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Woods Hole Oceanographic Institution

Patent Activity in the Seabed Mining Industry

by

Porter Hoagland III

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Technical Report

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Approved for Distribution:

David A. Ross
Director, MPOM

ABSTRACT

Patent issues are one way to observe the behavior of private firms and government agencies at a formative stage in an industry's development when, for strategic reasons, these participants are careful about disclosing details of their activities. The seabed mining industry is a good example of an industry in its formative stages. This industry has been characterized in large part by the research and development (R&D) of technology to recover minerals from deep ocean polymetallic nodules and to process them metallurgically into metal products. The nearly 400 seabed mining patents that have been granted worldwide are a rough measure of this R&D activity. Patent issues can reveal several interesting aspects of an industry: (a) the identity of participants; (b) the generic type of technology; (c) the technological concentration of patent holders; (d) the technological integration of patent holders; and (e) the timing of inventive activity. In some cases, industrial motivations and strategies may be inferred from these aspects. Moreover, seabed mining might be subject to the cyclical fluctuations of markets for the metals contained in polymetallic nodules. Patent activity could provide some insight into the nature of a possible seabed mining industry cycle.

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This paper was prepared as part of an economic analysis of industrial structure and behavior in the emerging seabed mining industry. The research was supported by the Pew Memorial Trust, the Marine Policy Center's Johnson Endowment Fund, and the Department of Commerce, NOAA, National Sea Grant College Program under grants Nos. NA80AA-D-0007 (R/S-7), NA83AA-D-00049 (R/G-7), and NA84AA-D-00033 (R/G-7).

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I. INTRODUCTION

A. SUMMARY

Seabed mining, a formative industry directed at the recovery and metallurgical processing of metals from deep ocean polymetallic nodules, has been characterized in large part by research and development (R&D) activity. An indirect measure of the extent of this R&D to date is that at least 50 private firms and eight public agencies from several countries hold seabed mining patents. As measured by patent issues, R&D activity commenced in the 1960s, reached a peak in the early to mid-1970s, and continues today at a greatly reduced pace. Recently, much of the industrial activity in seabed mining has been discontinued because of inclement metal market conditions, pessimistic forecasts for those markets, and other important factors.[1]

In the seabed mining industry a small amount of activity currently is directed at the clarification of access rights to exploration sites on the deep seabed.[2] When the world's metals markets rejuvenate and if the legal regimes for seabed mining stabilize, one might expect a resurgence of activity in the industry. Ultimately such activity may be expressed through innovation (the commercial employment of previously-developed inventions) using knowledge generated in the first round of activity.

If seabed mining becomes a commercial reality, then the recent decline in seabed mining activity may represent the downside of the industry's first cycle. This cycle could be reflected through patent activity even before the industry enters into commercial production.[3] Cyclical fluctuations are characteristic of established markets for the metals contained in nodules: particularly those of nickel, cobalt, copper, and manganese.[4]

In some countries, concern for supplies of strategic materials may actually accelerate the commercialization of seabed mining. Japan, for instance, is sponsoring a nine year R&D project to develop a manganese nodule recovery system.[5] The project is intended to culminate in 1990 when the preponderance of seabed mining patents worldwide, which were issued during the first cycle, will begin to expire. As patents expire, the technology that they describe can be manufactured, sold, or used without restriction. It is possible, therefore, that this increased availability of technology could spur a renewed industrial interest and reinforce the tendency for cyclical behavior in seabed mining activity.

The first section of this paper describes the seabed mining industry in terms of data that have been abstracted from publicly-disclosed patent activity. Those firms that embody the industry as well as those firms and engineers that are potential participants or entrants into the industry are identified. Several of the seabed mining firms have joined together in ventures known as "consortia."[6] The consortia are compared in terms of concentration in the number of patents held and in the number of claims made on these patents. Firms within each consortium also are compared in terms of patenting concentration, and the primary patenting firms (PPFs) are identified for each consortium. Relative emphasis, or U.S. seabed mining patent activity as a percentage of total U.S. patent activity, is examined in the case of each PPF and is compared among PPFs. The timing of patent activity for each consortium is depicted graphically. The timing of patent activity for all firms or engineers may provide clues about the period of a cycle in the industry.[7]

This study makes no real attempt at a qualitative comparison of patents, except to differentiate patents (including claims) into generic technological categories. Generic categories help describe the array of technological solutions to the two broad problems faced by seabed miners: recovery and metallurgical processing of polymetallic nodules. The spread of patent activity across generic technological categories is examined for the consortia and potential entrant firms to suggest the possibilities for vertical integration. Seabed mining firms may have tended to converge on a specific set of recovery technologies, although this convergence is not immediately apparent from observations of patent data. Furthermore, any useful qualitative comparison may have to await the actual commercial operation of seabed mining technology.

Patents might also provide insight into the behavior of firms and governments as they seek protection for their intellectual properties (patents and trade secrets). Possible motivations and strategies of some of the consortia and major government seabed mining efforts are inferred from information developed in the first section of this paper. The motivations include the commercial development of new sources of minerals to supplement dwindling onshore sources; the protection of market position; the sale of ideas, experience, or technology; and entrance into a potentially successful industry. The strategies involve either patenting or keeping trade secrets:

each may be employed to protect intellectual property. Patents might be used to protect technology from other firms outside of a particular consortium (or even from other prospective member firms within a consortium). Patents also might be sought to fence-in an invention, to substitute for a proven technology, to exhibit technological capability with the intention of attracting customers or investors, or to package technology in order to facilitate the licensing or sale of certain rights.[8]

B. METHODS

Patent data used in this study were obtained primarily through a search of the "Official Gazette" of the U.S. Patent and Trademark Office. The comprehensiveness of this search was checked and confirmed through a computer search of U.S. patents in the CLAIMS database.[9] In addition to these searches, reference was made to earlier patent searches and published sources.[10] Other sources are referenced in the text where appropriate. None of the former patent searches provide a current, comprehensive examination of patents related only to both seabed polymetallic nodule mining and processing. Moreover, this study is believed to be the first public attempt at analysis of the strategies and motivations of the developing seabed mining industry based upon an important indicator of preproduction activity: patenting.

The majority of seabed mining patents have been issued in those countries where private firms or government agencies have been the most active participants in the seabed mining industry: the United States, West Germany, Canada, the United Kingdom, the Soviet Union, Japan, and France. In many cases, firms have patented their inventions in more than one country to provide extra protection for that invention. Seabed mining patents granted in countries other than the United States were searched by three methods. First, foreign nodule recovery patents were searched at the Patent and Trademark Office files in Crystal City, Virginia, under the same classes and subclasses that U.S. patents were searched in the "Official Gazette." Second, both nodule recovery and metallurgical process foreign patents were discovered in publications. Third, a computer search of an international patent database, INPADOC, was conducted to locate both nodule recovery and metallurgical process patents.[11]

From the data collected, it is evident that more seabed mining patents have been granted in the United States than in any other country. In fact, over two-thirds of all the seabed mining patents discovered in this study have been issued in the United States. West Germany, with less than one-sixth of all patents, is a distant second. It is probable that most seabed mining firms envisioned the United States as the primary location for the manufacture, use, or sale of seabed mining technology, and therefore patent rights were perceived as more valuable there.[12] This phenomenon may be an artifact of the search methods, however, since it has been much easier to locate U.S. patents in the United States. For example, preliminary results from a separate review of seabed mining patents in Japan revealed 27 patents held by Japanese nationals. Only ten of these were identified in manual searches conducted for this study, and none were identified through the computer search.[13] This study, as in any patent search, cannot claim to be all-inclusive, and foreign patents have been especially difficult to search because of language barriers and differences in classification systems. Nevertheless, this is believed to be the most comprehensive and current collection of patent information available on the seabed mining industry. Any missing information should have a minimal impact on the conclusions of this study.

II. SEABED MINING PATENT DATA

A. SEABED MINING PATENT ASSIGNEES

A1. Consortia. Several of the world's largest private firms have entered into partnership arrangements or joint ventures for the purpose of seabed mining. These arrangements or ventures are referred to here as seabed mining consortia. The consortia are the mostly private groups: Ocean Mining Associates (OMA), the Kennecott Consortium (KCON), Ocean Management Incorporated (OMI), and Ocean Minerals Company (OMCO); and the mixed public-private groups: the Association Française pour l'Exploitation et le Recherche des Nodules (AFERNOD) from France and the Japanese Deep Ocean Resources Development Company (DORD). Figure 1 depicts the organization of seabed mining consortia firms. In many cases, only a few companies that participate in each consortium hold patent rights. With patent data, therefore, it may be possible to begin to unravel intraconsortium patenting

Figure 1

ORGANIZATION OF THE SEABED MINING CONSORTIA

CONSORTIUM MEMBER & SHARE	PARENT	NATIONALITY
OCEAN MINING ASSOCIATES (OMA): formed May 1974		
Essex Minerals Company (25%)	U.S. Steel Corporation	U.S.
Union Seas Inc. (25%)	(Union Mines, Union Miniere S.A.), Société Générale de Belgique	Belgium
Sun Ocean Ventures (25%)	Sun Company Inc.	U.S.
Samim Oceans Inc. (25%)	Ente Nazionale Idrocarburi (ENI)	Italy
Deepsea Ventures (Service Contractor for the Consortium)		
KENNECOTT CONSORTIUM (KCON): formed January 1974		
Kennecott Corporation (40%)	(SOHIO), BP	(U.S.), U.K.
RTZ Deepsea Mining Enterprises Ltd. (12%)	Rio Tinto Zinc p.l.c.	U.K.
Consolidated Gold Fields p.l.c. (12%)	Consolidated Gold Fields p.l.c.	U.K.
BP Petroleum Development Ltd. (12%)	British Petroleum Company p.l.c.	U.K.
Noranda Exploration Inc. (12%)	Noranda Mines Ltd.	Canada
Mitsubishi Corporation)	Mitsubishi Group (leader)	Japan
Mitsubishi Metal Corp.) (12%)	"	Japan
Mitsubishi Heavy Industries Ltd.)	"	Japan
OCEAN MANAGEMENT INCORPORATED (OMI): formed February 1975		
Inco Inc. (25%)	Inco Ltd.	Canada
SEDCO Inc. (25%)	SEDCO, Inc.	U.S.
Arbeitsgemeinschaft Meerestechnische Rohstoffe (AMR) (25%)	(Metallgesellschaft A.G. (Preussag A.G. (Salzgitter A.G.	F.R.G.) F.R.G.) F.R.G.)
Deep Ocean Minerals Company (DOMCO) (25%)	23 Companies led by Sumitomo	Japan
OCEAN MINERALS COMPANY (OMCO): formed November 1977		
Amoco Ocean Minerals Company (31%)	(Amoco Minerals), Standard Oil	U.S.
Lockheed Systems Company) (31%)	(Lockheed Corporation	U.S.
Lockheed Missiles and Space Company))	((Lockheed Corporation	U.S.
Billiton B.V. (31%)) Ocean Minerals Inc.	(Royal Dutch/Shell	Netherlands
B.K.W. Ocean Minerals B.V. (8%))	(Royal Boskalis Westminster	Netherlands
ASSOCIATION FRANCAISE POUR L'ETUDE ET LA RECHERCHE DES NODULES (AFERNOD): formed 1974		
Institute Française de la Recherche et l'Exploitation de la Mer (formerly CNEXO) (70%)	French Government	France
Commissariat á l'Energie Atomique (CEA) (20%)	French Government	France
Société Métallurgique le Nickel (SLN) (6%)	IMETAL, Elf Aquitaine	France
Chantiers du Nord et de la Méditérranée (CNM) (4%)	Schneider S.A.	France
DEEP OCEAN RESOURCES DEVELOPMENT CORPORATION (DORD): formed September 1982		
48 Companies (including the members of the Deep Ocean Minerals Association (DOMA)) that coordinate activities with MITI		Japan

(and perhaps R&D) strategies. Some possible strategies are described in greater depth in section III.

A2. Potential Entrants. Several other large private firms have conducted seabed mining R&D and hold patent rights to seabed mining inventions. These firms have not joined with others to plan for or conduct seabed mineral development and are generally not considered active members in the industry. These firms, which include Bendix, Bethlehem Steel, Dow Chemical, General Dynamics, Global Marine, Union Carbide, Westinghouse, and others, are considered here as potential entrants to the seabed mining industry. Patents held by individuals or institutions in the Soviet Union have been included in this category as well.[14]

A3. Engineers. Other smaller firms or individuals hold patents to seabed mining inventions. This group, referred to here as engineers, includes small engineering firms and patent development companies. In some cases, it may be inaccurate to distinguish between potential entrants and engineering firms. Some potential entrants may be in the engineering business: conducting R&D with the intention of selling experience or patent rights to more active firms.[15] Some engineers may become involved in joint ventures. In fact, the Continuous Line Bucket Syndicate (CLB), an early noncommercial R&D and exploration venture, was organized primarily through the efforts of two engineers, Commander Yoshio Masuda of Japan and Dr. John Mero of the United States.[16]

A4. Who holds seabed mining patents? Figure 2, parts A, B, and C, lists the firms, agencies, or individuals that hold seabed mining patents. These entities have been classified as consortium members or affiliates, potential entrants, or engineers. Potential entrants and engineers are further separated by nationality. The total number of nodule recovery patents and metallurgical processing patents have been identified for each entity. Patents granted in the United States and in other countries have been included regardless of whether the same invention has been patented by the same entity in more than one jurisdiction.[17]

Figure 2, Part A lists firms or agencies that are members of or in some way affiliated with members of seabed mining consortia. Because there has been no examination of patent licensing agreements, some of the affiliations represented here may be tenuous. For example, Shell Oil is a subsidiary of Royal Dutch/Shell, which in turn is a parent of the OMCO consortium member

FIGURE 2

A. CONSORTIUM MEMBERS OR AFFILIATES THAT HOLD SEABED MINING PATENTS

		Recovery	Processing	Total
OMA	Newport News Shipbuilding & Drydock	11	--	11
	Deepsea Ventures	15	39	54
	Union Miniere	3	--	3
	Metallurgie Hoboken-Overpelt*	--	1	1
	Technomare*	3	--	3
		32	40	72
KCON	Kennecott	4	50	54
	Bear Creek Mining*	2	--	2
	Mitsubishi Kaihatsu K.K.*	2	--	2
		8	50	58
OMI	Earl & Wright*	1	--	1
	Howaldtswerke-Deutsche Werft*	4	--	4
	Inco	16	11	27
	Metallgesellschaft	1	1	2
	Preussag	6	2	8
	Salzgitter	3	--	3
	Sumitomo Metal Mining	5	1	6
		36	15	51
OMCO	Lockheed Missiles and Space	1	--	1
	Shell Oil*	2	2	4
	Baggermaatschappij Bos & Kalis*	1	--	1
		4	2	6
AFERNOD	CEA	11	4	15
	CNEXO (IFREMER)	1	--	1
	SLN	1	3	4
	CNEXO & SLN	3	--	3
	CNEXO, SLN, and Tetra Tech	2	--	2
		18	7	25
DORD	AIST	1	--	1
	Mitsui Zosen	1	--	1
	Others	--	5	5
		2	5	7
CONSORTIA TOTALS		100	119	219

*(Not a consortium member, but related to a consortium member through a common parent firm).

