals two trends of great significance to seabed resources generally.

First, technology for underwater exploitation has advanced with remarkable rapidity. One author, writing in 1974, noted that the underwater production of petroleum had attained the level of the overall production in 1948.8 Exploitability has also been achieved at progressively greater depths. A study by the National Petroleum Council in 1969 predicted that “a technical capability will be developed to provide a complete system for exploration and exploitation . . . in water depths approximating 4,000-6,000 feet (1,219-1,819 meters) within the next decade, if warranted by economic factors.”9 These figures far exceed the seaward depth of the continental shelf, which typically drops off into the continental slope at about 130 meters.10 Exploitation, once limited to the shelf, may now be conducted on the continental margin (which includes the shelf and slope) and beyond.

Second, national claims, either to control of the resources or to full sovereignty over the seabed, have coincided with the advances in exploitability. Some countries claim rights over the continental shelf without defining the geographic extent of the zone covered: e.g., Do-

6. Id. at 79.
7. FRIEDMANN, supra note 4, at 19.
8. R.-J. DUPUY, THE LAW OF THE SEA 13 (1974). An increasing percentage of petroleum production is derived from offshore deposits. For example, offshore oil and gas production in the United States, which in 1956 represented one percent of the total, accounted for 10 percent of production in 1966 and 15 percent in 1969. On a worldwide basis, offshore production had already reached the 15 percent figure as of 1966. FRIEDMANN, supra note 4, at 20. Offshore drilling presently yields 19 percent of total world output, “but in the years ahead, probably in the late 1980’s, it is expected to provide at least half the world’s production.” Gardner, Offshore Oil—Only the Beginning, 72 OIL & GAS J., May 6, 1974, at 123, 125.
10. FRIEDMANN, supra note 4, at 10. See id. at ch. 2 for an exposition of oceanbed topography.
minican Republic (1952), Iran (1955). Other countries incorporate in national legislation one of the two criteria for demarcation in the Convention on the Continental Shelf: e.g., Israel (1953), Honduras (1965), Argentina (1966)—exploitability; Pakistan (1950), Portugal (1956)—200 meter depth. Several Latin American countries, such as Peru (1947) and Chile (1947), extended their sovereignty over the seabed up to a distance of 200 miles from the coast and did not subsequently ratify the Convention on the Continental Shelf. Forty-nine countries have ratified, fully or with reservations, the Convention on the Continental Shelf; and as shown in the preceding paragraph, the Convention's exploitability test, if applied without regard to the requirement of adjacency, can be transformed by advancing technology into a rubber boundary.

That hydrocarbon deposits are not limited to the continental shelves, as evidenced by the recent discovery of oil in the Gulf of Mexico at a water depth of over 3,500 meters, in itself suggests that further appropriations of the seabed will be made. But what really focuses attention on the seabed beyond continental shelves and margins is the wealth of manganese dioxide concretions, commonly called nodules. These occur at great depths on the surface of the seabed, so that unlike hydrocarbon deposits no drilling is involved in their exploitation. The nodules are conservatively estimated to cover 25 percent of the seabed to a volume of 600 billion tons.

The Appendix to this Comment reproduces certain much-quoted figures concerning the tonnage of various metals that is probably con-

11. Dupuy, supra note 8, at 67.
14. Hjertansson, supra note 2, at 22.
16. Alexander, supra note 5, at 78.
17. Mero, Potential Economic Value of Ocean-Floor Manganese Nodule Deposits [hereinafter cited as Nodule Potential], in Papers from a Conference on Ferromanganese Deposits on the Ocean Floor 191, 195 (D. Horn ed. 1972). This collection contains 30 essays and abstracts, together with bibliography, dealing with all aspects of the nodules; it will hereinafter be cited as Ferromanganese Deposits.
18. Dupuy, supra note 8, at 26-27. The classic, if now somewhat dated, study of this resource estimates the nodule tonnage for the Pacific Ocean at 1.7 trillion tons. J. Mero, The Mineral Resources of the Sea 174-75 (1965). Mero was possibly the first person to recognize in the nodules a potential mineral resource, and his book captures the imagination by his style of presentation as much as by the content. "Even if only about 1% of the nodules in the Pacific Ocean prove economic to mine, the reserves of many metals in the nodules will still be measured in terms of thousands of years at the present rates of free world consumption." Id. at 234. "[I]n many cases, the elements are accumulating in the nodules faster than we could consume them . . . ." Id. at 279. See also Nodule Potential, note 17 supra.
tained by the nodules. It suffices to note here that the nodule reserves of several vitally important metals, including aluminum, manganese, copper, nickel, and cobalt, multiply known land reserves of the respective metals by a factor of thousands or even hundreds of thousands. While it would be misleading to describe any of these metals as presently in acute shortage, the significance of the nodules is further illustrated by the fact that known land reserves of copper and cobalt are each equivalent only to a 40 years' supply, based on the 1960 world rate of consumption.\(^1\)

Accepting LaQue's conservative projection of 1985 as the beginning of commercial exploitation of the nodules\(^2\) and considering also the preliminary exploration that will take place before that date, pressure for appropriation or unilateral licensing of the seabed beyond the continental margins may be expected to rise rapidly. But developing countries may not be able to maintain such claims. These countries could not point for justification either to contiguity or present dependence on the resource, as they did in claiming management rights over coastal fisheries. They lack capital to finance their own exploitation,\(^3\) and they lack navies to carry out the policing necessitated by the fact that the collection of nodules can be accomplished from migratory vessels, in contrast with the durable or permanent installations required for production of hydrocarbons.\(^4\) Many developing countries are land-based producers of the metals found in manganese nodules, and the alternate source of supply may lower the prices received for these metals.\(^5\) But that is all the more reason why industrialized states which presently import these metals will likely press their own right to exploit the seabed, while vigorously resisting Third World attempts to limit their prerogative.\(^6\)

\(^{19}\) See Appendix infra. The land reserves may meet demand for much more than 40 years, however, as new deposits are discovered, extractive techniques improved, and rising prices make economic the mining of lower grade ores. MERO, supra note 18, at 276.


\(^{21}\) For the exploitation of manganese nodules, "capital costs are likely to approximate $100 million." Christy, A Social Scientist Writes on Economic Criteria for Rules Governing Exploitation of Deep Sea Minerals, 2 INT'L LAW. 224, 228 (1968). More recent estimates have been much higher. One industry official placed total development and capital funding requirements at $300 to $500 million. Statement of J. Wenzel, Current Developments, infra note 80, at 10. But see note 141 infra and accompanying text.

\(^{22}\) DUPLU, supra note 8, at 13.

\(^{23}\) Christy, supra note 21, at 228; U.N. Doc. TD/B/C.1/170 paras. 11-18 (1975).

\(^{24}\) For industrialized states, exploitation of the seabed may secure to them the self-sufficiency as to mineral resources which in large part prompted 19th century colonialism. The United States, albeit mineral-rich as compared to Western Europe, is
For these reasons, the only way developing countries are likely to share in the benefits from exploitation of seabed minerals is through some form of international profit-sharing. For example, an international seabed resource authority, functioning as a kind of registry, could redistribute funds derived from licensing; or the authority could realize revenues directly through its own exploitation of the resource. But judging from the history of offshore hydrocarbon production, if there is to be any meaningful internationalization of seabed minerals, it must take place soon.

II

INTEREST BLOCS

The obvious confrontation is between industrialized countries and developing countries, but there are many rifts that divide the two groups internally, as well as bonds of interest which unite some sections of one group with some in the other. This crossing of factional lines merits close attention because it suggests possibilities of compromise along which agreement may be reached.

For those few countries with the capital, technology, and maritime strength required for exploring and exploiting blocks of the seabed, it might seem logical to press for a seabed regime that amounts to colonization in everything but name. According to this view, the self-interest of industrialized countries would best be served by confining national sovereignty to a narrow coastal band and giving miners open access to seabed minerals. International control of the seabed beyond the zone of national sovereignty would be minimized. This arrangement derives logically from traditional concepts of freedom of the sea. The “Common Heritage” doctrine would thus be analogized to freedom of the sea, and exploitation of the seabed would take place under the same rule-of-capture principles as fishing in the high seas, that is, regulated only by such bilateral and multilateral conventions as states may freely choose to conclude among themselves. While lawyers make fine distinctions between “property rights” and “resource jurisdiction,” the exploiting state would effectively control the seabed area during the term of exploitation.

The extreme position outlined above has been advocated by the Soviet bloc, which has been a model of consistency in opposing

at present totally dependent on foreign sources for its supply of cobalt, manganese, and nickel, and partially dependent for aluminum and copper. Alexander, supra note 5, at 80, 85. Manganese nodules supply all five metals in abundance. See text accompanying note 19 supra and Appendix infra.


26. Id. at 421-24.
international control of the seabed. This bloc (consisting of Bulgaria, Byelorussia, Czechoslovakia, Hungary, Poland, Ukraine, and the Soviet Union) was alone in voting against a General Assembly resolution deciding to convene a conference in 1973 to deal with the establishment of an international regime for the seabed. A resolution declaring the seabed beyond national jurisdiction to be free from any claim or exercise of national sovereignty was passed in the General Assembly by a vote of 108 to none, but the Soviet bloc abstained. And the Soviet bloc, together with virtually every other industrialized country, voted against a resolution declaring a moratorium on seabed exploitation pending establishment of an international regime.

Significantly, the Soviet bloc has stood alone among industrialized countries in its hard line against creation of an international seabed resource authority. The United Kingdom, France, and the United States, for example, have long since espoused the concept of an international agency with at least the power to allocate areas for exploitation. France and the United States have also indicated willingness to accept the control of seabed resources by the coastal state within 200 miles of its coast.

The official United States position, as reflected by President Johnson more than a year before Ambassador Pardo's note verbale, actually anticipated the latter's "Common Heritage" formulation:

[U]nder no circumstances . . . must we ever allow the prospects of rich harvest and mineral wealth to create a new form of colonial competition among the maritime nations. We must be careful to avoid a race to grab and to hold the lands under the high seas. We must

27. The "Soviet bloc" does not include a number of socialist states, for example, Albania, Cuba, Mongolia, Romania, and Yugoslavia. The latter has aligned itself with the Group of 77 (see text accompanying note 51 infra); another Communist state, the People's Republic of China, in common with many developing countries, has claimed the control of ocean resources within 200 miles of its coast. Dupuy, supra note 8, at 22. In like manner, many allies of the United States, notably the Latin American countries, do not share its resistance to assertions of sovereignty over the seabed.

33. See note 3 supra.
ensure that the deep seas and the ocean bottoms are, and remain, the legacy of all human beings.\textsuperscript{34}

Why are many industrialized nations, the United States in particular, ready and even anxious to forego an open access regime for seabed minerals, a regime which would effectively reserve to them the lion’s share of the resource? While the parsing of reasons behind the policies of nations necessarily involves a degree of speculation, the present widespread acceptance among industrialized states of internationalization of the seabed seems to depend on a variety of military and economic considerations.

There is a question of long-term security, that is, how stable a regime of \textit{laissez-faire} is likely to be, given that it would be deeply and increasingly resented by the overwhelming majority of the international community. “[A]lthough a regime of unrestricted access to, and exploitation of, the sea-bed beyond a narrow coastal belt can be imposed and maintained through the exercise of power, the political cost of this exercise of power would grow and is likely in the long run to become intolerable.”\textsuperscript{35}

Long-term considerations often yield to the prospect of immediate gains, but shorter-term considerations also support an international seabed regime. Either open access or colonization is apt to produce conflicts among competing users. Even assuming the parties would resolve all disputes peacefully, negotiations would be long and expensive, with little likelihood of being respected by non-parties. The resultant insecurity of tenure would add to the cost of exploitation and the difficulty of attracting capital. Open access, modified by a number of bilateral and multilateral conventions, now governs ocean fisheries, and the rapidly growing list of overfished stocks testifies to its failure.\textsuperscript{36} Seabed minerals are not, like fish, a migratory resource, but a \textit{laissez-faire} mining regime would probably be accompanied by overcapitalization, poaching on prime sites, reckless disregard of environmental impact, and other problems characteristic of the common pool.\textsuperscript{37}

\textsuperscript{34} Remarks at the commissioning of the new research ship, the “Oceanographer,” July 13, 1966, in \textit{WKLY. COMPL. PRES. DOC.} 930, 931.