FIGURE 2 (Continued)

B. POTENTIAL ENTRANTS THAT HOLD SEABED MINING PATENTS

		Recovery	Processing	Total
U.S.	Bendix	1	--	1
	Bethlehem Steel	3	1	4
	Chevron Research	--	1	1
	Combustion Engineering	--	1	1
	Dow Chemical	--	2	2
	Ethyl Corporation	--	7	7
	General Dynamics	2	--	2
	Global Marine	5	--	5
	Mobil Oil	1	1	2
	Republic Steel	--	1	1
	Sherex Chemical	--	1	1
	Summa Corporation	2	--	2
	Tetra Tech	1	--	1
	Union Carbide	--	1	1
	UOP	--	6	6
	Westinghouse Electric	6	--	6
F.R.G.	Bayer and Duisburger Kupferhütte	--	1	1
	Deutsche Babcock & Wilcox	2	--	2
	Demag L.M.S.	1	--	1
	Friedrich Krupp	2	--	2
	Gesellschaft für Kernforschung	2	--	2
	Klein, Schanzlin & Becker	5	--	5
	Orenstein & Koppel	4	--	4
Canada	Sherritt Gordon Mines	--	1	1
Holland	Grupping A.W.J.	1	--	1
	IHC Holland	3	--	3
France	EMH	1	--	1
	SGCEM	3	--	3
	SOFREM	--	1	1
USSR	Gold Mining Institute	3	--	3
	Leningrad Mining Institute	1	--	1
	Moscow Mining Institute	3	--	3
	Ust-Kamenogorsk Nonferrous Institute	1	--	1
	Transportation Cons. Res. Institute	1	--	1
POTENTIAL ENTRANT TOTALS:		54	25	79

Figure 2 (Continued)

C. ENGINEERING FIRMS AND ENGINEERS THAT HOLD SEABED MINING PATENTS

		Recovery	Processing	Total
U.S.	Anonymous	1	--	1
	Baird	1	--	1
	Benthos	1	--	1
	Cato Research	--	2	2
	Dane	2	--	2
	Diggs	3	--	3
	Gardner	1	--	1
	Girden	1	--	1
	Guntert	2	--	2
	Haggard	1	--	1
	Hawaii Marine Research	3	--	3
	Interior Department	--	2	2
	Krutein	2	--	2
	Mero	1	1	2
	Nelson	2	--	2
	Rossfelder	1	--	1
	Scientia Corporation	1	--	1
	Stechler	1	--	1
	Taylor	1	--	1
	University Patents	--	1	1
	Wanzenberg	4	--	4
	Willums (Nor-Am Resources Technology)	5	--	5
F.R.G.	Meixner	--	1	1
	Ramm	1	--	1
	Scheffler	--	1	1
	Tax	2	--	2
	Van Peteghem	--	1	1
	Walz	2	--	2
	Weinhands	3	--	3
U.K.	Anonymous	--	2	2
	Asotoff	--	1	1
	Cronjager	--	1	1
	Industry Secretary	1	--	1
	Sridhar et al.	--	1	1
Canada	Ball	1	--	1
	Canadian Patents & Development	--	2	2
	Illis	--	1	1
	Roever	--	1	1
	Weston	--	4	4

Figure 2 (Continued)

C. ENGINEERING FIRMS AND ENGINEERS THAT HOLD SEABED MINING PATENTS (Continued)

		Recovery	Processing	Total
France	Mouret	--	2	2
	Remlinger	1	--	1
	Tardivat	1	--	1
Japan	Masuda	4	--	4
	Nagoya	--	1	1
	Saito	2	--	2
	Toritani	1	--	1
	Tsutsumi	1	--	1
	Yoshishige	--	1	1
USSR	Andreev	1	--	1
	Geier	1	--	1
	Istoshin	1	--	1
	Lezgintsev	1	--	1
	Mamaeb	1	--	1
	Shevelev	1	--	1
Switzerland				
	Hody	(see: Willums--U.S.)		
Norway	Thorsen	--	2	2
	Willums	(see Willums--U.S.)		
Belgium	Anonymous	--	1	1
South Africa				
	Hervieu	1	--	1
ENGINEER TOTALS:		61	29	90
TOTALS FOR ALL SEABED MINING PATENT HOLDERS:		215	173	388

Billiton. Although difficult to verify, this relationship may facilitate the licensing of patented seabed mining technology. Other affiliations are clearer. Deepsea Ventures Incorporated (DVI) is a service contractor for the OMA consortium; Newport News Shipbuilding and Drydock (NNS&D) spawned DVI in the late 1960's and holds no seabed mining patents after 1970. Earl & Wright, an engineering firm, is a subsidiary of OMI consortium member, SEDCO. Sumitomo Metal Mining and Mitsubishi are correctly represented as members of the OMI and KCON consortia, respectively. These two firms are also members of the Japanese consortium, DORD.

Potential entrant firms have been arranged in Figure 2, Part B in alphabetical order by nationality. Some of these firms may have been hired by or may have conducted joint research with the more active seabed mining firms. For example, Tetra Tech holds a joint patent with CNEXO and SLN, members of the French consortium AFERNOD. AFERNOD, which is led by French governmental agencies, has hired engineering firms to undertake feasibility studies on seabed mining. One of these firms, Alsthom-Atlantique, is a parent of patent-holder Société Générale de Constructions Eléctriques et Mécaniques (SGCEM). Several of the potential entrant firms are subsidiaries of firms that might be considered large enough to participate in seabed mining alone or as a consortium member. SGCEM falls into this category as well as Deutsche Babcock & Wilcox A.G., an affiliate of the U.S. marine construction company, McDermott, and Demag L.M.S., a subsidiary of Mannesmann A.G.

Figure 2, Part C lists engineers, including small engineering firms and patent development firms, in alphabetical order by nationality. It is unknown to what extent any of these patents have been licensed to other firms or to the seabed mining consortia. Metallgesellschaft has cited the technologies patented by Demag (see potential entrants), James Ball, Jan-Olaf Willums, and Dieter Hody as potentially innovative.[18] Mero and Masuda were largely responsible for promoting early seabed mining fervor in the 1960's.

B. PATENT CONCENTRATION

B1. Patents. Once the identities of patenting firms are known, a rough picture of relative inventive activity can be drawn by comparing the numbers of patents held by these firms.[19] Figure 3 reveals the "concentration" or the percent of total nodule recovery, total metallurgical processing, or total seabed mining patents held by consortia, potential entrants, or engineers.

Figure 3

PATENT CONCENTRATION

(Percent of All Seabed Mining Patents)

PATENTEE	NODULE RECOVERY		METALLURGICAL PROCESSING		TOTAL	
	No.	(%)	No.	(%)	No.	(%)
OMA	32	(15)	40	(23)	72	(18)
KCON	8	(4)	50	(29)	58	(15)
OMI	36	(17)	15	(9)	51	(13)
OMCO	4	(2)	2	(1)	6	(2)
AFERNOD	18	(8)	7	(4)	25	(6)
DORD	2	(1)	5	(3)	7	(2)
Consortia Total	100	(47)	119	(69)	219	(56)
Potential Entrants Total	54	(25)	25	(14)	79	(20)
Engineers Total	61	(28)	29	(17)	90	(23)
Industry Total	215	(100)	173	(100)	388	(99)

Seabed mining consortia firms as a group hold more nodule recovery and metallurgical process patents than either the potential entrants or engineers. Interestingly, potential entrants and engineers considered together hold more nodule recovery patents than the consortia as a group. Evidently, potential entrant firms and engineers have tended to emphasize recovery technology. In fact these firms rarely have patented both types of technology; only three firms or engineers have both nodule recovery and metallurgical process patents. The consortia have tended to emphasize both recovery and processing technology, which may reflect interests in achieving vertically integrated operations. The consortia hold over two-thirds of the metallurgical process patents indicating that this area may be technologically more complex.

In this comparison of patent concentration, OMA clearly holds the highest concentration with almost one-fifth of all seabed mining patents; Figure 3 shows OMA's primary position in nodule recovery and its secondary position in metallurgical processing. KCON follows OMA almost solely on the basis of its metallurgical processing patent concentration in which it holds 29 percent of all patents. OMI places third in the comparison with 13 percent of all seabed mining patents.

B2. Claims. Patent concentration is necessarily a rough picture of R&D activity and technological achievement, because it does not compare the actual inventions on a qualitative basis. Moreover, patent concentration does not measure the number of new technological concepts that together may describe and define a particular invention. In U.S. patents, individual "claims" are made on these new technological concepts as part of a description of an invention. Figure 4 shows the concentration of claims on U.S. patents only. Although this representation of R&D activity still cannot compare inventions qualitatively, it may provide a better measure of the number of new technological concepts that accompany seabed mining patents.[20]

In this comparison of claims concentration, the consortia remain in almost the same positions as in the patent concentration comparison, with at least two notable exceptions. First, OMA has a greater number of metallurgical process claims than KCON. OMA actually averages over 15 claims per process patent while KCON averages only nine. Second, OMCO has surpassed KCON and AFERNOD in its concentration of nodule recovery claims. Lockheed made 99 claims on its one remote-control, bottom-crawler recovery system patent. With

Figure 4

CLAIMS CONCENTRATION

(Percent of all claims made on U.S. seabed mining patents)*

PATENTEE	NODULE RECOVERY No.	NODULE RECOVERY (%)	METALLURGICAL PROCESSING No.	METALLURGICAL PROCESSING (%)	TOTAL No.	TOTAL (%)
OMA	430	(28)	614	(37)	1044	(33)
KCON	33	(2)	492	(30)	525	(16)
OMI	148	(9)	143	(9)	291	(9)
OMCO	110	(7)	19	(1)	129	(4)
AFERNOD	89	(6)	19	(1)	108	(3)
DORD	5	(0.3)	N.A.	(N.A.)	5	(0.2)
Consortia Total	815	(52)	1287	(78)	2102	(65)
Potential Entrants Total	283	(20)	221	(13)	504	(16)
Engineers Total	461	(28)	133	(8)	594	(19)
Industry Total	1559	(100)	1641	(99)	3200	(100)

*(Note: Claims data were available only for U.S. patents.)

the exception of OMA member, Union Miniere, which has made 109 claims on two recovery patents, no other seabed mining patent comes close to Lockheed's in total number of claims. This may be an important indicator of patent strategy in the case of the OMCO group.[21]

B3. Intraconsortium patents and claims. Concentration data indicate the relative importance of consortia patent activity, at least in the amount of activity, when compared to the patent activity of potential entrants and engineers. It may prove useful, therefore, to examine more closely the concentration of patents and claims within individual consortia. Figure 5 shows the percent of total patents and total claims on U.S. patents for the members of each consortium. The primary patenting firms (PPFs) in each consortium can thereby be identified.[22] Deepsea Ventures (including eight patents held by Newport News Shipbuilding and Drydock) and Kennecott are overwhelmingly the lead patenting firms in their respective consortia. Because the OMA and KCON groups are the leaders in industrywide patent and claims concentrations, one might conjecture that Deepsea Ventures and Kennecott have been the most active firms in seabed mining R&D, with Kennecott clearly emphasizing metallurgical processing work. In the cases of OMI and AFERNOD, patent and claims activities are distributed among more of the member firms or agencies, although Inco and CEA are clearly the respective leaders. In OMCO's case, Lockheed holds only one of six total patents, but has made over three-quarters of the claims. The available evidence is insufficient to draw conclusions for DORD, but the Agency of Industrial Science and Technology (AIST), an affiliate of the Japanese Ministry of International Trade and Industry (MITI), has been conducting a large-scale manganese nodule R&D project with the assistance of about 16 private companies.[23]

C. RELATIVE EMPHASIS

Concentration data reveal those firms and agencies that have been most active in patenting, and therefore possibly also in R&D, in the seabed mining industry. But concentration explains little about the emphasis within a firm or agency on seabed mining R&D. Figure 6 shows U.S. seabed mining patents as a percent of all U.S. patents granted to PPFs during 1969-80.[24] Data on four large potential entrant firms has been included for comparison. Again, Deepsea Ventures leads with over two-thirds of its total patent activity directed toward seabed mining. CNEXO and SLN follow with only one-quarter of

Figure 5

INTRACONSORTIUM PATENTS AND CLAIMS CONCENTRATION

(Percent of patents and claims held by consortium member firms)*
(Primary Patenting Firms [PPFs] are underlined)

	Total Consortium Patents	Total Consortium Claims*	Consortium Member Firms	% of Own Consortium Patents Held	% of Own Consortium Claims* held by PPF
OMA	72	1044	DVI and NNS&D	90	87
			Union Miniere	4	10
			Met. Hob.-Overp.	1	2
			Technomare	4	1
KCON	58	525	Kennecott	93	99.8
			Bear Creek Mining	3	--
			Mitsubishi K.K.K.	3	0.2
OMI	51	291	Inco	53	68
			Preussag	16	6
			Sumitomo M.M.	12	13
			Salzgitter	6	3
			Metallgesellschaft	4	--
			Earl & Wright	2	7
			How. Deut. Werft	8	1
OMCO	6	129	Lockheed	17	77
			Shell Oil	66	23
			Bag. Bos & Kalis	17	--
AFERNOD	25	108	CEA	60	68
			SLN	26	14
			CNEXO (IFREMER)	14	18
DORD	7	5	AIST	14	100
			Mitsui Zosen	14	--
			Others	74	--

*(Note: Claims data were available only for U.S. Patents.)

Figure 6

RELATIVE EMPHASIS

(U.S. seabed mining patents as a % of all U.S. patents by PPF during 1969-80)

PPF	All U.S. Patents 1969-80	U.S. Seabed Mining Patents 1969-80	U.S. Seabed Mining Patents as a % of all Patents: 1969-80
DVI (and NNS&D) a/	54	38	(70)
CNEXO b/	6	1.5	(25)
SLN b/	6	1.5	(25)
Kennecott	223	33	(15)
Preussag	18	2	(11)
Inco, Inc.	446	13	(3)
Sumitomo Metal	N.A.	2	N.A.
Lockheed M&S	41	1	(2)
CEA	821	4	(1)
AIST c/	56	N.A.	N.A.
Potential Entrants			
Global Marine	84	3	(4)
Bethlehem Steel	468	4	(1)
General Dynamics	490	4	(1)
UOP, Inc.	2425	4	(0.2)

a/ 100% of DVI's relative emphasis during this period was spent on seabed mining patents. NNS&D has obtained some patents in other areas during this period.

b/ CNEXO and SLN have one joint and two separate U.S. seabed mining patents.

c/ AIST holds one 1983 U.S. seabed mining patent.

their patent activity in the seabed mining area, and Kennecott takes a distant third with 15 percent of its total patent emphasis in seabed mining.

Several firms or agencies, including UOP, CEA, General Dynamics, Bethlehem Steel, and Inco, obtained many patents in different areas during this period, a good reflection of their extensive R&D capabilities. But, and perhaps not too surprising in light of the concentration data, these firms expended a very low percentage of their total patenting emphasis on seabed mining technology. Indeed, many consortium member firms expended relatively less emphasis on seabed mining patents than did potential entrants. One advantage in forming a consortium may be the allocation of responsibilities such that those firms with particular expertise in an area such as seabed mining R&D undertake the bulk of the work in R&D and patenting. Lockheed, Kennecott, and Deepsea Ventures may be examples of this kind of distribution of responsibility.

D. TIMING OF PATENT ACTIVITY

The timing of patent activity is an important quantitative measure of the rate of invention in an industry.[25] R&D usually is a prerequisite to invention. Therefore, the timing of patent activity may provide a rough measure of the timing of R&D activity. This is especially useful in an understanding of the seabed mining industry, because much of its efforts have been directed at R&D.[26] If the seabed mining industry is cyclical in nature, a trait that generally is characteristic of mining industries, an examination of patent timing may help to describe the nature of the cycle.[27]

The timing of patents for the entire seabed mining industry is depicted in Figure 7. (The numbers along the X-axis of the figure represent, on top, the years in which patents were granted and, underneath, the years in which those patents will expire.) The first seabed mining patents were issued in the mid-1960's, and patent activity has continued from that date until the present. The preponderance of patents were granted between 1973 and 1978. Thus a period of patent protection exists for most seabed mining patents until 1990-95.