\textsuperscript{35} Pardo, \textit{supra} note 3, at 368.

\textsuperscript{36} \textit{See} Friedmann, \textit{Selden Redivivus—Towards a Partition of the Seas?} 65 \textit{AM. J. INT’L L.} 757, 763 n.18 (1971). Dupuy argues that, with respect to the ocean fisheries, 20th century cultures have retained the habits of the fourth millennium B.C.—we content ourselves with hunting instead of raising the living species of the sea, which, though it covers 71 percent of the surface of the globe, furnishes only two percent of our food. Despite the modest level of this harvest, it is destroying the biological resources because of the primitive methods employed, which exclude any concern for rational cultivation. Dupuy, \textit{supra} note 8, at 10.

\textsuperscript{37} The possible incidence of common-pool problems in connection with seabed mining is discussed at notes 145-58 \textit{infra} and accompanying text.
The question of military security also weighs heavily with the United States. The strategic balance at present depends on submarine weapons.\textsuperscript{38} The United States fears that if nations are allowed to assert jurisdiction over portions of the seabed for the purpose of exploitation, they will by the process dubbed "creeping jurisdiction"\textsuperscript{39} attempt to regulate military activities, such as passage of submarines, on or above those portions.\textsuperscript{40}

Thus, the United States and many other industrialized countries favor an international mechanism for the purpose of limiting assertions of jurisdiction and allocating claims to countries that apply for exploitation permits; the international organ administering this process would serve to record claims and settle disputes, while the actual exploitation would be carried out by countries or private parties certified by countries. The United States in particular seeks an international regime for the purpose of limiting the quantum of jurisdiction which might otherwise be claimed by exploiting nations. This arrangement would favor American military interests without seriously impinging on private American interests in the development of minerals from the seabed.\textsuperscript{41}

But minimizing international disputes and assuring American military interests, however strongly these goals are supported by the State and Defense Departments, may not finally determine United States policy where the interests of the American petroleum and hard mineral industries are at stake. These industries favor unilateral licensing,\textsuperscript{42} and they are fearful that the seabed resources will be extensively mined by other industrial nations while the United States vainly marks time in seeking international regulation.\textsuperscript{43} The industries' views are shared by the Department of Interior, which as early as 1970 had issued exploration permits for areas extending as far as 300 miles from the coast at depths ranging from 198 to 1,525 meters.\textsuperscript{44}

\textsuperscript{39} Newton, supra note 31, at 82 n.28.
\textsuperscript{40} See Friedmann, supra note 4, at 50. \textit{But see} Coase, infra note 131, at 1163-64. Fears that United States oceans policy would be wholly dominated by military considerations have proved unrealistic. See note 32 supra and accompanying text. Also, President Ford has recently signed into law a 200 mile fishery conservation zone. 12 \textit{Wkly. Comp. Pres. Doc.} 644 (Apr. 19, 1976).
\textsuperscript{42} See note 46 infra and accompanying text.
\textsuperscript{44} Friedmann, supra note 4, at 62-63, 98.
The petroleum and hard mineral industries also carry great weight
in the United States Congress, and obstacles to American acceptance of
international seabed regulation may take the form of inconsistent con-
gressional legislation or failure to achieve approval by the two-thirds
majority of the Senate necessary for treaty ratification. Preliminary
studies and statements formulated by the Senate and the House of
Representatives have backed the position taken by industry.45 National
licensing of seabed exploitation beyond the continental margins would
have been instituted had any of a series of deep seabed hard mineral
resources bills been enacted.46 Opponents argued in part that unilateral
action by the United States should be postponed at least pending the
outcome of the Third United Nations Conference on the Law of the
Sea;47 that Conference has met at Caracas in 1974, Geneva in 1975, and
New York in 1976 without reaching agreement on a seabed regime. Cer-
tainly the likelihood of direct congressional action has grown and may
include rejection in the Senate of whatever treaty finally evolves. The
continuing energy problems of the United States may also prompt uni-
lateral licensing.

The threat of unilateral licensing lies thinly veiled behind the
announced positions of industrialized countries at the Law of the Sea
Conference. The intention is "to at last induce the delegations to get
down to business. If they see that Uncle Sam does not mean to be tied
down by procedural wrangles or endless debate or unworkable sugges-
tions, progress might begin."48 The "unworkable suggestions" which the
speaker had in mind are glossed earlier in his testimony as precisely
the control of exploitation of seabed minerals by an international
mechanism favored by the vast majority of developing countries:

France, the United Kingdom, the USSR and the United States dele-
gations have made it clear that they would not support a multilateral
convention with such a provision. This in effect means that if the
sponsors of the exclusive Authority insist, there will not be a realistic
multilateral convention.49

The perceived intransigence of developing countries in stipulating for

45. See, e.g., SPEC. SUBCOMM. ON OUTER CONTINENTAL SHELF, 91ST CONG., 2D
SESS., REPORT TO THE SENATE COMM. ON INTERIOR AND INSULAR AFFAIRS (Comm. Print
46. E.g., S. 2801, H.R. 13904, 92d Cong., 1st Sess. (1971). The current version is
47. Knight Statement, supra note 43, at 59-60. Since this testimony, Knight has
completely reversed his position. He now espouses unilateral action by the United States
to prevent the "underdeveloped nations [from] plundering the wealth and destroying the
political institutions of western civilization." 121 CONG. REC. 18,827 (daily ed. Oct. 28,
1975).
49. Id. at 37.
exploitation by an international mechanism is thus met with the perceived intransigence of industrialized countries in rejecting that possibility out of hand.

A bemused observer might well inquire what difference it makes who supervises the exploitation once it is decided who shares in the revenues and in what proportion. The answer requires fuller consideration of the interests of developing countries.

Those countries which in Cold War terminology constitute the Third World have acquired another designation, especially in the context of the United Nations: the Group of 77.50 With the exception of Yugoslavia, it consists entirely of states from Africa, Asia, and Latin America, united to pursue their common interests in the United Nations system and now numbering over 100 countries51 out of a total United Nations membership of 138.

With this majority, the Group of 77 clearly stands to enhance its position in world affairs with each increase in the effective power of the United Nations and allied international organizations. For the Group of 77, the functional difference between an international authority that would itself exploit the resource and an agency for collecting license fees is as great as that between having a real say in policy determinations and accepting gratuities, like loyal retainers at the hands of their betters. The Mexican delegate expounded this position succinctly:

[T]he international community, as the owner of the area and its resources, [has] the right to share directly in their development until it [acquires] the technical and financial means to exploit them by and for itself. [N]othing [can] justify a system of operating permits which would assign to the legitimate owner the role of a mere spectator.52

Developing countries' interest in management of the deep seabed is not simply rhetorical. Pollution of the sea as a result of mining operations would potentially affect all countries; accordingly, the choice of liability rules and environmental standards should be made by the international community, not solely by the exploiting states. Perhaps developing countries are wrong to attach such importance to power over policy; if so, why are industrialized countries determined not to give it to them?

51. Id. One hundred and three members of the Group of 77 participated at the Caracas Session. Miles, An Interpretation of the Caracas Proceedings, in CARACAS AND BEYOND, infra note 82, at 39, 40-41.
52. Declaration of the Mexican delegate, U.N. Doc. A/AC.138/SC.I/SR.40, at 116. (Mar. 20, 1972). It is precisely this characteristic of an open access regime for seabed mining, where "the owner of the area" has no control over the exploitation, that supports an analogy to traditional colonialism.
Besides the ultimate goal of strengthening its voice in world affairs, the Group of 77 also has two immediate objectives in pressing for a maximalist seabed regime, *i.e.*, a regime with maximum international control. One objective is to assure that marine technology is transferred from industrialized to developing countries. Arguing from General Assembly declarations, such as Resolution 2749,\(^5\) that the exploitation of the seabed should be conducted for the benefit of all humanity, the Group of 77 holds that exploiting members of the international community have an obligation beyond the redistribution of financial profits: namely, an obligation to pool the results of scientific research carried out in the international zone, to train technicians from developing countries, and to share the different technological processes related to oceanography.\(^5\)\(^4\)

The delegate from Nicaragua has argued that this broad program for technological transfer should be included in the basic conditions of any international agreement on seabed management:

The principle of equality should be applied as early as the stage at which the possibilities for profit-sharing [are] identified; accordingly, attention should be paid to the limitations imposed on countries by the inadequacy of their human resources, skills and technology and the difficulties resulting from restricted economic potential. The criteria for dealing with the common heritage . . . should relate not only to the distribution of the ultimate profit, but also to the factors which [determine] its volume, its terms and conditions and its nature.\(^5\)\(^5\)

The flow of money cannot of itself meet the needs of development, but "its association with technological capital has the effect of creating wealth which feeds on itself after a certain level of development is reached."\(^5\)\(^6\)

The other immediate objective in seeking a maximalist international seabed regime is to safeguard the interests of land-based producers of seabed minerals. Whatever depressive effect the production of seabed minerals would have on prices in world markets must be borne mainly by developing countries, absent appropriate adjustments. A study prepared by the Secretary-General shows that in the 1960's well over half the total world exports of copper and manganese ore came from developing countries, while for nickel ore the figure was over 90 percent.\(^5\)\(^7\) Unquestionably a major ground for the resistance to a maximal-

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53. See note 29 *supra* and accompanying text.
54. DUPUY, *supra* note 8, at 28-29.
56. DUPUY, *supra* note 8, at 29 n.11.
57. Possible Impact of Sea-Bed Mineral Production in the Area Beyond National Jurisdiction on World Markets, with Special Reference to the Problems of Developing
ist international regime by industrialized countries is the fear that such a regime would be manipulated by land-based producers to forestall seabed exploitation altogether. This possibility was discussed at the hearings on S. 2801\(^5\) by various witnesses\(^6\) and was reiterated in an analysis of the Caracas Session of the Law of the Sea Conference by two American negotiators.\(^6\)

This fear seems based on the kind of Cold War thinking that divides the world into monolithic entities whose members are bound in an absolute cohesion. Whether or not such entities exist, the Group of 77 certainly is not one. Many of its members are not net exporters of minerals; these countries, such as Turkey, Thailand, Afghanistan, Pakistan, Uruguay, Sudan, and Tanzania,\(^6\) have a real stake in the sharing of profits derived from seabed exploitation. Furthermore, the interests of land-based producers of hydrocarbons seem adequately protected by

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Countries: A Preliminary Assessment, U.N. Doc. A/AC.138/36 annex I, tables A-3, 4, 5 (1971) [hereinafter cited as Impact Assessment]. The possibility of compensatory financing by the international mechanism for net exporters of minerals among the developing countries is discussed at text accompanying notes 67-68 infra. The study of the Secretary-General also noted, however, that of the various markets considered, only the prices of manganese and cobalt were likely to drop in the near future as a result of competing seabed production. Impact Assessment paras. 14-26. The most recent study of the Secretary-General confirms this finding. U.N. Doc. A/Conf.62/37 para. 35 (1975).

58. See note 46 supra and accompanying text.
60. Stevenson & Oxman, supra note 32, at 9:

The essential problem is that all of the proposals [for a maximalist regime] say little if anything about how the mining system would in fact work. . . . In particular, the essential interest of consumers in assuring that exploitation does take place and that the minerals are freely available on the market without artificial restraint or price-fixing is not protected if there is no assurance that the conditions of exploitation are workable. It has been argued that since the vast majority of states are direct or ultimate consumers of the metals involved, leaving these matters to the Authority is not prejudicial. However, the political power of the land-based producers within the Group of 77 in this negotiation, and the absence of more vigorous and widespread assertion of consumer interests at the Special Session of the UN General Assembly in the spring of 1974, would indicate the opposite.