In the United States, the process of application for the issue of a patent on an invention takes an average of two years due to a tremendous backlog of patent applications and a limited examining staff at the Patent and Trademark Office.[28] This rule-of-thumb holds true for seabed mining patents as well. (Figure 8 shows the cumulative number of U.S. seabed mining patent

Figure 7: TOTAL SEABED MINING PATENTS WORLDWIDE 1965—1984

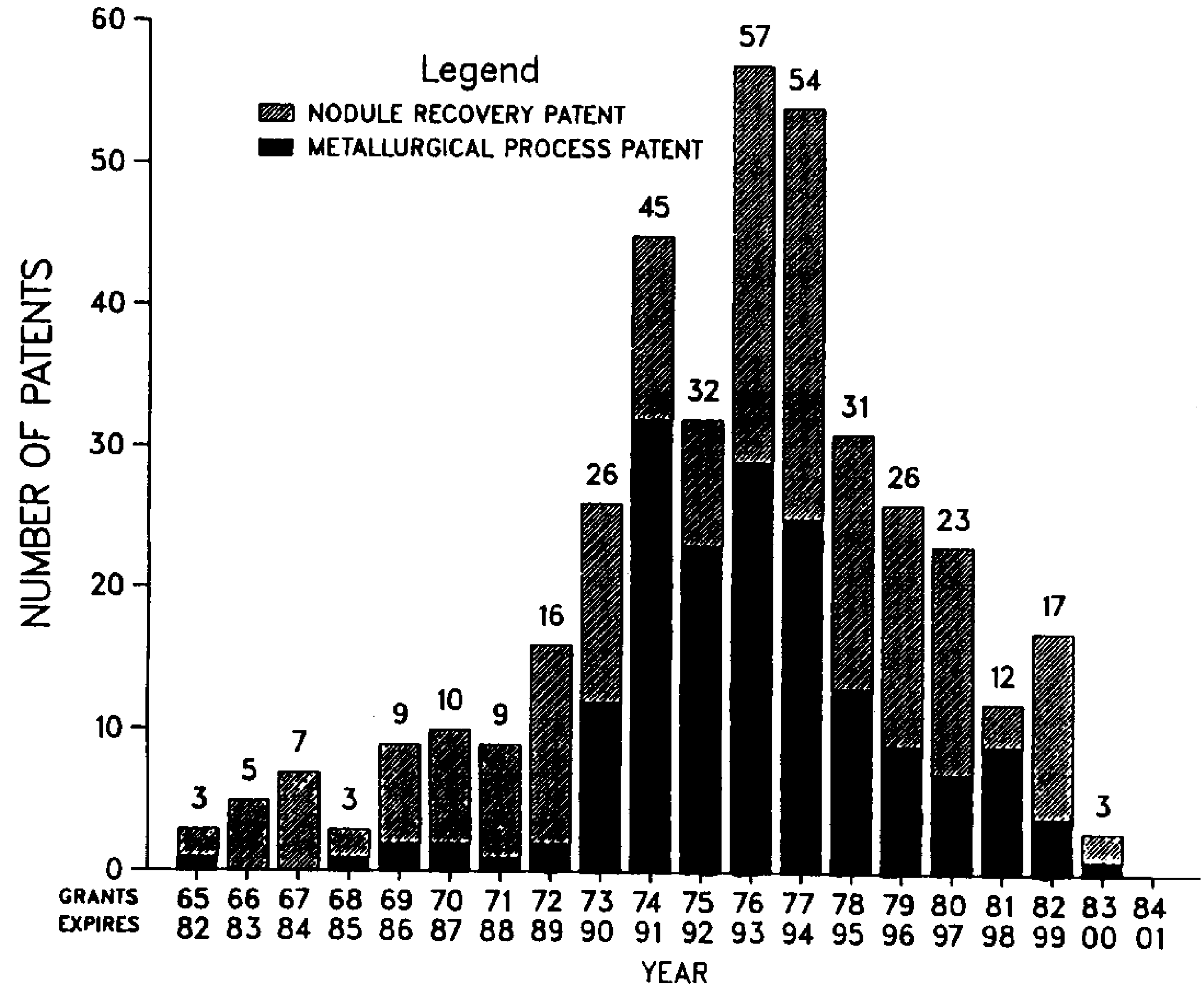
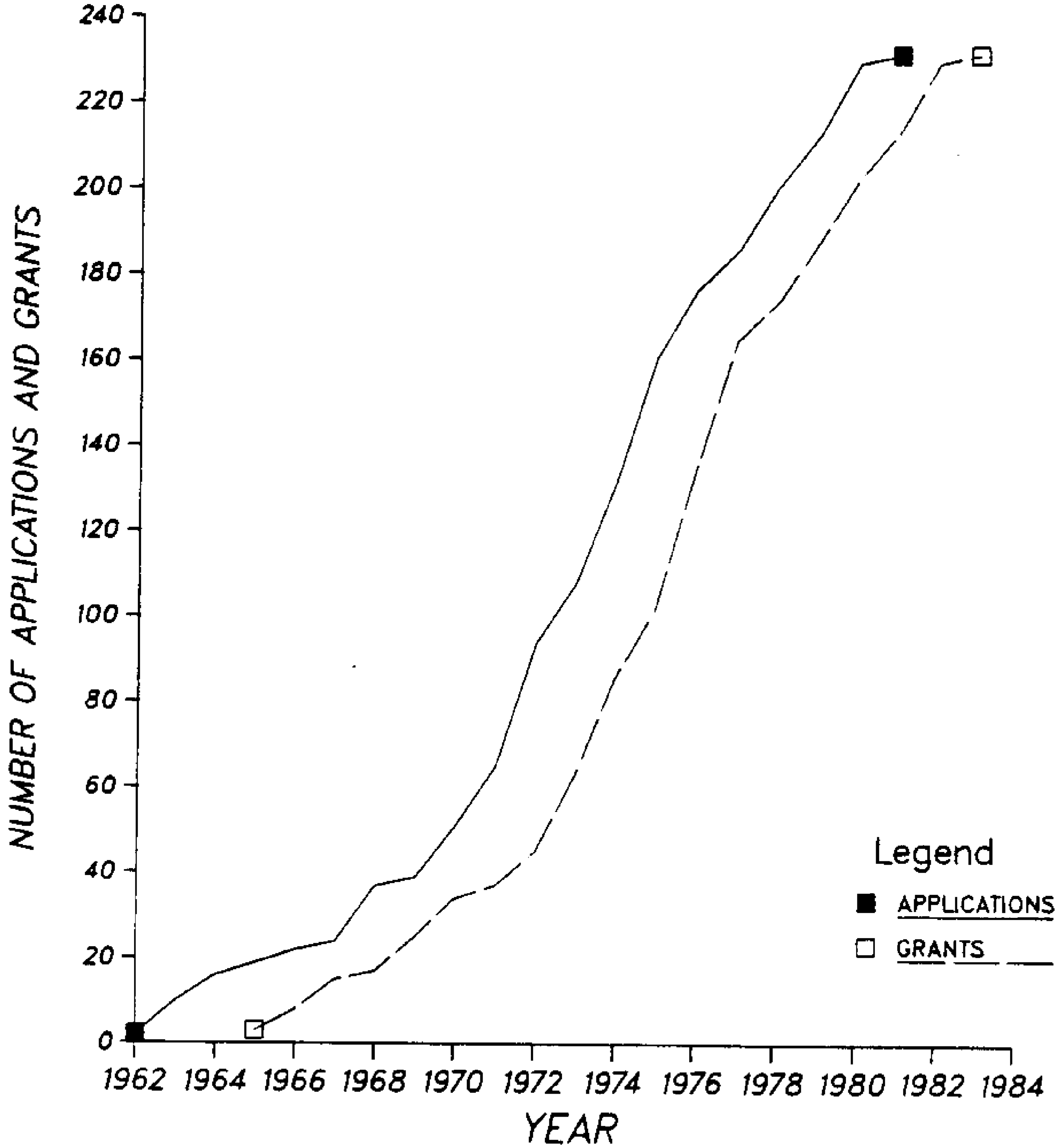


Figure 8: COMPARISON OF RATE OF INCREASE IN U.S. SEABED MINING PATENT APPLICATIONS AND GRANTS 1962–1983



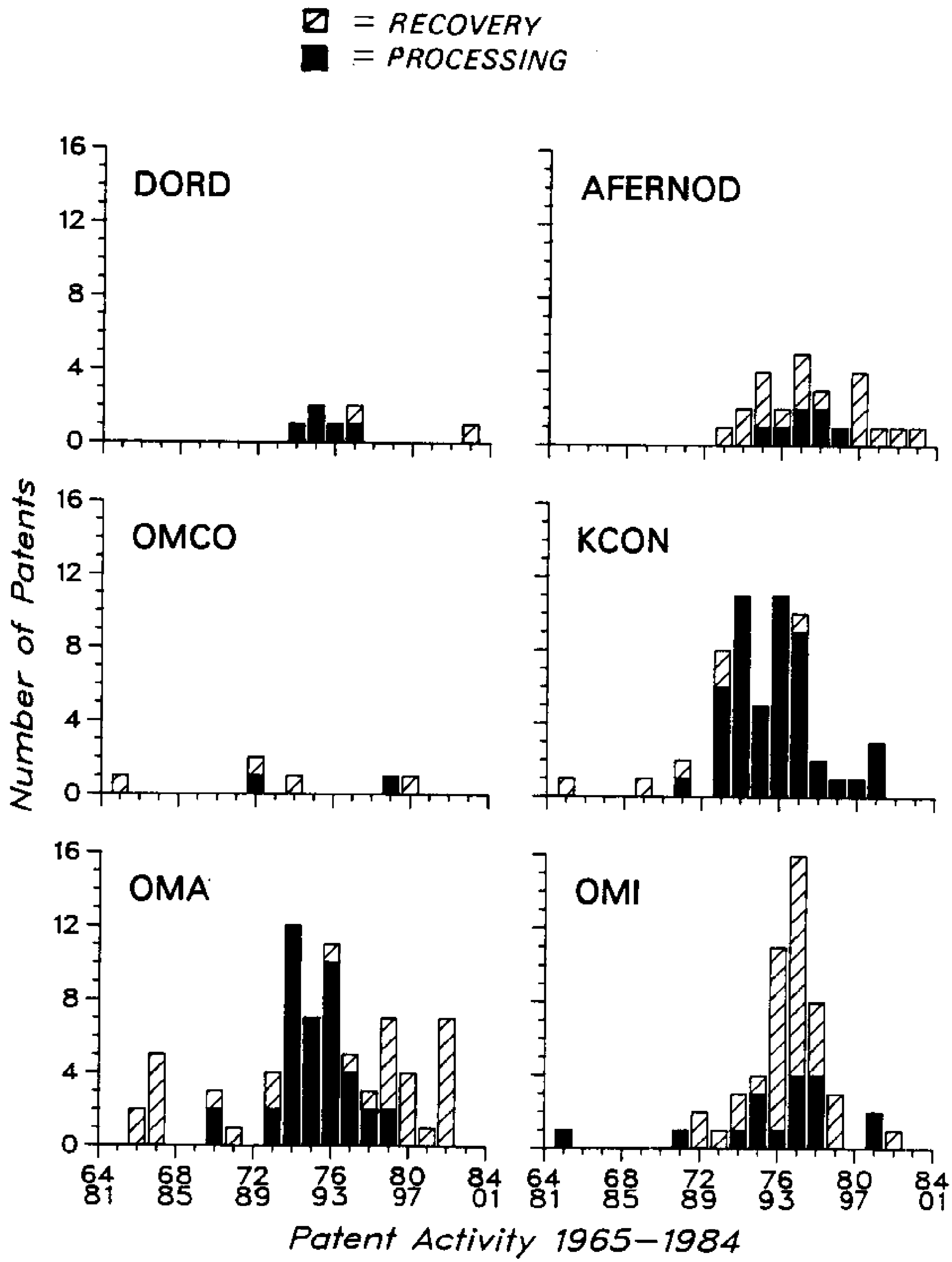
applications and grants at any moment in time and displays the approximate two year lag between applications and grants.) Because most seabed mining patents were granted between 1973 and 1978, it follows that applications for these patents most likely were filed between 1971 and 1976.

As roughly indicated by this timing pattern, most seabed mining R&D, which resulted in applications filed during 1971-76, must have taken place in the late 1960's and early 1970's. Although the lag structure for seabed mining R&D to economic conditions in the metal markets is unknown in this industry, a complex interaction of factors probably worked first to spur and then to slow seabed mining R&D. These factors may be related to economic signals, political events at the Law of the Sea Conference, and legal uncertainties associated with the status of exploration and exploitation sites. R&D accelerated during the early 1970's when economic conditions generally were bright. Subsequent to the time of the 1973-74 recession, which was precipitated by the energy crisis, seabed mining patent activity levelled-off and declined steadily thereafter. Thus, if a seabed mining R&D cycle exists, the period can be very crudely estimated at twenty years.[29]

Interestingly, if this period should persist, the next upswing would occur in the early 1990's. This coincides with the beginning of the expiration dates for the bulk of the seabed mining patents. As these patents expire, the technology that they describe can be manufactured, sold, or used without restriction. This increased availability of technology might then enhance a renewed industrial interest and reinforce the tendency for cyclical behavior in seabed mining activity.

It is known that the consortia had constructed timetables for their R&D programs.[30] When their programs had been completed, the consortia decided not to continue seabed mining R&D. It is possible, therefore, that the individual strategies of the seabed mining consortia may have been important factors in shaping this round of patent activity. The timing of patents for the individual consortia is depicted in Figure 9. The consortia, OMA, OMI, KCON, and AFERNOD, show a large increase in patent activity at approximately the same time as they were formed. The technological groundwork which preceded the patent activity may have helped contribute to the formation of these consortia. Some of the patents that preceded consortia formation may have been sought to advertise technological capability and attract partners or customers. The primary patenting firms may have sought patents in part to

Figure 9: **TIMING OF PATENT ACTIVITY BY SEABED MINING CONSORTIA**



protect themselves from their prospective partners (otherwise, they would have to reveal unprotected know-how). As the consortia were formed, additional know-how protection could be written into their joint venture agreements. Once the first round of R&D had occurred, and patents had been obtained, the technology was protected for a seventeen year period. While envisioning a diminishing rate of return on additional research in the absence of immediate commercial development, patent holders could then afford to back off on R&D and await more favorable economic conditions before commercial utilization of their technology. These strategies are examined in greater detail in section III.

E. SPREAD OF PATENT ACTIVITY

The production of metals from seabed nodule ores involves two broad problems: the recovery of nodules from the deep seabed and the metallurgical processing of those nodules. Each problem can be separated into several generic categories of technology (see Appendix). The recovery of nodules from the deep seabed consists of collection, lift, surface support, and transportation technologies. The metallurgical processing of nodules consists of reduction, extraction, and electrowinning of nickel and copper, and the beneficiation of other metals like cobalt or manganese. Figure 10 shows how the patent activity of consortia and potential entrants is spread across generic categories of seabed mining technology.[31]

The spread of patent activity may have important implications for the vertical integration of firms in an active industry. The extent to which a firm has the ability to recover and metallurgically process seabed nodule ores reveals its technological position within an industry and may have some importance with regard to its eventual commercial success.[32] As depicted in Figure 10, in general, the consortia are more vertically integrated than individual potential entrant firms. Two consortia, OMA and OMI, have patented technology in each generic category and appear more vertically integrated than the other consortia. The spread of patent activity reaffirms the conclusion drawn earlier from the concentration data that potential entrants have tended to focus on either recovery or processing technology. In very few cases, such as Bethlehem Steel and Mobil Oil, potential entrants have patented both nodule recovery and metallurgical processing technology.

Generic categories of technology can be further subdivided into specific

Figure 10

SPREAD OF PATENT ACTIVITY ACROSS GENERIC TECHNOLOGICAL CATEGORIES

	RECOVERY				METALLURGICAL PROCESSING			
	Collection	Lift	Surface Support	Transport	Reduction	Extraction	Electrowinning	Recovery of Other Metals
CONSORTIA								
OMA	•	•	•	•	•	•	•	•
KCON	•	•	•		•	•	•	•
OMI	•	•	•	•	•	•	•	•
OMCO	•	•	•			•		•
AFERNOD	•	•	•		•		•	•
DORD	•	•	•		•	•		
POTENTIAL ENTRANTS								
Bayer					•	•		
Bendix	•	•	•					
Bethlehem Steel	•	•	•	•	•			
Chevron Research					•			
Combustion Engineering					•			
Deut. Babcock & Wilcox	•							
Demag L.M.S.	•	•						
Dow Chemical					•	•		
Duisburger Kupferhutte	(see Bayer)							
EMH		•	•					
Ethyl Corporation					•			
Friedrich Krupp	•	•						
General Dynamics	•	•	•					
G. für Kernforschung	•	•						
Gold Institute (USSR)	•	•	•					
Grupping A.W.J.	•	•						
IHC Holland		•						
Klein, Schanzlin & Becker		•						
Leningrad Mining Inst.	•							
Mobil Oil	•	•	•		•			
Moscow Mining Inst.	•							
Orenstein & Koppel	•							
Republic Steel					•			
Sherex Chemical						•		
Sherritt Gordon Mines					•			
SGCEM	•	•	•					
Summa Corporation	•	•	•					
SOFREM					•			
Tetra Tech	•	•						
Union Carbide							•	
UOP					•	•	•	
Transp. Cons. Inst.	•	•						
Ust-Kamenogorsk Nonferrous		•						
Westinghouse Electric	•	•	•					

technologies. For example, at least six specific technologies compose the generic category of collection: sampler, CLB bucket, towed sledge, hybrid bucket/sledge, robot crawler, and autonomous shuttle. The generic categories of recovery and metallurgical process technologies have been subdivided in Figure 11 by consortia.[33] Patent activity across specific technological solutions within a generic category may have important implications for technological performance relative to rivals. For instance, AFERNOD members hold patents on four out of the six collection technologies, including the autonomous shuttle, which is radically different in concept from technologies patented by other firms. AFERNOD's diversification within this generic category reveals a flexibility that eventually might allow it to operate with the most commercially successful specific solution to the collection problem.

Under conditions of commercial operation, and especially after patent protection expires, one might expect operators to converge upon the most effective technology.[34] If specific categories are broad enough to allow more than one patent on each specific technology, i.e., substitutes, as appears to be the case in many seabed mining technologies, then convergence could occur even before the industry becomes commercial. The spread data show that several consortia have patented components of hydraulic systems: towed sledges, robot crawlers, waterpumps, and airlifts, among others. In fact, hydraulic systems are the purported technology of OMI, OMA, KCON, and OMCO.[35] The Japanese are conducting a large-scale R&D project directed at developing a hydraulic system.[36] Recently, the French have indicated their intentions to move away from the autonomous shuttle concept and towards the hydraulic system.[37] Thus convergence upon a perceived most effective technology is possible even before commercial operations. But, because patents have been granted on many kinds of technology, this convergence is not immediately apparent from observations of patent activity.

III. MOTIVATIONS AND STRATEGIES

A. OCEAN MINING ASSOCIATES (OMA)

The OMA consortium was an early commercial pioneer in seabed mining research and exploration. The operating arm of the consortium has been Deepsea Ventures (DVI), a company spawned by Tenneco-controlled Newport News

Figure 11

SPREAD OF CONSORTIA PATENT ACTIVITY ACROSS SPECIFIC TECHNOLOGICAL CATEGORIES
(Recovery and Metallurgical Processing)

	OMA	KCON	OMI	OMCO	AFERNOD	DORD
COLLECTION						
Sampler	●	●	●	●	●	●
Bucket (CLB)					●	●
Towed Sledge	●		●		●	●
Hybrid Bucket/Sledge						
Robot Crawler		●	●	●		
Autonomous Shuttle					●	
LIFT						
Wire Rope					●	●
Water Pump	●		●	●	●	
Airlift	●	●				●
Moonpool	●			●		●
Gimballed Derrick	●			●		
Pipe Handler	●			●		
Shuttle					●	
SURFACE SUPPORT						
Ore Carrier	●					
Semisubmersible					●	
Drillship			●	●		
Vertical Vessel						
Other Vessel	●	●	●	●	●	●
Navigation				●		
TRANSPORT						
Ore Carrier	●		●			
Docking System			●			
Loading System			●			
REDUCTION						
Comminution	●	●	●		●	
Acid Leach	●	●	●	●	●	
Ammoniacal Leach	●	●	●			
Acid Halide Leach	●	●				
Smelting	●	●	●		●	
Cuprion		●				
Gaseous	●	●	●		●	
Other	●	●				
EXTRACTION						
Nickel	●	●	●	●	●	
Copper	●	●	●	●	●	
Cobalt	●	●	●	●	●	
Manganese	●		●			
Other	●	●			●	
ELECTROWINNING						
Nickel	●	●			●	
Copper	●	●	●		●	
Cobalt	●		●			
Manganese	●					
OTHER RECOVERY MEANS						
Cobalt	●	●		●	●	
Manganese	●	●	●			
Molybdenum	●	●	●			
Zinc	●				●	
Others	●					

Shipbuilding & Drydock (NNS&D) in the late 1960's. In 1970, DVI was employed by Tenneco and Metallgesellschaft to conduct R&D, exploration, and testing. In May 1974, OMA was formed as a U.S. partnership between Tenneco and several Japanese companies (JAMCO). By November of that year, U.S. Steel, the largest steel producer in the United States and a major manganese consumer, and Union Miniere, a Belgian mining concern with a major position in the world cobalt market, had joined OMA. In 1977, Sun, a diversified U.S. energy company, joined the consortium, and Tenneco and JAMCO withdrew their memberships. In late 1980, ENI, the Italian national oil company, became a partner in the consortium. ENI was to contribute funds until it had matched those already contributed by the other partners. ENI's share in the partnership grew commensurate with its financial contributions. OMA was perhaps the the most active consortium through 1982, when its activities were sharply curtailed and its mining vessel was decommissioned.[38]

The timing of patent activity by OMA firms reveals an interesting pattern as shown in Figure 9. Initially, patents were obtained in the late 1960's by NNS&D on recovery technology. This patent activity may have been conducted with the intent of attracting investors to a commercial joint venture. Indeed, Tenneco joined first with Metallgesellschaft (now an OMI member), then with several Japanese companies, to conduct exploration, testing, and R&D. During the period 1973-1977, most of OMA's metallurgical processing patents were granted. It is apparent that the consortium was spreading its technological capabilities to achieve a more vertically integrated operation as its internal structure was changing. DVI may have been especially concerned with patenting first to protect the technology that it had developed itself and second to increase the company's value in terms of technological capability.

DVI patented several recovery technologies in the early 1980's. Seven patents were granted in 1982. DVI may have felt that its latest recovery technology, which had been updated from the late 1960 designs and possibly kept under wraps, should be patented before its R&D program was curtailed. These patents extend protection for this technology until the turn of the century. Although ENI did join OMA in 1980, the other consortium members had slowed their program funding considerably. Essentially, ENI was "buying" the technology that had been developed earlier by Deepsea Ventures for the OMA R&D program. When OMA sharply curtailed its operations in 1982, DVI placed its patent rights up for claim by the OMA partners.[39]

As a consortium, OMA leads all other consortia in patents and claims. Deepsea Ventures (including NNS&D) is clearly the primary patenting firm for OMA, and its R&D emphases have been directed predominantly (70%) at seabed mining. DVI's patent activity is spread across all categories of generic technology. DVI appears to have pursued a strategy of patenting in order to demonstrate technological prowess. For example, in its exploration license application filed under the requirements of U.S. law, OMA has claimed that its program "has developed innovative technology in the fields of marine science, ocean engineering, mineral processing and product utitilization. Evidence of this innovation is an inventory of more than 300 related patent cases, of which almost 200 have been allowed or granted to date."[40]

An additional strategy employed by DVI may have involved fencing-in. A company can fence-in an invention by obtaining patents on similar inventions that are only slight variations on the original. In this way a technological breakthrough can be protected from other firms that seek a portion of the patent monopoly through patenting their own similar inventions or substitutes.[41] Many of DVI's recovery patents modify one or more attributes of earlier patents that describe its "towed dredgehead with rake" (see Figure 12) and associated lift and surface support systems.[42] The real test of fencing-in, however, is whether the similar patents are actually employed by the patenting firm or just left asleep. In a not-yet-commercial industry like seabed mining, it may be impossible to determine the extent of fencing-in because few of the patented inventions become innovations, or commercially useful technology.

B. KENNECOTT CONSORTIUM (KCON)

KCON was formed as an unincorporated joint venture in January 1974. The original participants in the venture included Kennecott, a major copper producer and wholly owned subsidiary of Standard Oil (Ohio); the British mining houses: Rio Tinto Zinc and Consolidated Gold Fields; Noranda, a diversified natural resources company from Canada; and three Mitsubishi group companies from Japan. In 1977, British Petroleum (BP) joined the venture (BP also has a 53 percent ownership of SOHIO). Kennecott has controlled the joint venture, however, with a 40% share; the remaining participants, including BP, each hold 12% shares. Exploration and technical development activities were

United States Patent [19]

Latimer et al.

[11] **4,346,937**

[45] **Aug. 31, 1982**

[54] **DREDGING APPARATUS INCLUDING SUCTION NOZZLES**

[75] Inventors: **John P. Latimer; Robert M. Donaldson; Ted W. Christian; Glenn E. Miller**, all of Newport News, Va.

[73] Assignee: **Deepsea Ventures, Inc.**, Gloucester Point, Va.

[21] Appl. No.: **155,316**

[22] Filed: **Jun. 2, 1980**

[51] **Int. Cl.**[3] **E02F 7/00**

[52] **U.S. Cl.** **299/8**; 37/57; 37/DIG. 8

[58] **Field of Search** .... 299/8, 9; 37/57, DIG. 8

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Primary Examiner—Ernest R. Purser
Attorney, Agent, or Firm—Barry G. Magidoff

[57] **ABSTRACT**

There is provided a dredge vehicle supporting a dredge assembly for collecting ore particles from the ocean floor. The dredge assembly includes several nozzles extending forwardly of the supports for the vehicle, pump means for developing a suction flow into and through the nozzles and a screen to separate the ore particles from most of the water before feeding the ore into, e.g., an airlift system leading to a surface vessel. Preferably, an intake of clear water from above the vehicle is used to carry the ore to and up the airlift system.

Advantageously, the water flows straight through the system and exhausts from the rear of the vehicle, and mud is cleared from the ore before bringing the ore to the surface.

22 Claims, 9 Drawing Figures

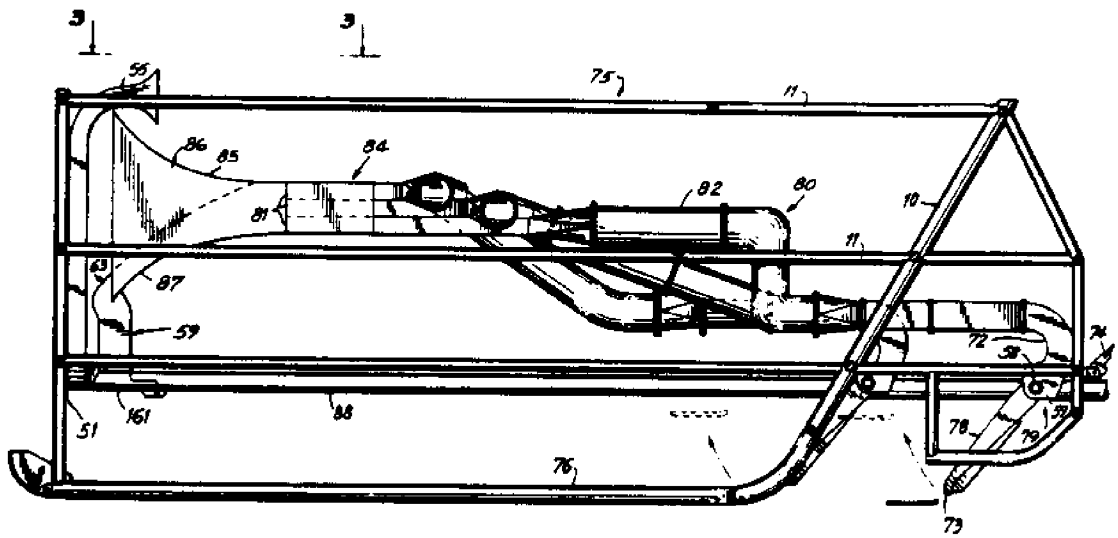

Figure 12: DREDGEHEAD FOR OMA'S HYDRAULIC RECOVERY SYSTEM

discontinued in the late 1970's, but KCON has been active in seeking access to mine sites through legal procedures.[43]

Kennecott has been the primary patenting firm for KCON with 93% of the consortium's seabed mining patents. In 1969, Kennecott patented a robot-crawler collection and hydraulic lift system (see Figure 13); and in 1973, before KCON was assembled, Kennecott patented an air-lift recovery system.[44] These patents may have been used to attract investors, although it is unclear whether the collection technology has ever been tested. From 1973 through 1981, and especially during 1973-1977, Kennecott received numerous patents on metallurgical processes. Indeed, Kennecott leads the industry in number of process patents (just trailing DVI in claims on those patents). This leadership in the processing area is consonant with Kennecott's extensive metallurgical R&D capabilities, and, in fact, from 1969 to 1980, Kennecott's seabed mining patents accounted for only 15% of its 223 patents.

Especially through the development of its renowned "cuprion" reduction process, Kennecott has clearly demonstrated technical prowess in the metallurgical aspects of seabed mining (see Figure 14). It is possible that Kennecott has devised its patent activity to fence-in the cuprion process, as several patents describe that process or variations of it.[45] Confirmation of that strategy must await commercial activity in the seabed mining industry. To some extent, Kennecott may have patented its technology to protect itself from prospective joint venture partners. Patents have been obtained by Kennecott in several countries where other KCON members have large operations: Canada, the United Kingdom, Australia, and South Africa.[46]

C. OCEAN MANAGEMENT INCORPORATED (OMI)

The OMI consortium was organized in 1975 as a U.S. partnership managed by a jointly-held corporation. The partners are Inco, the leading world nickel producer; Sedco, a U.S. marine operator; AMR, a West German partnership shared by Metallgesellschaft, a large nonferrous metals company, Preussag, a major extractive resources company with extensive marine operations, and Salzgitter, a state-owned diversified steel company with interests in shipbuilding and marine operations; and DOMCO, a complex Japanese joint-venture of 24 companies led by Sumitomo, one of the largest trading houses in Japan. OMI has conducted successful tests of a towed-sledge, hydraulic recovery system; in 1978 large amounts of nodules were recovered from the Pacific. Site-specific

July 22, 1969 **J. R. GRAHAM ET AL** **3,456,371**

PROCESS AND APPARATUS FOR MINING DEPOSITS ON THE SEA FLOOR

Filed May 6, 1965 6 Sheets-Sheet 2

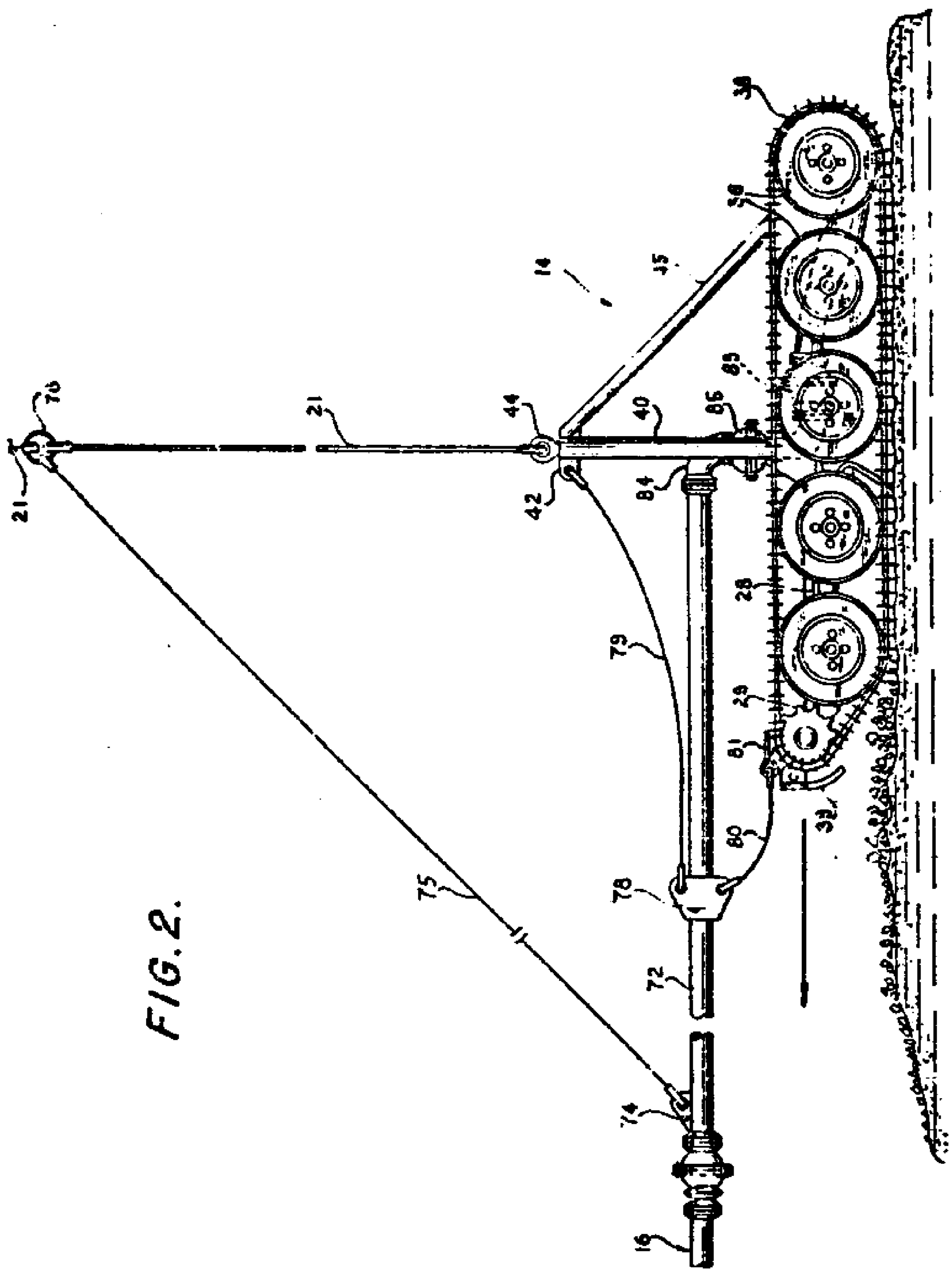

FIG. 2.