61. The Impact Assessment, supra note 57, paras. 59, 94-97, lists the importance of various minerals as foreign exchange earners for developing countries. Division is made according to whether the given mineral was a “major” foreign exchange earner (above 10 percent of the value of the country’s total exports), an “important” earner (three to 10 percent), or a “minor earner” (less than three percent). Of the countries mentioned in the text, only for Uruguay did any of the listed minerals represent even a minor foreign exchange earner. Petroleum exports earned 0.3 percent of the value of Uruguay’s total exports.
the emerging consensus on a 200 mile economic zone,\textsuperscript{62} since hydrocarbon exploitation in the abyssal depths beyond the 200 mile zone is still a distant prospect.\textsuperscript{63} Current hydrocarbon producers might therefore support seabed exploitation by way of assuring the supply of hard minerals for their own industrialization.

Twenty-three developing countries export substantial quantities of manganese, copper, and nickel,\textsuperscript{64} all of which would be yielded by exploitation of manganese nodules. They alone out of the Group of 77 would potentially stand to gain from non-exploitation of the seabed, and even that depends on their ability to price their exports in excess of the added income they would derive from seabed production.

It appears to this writer that securing these countries from harmful competition by seabed miners should be a primary concern no matter what seabed regime is ultimately chosen. These countries are among the world's poorest; only two out of the 23 had a per capita gross domestic product in 1968 exceeding $US600 per year,\textsuperscript{65} and for five out of the 23, with a population at mid-year 1967 of about 650 million, the figure was less than $US100 per year.\textsuperscript{66} Any system of seabed exploitation which in effect redistributes income from these desperately poor nations to the wealthy would be inequitable and might result in reprisals by the Third World.

Moreover, the interests of land-based producers can be protected without resort to non-exploitation. One suggestion to prevent transfer of real income from producers to consumers, without interfering with the benefits of technological progress, would be for the international mechanism to allocate revenues from exploitation as compensatory fi-

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\textsuperscript{62} U.S. DEP'T STATE, A CONSTITUTION FOR THE SEA 10-11 (1976): "The strong consensus among developed and developing nations alike is for extensive coastal state control over [marine] resources out to 200 miles from shore." See also 1975 Geneva Session, supra note 60, at 764.

\textsuperscript{63} FRIEDMANN, supra note 4, at 25.

\textsuperscript{64} The countries are: Bolivia, Brazil, Chile, China (Taiwan), Cuba, Gabon, Ghana, Guyana, Haiti, India, Indonesia, Ivory Coast, Mexico, Morocco, Nicaragua, New Caledonia (Territory of France), Peru, Philippines, South Korea, Trinidad-Tobago, Uganda, Zaire, and Zambia. Impact Assessment, supra note 57, tables 11-13, at 33-36 (based largely on 1969 data). Nodules would also become an important source of cobalt supply, but cobalt is a relatively minor item in world trade. Cobalt recovery is a secondary activity of large copper mining operations in three developing countries (Morocco, Zaire, and Zambia), amounting to less than six percent of their total exports. Id. para. 19.

\textsuperscript{65} Chile, Trinidad-Tobago. Possible Methods and Criteria for the Sharing by the International Community of Proceeds and Other Benefits Derived from the Exploitation of the Resources of the Area Beyond the Limits of National Jurisdiction, U.N. Doc. A/AC.138/38 table 2 (1971) [hereinafter cited as International Sharing].

\textsuperscript{66} The countries are: Haiti, India, Indonesia, Uganda, and Zaire. Id.
nancing to land-based exporters of seabed metals. If necessary, a tax on imports of seabed metals could also be imposed, the tax to be related to the decrease in metal price from an agreed initial "equilibrium" level. An arrangement of this kind could provide a supply of metals to meet increased demand from consuming countries, at unit prices equal to or less than what they presently pay, without loss of income by producing countries.

One reason for this extended treatment of the problem of land-based producers is to indicate where rifts might occur within the Group of 77. Another rift, potentially of nearly as great significance as the division between industrialized and developing countries, is the division between coastal and land-locked or shelf-locked countries. This division is accentuated by the methodological divergence between extension of national jurisdiction versus the Common Heritage concept. Insofar as the wealth of the seabed is immediately realizable only in the continental margins, both land-locked and shelf-locked countries are prejudiced by extensions of national jurisdiction. At the same time, the "discovery of the seabed" has enormously promoted the position of geographically disadvantaged countries by virtue of the Common Heritage concept, which attempts to eliminate discrimination between peoples arising from their different situations with respect to the sea. Augmented by the shelf-locked states, the land-locked states number about 40 and might muster the one-third of the votes necessary to block action at the Conference.

The potential strength of the geographically disadvantaged group has not materialized to date, probably out of reluctance to jeopardize the solid front so far presented by the Group of 77. A 200 mile economic zone for coastal states has attracted broad support, and the credibility of a maximalist international regime would seem proportionately diminished by the closure of this vast area adjacent to states' coastlines. The economic zone adopted should provide for part payment to the international authority out of total revenues, along the lines of the United States

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68. Id.
69. The phrase is taken from Dupuy, supra note 8, at 21.
71. Dupuy, supra note 8, at 21.
72. Note 62 supra.
73. 1 PACEM IN MARIBUS 2 (E. Borgese ed. 1971):
1 If an Ocean Regime controlled the dispositions of all resources beyond the traditional three-mile limit, it would possess billions of dollars of assets, even under existing technologies of recovery. If, on the other hand, its authority began 200 miles or more from every coastline, the present economic value of its resources would be negligible.
trusteeship proposal. This would permit redistribution of income to states without economic zones and might also fund the international authority’s own exploitation. But such an arrangement is very unlikely, absent strong pressure from geographically disadvantaged countries.

If the economic zone were to be reserved exclusively to the riparian state, numerous regional seas, such as the Caribbean, would become economic lakes, which riparian states could carve up among themselves or treat as undivided property of the group. Regional treatment could effect a conciliation between the interests of riparian and land-locked countries where the two groups are neighbors of a comparable level of development and arrange to share the benefits from the regional sea. This trend toward regionalism has long been evident among Latin American countries and was recently confirmed by the Declaration of Santo Domingo. Where such regionalism fails to materialize, the egalitarian force of the Common Heritage concept will have been substantially diluted by developing states, the very states that advocate it most strongly.

III

THE ENVIRONMENTAL IMPACT OF SEABED MINING

The environmental impact of seabed mining is largely conjectural at this time, although proponents of seabed mining have sometimes stated flatly that exploiting manganese nodules will not harm the marine environment. Proponents also claim that development of this resource may indirectly benefit the terrestrial environment in various ways. Our dependence on land mines for ores of the various nodule metals will be lessened. Manganese may replace lead as an antiknock additive in automotive fuels. Nodules can be used to cleanse stack gases in

75. See generally DUPUY, supra note 8, at 40-45.
78. E.g., Nodule Potential, supra note 17, at 192.
79. "[F]ull-scale development of these deposits as a source of industrial metals will allow society to close many of the sulphide mines on land which are presently a substantial source of air and land pollution . . . ." Id.
80. Hearing on Current Developments in Deep Seabed Mining Before the Subcomm. on Minerals, Materials and Fuels of the Senate Comm. on Interior and Insular Affairs, 94th Cong., 1st Sess. 246-48 (1975) [hereinafter cited as Current Developments]. John E. Flipse, the president of Deepsea Ventures, has indicated that his firm plans to recover manganese from nodules for this developing market. Id. at 21-22. According to Mero, the nodules might be used to convert unburned hydrocarbons in automobile
factories. An abundance of cobalt and nickel would make economically feasible the use of stainless steels, with great corrosion resistance, in place of carbon steel. But the glow of such anticipations is considerably dimmed by a realistic appraisal of the environmental hazards of seabed mining.

Removal of the nodules will not produce so gross a disturbance as is entailed by most kinds of terrestrial mining, since the dredge heads will cut only a few centimeters into the ocean floor; however, it does not follow that the environmental harm of seabed mining will therefore be negligible. The mining operation will have effects at the surface of the seabed and throughout the water column, especially the upper layers. These effects will vary, depending on the characteristics of the particular operation. Some destruction of marine life and release of sedimentary material at various points of the water column is inevitable, and these problems will be compounded if the mining operation includes either beneficiation or refining of the nodules at sea.

Collection of nodules will be accomplished by scraping the ocean floor with buckets or by use of a pumping system, but both methods

exhausts. *Nodule Potential, supra* note 17, at 202. Other researchers say the nodules can boost yields in petroleum refining operations. *Current Developments 248.*

81. *Nodule Potential, supra* note 17, at 201.

82. Remark of J. Mero in *Law of the Sea: Caracas and Beyond* 341 (F. Christy *et al.* eds. 1975) [hereinafter cited as *Caracas and Beyond*]; *Nodule Potential, supra* note 17, at 201.

83. Roels, *Will Nodule Mining Disturb the Marine Environment?* 8 *Marine Tech. Soc'y J.*, Sept. 1974, at 17, 18 [hereinafter cited as *Nodule Mining*]. Roels' study is a pioneer effort conducted on behalf of the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. NOAA continues to conduct research in this field; reports through April 19, 1976, on the progress of the Deep Ocean Mining Environmental Study ("Project DOMES") may be obtained by request from NOAA, Pacific Marine Environmental Laboratory, 3711-15th Avenue N.E., Seattle, Wash. 98105. The DOMES Project Preliminary Report, August 1976, will be available shortly from Marine Ecosystems Analysis Program Office, Environmental Research Laboratories, NOAA, Boulder, Colo. 80302.


Two principal types of deep mining systems are being developed. One, a mechanical system known as the continuous line bucket (CLB), consists of a long loop of cable to which specially designed dredge buckets are attached at intervals of 25 to 50 m. A traction drive (on the mining ship) moves the cable so that buckets descend into the ocean, are dragged across the seabed to scoop up nodules, and return to the surface to deposit their load.

A second, hydraulic recovery method consists of a length of pipe suspended from a mining ship; a sea floor device (dredge head) designed to collect nodules, screen out those larger than a certain size, and feed the rest to the bottom of the pipeline; and some means of pumping water up the pipeline with sufficient velocity (about 4 m/sec) to transport the nodules as well. The bottom device is either self-propelled or dragged across the bottom by the pipe string, depending on the design. Both conventional centrifugal pumps and compressed air injected into the pipe (air-lift pumping, in which the air
will result in destruction of macrobenthic organisms in the path of the mining machine. The depths at which mineable nodules occur, and the water column above such nodules, are typified by low biological activity, so that only a small fraction of the marine faunal biomass is potentially affected by the dredge heads. Despite these findings, the deep seabed, like desert, tundra, and other environments hostile to man, is not barren. It is the habitat of numerous animals, including echinoderms, coelenterates, molluscs, and sponges.

The marine benthos is an important ecological group because it occurs over most of the earth's surface and is of consequence in the economy of the sea. Benthic animals modify the physical and chemical properties of sediments.

Very little is known of these organisms and their role in the food chain. Their ability to repopulate dredged areas is speculative, since some of the species have extremely slow reproductive cycles. One way to counter this effect on larger organisms might be to mine any given area of the seabed in strips, so that organisms in the undisturbed strips can re-establish themselves in the adjacent strips raked by the dredge heads. Studies cited by the Department of the Interior have also

bubbles provide enough buoyancy to raise the entire column of water and nodules) are being considered.


86. B. HEEZEN & C. HOLLISTER, THE FACE OF THE DEEP 29, 441-42 (1971). Manganese nodules also accumulate in areas of greater biological activity, but there they tend to be buried by the rapidly accumulating biogenous and lithogenous sediments, so that they are limited both as to size and accessibility. M. GROSS, OCEANOGRAPHY 42 (2d ed. 1971).

87. Environmental Impact, supra note 85, at 36-37.


89. Draft Environmental Statement, supra note 84, at 2.124.

90. Id. at 2.141.

91. Nodule Mining, supra note 83, at 19. Tindarid callistiform, a benthic clam, requires 200 years to reach sexual maturity. Draft Environmental Statement, supra note 84, at 3.34.

92. Nodule Mining, supra note 83, at 19. The present state of seabed mining technology is such that a substantial portion of any given mining area will not be disturbed by the operation:

Sweep efficiency [the percentage of the area actually swept by the dredge
recommended the regulation of seabed mining to prevent depletion of species by aggressive exploitation.\textsuperscript{93}

The effect of seabed mining on the microbenthos is also speculative. Benthic bacteria play an important part in the food chain, releasing plant nutrients back into the system and converting detritus and dissolved organic matter into a particulate form that can be utilized by larger organisms.\textsuperscript{94} This bacterial activity results in the high nutrient level of deep ocean waters; the world's greatest fisheries are located wherever these waters, through the process of upwelling, rise to the surface.\textsuperscript{95} Seabed mining, in disturbing the bottom sediments, will upset the chemical and adsorptive equilibria between the sediment surface and the water column. Re-establishment of equilibria may require decades.\textsuperscript{96} How bacterial activity will be affected is yet to be determined.\textsuperscript{97}

Benthic bacteria may be affected in another respect, since the nodules, like coral reefs, are themselves habitats for various protozoans and other microbes, making the surface of the nodule "perhaps the most densely populated site on the deep sea floor."\textsuperscript{98} Moreover, these microbes now appear to play a significant role in the development of the nodules. Certain bacteria oxidize the manganous ion to an insoluble tetravalent state, which ion then precipitates onto the growing nodule; the resultant manganese oxide then acts as a scavenger, attracting other cationic components of nodules, such as iron, copper, cobalt, and nickel, which are known to adsorb strongly on manganese oxide.\textsuperscript{99} Concerning the hazards of human intervention in this cycle, one scientist ob-

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\textsuperscript{93} Siapno, \textit{Exploration Technology and Ocean Mining Parameters}, in \textit{Current Developments}, supra note 80, at 207, 238.

\textsuperscript{94} Id. at 2.127.

\textsuperscript{95} Id. at 3.26.

\textsuperscript{96} Id. at 3.9.

\textsuperscript{97} Id. at 3.9, 3.38-3.39; \textit{Nodule Mining}, supra note 83, at 18.


\textsuperscript{99} Ehrlich, \textit{The Role of Microbes in Manganese Nodule Genesis and Degradation}, in \textit{Ferromanganese Deposits}, supra note 17, at 63, 66. Ehrlich concludes:

The optimum requirements for biological catalysis of Mn(II) oxidation include available Mn(II) and oxygen and a low concentration of organic matter. The adsorption of Mn(II) by Mn(IV) and the subsequent oxidation of the adsorbed Mn(II) to Mn(IV) is the key to nodule growth.

\textit{Id}. Another researcher, Greenslate, suggests that nodules form around a skeleton of biotically derived tubules and chambers. \textit{Manganese Nodules (I)}, supra note 98, at 503.
serves that the bacteria "may be involved in an ecological unbalance as a result of large-scale nodule mining. If we visualize nodules as exerting an important control on the concentration of heavy metals in sea water at the water sediment interface . . . , then their removal is likely to result in an abnormal rise in heavy metal concentration." Conceivably, the increased ionic concentration could be offset by faster nodule formation.

Numerous factors may offset the locally detrimental effects on the seabed of ocean mining operations. It has recently been estimated that fewer than 10 ventures are likely to become operational within the next decade, and the seabed surface affected by their combined activity over a period of many years will still be a tiny percentage of the total surface area. Disturbance of sediments by such naturally occurring oceanographic phenomena as turbidity currents and upwelling, as well as slumping along continental margins and on highlands within ocean basins, takes place on a much larger scale than would result from seabed mining. But slumping, turbidity currents, and upwelling, though forces of great magnitude, tend to recur at specific localities, for example, at the mouths of rivers and along coasts, so that the effect of these forces in areas of interest to seabed miners may be small. "The significance of the human intervention is that an aggressive exploitation of the ocean floor may process, indiscriminately, large parts of the ocean basin whereas the natural processes are not uniformly distributed in

100. *Ferromanganese Deposits*, supra note 17, at 70. Ehrlich, like Roels, supra note 97, is uncertain what effects such an increase would have. Responding at a conference to Mero's paper (*Nodule Potential*, supra note 17), Ehrlich stated:

I think I would take issue with your statement that nodule mining in the sea, unlike mining on land, is a method that involves no environmental damage. I think we have no knowledge that it won't. . . .

There may be great permutation over the long range of mining in the sea, because we must not forget that the trace elements that the nodules contain . . . are vital to life in low concentrations, and I think these concentrations in the sea and in the sediment may be severely affected by large-scale removal of the nodules. . . .

I think it may have long-range consequences for the oceans as a whole. We have no idea on what the consequences of mining will be and this is something that needs to be investigated. If it does have an effect I think mining technology will have to take this into account and there may have to be modifications in the methods of mining.


103. *Id.* at 336-37; Draft Environmental Statement, supra note 84, at 3.6, 3.35.

104. *Gross*, supra note 86, at 37, 95. One study estimates that "roughly 0.1% of the ocean bottom—usually the same relatively limited vulnerable areas—are perturbed by slumping and turbidity currents every 100 years." Draft Environmental Statement, *supra* note 84, at 3.6 (emphasis added). *See also id.* at 3.23.
intensity or frequency. The biological consequences of the latter are known empirically to be capable of accommodation by the deep ocean life, but there is serious concern about the former's effect . . . "

Seabed mining will also affect upper layers of the water column because the dredge heads, in addition to stirring up sediment by their passage, will capture and transport a certain amount of sediment together with the nodules. This will occur under both the bucket and pumping systems, and the latter system will also bring quantities of near-bottom water to the surface. Such discharges could introduce foreign organisms and stimulate phytoplankton growth in the euphotic zone. Study to date has confirmed both effects. How substantial the consequences will be is unclear. The mining operation may prove beneficial (by acting as an artificial upwelling) or detrimental (if, for example, oxidation of sedimentary material produces anoxic conditions); or it may prove innocuous since preliminary findings indicate that the discharge from the mining operation will be very diluted after mixing with surface waters.

In addition to immediate inhibition or stimulation of biological activity, sedimentary discharges could indirectly but fundamentally disturb the entire marine food chain, for example, by interfering with light penetration in the euphotic zone and so influencing photosynthesis. The manganese nodules are typically associated with red-clay deposits. Red clay is extremely fine-grained; over 80 percent of its particles have a fundamental particle size of less than 30 microns in diameter, making it the finest of all ocean sediments. In its fundamental size, the sediment can remain in suspension "almost indefinitely" and, when discharged in the course of a mining operation, would turn the surface...

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105. Draft Environmental Statement, supra note 84, at 3.6.
106. Id. at 3.21-3.22.
107. Environmental Impact, supra note 85, at 36. The stimulation of phytoplankton growth is thought to be caused by increased concentrations of trace elements or release of sediment-associated vitamins. Draft Environmental Statement, supra note 84, at 3.28.
108. Environmental Impact, supra note 85, at 37. In another article derived from the same project, the authors note that, under certain conditions, mining effluent might have to be sprayed over the surface to ensure rapid mixing. Amos et al., Effects of Surface-Discharged Deep-Sea Mining Effluent, in Ferromanganese Deposits, supra note 17, at 271, 278.
110. MERO, supra note 18, at 127, 140.
111. HEEZEN & HOLLISTER, supra note 86, at 630-31.
112. MERO, supra note 18, at 122. Another writer estimates the sediment may remain suspended for a year. Manganese Nodules (II), supra note 84, at 646. "It is very important to note that it requires less current speed to maintain material put into suspension than to erode the same material off the bottom." Draft Environmental Statement, supra note 84, at 3.8.
of the ocean a reddish brown. Depending on how widespread mining activity ultimately becomes, tens of thousands of square miles of ocean may be affected. One cannot assume, however, that the effects of resuspension will be measured by the sinking rate of red clay in its fundamental particle size. This sediment tends to agglomerate in particles one to several orders of magnitude larger than the fundamental particle size. Unless resuspension somehow breaks down the agglomerate particles, the red clay should settle out of the mixed layer quite rapidly, possibly in a matter of days.

If large-scale disturbance of the euphotic zone were to occur, then seafloor mining would unquestionably have grave environmental consequences. Sunlight penetrates only the upper 100 meters or so of the water column; in this narrow layer, solar energy is harnessed by plants to begin the marine food cycle. All other life in the oceans depends on this first step.

From an ecological standpoint, the most important technological problem in raising the nodules will therefore be to minimize the amount of sediment brought to the surface. All systems under consideration have components to separate the nodule from surrounding sediment. The bucket system seems to have an advantage in that much of the finer sediment is washed out of the dredge buckets as they rise through the water column to the mining vessel. The pumping system will raise significant quantities of sediment unless trap valves are placed at intermediate depths in the pipeline. Since the raising of much sediment along with nodules would place an additional strain on mining equipment and cut down on the payload, the miners themselves will want to leave the sediment in place. But this is no great reassurance. By analogy, American tuna fishers do not want to capture porpoises along with tuna, but they have killed thousands of porpoises annually rather than abandon a large-scale method of taking tuna. Mining modifications in order to screen sediment must similarly be compatible with large-scale collection of the nodules.

115. E.g., a chute with water jets, heavy spring rake tines, a radial tooth roller, harrow blades and water jets, or spaced comb teeth. Id. at 3.20.
116. Id. at 3.21.
117. Id. at 3.21-3.22.
118. See Coggins, Legal Protection for Marine Mammals, 6 ENV. L. 1, 5-6 & n.18 (1975).
119. Nodule Mining, supra note 83, at 18.
Whatever one's assessment of the environmental risks involved in collecting the nodules, there is agreement that these risks will greatly escalate if all or a portion of the process of metal extraction takes place at sea. Refining yields vast quantities of waste from the nodules and chemical reagents employed in the metallurgical process. This waste would certainly be dumped into the sea rather than transported to land. Even if the bulk of the refining were performed at land-based plants, the mining operation would save transportation costs through on-site beneficiation, which would remove water and clay making up much of the nodules' weight.

American companies seem to have rejected, at least for the first generation of mine sites, the possibility of refining at sea. Reagents would have to be transported from land to the site; power supply and maintenance of personnel at sea for long periods are other complicating factors. However, industry has a strong incentive to overcome these problems, since there would be a substantial gain in the profitability of the venture if the desired metals could be extracted shipboard and the waste returned immediately to the sea.

The foregoing discussion shows that seabed mining will create hazards for the marine environment. From this standpoint, how may the industry best be regulated? There are three alternatives: no regulation, national regulation, and international regulation.

Unregulated mining operations would discharge quantities of sediment and tailings into the sea, with possibly severe environmental consequences. The industry might, in effect, sell its pollution right; for example, other users of the sea might pay the miners to make technological modifications or buy out the industry altogether. But it is difficult to imagine a market developing for pollution rights. The parties adversely affected by seabed mining are so numerous and so diverse that transactions costs would be high, and many potential buyers would defer in hopes that other buyers would acquire the right without the former having to contribute. Also, payment would probably have to be made to potential as well as actual miners. If no market develops, then a

120. Id. at 17; Frank, supra note 113, at 819; Manganese Nodules (II), supra note 84, at 646.
121. See MERO, supra note 18, table XXVII, at 179.
122. Frank, supra note 113, at 819.
123. Nodule Potential, supra note 17, at 200. The text by no means exhaustively enumerates the environmental hazards of seabed mining. Additional complications have been envisioned. "Systems with large energy requirements may require a nuclear reactor power source." Draft Environmental Statement, supra note 84, at 1.47. Whether on land or sea, "operations that involve discarding all but the copper and nickel must dispose of millions of tons of residues that contain manganese and other toxic metals in oxide form." Manganese Nodules (II), supra note 84, at 646. See generally Frank, supra note 113.
system of unregulated seabed mining would not mitigate detrimental effects of mining on the marine environment.124

If the industry were regulated by national legislation, then individual mining operations would be confronted with various standards of environmental protection. However, national standard-setting would quickly degenerate to the lowest common denominator. This is because a state could control all mining activity only within its own resource jurisdiction; an immediately adjacent mining operation might exploit under a much looser standard, probably without regard to harmful effects caused within the stricter state’s resource jurisdiction.125 A state with strict standards would only be pricing its nationals out of competition, and perhaps not even that since its nationals might be able to mine, or to invest in mining, under the flag of a less restrictive state.126 Unless states freely chose to maintain a uniformly high level of environmental protection, national standard-setting would do little to mitigate environmental detriments from seabed mining.