Figure 13: REMOTELY-CONTROLLED "GATHERING VEHICLE" OR "TRACTOR" ASSIGNED TO KENNECOTT

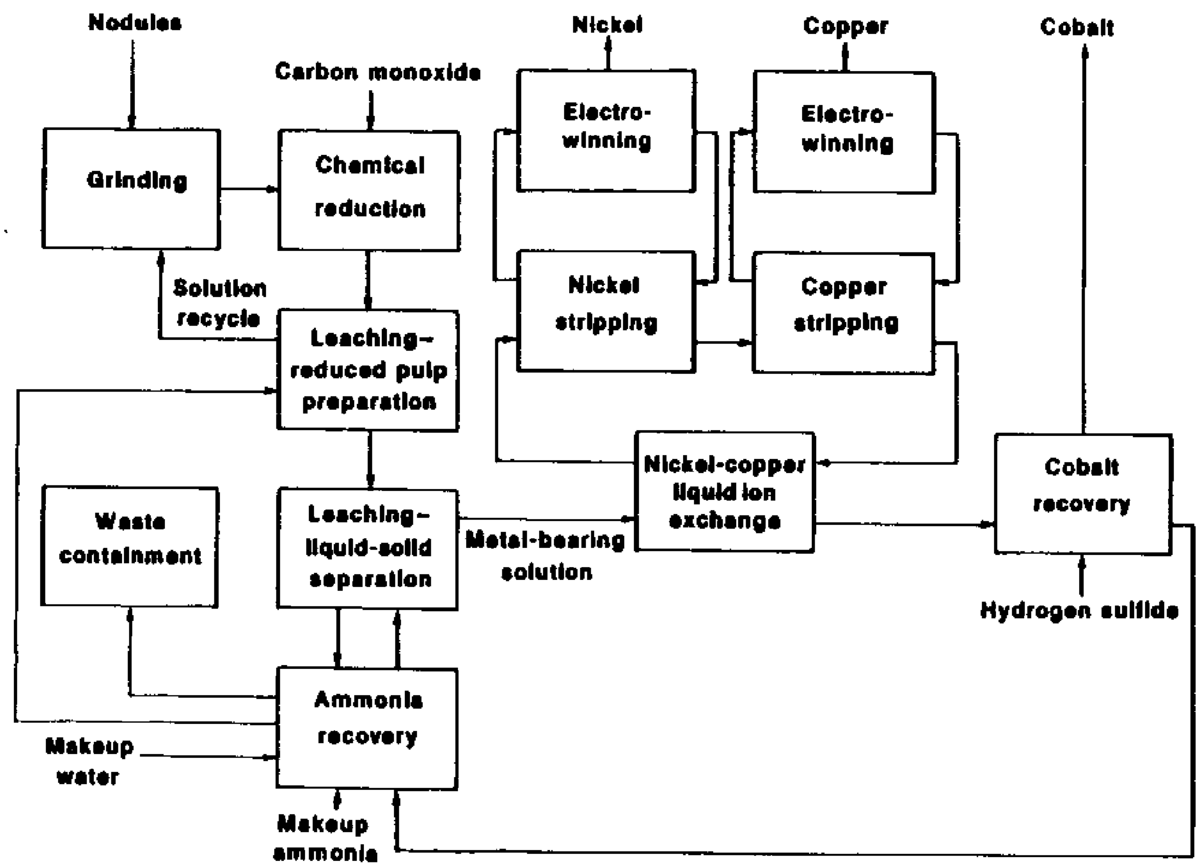

Figure 14: KENNECOTT'S CUPRION AMMONIACAL LEACH METALLURGICAL PROCESS: SIMPLIFIED FLOWSHEET

Source: B.W. Haynes, S.L. Law, and R. Maeda. 1983. "Updated Process Flowsheets for Manganese Nodule Processing." Bureau of Mines Information Circular 8924. Washington.

exploration activities were discontinued after 1980. Recently, the AMR group has filed for an exploration license on its own in West Germany, although it remains a partner in OMI. Several of the Japanese companies, especially Sumitomo, have been involved in the Japanese consortium, DORD.[47]

OMI member firms hold about 13 percent of all seabed mining patents and approximately nine percent of claims. Inco clearly holds more seabed mining patents than its partners, although several OMI partners or their subsidiaries also have patented seabed mining technology. Inco, however, has exerted a very small percentage (3%) of its extensive R&D capabilities towards seabed mining as measured by patent activity. Inco has directed its efforts at a towed sledge, hydraulic recovery system and pyrometallurgical ore reduction processes that are similar to its existing nickel ore beneficiation processes. Other OMI partners or their subsidiaries have patented or employed additional seabed mining technologies. Sedco's Earl & Wright engineering subsidiary has patented a robot crawler type collector (see Figure 15) and the Sedco 445, a converted offshore hydrocarbon drillship, has been used for surface support. Inco, Metallgesellschaft, and Sumitomo have participated in the CLB Syndicate's research activities. Preussag has been involved in other marine mineral technology development activities such as the recovery of metalliferous muds from the Red Sea. Preussag holds a number of patents on seabed samplers and on a nodule-collecting magnetic drum. One Salzgitter subsidiary, Howaldtswerke Deutsche-Werft, has patented a combination ship and pier surface support and transport system (see Figure 16). Salzgitter itself has patented a recovery system that concentrates nodules by dragging an open-ended collector along the seabed from a surface vessel. Another vessel follows with a conduit that collects and lifts the concentrated pile of nodules. Sumitomo Metal Mining has patented yet another towed sledge design.[48]

The OMI partnership agreement creates additional protection for intellectual property or know-how that has not yet been patented. The agreement permits all of the member firms to manufacture, use, or sell know-how developed by any one firm during OMI projects. These rights are subject to royalties, however, if the firm that employs the know-how is not the same one that developed it. Moreover, although the member firms may participate in seabed mining projects which are sponsored by their respective national governments (e.g., AMR and DOMCO), the use of OMI know-how in these projects requires the specific written consent of all the other OMI members.[49]

June 27, 1972 E. P. JOHNSON 3,672,725

DEEP SEA MINING METHOD AND APPARATUS

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FIG-1

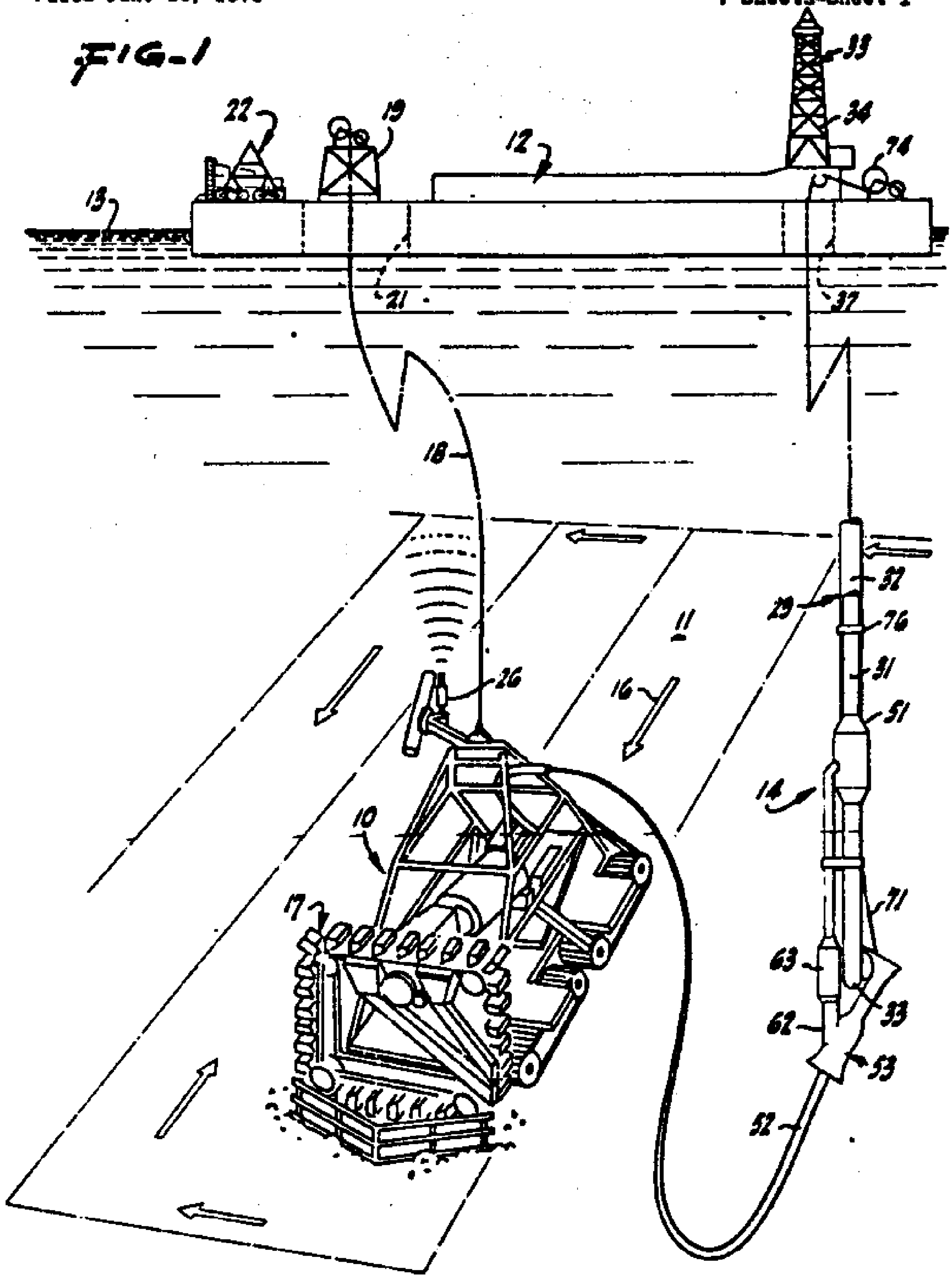

Figure 15: EARL & WRIGHT'S REMOTELY-CONTROLLED "MOBILE MINING VEHICLE" AND HYDRAULIC RECOVERY SYSTEM

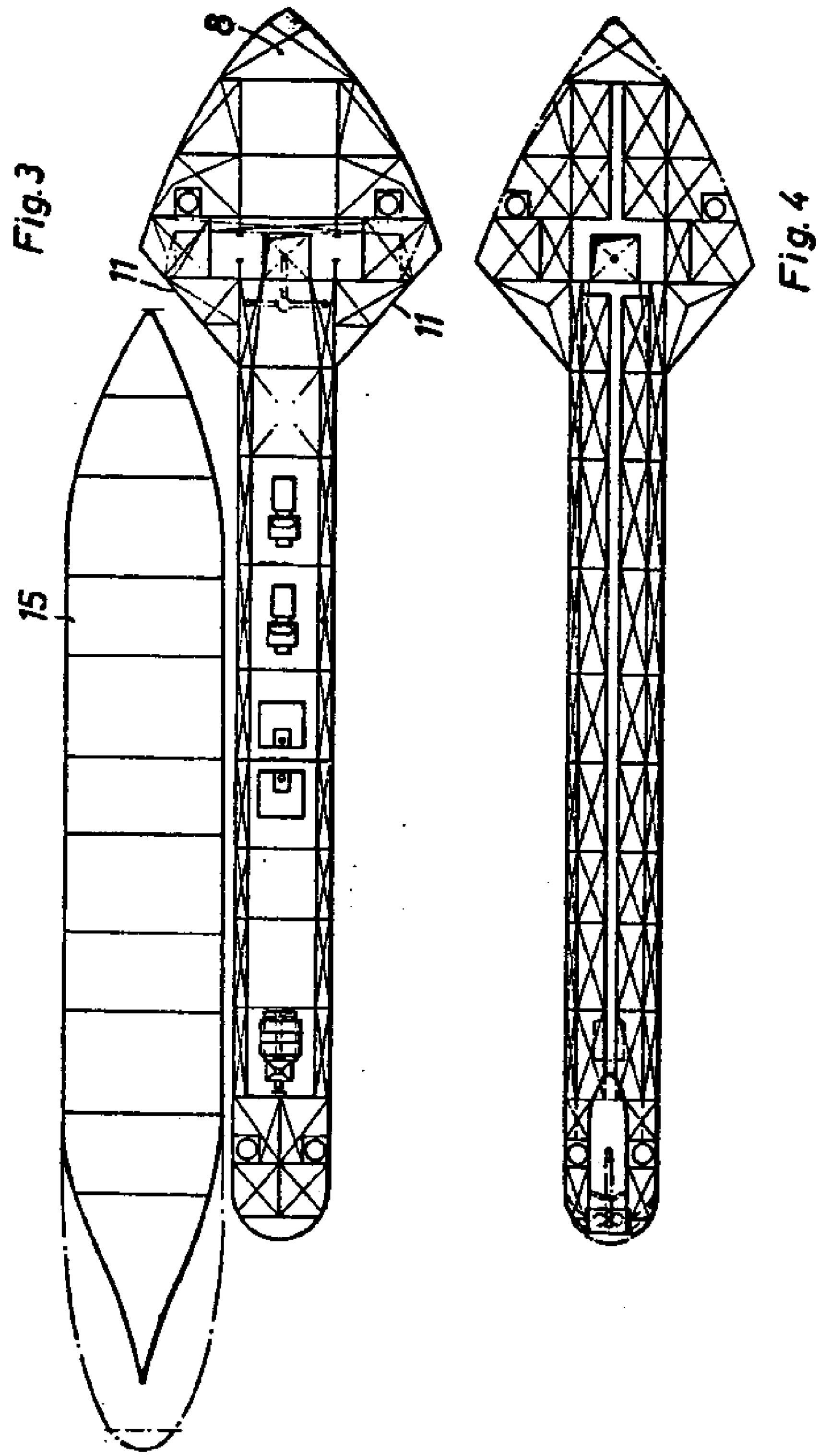

Figure 16: HOWALDTSWERKE DEUTSCHE WERFT'S SHIP AND PIER SURFACE SUPPORT AND TRANSPORT SYSTEM

Earl & Wright's robot crawler collector was patented in 1972, before the consortium was organized. This technology may have been developed and patented with the intention of displaying technological capability and thereby attracting customers to Sedco's marine operator business. In fact, Sedco's drillship (also designed by Earl & Wright) was converted and used for prospecting activity after Sedco joined the consortium, although Sedco contributed (in accordance with its 25% share of OMI) to the conversion.

Inco's patent activity may have been inspired in good measure by interest in preserving its dominant position in the world nickel market. Inco is also a substantial producer of copper and cobalt. Inco is a vertically integrated metals company that mines, processes, and produces rolling mill, forged, and machined products. Inco has also developed metallurgical processes for recovering nickel and cobalt from laterites, which are oxide ores similar to nodules. By obtaining patents in the recovery and processing areas, Inco ensures its ability to enter the seabed mining business or perhaps exclude others through the patent monopoly. Inco thereby protects its future market position if in fact seabed mining does become a competitive means of producing metals.

The DOMCO group, led by Sumitomo, may have participated in the OMI consortium at least in part as a learning experience. Sumitomo has also taken a lead role in DOMA, the Japanese public association that was established to coordinate public and private efforts in the development of a seabed mining industry; in DORD, the Japanese seabed mining consortium; and in the Technology Research Association for the Manganese Nodule Mining System, which manages the Japanese large-scale R&D project. Sumitomo has gained valuable experience as an OMI member. Sumitomo Metal Mining holds U.S. patents on a nodule survey apparatus, a towed sledge, and a sulfur dioxide reduction process.[50] Although the direct transfer of technology to another consortium without licensing agreements has been prohibited in the joint venture agreement, it is probable that at least some of the experience gained has been transferred to other Japanese seabed mining efforts.

The motivations and strategies of the AMR group are perhaps best understood as a combination of those already mentioned for other OMI partners. Metallgesellschaft, as a diversified and vertically integrated metals producer, clearly gains from the discovery of new potentially recoverable resources that can be added to its resource base.

Metallgesellschaft also to some degree may have an interest in protecting its existing market position. Preussag also has an interest in increasing its resource base, but, more importantly, the company has sought customers or investors for its marine mineral technology development and exploration talents: hence its several seabed sampler patents. Salzgitter, as a steelmaker, may have been attracted to seabed mining to increase its access to nickel and manganese supplies. Salzgitter's surface support and transport patent reveals an interest in bringing its shipbuilding capabilities to bear on seabed mining problems. Although Salzgitter is managed as a private concern, it is owned by the government of West Germany, which may have been concerned with securing stable supplies of strategic metals such as cobalt.

D. OCEAN MINERALS COMPANY (OMCO)

The OMCO consortium was organized as a U.S. partnership in November of 1977. The consortium is led by Lockheed, a major U.S. defense contractor and R&D vendor--particularly in the aerospace industry. Other members include Amoco Ocean Minerals, a subsidiary of Standard Oil (Indiana), a major oil and gas producer and also a producer of metals such as copper, cobalt, and nickel; Royal Boskalis Westminster, the large Dutch marine and civil engineering firm; and Billiton, a nonferrous metal producing subsidiary of Royal Dutch/Shell. Lockheed is the prime contractor for OMCO and thus earns revenues from the other consortium members through its seabed mining R&D.[51]

In contrast with the other seabed mining consortia, the OMCO group has sought few patents. Lockheed has patented its recovery system which includes a self-propelled, bottom-crawling miner vehicle that is attached by a flexible linkage to a "buffer" on the end of a pipestring (see Figure 17).[52] The system uses hydraulic water pumps and dewatering devices aboard the surface vessel. Lockheed has made 99 claims on its patent--more than can be found in any other seabed mining patent. In view of the fact that Lockheed as a company is primarily engaged in R&D and high technology contract work, it is probable that its main patent strategy has involved attracting customers or investors. Lockheed has made its technology easier to display and market by placing it in one package.