Regulation of the industry by international convention has the potential of achieving a high uniform standard of environmental protection, such as is unlikely to evolve through the practice of individual states or an unregulated industry. Moreover, neither industrialized nations, who seek a steady supply for their resource needs,127 nor

124. The view is widely held that governmental regulation for protection of the marine environment is economically justifiable. See, e.g., Sweeney, Tollison, & Willett, Market Failure, the Common-Pool Problem, and Ocean Resource Exploitation, 17 J. LAW & ECON. 179, 182, 192 (1974); Cooper, An Economist’s View of the Oceans, 9 J. WORLD TRADE L. 357, 365 (1975); Brunet, Musing on the Bottom, 1974 U. ILL. L. FORUM 251, 263-67. Even Eckert, probably the staunchest proponent of unregulated seabed mining, argues that significant pollution resulting from the operations “should be controlled in some fashion (such as by regulations or taxes) if it were determined that the total value of production to society was greater with increased output of metals and more pollution or with decreased metal output and less pollution, taking into account the transactions cost of imposing regulations or taxes.” Eckert, Exploitation of Deep Ocean Minerals: Regulatory Mechanisms and United States Policy, 17 J. LAW & ECON. 143, 149-50 n.30 (1974).


126. The president of Deepsea Ventures has indicated his firm will “go foreign” unless the United States enacts

A good law . . . with enough protection and enough incentives to offset the taxes and the restrictions, including environmental restrictions, found in the United States, or foreign domestication.

Otherwise, we will go foreign. If there is any message I can bring you, it is that there are foreign nations that will welcome this kind of business activity. Will their incentives be any better than those in the United States?

We have not seen any, in the United States.


developing countries, who may place their need for industrialization above environmental concerns, will likely be fastidious if international regulation fails to materialize. Only the international regulator is likely to respond to the needs of land-locked and other states whose current use of the high seas is limited. These states will seek to prevent marine pollution which might affect their own subsequent exploitation.

International regulation has potential problems along with its advantages. If the international regulatory agency is also charged with distributing revenues from seabed mining, the agency may be pressed to loosen environmental standards in order to increase revenues. Policing may be more controversial, because of problems of sovereignty, than would be the case under national standard-setting. On balance, however, international regulation offers the best chance for exploiting seabed resources while preserving the marine environment.

IV

THE ECONOMIC IMPLICATIONS OF ALTERNATIVE SEABED REGIMES

Economic analysis of seabed mining must confront the same question raised by the preceding section on the marine environment: should the industry have open access to the seabed, or should it be regulated by nations acting severally or through an international agency?

Economic analysis is complicated because of the elusiveness of some of the concepts. What are the "benefits" which exploitation should be geared to maximize? The balance sheet translates the wealth of the seabed into profits, consumer goods, alleviation of balance-of-payments problems. Another viewpoint emphasizes the creation of a more equitable international order through worldwide participation in managing the "Common Heritage." The two kinds of benefits may not be mutually exclusive, but the "balance sheet" benefits are very difficult to price relative to the benefits of "equitable" exploitation. A closely

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129. This latter benefit may nevertheless carry great weight with policy makers. The only real justification for a technologically advanced country like the United States to submit its ability to harvest this potential new resource to international rules and procedures is the desire to help achieve a fundamentally new and equitable legal order in ocean space. The creation of viable international institutions ... gives to all mankind the opportunity to work cooperatively with resources of great value and furthers the possibility ... of ensuring a more stable and secure world order.

Ratiner & Wright, supra note 127, at 18. See also note 134 infra. Ratiner has been a
related question is whether the benefits should be weighted according to who is receiving them:

[O]ne way you could maximize the benefits from the sea mining industry is to start with the concept that the world is a collection or set of individuals. In this context, given certain conditions . . . the introduction of sea mining will, in fact, act to maximize the gross national product of the world, gross world product, and to raise on the average the standard of living of all.

If, however, you complicate the problem of optimization by the introduction of national states, and by the introduction of other institutional entities, corporations primarily, the optimization problem gets very messy indeed, and this is where, of course, we are at the moment.130

Many economists who favor open access simplify the analysis by pointing out that, strictly speaking, the economic efficiency of proposed seabed regimes is distinguishable from such factors as strengthening international organizations and income redistribution. These other factors are alternative criteria by which to judge proposed regimes, and perhaps for political reasons they will be preferred to the efficiency criterion; but in that case, these economists argue, there is no inherent likelihood that the regime judged desirable by these other factors will also turn out to be efficient.131

The economic argument for open access also relies heavily on the assertion that nodule mining does not present a significant common-pool problem.132 This is asserted to be so because nodules are not a fugitive

member of the United States delegation to the United Nations Seabeds Committee and to the Law of the Sea Conference.

130. Remarks of G. Pontecorvo, CARACAS AND BEYOND, supra note 82, at 164.
131. Sweeney, Tollison, & Willett, infra note 132, exemplify this economic approach:

It may well be that revenue sharing is a desirable way of making operational the concept of "common heritage," but it would only be by chance that the taxation and regulation designed to ensure efficiency will generate just exactly the amount of revenue for sharing that is "fair." States may want to share less than 100 percent—or more than 100 per cent—of this revenue. It would be an error to tie revenue sharing too closely to taxation for regulation, for this would cause needless trade offs between efficiency and revenue sharing.


resource: unlike fish and oil, the nodules are not migratory and do not flow markedly. Unlike fish, where the size of the stock determines its rate of growth, the reproduction rate of nodules appears independent of the total stock of nodules. Unlike oil, a migratory resource within a defined reservoir that presents production nonseparabilities among the various wells into the reservoir, nodule mining at one location would not affect the efficiency of nodule mining elsewhere. And because of the presumed high cost of entry into the ocean mining industry, there should be a small number of miners relative to fishers and oil producers. From the fact of limited entry, two consequences are deemed to follow: the transactions costs to miners of resolving among themselves any common-pool problems that may arise will be low; and claim-jumping (a free-rider problem) will not occur because exploration costs will be only a small part of the miner’s total expenses and because a mine site rich enough to support one mining operation may not be rich enough to support two.\textsuperscript{138}

The present writer takes the position that the economic argument for open access fails because that argument relies on a cloistered view of economic efficiency and seriously underestimates the common-pool problem in seabed mining.\textsuperscript{134}

The existence or absence of an internationally agreed upon regime for exploitation of manganese nodules will affect investment and pro-

\textsuperscript{179} (1974). The latter two articles detail reasons why seabed mining will not involve a common-pool problem. Coase and Clarkson do not deal with the common-pool problem and appear to favor assertion of coastal state jurisdiction over seabed resources, as in the case of the North Sea. Eckert, on the other hand, rejects any limitation on access to the nodules, at least for the present. Eckert’s extreme opposition to the governmental creation of property rights in nodule deposits seems unique and is anathema to the United States mining industry. See Eckert, 17 \textsc{J. Law \\& Econ.} 143-44 & nn.1-3.

\textsuperscript{133}. The text abstracts arguments from Eckert, \textit{supra} note 132, at 154-63, and Sweeney, Tollison, \& Willett, \textit{supra} note 132. These articles are more detailed than can be indicated here, especially in their treatment of the free-rider problem. Both common-pool and free-rider problems are possible consequences of treating a given resource as common property, but the two problems must be distinguished analytically since the latter will result in too little investment and production while the former will result in too much. What matters for present purposes is that solution of either problem requires the establishment of clear and enforceable rights to a fixed resource.

\textsuperscript{134}. One may also criticize the \textit{laissez-faire} approach to seabed mining as restricting the benefits to industrialized nations and burdening efforts to achieve international cooperation. Coase, \textit{supra} note 131, at 1174, answers these criticisms by noting that there is a degree of hypocrisy in the present policy [tending toward international regulation] which reserves the least valuable part of the ocean floor “for the benefit of mankind” and then puts it in the charge of the kind of organization least likely to use it productively. The policy I advocate not only serves the economic interests of the United States but, by increasing the production of wealth from ocean resources, will really benefit mankind.

The sole purpose of this section is to show that the argument in favor of regulation rests on a sound economic basis. Readers seeking a full exposition of the above criticisms are referred generally to Pardo, \textit{supra} note 3, and \textsc{Friedmann, supra} note 4, at 62-81.
duction decisions in the mining industry, whether the trade-offs made by diplomats in shaping the regime are "economic," "political," or even whimsical. That is, the existence of agreement is in itself of economic import, over and above the specific provisions of that agreement. The United States presently seeks to negotiate a seabed regime that is broadly acceptable to both industrialized and developing countries. Proponents of open access must necessarily contend that it will achieve efficient exploitation even though open access will be rejected by the Group of 77 and may not be acceptable to all industrialized nations. Open access would become no access if unstable conditions thwart efforts to mine.

American companies have indicated that the start-up costs for a seabed mining operation will run to hundreds of millions of dollars. There has been abundant congressional testimony to the effect that private financing of such a sum will not be forthcoming unless exploitation rights in the nodule deposits can be established with certainty. But investments in the new industry could be in jeopardy whether or not the Law of the Sea Conference results in a convention to which the United States is a party. On the one hand is the fear that American mining interests will be sacrificed at the conference table. On the other hand, if negotiations produce no broadly acceptable convention, then investors may well be intimidated by the quantum of risk involved in a mining operation conducted in an uncertain political climate thousands of miles from the mining company's domicile. Institutional lenders are understandably wary of backing seabed mining, since the new industry presents many unresolved legal and political ramifications, and techniques for capturing and refining the nodules are untested on a commercial scale. At least for American bankers, an open-access regime

135. Statement of M. Dubs, Current Developments, supra note 80, at 4; Statement of J. Flipse, id. at 8-9; Statement of J. Wenzel, id. at 10-11; Statement of C. Houseman, id. at 13.

136. Some countries resolve the financing problem in seabed mining through various kinds of government participation. U.N. Doc. A/Conf.62/25 at 7, 23-25 (1974). Insurance by the United States against the exceptional risks of seabed mining may convince American bankers to finance these operations. Colloquy between the Hon. L. Metcalf and C. Houseman, Current Developments, supra note 80, at 16, 19. Such government participation would very likely be the opening wedge for regulation and is rejected by proponents of unregulated mining. E.g., Coase, supra note 131, at 1169; Clarkson, supra note 132, at 138-39. However, if the congressional testimony, supra note 135, is taken at face value, financing will not otherwise be available, and exploitation will not occur. This argues that some regulatory costs are justified, since the alternative is to forego the benefits of seabed mining altogether. On the other hand, an insurance scheme does nothing to lessen the risks of not having exploitation rights in the nodules since it does nothing to create such rights; the insurance scheme merely spreads the inefficiencies of open-access mining (see notes 138-58 infra and accompanying text), thereby subsidizing the miners. This would be as silly as the Fisherman's Protective Act, whereby the United States reimburses tuna fishers arrested by certain Latin American countries for fishing without a license. See Nye, Ocean Rule Making from a World Politics Perspective, 3 Ocean Dev't & Int'l L. 1, 44-45, 49 (1975).
unacceptably compounds the risks.\textsuperscript{137}

The possibility of reprisals by objecting nations, in addition to its effect on the availability of financing, complicates the computation of operating costs by the mining industry and may impose political costs on countries whose nationals conduct seabed mining.\textsuperscript{138} The Group of 77 would certainly retaliate against unilateral action to mine the “Common Heritage,” since the Group of 77 holds that the international seabed may be exploited only with the approval of the international community. Certain industrialized nations might also resist open access. Such resistance could be motivated by ideological or environmental concerns. Also, countries such as Japan and West Germany would be vulnerable to pressure by the Organization of Petroleum Exporting Countries (OPEC), which thus far has stood firm among the Group of 77. Nations heavily dependent on imported oil might well postpone nodule mining, and resist the unilateral exploitation of others, rather than jeopardize their oil supplies.

Retaliation could take several forms; the non-mining nations would have various legal and political options, which would be augmented by the possibility of physical interference.

Unilateral seabed development would likely be declared to be a “pirate” operation open to seizure and interference by other nations, and one or more radical nations might... sponsor such interference with the operations. ... [S]ome nations might even seize any property of the mining companies engaged in seabed exploitation found in those countries. Such seizures might be justified as a form of retaliation for the “piracy” of the common heritage of mankind.\textsuperscript{139}

The non-mining nations would probably conclude a seabed convention among themselves, and this convention may be expected to give little protection to the interests of those countries which had initiated or countenanced pre-convention mining. Condemnatory resolutions would be passed in the United Nations, and these, along with the

\textsuperscript{137} Houseman Statement, \textit{supra} note 135, at 13:

I am aware that, under existing international law, there is no apparent restriction on any nation, individual, or company, undertaking deep seabed mining in their exercise of freedom of the seas.

However, in view of the demonstrated desire of the international community to establish control over such activity, the present absence of political sponsorship and security of tenure constitutes an unacceptable business risk to a financial institution.

I would also question the prudence of a board of directors of a publicly held company who authorized a major investment in a deepsea mining project at this time.

\textsuperscript{138} This analysis is deeply indebted to the discussion of unilateral action in Charney, \textit{The International Regime For the Deep Seabed: Past Conflicts and Proposals For Progress}, 17 \textit{Harv. Int’l L.J.} 1, 34-37 (1976).

\textsuperscript{139} \textit{Id.} at 35.
convention, might put mining countries in a difficult legal position if suit were brought against them before an international forum.

Proceeding under the eventual convention or other form of multilateral accord, other nations will probably commence to mine the seabed. There is no reason to expect that nations which had exploited unilaterally will be able to monopolize mining technology and hardware. To the contrary, several OPEC members, individually or through a consortium, could finance seabed operations, and nations mining unilaterally may find their industries only too happy to conduct exploitation on behalf of countries offering the kind of security lacking under an open-access regime. Moreover, it has been claimed that highly remunerative seabed mining, using continuous line bucket dredging and relatively unsophisticated refining technology, can be conducted at a fraction of the costs mentioned at the congressional hearings, in which case many nations, developing as well as industrialized, could finance their own mining. These low-budget operations would provide a powerful incentive, both as a political gesture and to save exploration costs, to poach on mine sites commenced unilaterally. Poaching, in turn, could render the mine site uneconomical for the original, high-cost developer. But to ward off the poacher would require bribery or a display of force, both of which may be expensive for the developer.

Open-access seabed mining will have serious political costs that may well exceed the expenses of the government bureaucracy that would be generated were a regulatory regime adopted. Mining countries might find their other foreign policy objectives, such as free navigation through major straits, in jeopardy. Hostility and incidents resulting

140. See note 126 supra and accompanying text.
141. See Nodule Potential, supra note 17; Mero, The Great Nodule Controversy, in CARACAS AND BEYOND, supra note 82, at 343, 344-47. In response to questioning, Mero commented:

[T]hese high-technology, high-cost systems naturally scare the developing nations from the idea that they will be able to . . . mine and process the nodules, even though those nations probably will be able to buy that technology, . . . but the way I am proposing is a simpler way and a cheaper way and one . . . that any nation that has any kind of industrial base at all can operate. I think that this can be done at a level of a few hundred thousand tons per year at a capital investment of about $10 million.

Id. at 354.
142. Sweeney, Tollison, & Willett, supra note 132, at 189-92, argue that claim-jumping will be negligible in the seabed mining industry. But their analysis turns on a number of questionable assumptions. They argue that exploration costs will be an insignificant part of the present value of total costs and revenues; this would not be the case if the technologically modest system proposed by Mero, supra note 141, is adopted. They rely also on the abundance of “good” mining sites; but if there is such an abundance, there may still occur great variation of value even among “good” sites. In contrast to nodule miners, the “old West claim-jumper” is said to have had little time horizon beyond the one claim seized. But some nodule miners may also have short-term goals, including disruption of the original exploiter.
from objecting nations' retaliatory efforts will absorb diplomatic energies, complicate other negotiations, and threaten world security. No doubt many elements within mining countries will demand military demonstrations, or even reprisals, on behalf of miners. These political costs will not be borne by the mining industry. They will be an externality, like environmental degradation, burdening society as a whole. Thus, open access may be uneconomic even though mining companies turn a profit.

Seabed mining under an open-access regime would work substantially to the detriment of both industrialized and developing nations. If financing proved unavailable or retaliation were to halt mining, no one would realize benefits. Even were mining profitably conducted, mining nations would suffer heavy political costs. Also, transfer of technology and income redistribution to non-mining countries would not take place. Lastly, the effect of unilateral action "would be to deny recognition of the power of either political group to govern international relations."

Even if seabed mining could be conducted in a political vacuum, the argument for open access might still fail because of the common-pool problem. To demonstrate the common-pool problem in seabed mining, it is necessary to clarify certain characteristics of the nodule resource.

At least one prominent expert contends that the nodule resource is virtually inexhaustible, and raw numbers seem to support the contention. However, nodules are not uniformly distributed over the ocean floor, and sites require a minimum density to be mined economically. Sites will also be more or less desirable according to factors such as their topography, weather conditions at the surface, and proximity to refineries and markets. Nodules vary significantly in assays of the respective mineral components, even within a relatively small patch of seabed. Efficient mining may require a specific configuration of all

143. Miners could, of course, employ self-help: "if the total cost of driving off [the claim-jumper], including [the claim-jumper's] retaliation, is less than [the exploration cost], then [the explorer] should be willing to incur these costs (including the damage of retaliation) and by this very willingness will effectively prevent claim-jumping." Sweeney, Tollison, & Willett, supra note 132, at 190 (emphasis in original). Nodule mining will take place on the high seas, and nations will likely be party, directly or indirectly, to many of the operations. Taking these factors into account, even assuming that miners could afford to maintain a credible deterrent, the costs of self-help in terms of international turmoil would be intolerable.

144. Charney, supra note 138, at 37.

145. Flipse, supra note 126, at 327.

146. "With presently envisioned mining systems the lowest concentration that can be feasibly mined is about 1.0 lb/ft²." Siapno, supra note 92, at 227-28.

147. See MERo, supra note 18, table XXX at 182-221 and figure 63 at 226.

148. Eckert, supra note 132, at 147 & n.18.
these variables. Nodules should therefore be considered a scarce resource. Efficient exploitation of scarce resources may require that access be limited to exploiters willing to pay a scarcity rent. Where scarce resources are treated as free goods, the resource tends to be developed wastefully, often by over-investment in exploitation, as has happened in many fisheries. This is the paradigm of the common-pool problem.

Common-pool inefficiencies in nodule mining could take a variety of forms. Since prime sites are limited, there would be a race for discovery, much like a gold rush, in an unregulated industry. Successful explorers would benefit, but there would be a net waste of resources because of too rapid a rate of search by the industry as a whole. The discoverer of a prime site would not, however, have an exclusive right to the deposit. To forestall poaching, it might also be necessary to exploit rapidly, with greater investment in capital and labor than would otherwise be necessary to mine the site. Such greater-than-optimal rates of exploitation can dissipate much of the value of the resource. Even where the nodules in a given deposit, if they could all be recovered, would be adequate to support numerous mining operations, the site may still not be economic for more than one miner since the sweep and dredge efficiencies under present technology are well under 100 percent. Alternatively, multiple miners may operate profitably but increase each other's unit costs. This is closely analogous to the common-pool problem that arises when a given stock of fish or pool of oil is treated as a free good.

149. Flipse, supra note 126, at 329:

Our approach is sufficiently sophisticated . . . that if we had to go from one deposit of nodules to another deposit, it would cost us anywhere from 30 to 75 percent of our capital investment . . . You must design both your mining system and your processing system to suit the deposit, and to be a continuing economic operation you must have continuing access to one deposit . . .

150. Other writers reaching this conclusion include Hammond, Manganese Nodules (I), supra note 98, at 502, and Eckert, supra note 132, at 152.

151. Cooper, supra note 124, at 359-60.

152. Examples of such waste in various resources are discussed in id. at 360 and sources cited therein. See also Christy, Property Rights in the World Ocean, 15 NATURAL RESOURCES J. 695, 698-701 (1975).

153. The dredge will only be able to sweep 45 to 65 percent of the seabed within the mining site, see note 92 supra; in addition, the dredge head will retrieve only a portion of the nodules actually encountered. The dredge efficiency is estimated to range from 30 to 70 percent. Siapno, supra note 92, at 237-38.

Nevertheless, so long as open access prevails, the insufficiency of a given site to support more than one miner will actually promote a race to exploit that site, especially if the assays are very attractive.

154. For example, the dredge head may pass over previously mined swaths. Also, the turbulence generated by the activity of several miners at a given site may cause many nodules to float away from the bottom, since the nodules have a specific gravity of only
Proponents of open-access mining have attempted to distinguish the common-pool problem in nodules from that in oil or fish, contending that the former will be negligible or easily resolved by bargaining between the miners themselves.\textsuperscript{155} This contention necessarily assumes that seabed mining will be characterized by limited entry. If few miners were to appear, there might be plenty of attractive sites for the immediate future, and the miners could negotiate solutions to allocation problems at low transactions costs. The more numerous the miners, the higher would be the incidence of common-pool problems and the more expensive their settlement by private negotiation. In short, the efficiency of an open-access regime seems inversely related to the number of miners.

The nodules, however, will probably attract many miners under an open-access regime, despite the high entry fee. Should the first commercial operations survive retaliation and prove profitable, private financing will be more easily obtained by newcomers, and the original miners may operate additional sites. The problem of financing may also be solved by formation of consortia to spread the risk. But much more is involved than private, profit-motivated exploitation. Governments of industrialized nations seeking self-sufficiency in mineral resources might decide to fund exploration, development of technology, or entire mining operations.\textsuperscript{156} The wealthier developing countries might undertake seabed mining to further their own industrialization. Even land-based producers might participate rather than see their land mines close without a replacement source of income. Finally, advancing technology may well produce low-cost mining systems which open up the seabed to many additional ventures, public and private; there are indications that such systems already exist.\textsuperscript{157} Accordingly, if a seabed industry were permitted to develop without regulation, the industry would have many participants involving countries throughout the world.\textsuperscript{158}

The prospects for efficiency from open-access mining are therefore bleak. Unregulated mining would be initially hard to finance and probably inefficient to maintain in the face of international retaliation. Surviving these difficulties, unregulated mining would attract numerous participants and eventually generate common-pool problems. These factors indicate that a seabed regime will not be economically efficient

\textsuperscript{2.0.} Eckert, supra note 132, at 148. The dredge heads seem likely to miss these displaced nodules.

\textsuperscript{155.} See text accompanying notes 132-33 supra.


\textsuperscript{157.} See note 141 supra and accompanying text.

\textsuperscript{158.} Pontecorvo, supra note 130, at 165, also reaches this conclusion.
unless it can confer clear and enforceable exploitation rights in the nodules.

That open-access mining will not achieve efficiency does not necessarily mean that regulatory schemes will do so. There are inherent costs of regulating. A regulatory scheme requires money to create, to administer, and to police. It is also safe to predict that the regulatory agency, like any political creation, will serve other ends in addition to economic efficiency and that these other ends may dictate certain anti-efficiency measures. Beyond the inherent costs, the regulatory scheme must actually be able to define and enforce rights in the resource, or else the economic rationale for regulation fails. An efficient regulatory regime for the seabed must permit orderly exploitation while minimizing attendant costs of regulating. Since there will be a limited number of suitable sites, the regulatory regime should also exact a scarcity rent from exploiters. Given the broad classification of regulatory mechanisms into national and international, which of the two is more likely to satisfy the efficiency criterion?