Lockheed has a pending patent application in the United Kingdom on one attribute of its recovery system, the buffer.[53] The buffer serves an important function as a temporary storage receptacle for the nodule-water

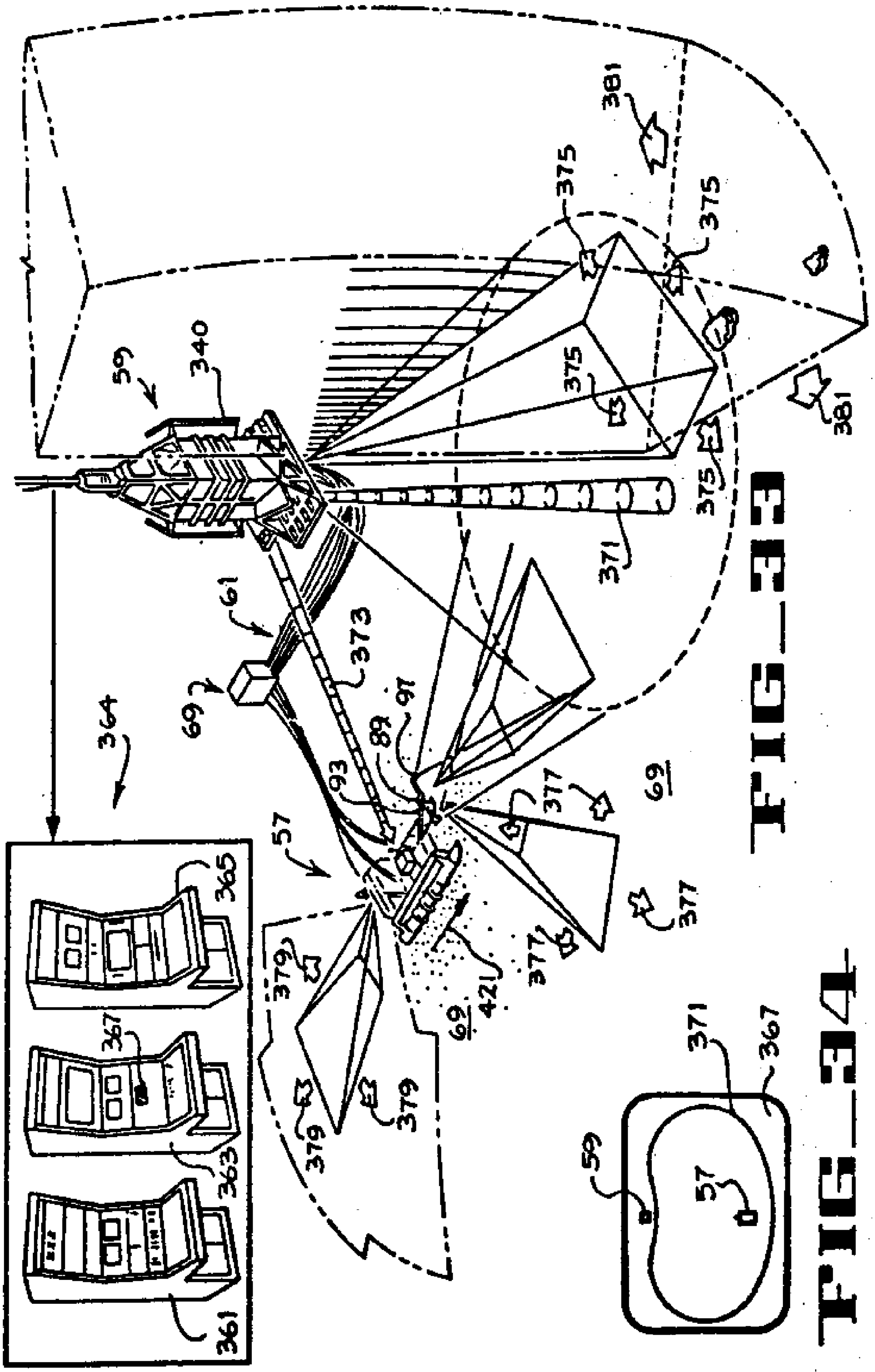

Figure 17: LOCKHEED'S SELF-PROPELLED, BOTTOM-CRAWLING MINER VEHICLE AND BUFFER

slurry that is pumped from the bottom-crawler. This storage capability, as well as controlled variations in the speed of the miner vehicle, enable the nodule slurry to be pumped through the pipestring to the surface vessel at a constant rate. It is possible that Lockheed envisions the buffer as the most innovative and potentially marketable attribute of its recovery system.

Shell Oil has obtained at least two patents that may have seabed mining application: one is an underwater locating device, and the other is a submarine dredging apparatus.[54] The latter may have greater application to additional kinds of marine mineral deposits. It is unclear whether the OMCO consortium might have access to technology patented by a firm such as Shell Oil which is an affiliate of Royal Dutch/Shell, the parent of OMCO member, Billiton. Shell also holds patents on copper, cobalt, and nickel extraction processes.[55]

Baggermaatschappij Bos & Kalis, a former subsidiary of Royal Boskalis Westminster, holds a 1974 patent on a lift system for seabed minerals that employs a suction pump. As in the case of Shell Oil, this firm is related to the consortium only through a parent firm, and therefore OMCO's access to this technology is unclear. Because the patent was obtained in 1974 (before OMCO's formation), the patent may have been sought to attract customers to Boskalis' marine engineering business.[56]

Other than Shell's patents, no metallurgical processes have been patented by the OMCO consortium. The Colorado School of Mines Research Institute (CSMRI) has worked to develop a "high temperature, high pressure sulfuric acid leach" nodule metallurgical process, the purported technology of the OMCO group.[57] This process is derived from a similar process used on nickel laterites at Moa Bay, Cuba and has been described on a flowchart by the U.S. Bureau of Mines.[58] Because the nodule process has not been patented, it is possible that certain aspects of it are being kept secret.

E. ASSOCIATION FRANCAISE POUR L'ETUDE ET LA RECHERCHE DES NODULES (AFERNOD)

AFERNOD is a French syndicate that was formed in 1974. AFERNOD is almost entirely governmental, although two private companies hold minor shares. IFREMER (formerly CNEXO), the French national agency for ocean research and development, leads the consortium with a 70% share. CEA, the French atomic energy agency, is the next largest shareholder with 20%. Société Métallurgique le Nickel (SLN), the major French nickel producer and joint subsidiary of IMETAL and Elf Aquitaine, and Chantiers du Nord et de la Méditérranée (CNM), a shipbuilder and subsidiary of the Schneider conglomerate, each hold approximately 5% shares. Recently, IFREMER and CEA have continued R&D work together as a "groupement d'interêt public" under the name, GEMONOD. AFERNOD's activities lately have been restricted to the acquisition of exploration and mine site licenses.[59]

Other French agencies and private concerns have been involved in the French seabed mining effort. From 1977 through 1980, the French equivalent of a combined U.S. Geological Survey and U.S. Bureau of Mines, BRGM, participated with a 1% share in AFERNOD. In the late 1970's, AFERNOD engaged the services of a number of companies, known informally as the "Corano Club," to evaluate the feasibility of developing hydraulic recovery systems. These companies included: Alsthom-Atlantique, Ateliers et Chantiers de Bretagne (ACB), Cie Françaises d'Enterprises Métalliques (CFEM), Coflexip, Comex, and Fougerolle. In addition to these companies, Société Générale des Constructions Eléctiques et Mécaniques (SGCEM), a subsidiary of Alsthom-Atlantique, has patented CLB and towed sledge recovery technology.[60] AFERNOD also has worked with Tetra Tech, a U.S. engineering firm; CNEXO, SLN, and Tetra Tech hold jointly one patent on a box core sampler.[61]

The AFERNOD members together have obtained a relatively small total number of seabed mining patents, although more than the OMCO group. CEA clearly leads the group in patent activity as measured by concentration; however, seabed mining patent activity has been a very small percentage (0.5%) of CEA's total U.S. patenting emphasis.

The preponderance of AFERNOD's seabed mining activities has been directed at prospecting and exploration. IFREMER has conducted at least three seabed mining-related cruises aboard the RV Jean Charcot during which "Seabeam," a multinarrow beam echosounder, "Raie," a towed fish for seabed photography, and "Epaulard," an autonomous submersible for seabed photography and bathymetric surveys, have been deployed.[62]

One of AFERNOD's main R&D strategies, especially in the case of recovery systems, has been the development of expertise in more than one specific technology. AFERNOD was a participant in the now inactive CLB Syndicate. SLN and IFREMER have developed and tested both one- and two-ship CLB systems. SLN, CNEXO (IFREMER), and SGCEM hold patents on the two-ship CLB.[63] AFERNOD's principal research efforts, however, have been directed at the development of a remote-controlled, autonomous shuttlecraft, the préleveur libre autonome (PLA). CEA and CNM have designed and built a one-quarter scale model of the PLA. The PLA can be deployed from a surface vessel (probably a semisubmersible), descend to the seabed, recover nodules, ascend to the surface vessel, and discharge recovered nodules (see Figure 18). Between 8 and 14 shuttles can be deployed simultaneously. Ore carriers can transport nodules from the semisubmersible to an onshore metallurgical process plant and transport process-wastes for shuttle ballast in the opposite direction. CEA has patented the system.[64]

In the past, AFERNOD has expended a relatively small amount of effort towards the development of a towed sledge hydraulic recovery system. The work of the Corano Club in the late 1970's was directed at evaluating the feasibility of such a system. SGCEM has patented a "dredging bucket on a main frame with skids" (towed sledge), which has been tested in mud pits, and a water pump lift system that operates from a platform suspended under a surface vessel.[65] CEA has tested airlift recovery systems in lakes and mine shafts. Recently, the activities of the French group have been redirected away from the PLA system and towards further evaluation of a hydraulic recovery system. GEMONOD appears to be leading this effort.[66]

F. DEEP OCEAN RESOURCES DEVELOPMENT COMPANY (DORD)

DORD is a Japanese corporation formed by 48 Japanese companies with the prior assistance of the Japanese government. The history of Japanese involvement in seabed mining is complicated but appears to have proceeded in two distinct directions. On one hand, the Japanese government has pushed the development of a domestic seabed mining industry; on the other hand, certain private companies in Japan have participated in the activities of international seabed mining consortia. The Japanese government has received over 160 patent applications, many from inventors outside the country. Only 37 seabed mining patents have issued, and of these, 27 are held by Japanese inventors.[67]

The first Japanese seabed mining activities were sponsored privately. In 1968, the RV Hakuo Maru recovered two tons of nodules from the Pacific seabed with sampling devices. From 1969 through 1972, Masuda's CLB was tested in one-twentieth, one-tenth, and one-half scales. The Japan Natural Resources Association, a publicly-authorized corporation, helped to fund these tests in

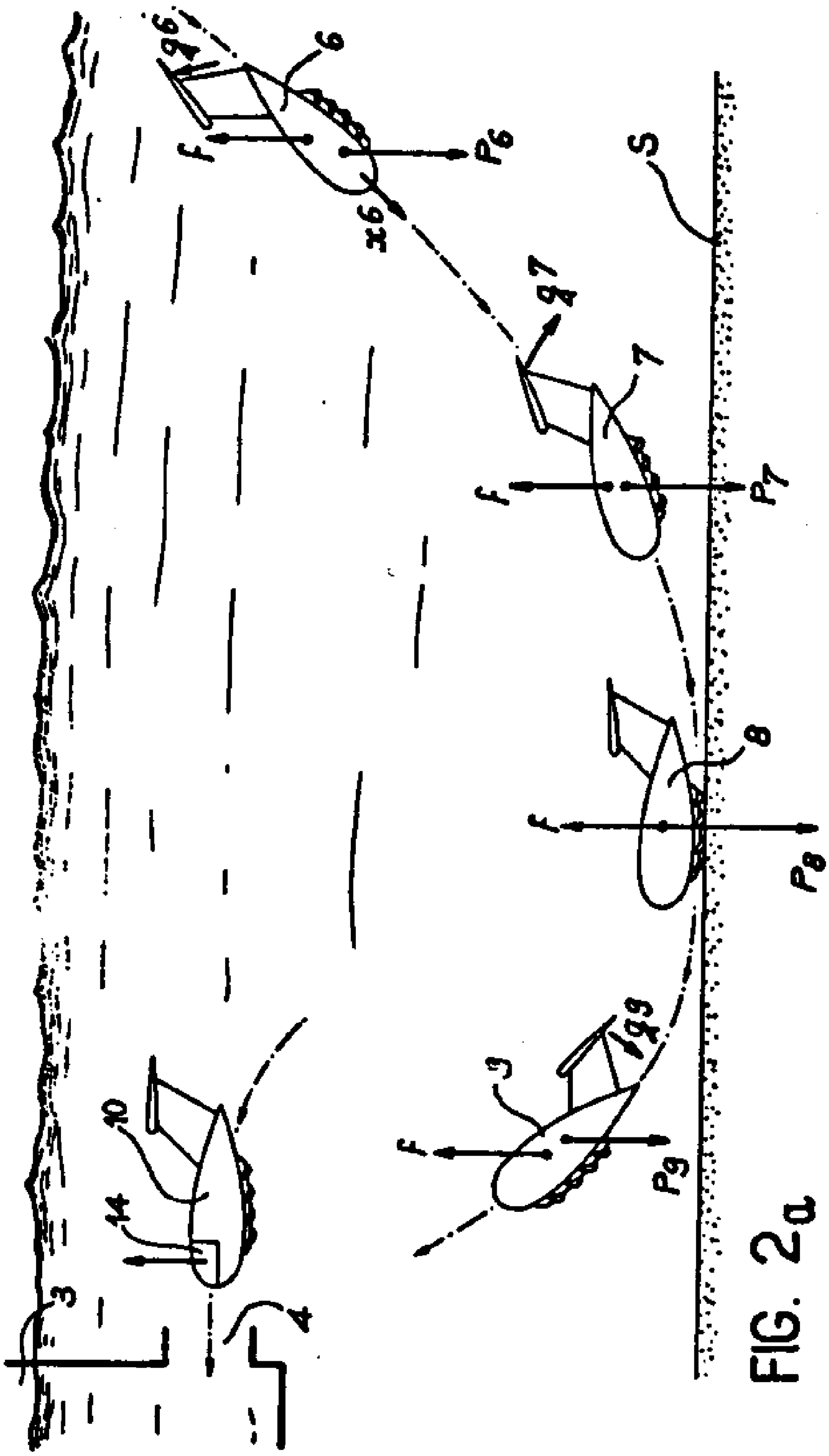

Figure 18: AFERNOD'S PRELEVEUR LIBRE AUTONOME (PLA) REMOTELY-CONTROLLED SHUTTLE

conjunction with Nippon Steel, Sanwa, Fuso, Furukawa, and, the three giants: Sumitomo, Mitsubishi, and Mitsui. When the noncommercial CLB Syndicate was formed in 1972, several of these companies became members.[68]

In the mid-1970's, Japanese seabed mining activities bifurcated. In January of 1974, three companies from the Mitsubishi group joined KCON. Three months later, JAMCO was formed and entered into a joint venture with Tenneco to use Deepsea Ventures. In February of 1975, a Sumitomo subsidiary (SODECO) joined Inco and AMR to form OMI. Later that year, twenty-three companies joined SODECO to form DOMCO. Of the three giant trading companies that had participated in earlier seabed mining R&D efforts, only Mitsui did not join an international consortium. Mitsui had worked earlier with Inco and has become involved in the government's large-scale R&D project. Mitsui Shipbuilding has patented a moonpool, and Mitsui O.S.K. Lines holds a 4% share of DOMCO.[69]

As a result of the coalescence of international consortia and the pace of seabed mining R&D efforts internationally, the Japanese government "targeted" the domestic seabed mining industry. In addition to sponsoring R&D activity and supplying low, fixed interest rate loans with conditional repayment schedules, Japan established the Deep Ocean Mining Association (DOMA) on March 30, 1974 as a publicly authorized association with a capital budget of Y500 million (about $1.7 million in 1974). The members of DOMA include the Japanese Ministry of International Trade and Industry (MITI) and 35 private companies engaged in the businesses of: general trading, mining, shipbuilding, steelmaking, shipping, electric appliances, and fishing. Ten DOMA companies are also members of international consortia. An official from Sumitomo Metal Mining became DOMA's first chairman. DOMA was formed to engage in R&D but not to exploit nodules on a commercial level. DOMA provided a forum for discussion on the formation of a commercial mining entity, and in 1982 DORD was incorporated as a joint venture of the 35 DOMA companies and 14 others.[70]

From 1975 through 1979, DOMA chartered the Hakurei Maru to conduct seabed surveys south of Hawaii. By 1977, Japanese exploration technology had advanced to the point where the government ordered the construction of the Hakurei Maru II, a geological survey ship designed specifically to explore for manganese nodules. This research vessel was equipped with high-speed underwater television developed by DOMA to photograph the seabed, an automatic nodule densitometer to translate the photographic data into nodule density data, sonar, telemetry, an underwater illumination system, and a towing system. The Hakurei Maru II was completed in 1980 by Shimonoseki Shipyards, a subsidiary of Mitsubishi Heavy Industries.[71]

Governmental concern for secure supplies of basic mineral commodities has fueled Japanese motivations to mine the seabed. Their strategy has been the development of technology as a foundation for a Japanese industry through public-private efforts. As technological breakthroughs are made in other countries, the Japanese examine these breakthroughs and work to improve the technology. In 1981, the Agency of Industrial Science and Technology (AIST), an affiliate of MITI, initiated a nine-year, $85 million, large-scale project to develop and refine a towed sledge, hydraulic recovery system.[72] AIST holds a U.S. patent on a towed sledge in which water jets separate nodules from sediment and push the cleaned nodules into the lift conduit.[73] Both waterpump and airlift systems have been investigated. A moonpool and a gimballed derrick are envisioned for the surface vessel. The lift pipe is enclosed in a wing-shaped fairing through which a fiber-optic electric power cable and air supply piping may be run. This fairing performs a function similar to a "pipestring drag reduction fin" patented by Deepsea Ventures.[74]

The Technology Research Association for the Manganese Nodule Mining System, composed of 20 private companies including Sumitomo, Mitsui, and Mitsubishi, is responsible for R&D work on the system. The project is scheduled to be completed at about the time when the bulk of seabed mining patents worldwide begin to expire. Thus, earlier technological breakthroughs will have been refined and then possibly brought into use when patent protection no longer exists for the original technology.