Since the task of the regulatory agency will be to determine who should exploit the nodule resource and what scarcity rent should be charged, the analysis begins by asking what method for performing this task is economically preferable. Economists of widely differing viewpoints agree that the efficient solution would be for the regulator to auction specified sites;\textsuperscript{159} the highest bidder for a given site would obtain exclusive exploitation rights in return for payment of the amount of the bid. Since the bid would represent the value of the site to the bidder, a competitive auction would allocate the rights at the outset to the most profitable user. The auction price would approach the present value of scarcity rent (if any) on a given site, based on present knowledge about future costs and prices and the quality of nodules from the site.\textsuperscript{160} The auction method would also reduce transactions costs:

Under unregulated exploitation or a registry claim system, numerous exploiters would race to be first to exploit [certain blocks of seabed], thereby creating overlapping or conflicting claims. . . . The bidding scheme centralizes all communication concerning exploitation of contiguous or identical portions of the sea. Instead of multiple bargains there is only one: the auction.\textsuperscript{161}

\textsuperscript{159} E.g., Coase, \textit{supra} note 131, at 1171; Eckert, \textit{supra} note 132, at 152; U.N. Doc. A/Conf. 62/25 at 72-73 & n.137 (1974); Cooper, \textit{supra} note 124, at 368. Allocation of mineral resources by auction would not be an innovation. "Such auctions, based on sealed bids, have been used successfully for offshore drilling rights in the United States, and for drilling rights in Alaska, generating substantial revenues for public authorities." \textit{Id.}

\textsuperscript{160} Cooper, \textit{supra} note 124, at 368.

\textsuperscript{161} Brunet, \textit{supra} note 124, at 274. Brunet discusses desiderata for an auction of
Detailed provisions of such an auction are not relevant here. It suffices
to say that allocative efficiency could be achieved through an auction of
mining sites, provided the regulatory agency kept down administrative
expenses and did not otherwise condition seabed mining with anti-
efficiency measures.

National and international regulatory agencies seem, in the ab-
abstract, equally capable of performing in the manner outlined above.
Auctions should be amenable to administration by a national or interna-
tional body. As to administrative expenses and anti-efficiency mea-
ures, these are not peculiar to either mode of regulation. But national
and international agencies respond to quite different kinds of interest
groups. A consideration of the pressures affecting the respective regu-
lators reveals that an international regulatory agency is the more likely
to pursue policies promoting economic efficiency.

National regulation of seabed mining will fail to prevent inefficien-
cies for much the same reasons it will fail to prevent environmental
degradation. Prospective miners, as shown earlier, should be as-
sessed a scarcity rent, preferably by auction of mine sites. But countries
attempting to charge this scarcity rent may find this impossible. Unless
nations divide up the seabed among themselves, an allocative method
rejected by the Group of 77, any nation could issue a license for any site
and no nation could effectively confer an exclusive exploitation right.
The miner interested in a given site would obtain a license from the
nation offering the cheapest package deal, typically a low flat fee, in
preference to entering an auction. Thus, auction schemes, like strict
environmental standards, would be undercut by countries with nominal
requirements costing miners little. A flat fee system would be highly
inefficient: it would generate a race to register claims for attractive
sites, and the regulator would then have to decide who among the
competing applicants was first or was best qualified, with abundant
opportunities for corruption. Individual speculators might be able to

seabed mining rights in the context of his analysis of the United States Draft Conven-
tion. He advocates a sealed-bid auction, even where only a single entity applies for a
particular site. The regulator would publish notice of all applications so that competing
entities could consider exploration of the site and submission of their own bids in light of
the first entity's interest. Since no entity could safely assume that it would be the sole
applicant, this arrangement would enhance competition and thereby help assure the
submission of a realistic bid. Id. at 275-76.

162. See notes 145-51 supra and accompanying text.

163. The American Mining Congress has sponsored a series of bills which would
initiate unilateral seabed mining regulation by the United States. These bills would
require the Secretary of the Interior to license exploitation of any given block by "the
first qualified person" who tenders the license fee. The amount of the fee has varied.
E.g., S. 2081, 92d Cong., 1st Sess. § 5(a) (1971) [$5,000]; S. 713, 94th Cong., 1st Sess.
§ 5(a) (1975) [$50,000], as amended, 94th Cong., 2d Sess. § 5(a) (1976) ["estimated
administrative and other costs"].
control vast areas of the seabed at a fraction of the scarcity rent, and these individuals may or may not be those who are able to exploit the nodules most efficiently.

The licensing fee is not the only anti-efficiency measure likely to be adopted by countries seeking to attract nodule miners. Limitations on liability and loose environmental standards are obvious examples. Licensing nations may have little concern for what transpires hundreds or thousands of miles from their coasts at the mining site; the licensing nation may even be land-locked. Meanwhile, many costs of seabed mining, including navigational hazards, broken submarine cables, and pollution, would be externalities thrust upon competing users of ocean space. Disruptions of this sort would probably require eventual resolution by international conventions to establish consistent allocations of liability. If such conventions were to become necessary, then national regulation would not have avoided the high transactions costs of international conferences, and the desirability of international regulation in the first instance will be attested.

It is important to recognize that adoption of these anti-efficiency measures will not be peculiar to poorer nations hoping to derive revenues from mining activities conducted by companies domiciled elsewhere. Industrialized countries, especially heavy importers of nodule metals, may decide that seabed mining is vital to their national interests and so foster the new industry by disguised or outright subsidies. An analogy might be drawn to the United States limitation on liability of nuclear power plants. Countries may also choose to guarantee loans to mining companies or reimburse miners for losses arising from interference with their operations. Under such provisions, investment choices would not reflect the actual risks of exploiting the nodules, and inefficient operations would flourish at the expense of society as a whole.

Some regulatory costs might be tolerated for the sake of clear and enforceable exploitation rights in nodule deposits, but it is doubtful that national regulation will fulfill even this minimum expectation. Nations and their licensees may or may not reciprocally recognize the exploitation rights conferred by other nations. The large majority of nations, those lacking present capacity to exploit the nodules, would have little or no incentive to recognize licenses issued by countries engaged in seabed mining. These non-mining nations, proceeding either under a convention or unilaterally, would instead issue licenses of their own. Reasona-
ble people could differ as to the legal validity of these licenses. As a practical matter, Lesotho's licenses, for example, might seem to carry less weight than those of the United States, but the credibility of a license is likely to be more a function of the licensee's ability to mine, than that of the licensing nation, and the licensee from Lesotho may be a Japanese company or even an American company. If Lesotho offers an attractive set of conditions, such as a flat fee, low taxes, and few environmental restraints, its licenses should find takers. Where conflicting licenses are issued, there would have to be a further allocation of the site as between the disputants. This two-step process, however effected, would be redundant, expensive, and uncertain.

There would be a fair chance under international regulation of avoiding these inefficiencies. Evidence to date indicates that the mineable nodules occur overwhelmingly in the international zone. Thus, if international regulation, with broad acceptance among industrialized and developing countries, were adopted at the outset, the resource would be administered essentially under the sole jurisdiction of the International Seabed Resource Authority (ISRA), and the ISRA could confer clear and enforceable exploitation rights. Miners could then calculate their risks with greater precision, and the attractiveness of nodule mining for private investors would be enhanced. Because of the ISRA's exclusive jurisdiction, it could adopt the auction scheme of allocation without danger of subversion by cheap licenses issued by competing national regulators. Thus, the entry fee for nodule mining would approxi-

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167. S. 713, see note 46 supra and accompanying text, attempts to prevent mining by American companies under foreign flags by providing, in section 4(a), that "no person subject to the jurisdiction of the United States shall engage directly or indirectly in the development of hard mineral resources of the deep seabed" except as authorized in the bill. The effectiveness of so generally worded a provision is doubtful.


169. This, again, assumes that the large majority of mining states would be parties to the seabed convention. Even so, the convention must make careful provision to reduce incentives and preclude opportunities to subvert the ISRA. For example, the inclusion of a mutual full faith and credit obligation might nullify the advantages of staying out of the international regime. A recent article outlines the operation of such a clause:

If a dispute as to the title to products from the ocean floor should arise between an enterprise operating under the regime and one operating under the general privilege customary law allows, and come before the courts of a third state party to the regime, the full faith and credit clause would bind that state's courts and assure that the claim based on the treaty regime would prevail. Hence states participating in the regime would enjoy among themselves an unambiguous advantage whenever transactions call for transnationally merchantable titles.

mate the scarcity rent, and efficient users would be selected in an objective manner at the initial allocation of sites.

An ISRA possessing exclusive regulatory power might, arguably, set too high an entry fee; this is essentially the opposite problem from that of competing national regulators, where the entry fee would likely be too low. The argument runs that the ISRA, relying on its exclusive jurisdiction, would reject the auction scheme in favor of an arbitrary and exorbitant entry fee, which in turn would preclude mining operations at any but the most attractive sites. However, the ISRA's revenues will presumably be based on royalties from production as well as entry fees. If the entry fee were such as to deter even miners willing to pay a scarcity rent, the rate of nodule production would be less than optimal, and the ISRA's net revenues, based on combined royalties and entry fees, may well be less than under an auction scheme. The revenue goals of the ISRA may therefore closely parallel the goal of economic efficiency. Both are served by an auction of mining sites, which would maximize revenues to the ISRA while achieving an economically optimal level of nodule production.

This raises the ultimate question in the whole course of negotiations over the regime for the deep seabed: does the international community in fact want to achieve an economically optimal level of nodule production, or will land-based producers among the Group of 77 successfully insist on an inefficient combination of production quotas, price supports, and other inhibitory regulation? While the outcome of the Law of the Sea Conference is still very doubtful, a reasonable prediction is that the conferees will tend increasingly to seek an efficient resolution of the nodule mining problem because it is in the self-interest of the overwhelming majority of nations to do so.

The ISRA will obtain no revenues for redistribution unless seabed mining occurs. Regulatory measures which depress the level of production will sustain high prices obtained by land-based producers but will

170. Cooper, supra note 124, at 369: Exploitation of seabed minerals will probably give rise to some pure rents which could be taxed away without economic loss. There might be no such rents; but more likely they will be substantial, particularly after appropriate technologies have been developed and shaken down. The history of oil discovery suggests large rents, and at a minimum normal profits tax on corporate income arising from extraction of ocean resources might be included here. In predictable contrast, economists favoring unregulated mining oppose royalty taxes as tending to reduce production below the economically optimal rate. E.g., Eckert, supra note 132, at 170-71.

171. The interests of land-based producers are analyzed at notes 57-68 supra and accompanying text.
generate lower revenues for the ISRA. The administrative expenses of
the ISRA will be constant or perhaps rise if an intricate series of controls
is adopted. Revenues left after deduction of expenses would probably
go to land-based producers as compensatory payments, based either on
the decline of market prices from established levels prior to seabed
mining or on the difference between market prices and projected higher
prices which land-based producers could have obtained for nodule
metals but for the production from seabed mining. Inhibitory regula-
tion would thus benefit the twenty-odd land-based producers among the
developing countries and hardly anyone else. In particular, those
among the Group of 77 who must import these metals will continue to
pay high prices without realizing significant revenues from the ISRA.

Nevertheless, the policy of the Group of 77, at least through the
1975 Geneva Session, has leaned heavily in the direction favored by the
group's land-based producers. Explanations for this seeming anoma-
ly are readily conjectured. Many developing nations are only recently
independent. Deep seabed mining, itself a matter of international con-
cern for less than a decade, can hardly be a pressing problem to most of
these new governments. Probably many countries have yet to appreciate
fully where their interests lie in regard to this issue or are using the
seabed controversy to further ideological ends or as a trade-off in the
negotiations. Since the bulk of developing nations see little in seabed
mining to affect them directly, it is natural that they would follow the
lead of the commodity exporters among the Group of 77, for whom the
issue is central. Even land-locked and mineral-poor developing coun-
tries may decide that they will realize greater benefits from Third World
solidarity, such as preferential pricing on their own mineral imports,
than from income distribution by an efficient seabed regime.