G. SOVIET UNION

Several research institutions in the Soviet Union have developed and patented seabed mining technology. This technology appears to have been adapted from that developed for mining placers and other deposits from shallow lakes and seas.[75] Although there is no Soviet "consortium" per se, the Yuzhmorgeologiya (Southern Production Association for Marine Geological Operations) has applied for registration as a pioneer seabed mining investor pursuant to provisions of the Law of the Sea Convention.[76] No patent activity has been identified from this institution.

In the Soviet Union, patents, as they are understood in the United States, are unavailable. Instead "author's certificates" that give recognition and some financial reward based upon use are granted to the inventor of a particular technology. Institutions in the Soviet Union successfully have sought seabed mining patent rights in other countries: the United States and West Germany, for example.

In the mid-1960's to early-1970's, the Soviet Academy of Sciences prospected, explored, and developed technology for ocean mineral recovery. Lately, this activity has been continued by the Ministry of Geology (an agency similar in role to the U.S. Geological Survey). Author's certificates have issued to the Moscow Mining Institute, the Leningrad Mining Institute, the National Nonferrous Research Institute at Ust-Kamenogorsk, the National Scientific Research and Planning Institute of the Gold Mining Industry (Gold Mining Institute), and several individuals for scraper dredges; excavator buckets; grab samplers; a cam-operated "walking" seabed miner with a guide beam; a seabed mining transport and test stand; among other things.[77] The Institute of Oceanology has successfully deployed a remote-controlled sampling robot to collect nodule samples.[78] An interesting design has been patented in West Germany, the United Kingdom, and Canada by the Gold Mining Institute. The patent describes a hybrid towed sledge-CLB system (see Figure 19). A towed sledge dislodges nodules from the seabed and then discharges them into a suction conveyor. The conveyor is continuous, and each individual section alternatively holds either air (for flotation) or nodules. The air sections are filled with water for the return to the seabed.[79]

Because their technology has been adapted from shallow water marine mining, it is uncertain whether the Soviet's patented seabed mining technology can be used successfully at great depths. Indeed, rumored increases in seabed minerals activities may reflect a concern within the Soviet Union for catching-up with the technology leaders from the United States, West Germany, France, and other countries.[80] This strategy is similar to that of the Japanese in their large-scale R&D project.

H. POTENTIAL ENTRANTS

Because of the diversity of potential entrants, it is difficult to generalize on their motivations and strategies. Most potential entrant firms have patented either recovery or metallurgical processing technology, but not both, and therefore they are unlikely to enter the industry alone as fully integrated seabed miners. Bethlehem Steel and Mobil Oil, two large

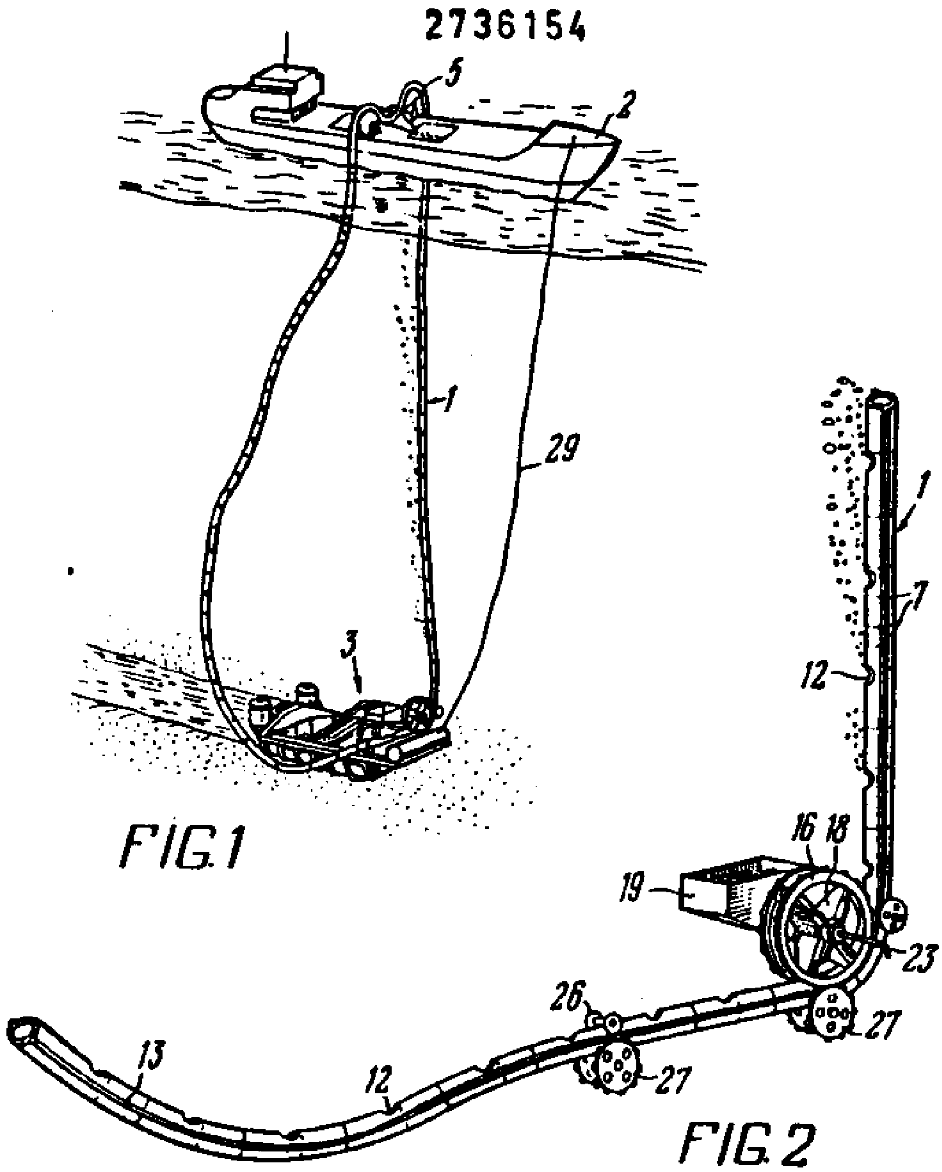

Figure 19: GOLD MINING INSTITUTE'S HYBRID TOWED SLEDGE-CLB RECOVERY SYSTEM

corporations that have patented both recovery and processing technology, are exceptions to this rule and might be considered as prime candidates for entry into the industry--if not alone, then as partners in one of the existing or some future joint venture. Bethlehem Steel can be seen as having motivations similar to those of U.S. Steel; Mobil Oil can be seen as having motivations similar to those of Sun, or perhaps BP or Standard Oil (Indiana), although Mobil has no major metal producing subsidiary. If indeed Shell Oil has no licensing agreements or other connection with the OMCO group through Royal Dutch/Shell, then it too would be considered as a likely potential entrant, although its affiliations may condition its options for participation in the industry.

Firms such as Westinghouse Electric and General Dynamics hold several patents in the recovery area and are large enough to be attractive joint venture partners. Nevertheless, they may have a greater interest in selling their engineering skills. Others, such as Ethyl Corporation, Dow Chemical, or UOP, Inc., which hold patents in the metallurgical processing area, may be looking to offer for license the rights to manufacture, use, or sell their patented technology. Certainly these firms also are potential R&D vendors or even joint venture partners. Ethyl did participate in some of the CLB Syndicate's efforts. A firm such as Global Marine additionally may have been interested in the technological spin-offs available from R&D in seabed mining that could be applied to its other marine operations and engineering activities.

I. ENGINEERS: CONTINUOUS LINE BUCKET (CLB) SYNDICATE

One might conjecture that the majority of engineers have patented their technology either to offer certain rights for license or to advertise their expertise in particular technological areas. Perhaps the most salient example of this kind of strategy is the CLB Syndicate. In this case, engineers had an important effect on the emerging structure of the industry. The Syndicate was organized in the late 1960's through the efforts of John Mero and Yoshio Masuda, two of seabed mining's earliest engineers and promoters. As an joint venture established solely for the purpose of R&D and prospecting, the Syndicate gave the 25 participating firms and government agencies a taste of the technological complexity of seabed mining. Some of the participants probably increased their interest in seabed mining at least in part as a result of participation in the Syndicate: the AMR group, Inco, Noranda, U.S. Steel, CNEXO, SLN, Sumitomo, and Mitsubishi. Others, such as Ethyl Corporation, continued at a very low level of activity. Still others lost interest altogether. Although there are indications that the industry has converged on a hydraulic recovery system concept, there are some who feel that the CLB, in its simplicity, may be the most effective seabed mining technology after all.[81] Masuda has begun to promote the concept for use on other kinds of marine minerals such as crustal deposits.[82]

IV. CONCLUSIONS

In a minerals industry that has focused primarily on R&D, observations of patent activity are one way to uncover and examine the behavior of participating firms and government agencies. Patent activity can reveal the identity of those entities that have proceeded far enough along in R&D to have invented something novel and useful that warrants protection. As one might expect, those firms or government agencies that have ventured together as seabed mining consortia hold the greatest concentration of seabed mining patents or seabed mining patent claims.

Within each consortium, one firm usually holds the great bulk of patents and claims. This is the primary patenting firm (PPF). An examination of the relative patenting emphasis spent on seabed mining in comparison with other research areas shows that most of the industry's PPFs have not emphasized seabed mining R&D. Deepsea Ventures (DVI) is the only outstanding exception. DVI is the acknowledged leader among PPFs in number of patents and claims and in relative emphasis on seabed mining. DVI has now offered its patent rights for sale to the OMA partners, decommissioned its prospective mining vessel, and scaled down its operations considerably. This is an important indicator that, at least for now, industrial activity in seabed mining has subsided.

The spread of patent activity across generic categories of technology is an indicator of the scope of the efforts of firms and government agencies in solving the problems of producing metals from seabed ores. In terms of patent activity, the consortia hold more patents in the different generic categories than do the potential entrants or engineers. This observation suggests that the consortia had aimed at achieving vertically integrated operations. OMA and OMI appear more vertically positioned than KCON, which has focused on metallurgical processing, or OMCO, AFERNOD, and DORD, which have focused on recovery. Hidden within the patent data is a more recent tendency for the consortia to converge on the hydraulic type of recovery system. This observation could indicate that specific technological categories are broad enough to permit the patenting of substitute inventions and that, even before the industry has become commercial, one kind of technology has been perceived as more effective than others. Characteristically, the Japanese R&D effort is aimed at refining the technology upon which the industry has converged.

Patent activity can enhance an understanding of the motivations and strategies of seabed mining firms. The motivations to undertake seabed mining R&D and patent activity include the development of new sources of minerals to supplement dwindling onshore sources; the protection of market position; the sale of ideas, experience, or technology; and the entry into a potentially successful industry. Seabed mining firms or government agencies may have used patents or trade secrets as strategic tools to help satisfy these motivations. The technological groundwork that preceded patent activity may have helped some firms attract joint venture partners. Patents may have been used to protect technology from other firms outside of a particular consortium. Patents also may have been sought to fence-in an invention, to substitute for a proven technology, or to package technology in order to facilitate the licensing or sale of certain rights. Once patent protection was sought successfully, seabed mining firms had a seventeen year lag period to await a more favorable business environment.

Patent activity for all firms and government agencies commenced in the late 1960's, peaked in the mid-1970's, and has fallen today to a reduced rate. This pattern is a rough representation of R&D activity in seabed mining and may indicate the possibility of a seabed mining industry cycle. If seabed mining is a cyclical activity, the next cyclical upswing could take place in the early 1990's. This upswing coincides with the beginning of the expiration dates for the bulk of the seabed mining patents. Activities by some enterprises, especially the Japanese government-sponsored R&D effort, appear to culminate at the same time. From an international perspective based upon patenting activity, one might very well expect to see a renewed industrial interest in seabed mining before the turn of the century.

The degree to which patent protection remains an important component of firm strategy in seabed mining is unclear. If and when another surge of seabed mining activity occurs, the technological information contained in the early patents undoubtedly will facilitate progress toward innovation and thereby speed the rate of eventual commercialization.

APPENDIX

THE GENERIC NATURE OF SEABED MINING TECHNOLOGY

In the recovery and metallurgical processing of seabed ores, certain technological problems can be identified. There may exist more than one apparently effective specific solution to each technological problem. In an embryonic industry, such as seabed mining, economic efficiency as determined through competitive operation has not yet selected the most effective specific solution. As a result, there exist generic categories of solutions to the technological problems of seabed mining. These generic categories can be an invaluable aid in understanding the strategies and motivations of firms and agencies within the industry.

A. NODULE RECOVERY

The technology that has been developed and patented for the recovery of nodules fits into four generic categories: (a) collection of the nodules from the seabed; (b) lifting the nodules from the seabed to the surface; (c) support for the lift and collector systems, usually a surface vessel; and (d) transport of the nodules to shore (Figure A1).

Nodule collectors can be classified into six basic designs. Buckets, towed sledges, a combination bucket and towed sledge design, and robot bottom-crawler vehicles are four types that are all directly connected to a surface support system. The fifth design is a remote-controlled, autonomous shuttle. Samplers, such as box corers and free-fall grabs also fit into the collector category.

There exist three basic lift system designs: nylon line (or wire rope) for the continuous line bucket (CLB) system; hydraulic lift through a steel pipestring, by which nodules and seawater can be either mechanically pumped or lifted by air-nodule-seawater density changes as a result of the injection of air; and unconnected, free diving and surfacing, remote-controlled shuttles. Additional attributes of a lift system also fit into this category for the purpose of differentiating technological capability among patent holders. These attributes include a moonpool, or center well through which collection and lift equipment is deployed from a surface vessel, a gimballed derrick that compensates for wave-induced ship motion, and an automatic pipehandler that

Figure A1

GENERIC AND SPECIFIC CATEGORIES OF NODULE RECOVERY TECHNOLOGY

COLLECTION	LIFT	SURFACE SUPPORT	TRANSPORT
Sampler	Wire Rope	Ore Carrier	Ore Carrier
Bucket	Water Pump	Semisubmersible	Docking System
Towed Sledge	Airlift	Drillship	Loading System
Hybrid Bucket/Sledge	Moonpool	Vertical Vessel	
Robot Crawler	Gimballed Derrick	Other Vessel	
Shuttle	Pipe Handler	Navigation	

GENERIC AND SPECIFIC CATEGORIES OF METALLURGICAL PROCESS TECHNOLOGY

REDUCTION	EXTRACTION	ELECTROWINNING	OTHER RECOVERY MEANS
Comminution	Nickel	Nickel	Cobalt
Acid Leach	Copper	Copper	Manganese
Ammoniacal Leach	Cobalt	Cobalt	Molybdenum
Acid Halide Leach	Manganese	Manganese	Zinc
Smelting	Other Metals	Other Metals	Other Metals
Cuprion			
Gaseous			
Other			

performs the mechanical chore of running an extremely long pipestring.