There is no real identity of interests, however, between those
developing countries with large commodity reserves and those essentially
without economic assets. Only the latter, the so-called "interdependent
poor," have a genuine interest in global economic redistribution, while
the "old rich" (industrialized nations) and the "new rich" (those with

Int'l L. 187, 189, 193-94, 197, 202 (1976) (indicating that the seabed issue within the
Group of 77 had become linked with the debate over commodities control in general).
173. Miles found indications of general unpreparedness among the Group of 77 at
Geneva, and even that some delegations simply had no instructions from their govern-
ments on the seabed issue. Id. at 193-94, 202.
174. The lack of interest shown by normally active moderates within the Group of
77 may be explained, Miles suggests, by the widely held belief that the ISRA's revenue
would be eaten up by operating costs and compensation paid to land-based producers
Id. at 202.
large shares of the world's basic commodities) will hardly be willing to jeopardize their advantages for the sake of a new economic order.  

Although both the old rich and the new rich will tend to go along superficially, they have little incentive to commit themselves to binding policies that the numerical preponderance of the interdependent poor may get passed in resolutions. Given modern history and differences of race and culture, the interdependent poor will gain vicarious satisfaction for a while from redistributions from the old rich to the new rich. And for a while, the new rich will see the poor as useful associates in pressuring the old rich. However, at some point the interdependent poor will need more concrete benefits.

For those states without substantial economic assets of their own, concrete benefits from seabed mining will only be realized by maximizing revenues, not by pursuing protectionist policies at the behest of land-based producers. The interdependent poor may continue to treat nodule mining as a solidarity issue within the Group of 77, but they will do so at the expense of whatever revenue benefits might accrue to them through the creation of an efficient seabed regime.

The land-based producers among the Group of 77 may themselves, in the last analysis, have more flexibility than they have hitherto shown. This is because they more than anybody stand to lose from a failure to achieve a broadly acceptable seabed regime. Compensatory payments, such as discussed earlier, offer less protection than a scheme of price controls and production quotas, but compensatory payments may well be preferred to the uncertainties of unilateral licensing or of a convention which failed to include the major consumer nations. Transfer of technology on favorable terms would not materialize. Moreover, the creation of workable international institutions, in which Third World countries have been able to maximize their political influence, would suffer a terrific setback from the failure of the Law of the Sea Conference.

If a broadly acceptable seabed convention is achieved, it will undoubtedly incorporate numerous compromises displeasing to economists. But economists would be very naive to imagine that international politics would not affect other regulatory approaches, including open

176. Id. at 175.
177. See notes 67-68 supra and accompanying text.
178. Land-based producers are well aware of the instability of commodity prices even without nodule mining. For example, copper prices fell from a high of $US 1.50/lb. in April 1974 to $US 0.62/lb. by December 1974 as a result of recession in industrialized countries. U.N. Doc. A/Conf.62/37 para. 33 (1975).
access and national regulation. Nor, as was shown earlier, are these other regulatory approaches inherently more likely to achieve efficiency. The large preponderance of nations, however, and the poorest nations most of all, have strong inducements for maximizing economic benefits from the seabed. It is not utopian to expect the goal of economic efficiency to assume prime importance as the Law of the Sea Conference progresses.

V

RECOMMENDATIONS FOR AN INTERNATIONAL SEABED RESOURCE AUTHORITY

Section II of this Comment showed that a majority of both industrialized and developing countries favor some sort of international seabed regime instead of open access or national regulation. Sections III and IV confirmed the desirability of an international regime from environmental and economic standpoints. The industrialized countries want a minimalist regime, which would leave exploitation to them while registering their claims and guaranteeing freedom of navigation. The developing countries want a maximalist regime, which would itself exploit the resource or directly supervise all exploitation. They hope such a regime would augment their strength in world politics, protect their stake in land-based production, and promote transfer of technology.

How should the Law of the Sea Conference choose as between the maximalist and minimalist alternatives? Governing this choice is the goal of safe, orderly, and equitable development, unanimously endorsed by the General Assembly. Which type of International Seabed Resource Authority (ISRA) will best promote such development?

The world remains overwhelmingly state-centric, and the industrialized countries have taken care to limit the basis of their participation in Third World development to moral duty rather than juridical obligation. The organs of the United Nations may recommend, and the General Assembly may exhort, but industrialized nations need do no more than listen. This writer submits that the needs of development must now be united with the means of enforcement. Lack of an international "public service fed by autonomous resources," the French scholar Dupuy argues, "is precisely why the common heritage should be used for development; this allocation of a property [has] revolutionary

significance” both from “the specificity of resources reserved for development” and the “methods of utilizing them.” By this analysis, the ISRA, and thereby developing nations, should have substantive control over seabed exploitation.

Administering the nodule industry will involve a wide range of functions, and this also calls for a regime with maximalist features. The ISRA must establish environmental standards and enforce them. In addition, the ISRA must have economic capabilities in order to raise revenue and supervise transfer of technology. The ISRA must comprehend the processes involved in exploration and exploitation and be able to price these processes, it must assess world markets, and it must engage in research, so as to manage, regulate, and tax the industry efficiently. Accordingly, broad supervisory power should be vested in the ISRA. It remains to consider how that power should be exercised.

The novelty of nodule mining and the importance of the marine environment dictate stringent measures for environmental protection. Baseline studies of pre-mining conditions should be undertaken at prospective sites. Standard-setting for the first generation of mining operations will necessarily involve conjecture since there is no data on the environmental effects of a full-scale mining operation. Although the ISRA will be feeling its way, standards for this first stage should be set before mining commences, so that miners can calculate their costs and risks with precision. Based on data derived from first-generation mining, the ISRA can revise its standards for later operations. The power to supervise includes inspection rights, and operations found in violation of environmental standards should be fined, suspended, or terminated. In addition, miners should be liable for all harm suffered by other ocean users as a result of environmental degradation from mining. These measures will ensure optimum pollution abatement by miners.\footnote{182}

Above all, broad acceptability of the ISRA and its prospects as a working entity depend on the means chosen for exploiting the nodule resource. Consumer nations, land-based exporters, and the many nations not directly involved in seabed mining all seek to share in the benefits. An efficient ISRA will generate the revenue and raw materials to meet these expectations. Accordingly, efficiency ought to be a prime criterion in the conduct of the ISRA. Commitment to an auction system for allocating sites is a key step in this direction.\footnote{183}

\footnotetext{181. Id. at 30.}
\footnotetext{182. See Randall, Coasian Externality Theory in a Policy Context, 14 Natural Resources J. 35, 38-45 (1974), analyzing the effect on environmental externalities of varying liability rules.}
\footnotetext{183. See notes 159-61 supra and accompanying text.
ISRA would not at the outset have the technology and capital to mine on its own, the auction system would in practical effect allocate first generation seabed mining to successful bidders from industrialized countries, under terms and conditions (e.g., environmental and safety standards) established by the ISRA.

Developing nations would lose little if the ISRA does not mine on its own at the outset. A monopoly on exploitation would entail delay and expense while the ISRA acquires technology and obtains financing, either by borrowing or exactions from member states. The auction, on the other hand, would yield revenue to the ISRA at an early date. At the same time, the auction would substantially accommodate the interests of industrialized nations. They would be assured that production from the seabed actually takes place and that they will have an opportunity to participate in the nodule industry. Thus, an auction scheme of allocation is not only attractive in theory but also offers a basis for compromise between developing and industrialized states at the Law of the Sea Conference.

These are recommendations for major policy choices to be faced in structuring an international property regime for seabed minerals. The choices actually made will determine whether the concept of the "Common Heritage of Mankind" is to be reduced to wistful mythology or implemented for universal development.

184. The auction scheme would be similar in effect to the "phased regime" proposed at the Geneva Session of the Law of the Sea Conference by Ambassador Engo of the Cameroons, Chairman of the First Committee. See Charney, supra note 138, at 41-42.

As the ISRA accumulates capital and technology, its activity could include submission of bids on its own behalf. Some preference might be given the ISRA bid in the interest of promoting global participation in the industry. But essentially the ISRA would base its decision to mine on its ability, as indicated by the auction, to do so efficiently.
APPENDIX

Reserves of Metals in Manganese Nodules of the Pacific Ocean

<table>
<thead>
<tr>
<th>Element</th>
<th>Amount of element in nodules (billions of tons)</th>
<th>Reserves in nodules at consumption rate of 1960 (years)</th>
<th>Approximate world reserves of element (years)</th>
<th>Ratio of reserves in nodules/land reserves</th>
<th>U.S. rate of consumption of element in 1960 (millions of tons/year)</th>
<th>Ratio of rate of accumulation of element in nodules/millions of tons/year</th>
<th>Ratio of rate of accumulation/rate of U.S. consumption</th>
<th>Ratio of world consumption to U.S. consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>25.0</td>
<td>600,000</td>
<td>L.6</td>
<td>0.04</td>
<td>0.18</td>
<td>4.5</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>43.0</td>
<td>20,000</td>
<td>100</td>
<td>200</td>
<td>2.0</td>
<td>0.30</td>
<td>0.15</td>
<td>2.0</td>
</tr>
<tr>
<td>Ti</td>
<td>9.9</td>
<td>2,000,000</td>
<td>L</td>
<td>—</td>
<td>0.30</td>
<td>0.069</td>
<td>0.23</td>
<td>4.0</td>
</tr>
<tr>
<td>V</td>
<td>0.8</td>
<td>400,000</td>
<td>100</td>
<td>4,000</td>
<td>0.8</td>
<td>2.5</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Mn</td>
<td>358.0</td>
<td>400,000</td>
<td>100</td>
<td>4,000</td>
<td>0.8</td>
<td>2.5</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Fe</td>
<td>207.0</td>
<td>2,000</td>
<td>500</td>
<td>4</td>
<td>100.0</td>
<td>1.4</td>
<td>0.01</td>
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<tr>
<td>Co</td>
<td>5.2</td>
<td>200,000</td>
<td>40</td>
<td>5,000</td>
<td>0.008</td>
<td>0.036</td>
<td>4.5</td>
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<tr>
<td>Ni</td>
<td>14.7</td>
<td>150,000</td>
<td>100</td>
<td>1,500</td>
<td>0.11</td>
<td>0.102</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Cu</td>
<td>7.9</td>
<td>6,000</td>
<td>40</td>
<td>150</td>
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<td>0.055</td>
<td>0.05</td>
<td>4.0</td>
</tr>
<tr>
<td>Zn</td>
<td>0.7</td>
<td>1,000</td>
<td>100</td>
<td>10</td>
<td>0.9</td>
<td>0.0048</td>
<td>0.005</td>
<td>3.5</td>
</tr>
<tr>
<td>Ga</td>
<td>0.015</td>
<td>150,000</td>
<td>—</td>
<td>—</td>
<td>0.0001</td>
<td>0.0001</td>
<td>1.0</td>
<td>—</td>
</tr>
<tr>
<td>Zr</td>
<td>0.93</td>
<td>100,000</td>
<td>100</td>
<td>1,000</td>
<td>0.0013</td>
<td>0.0065</td>
<td>5.0</td>
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</tr>
<tr>
<td>Mo</td>
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<td>30,000</td>
<td>500</td>
<td>60</td>
<td>0.025</td>
<td>0.0054</td>
<td>0.2</td>
<td>2.0</td>
</tr>
<tr>
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<td>100</td>
<td>100</td>
<td>1</td>
<td>0.006</td>
<td>0.00003</td>
<td>0.005</td>
<td>—</td>
</tr>
<tr>
<td>Pb</td>
<td>1.3</td>
<td>1,000</td>
<td>40</td>
<td>50</td>
<td>1.0</td>
<td>0.009</td>
<td>0.0009</td>
<td>2.5</td>
</tr>
</tbody>
</table>

1 All tonnages in metric units.
2 Amount available in the nodules divided by the consumption rate.
3 Calculated as the element in metric tons. (U.S. BUREAU OF MINES STAFF, 1956).
4 Calculated as the element in metric tons.
5 Including deposits of iron that are at present considered marginal.
6 Present reserves so large as to be essentially unlimited at present rates of consumption.