The surface support system can have several unique characteristics. Surface support is normally provided by a large ship, often a converted ore carrier or offshore oil and gas drillship. The support vessel can be equipped with collection and lift equipment such as a moonpool, a gimballed derrick, and automatic pipehandler, cargo bays, and extensive satellite and seafloor navigational equipment. The CLB system employes machinery to cycle bucket lines between one or two ships and the seabed. A semisubmersible platform may be used as surface support for a number of remote-controlled, autonomous shuttles.

Ore carriers can transport collected and lifted nodules to an onshore processing plant. Nodules can be pumped as a slurry in seawater, then dewatered and stored in cargo bays on the carrier. This aspect of seabed mining has not received as much attention as the seemingly more technical collection and lift designs. Until now, there has been no need for transportation of major quantities of nodules and so, during exploration activities, onboard support vessel storage has been the most common form of transportation. There do exist, however, some unique support vessel/ore carrier interface patents such as the moving "ship and pier" nodule transfer system designed in West Germany.[83]

B. METALLURGICAL PROCESSING

The chemical compositions of polymetallic nodules from different seabed areas are not usually identical. In general though, polymetallic nodules are composed of 25% manganese, 10% iron, 3% aluminum, 1.3% nickel, 1.25% copper, 0.25% cobalt, 0.05% molybdenum, and small amounts of numerous other elements. Clay minerals, calcium carbonate, silica, and water constitute valueless ore material, or gangue. Metals found in polymetallic nodules are not in the form of distinct minerals, as would often be the case for land-based ores, but instead are dispersed throughout a matrix of fine-grained manganese oxide and, to a lesser extent, iron oxide minerals.[84]

For several reasons, the determination of an efficient metallurgical process for polymetallic nodules presents a difficult problem. First, recoverable metal values are found embedded in a manganese oxide matrix and do not occur in separate minerals. Second, polymetallic nodules are oxide ores that do not lend themselves to separation by physical means as easily as the more common sulfide ores. Finally, between three and five metal values have been considered as recovery candidates while most land-based processes are geared to handle only one or two metal values.[85]

There are at least five comprehensive technologies recognized as commercially feasible for reducing polymetallic nodules. These technologies include Kennecott's "cuprion" ammoniacal leach, Inco's smelting and sulfuric acid leach, Deepsea Ventures' reduction and hydrochloric acid leach, a high temperature and high pressure sulfuric acid leach said to be preferred by the OMCO consortium, and a gas reduction and ammoniacal leach. In addition, other technologies such as a sulfur dioxide leach; Ethyl Corporation's ammonia carbonyl process; a nitric acid leach; an oxalic acid leach; ammonium-carbonate, -chloride, or -sulfide leaches; and various carbohydrate reduction processes have been examined.[86]

Most nodule metallurgical processes have been designed to recover at least copper, nickel, and cobalt. Some processes are capable of recovering manganese, usually in the form of ferromanganese or silicomanganese, or other metals such as molybdenum, zinc, vanadium, or yttrium. Detailed descriptions and flowsheets for metallurgical processes are beyond the scope of this paper and have been published elsewhere.[87] Nevertheless, as depicted in Figure A1, four broadly defined steps, or generic categories of technology, can be outlined.

The first step, reduction, involves the separation of metal values from the gangue. Some processes start with a "comminution", or the physical grinding of nodules, followed by drying to remove seawater. Comminution results in ore particles of a small size that facilitate chemical reaction. A Kennecott patent covers a step in which nodules are pelletized, or rolled into pellets, for more efficient metal extraction after comminution.[88]

Reduction can be accomplished either by smelting or by leaching with acids or ammonia. The objective of both smelting and leaching is to break-down, or reduce, the manganese oxide matrix and thereby release metal values. Smelting, also known as pyrometallurgy, involves heating the ore to a high temperature, and then removing the manganese and other gangue as a slag, or waste product. A matte, or high-grade alloy of copper, nickel, cobalt, and iron, that remains is dissolved in sulfuric acid prior to successive recovery steps. The acid leach technology involves the dissolution of manganese and the desirable metals. A sulfuric acid leach works most efficiently under conditions of high temperature and pressure. A hydrochloric acid leach requires first reducing manganese oxide with hydrogen chloride gas, precipitating iron out with the additon of water, and then releaching with aqueous hydrogen chloride. The ammoniacal leach technology dissolves only the desirable metals, and not the manganese. This technology must, however, be preceded by manganese oxide reduction achieved through exposure at high temperatures to a reducing gas like carbon monoxide or through exposure to the cuprous ion (an ionic state of dissolved copper) in the presence of carbon monoxide.

The second step, known as extraction, can be accomplished through a fluid, or liquid, ion exchange (FIX). The FIX technology employs an organic compound as a reagent with the capability of complexing with the desired metals. In this way a FIX reagent extracts metals such as copper and nickel (or even cobalt, manganese, and other metals) from the "loaded" acid or ammonia solution which results from the previous reduction step. The metals can later be selectively "stripped" from the FIX reagent by acids of varying pH values. Although there are many potential organic compounds that could be used as FIX reagents in the extraction of metals from polymetallic nodules, the General Mills Chemical Company holds a patent on one such reagent, called LIX-64N, which has proven effective and has been employed by Kennecott in some of its processes.[89]

The electrowinning of pure copper or nickel from an electrolyte is a third step. An electrolyte is a solution that conducts an electric current, and in this case, electrolytes are the acid solutions that contain the copper and nickel values stripped from the FIX reagent. The electric current is carried by metal ions through the electrolyte, and these metals are attracted, or electrowon, to a negatively charged cathode. It may also be possible to electrowin manganese and cobalt, although these metals also can be effectively recovered by other means.

A fourth step involves the recovery of additional metals by other means. Cobalt can be precipitated out of the raffinate, the leach solution that remains after the FIX extraction of nickel and copper, by adding hydrogen sulfide. Molybdenum can also be precipitated out of ammonia leach raffinate by adding lime. In Deepsea Ventures' reduction and hydrochloric acid process, cobalt is extracted by the FIX reagent along with copper and nickel, stripped by acid solution, and then precipitated by hydrogen sulfide. There are various processes for recovering manganese, often in the compound form of ferromanganese or silicomanganese. Other metals, such as zinc, vanadium, or yttrium, can be recovered through additional process steps if economically justified.

FOOTNOTES*

1. See generally: J.M. Broadus and Porter Hoagland III, "Conflict Resolution in the Assignment of Area Entitlements for Seabed Mining," San Diego Law Review 21 (1984): 541-576.

2. Ibid., 555-570.

3. J.M. Broadus, Social Scientist, Marine Policy Center, Woods Hole Oceanographic Institution, several personal communications, from February 1983 through May 1985. The cyclicality that one might expect from observations of patent activity or from R&D is different from what is generally known as the "business cycle." One normally would expect to see an increase in inventive activity in the early stages of the life of an industry. Contrary to immediate impressions, however, inventive activity in an industry does not necessarily terminate once everything necessary to accomplish the industry's productive tasks has been invented. Cost-reducing refinements to innovative technologies are one obvious continuation of inventive activity. Strategic behavior in an industry, such as the invention of substitute technologies, also may act to continue inventive activity. (See generally: Michael E. Porter, Competitive Strategy, New York: The Free Press, 1980, pp. 156-174.) In the particular case of the formative seabed mining industry, significant problems, which will require additional inventive activity before commercial operation, still exist. At the very least, these problems will involve scaling-up recovery and metallurgical processing systems to the commercial level.

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*References to individual seabed mining patents in these footnotes are made using an alphabetical prefix, which denotes the country in which the patent has been granted, followed by the number of the patent in that country. For example US4232903 is patent number 4,232,903 in the United States. The countries and prefixes are: Canada (CA); France (Fr); West Germany (FRG); Great Britain (GB); Japan (Ja); Soviet Union (SU); United States (US).

4. Margaret E. Slade, "Cycles in Natural-Resource Commodity Prices: An Analysis of the Frequency Domain," Journal of Environmental Economics and Management 9 (1982): 138-148; John E. Tilton, The Future of Nonfuel Minerals (Washington: The Brookings Institution, 1977), pp. 64-79. See also: Leonard L. Fischman, Project Director, World Mineral Trends and U.S. Supply Problems, Research Paper R-20 (Washington: Resources for the Future, 1980), pp. 25-33.

5. Hiroe Takahara et al., "Research and Development Project of Manganese Nodule Mining System in Japan," Proc. of 1984 Offshore Technology Conference (Houston); Technology Research Association of Manganese Mining System, "Now, Develop Resources of Deep Seafloor," Brochure (Tokyo, 1983); Japan, Ministry of International Trade and Industry, Agency of Industrial Science and Technology, "National Research and Development Program (Large-Scale Project)," Brochure (Tokyo: Japan Industrial Technology Association, 1982), pp. 8, 14.

6. Broadus and Hoagland, n. 1.

7. Broadus, n. 3. Also see n. 25-30 and accompanying text.

8. Patent strategies are thoroughly discussed by F.M. Scherer, Industrial Market Structure and Economic Performance, 2nd edition (Chicago: Rand McNally College Publishing, 1980).

9. The search was conducted using a combination of key words and classification numbers. The following classes were manually searched in the "Official Gazette": Excavating (38:8, 54, 58, 69, 71, 195); Metallurgy (75:21, 80, 72, 82, 103); Boring or Penetrating the Earth (175:6, 7, 8, 9, 10); Chemistry, Electrical, and Wave Energy (204:105, 106, 112); Mining or In Situ Disintegration of Hard Material (299:8, 9); and Chemistry--Inorganic (423:24, 32, 139). The manual search was cross-checked with the Claims Patent Files, accessed through the Dialog Information Retrieval Service (Alexandria, Va.: IFI/Plenum Data Company). The database was searched using the following keywords in varying combinations and forms: seabed, polymetallic, manganese, marine, deepsea, nodule, ores.

10. The additional patent searches are the following. A 1976 search organized by Oliver S. North, editor of the Mineral Exploration, Mining, and Processing Patents series (1964-1980), for the National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory in Seattle. Oliver S. North to John Padan, Letter (concerning seabed mining patent abstracts from the 1964-75 editions of Mineral Exploration, Mining, and Processing Patents), 8 December 1976. A more recent presentation of patents from the North series found in: United Nations, Ocean Economics and Technology Branch, Analysis of Exploration and Mining Technology for Manganese Nodules, Seabed Minerals Series, Vol. 2 (London: Graham & Trotman Limited, 1984). A 1977 publication by Manfred G. Krutein, a consultant and formerly an engineer with General Dynamics and Global Marine, Ocean Mining Patents (Los Angeles: Direct Import and Distribution, 1977). A 1980 search by the Office of Technology Assessment and Forecast (OTAF) of the Patent and Trademark Office on Patenting in Deep Ocean Mining for the Economic Policy Staff at the Department of Commerce. A 1980 study by Gale L. Hubred, now with Chevron Research but formerly with Kennecott's Ledgemont Laboratory, "Manganese Nodule Extractive Metallurgy Review 1973-1978," Marine Mining 2 (1980): 191-212. Internal reports published by Energy, Mines and Resources Canada: D.E.C. King and D.W. Pasho, "A Generalized Estimating Model for the Kennecott Joint Venture, Manganese Nodule Processing Facility," and "A Generalized Estimating Model for the Ocean Management Inc., Manganese Nodule Processing Facility," Internal Reports, Mineral Policy Sector, (Ottawa: December 1979). Exploration license applications submitted to NOAA by four consortia pursuant to the Deep Seabed Hard Mineral Resources Act of 1980: Ocean Mining Associates, "Application by Ocean Mining Associates for an Exploration License," Exploration Area "Gamma", Book I, 18 February 1982; Ocean Management, Inc., "Application for and Notice of Claim to Exclusive Exploration Rights for Manganese Nodule Deposits in the Northeast Equatorial Pacific Ocean," Application I, Volume 1: Application Area and Qualifications of Applicant, 19 February 1982; Kennecott Corporation, "Application for Exploration License under Public Law 96-283, The Deep Seabed Hard Mineral Resources Act, Based on Exploration Commenced before June 28, 1980 and In Accordance with NOAA's Rules and Regulations," 16 February 1982; Ocean Minerals Company, Application for License to Conduct Deep Seabed Mining Exploration Activities, 27 January 1982 (Washington: National Oceanic and Atmospheric Administration).

11. International Patent Data, accessed through Pergamon Infoline (Vienna, Austria: International Patent Documentation Center [INPADOC]). This database was searched using the same search logic employed in searching the CLAIMS database, n. 9.

12. One observer has noted that large firms usually patent in only those countries that are known for "technological capabilities and strong markets." It would be unreasonable to patent a technology "where there is little or no demand for it or insufficient capability to produce it." J. Davidson Frame, International Business and Global Technology (Lexington, Mass.: D.C. Heath and Company, 1983), pp. 107.

13. This example demonstrates that, because of the search methods used, it may appear that a greater amount of patent activity has occurred in the United States. Although it is thought that more patent activity has occurred in the United States, the conclusions of this study do not rely upon such a finding. The review of Japanese patents was conducted through communications with several knowledgeable sources on patent activity in Japan.

14. In a technological sense, institutions in the Soviet Union are best described as potential entrants. The Soviets have undertaken some R&D and prospecting activities; however, the extent of deepsea technological capability has been questioned. Ruth M. Linebaugh, "Ocean Mining in the Soviet Union," Marine Technology Society Journal 14 (1982): 21. The Soviet Union has announced its intention to become a seabed mining pioneer. Joseph S. Warioba to Preparatory Commission for the International Sea-Bed Authority, Letter referring to letter of application for registration as a pioneer investor under the provisions of the Law of the Sea Convention from the Soviet Union to PrepCom, LOS/PCN/31 (24 October 1983). But the lead institution, the Southern Production Association for Marine Geological Operations, holds no seabed mining patents that have been identified in this study.

15. For example, UOP, Inc., an affiliate of the Signal Companies and formerly known as Universal Oil Products, licenses patent rights through "process license agreements." These agreements allow clients access to all relevant technological know-how, patents, patent applications, and other transferable rights as well as supervisory, engineering, guarantee, and other

services supplied by UOP. Moody's Industrial Manual, 1981 edition (New York: Moody's Investors Service). UOP is involved primarily in petrochemical technologies. UOP holds four seabed mining metallurgical processing patents, but this represents only 0.2% of its total patent activity from 1969 through 1980.

16. Michel Gauthier, Centre Océanologique de Bretagne, Centre National pour l'Exploitation des Océans, personal communication with Katherine F. Wellman, Marine Policy Center, Woods Hole Oceanographic Institution, 16 March 1982.

17. Although anyone, even a foreign national, may obtain a patent from the U.S. government, patent protection only exists within the jurisdiction of the United States. Several firms or government agencies hold patents in several different countries on the same invention; this is done for the purpose of expanding patent protection, although the kind of protection available may differ depending upon the jurisdiction. See generally: United Nations, The Role of the Patent System in the Transfer of Technology to Developing Countries (New York: 1975). To the extent that inventive activity, or even R&D, is measured by patent activity, the inclusion of all patents obtained by a company in a counting exercise may overestimate inventive activity.

18. Metallgesellschaft A.G., "Manganese Nodules--Metals from the Sea," Review of the Activities, Edition 18 (Frankfurt am Main, West Germany: 1975): 27-35.

19. It is assumed that the patent searches conducted for this study were comprehensive enough to provide a meaningful comparison of patent activity. No search, however, can claim to be fully comprehensive. A further difficulty is encountered in measuring R&D by patent activity, since clearly R&D could be conducted without patenting. Patents are a better measure of the rate of invention and, when used with care, may indicate R&D trends. J. Balderston et al., Modern Management Techniques in Engineering and R&D (New York: Van Nostrand Reinhold Company, 1984): 201. The relationship of R&D to patent activity may also vary with other factors, especially the size of the firm,

research expenditures, and the number of employees. John Bound et al., "Who Does R&D and Who Patents?," Zvi Griliches, ed., R&D, Patents, and Productivity (Chicago: The University of Chicago Press, 1984): 21-54.

20. A patent application consists of two parts: the specification and the claims. The specification is a written description of the invention. It concludes "with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention." Novelty, patentability, and questions of infringement are judged on the basis of the claims. U.S., Department of Commerce, Patent and Trademark Office, General Information Concerning Patents (Washington: U.S. Govt. Ptg. Ofc., 1982). One possible drawback to comparing total number of claims is that they are allowed to be "dependent"; in other words, one claim can refer back to and restrict an earlier claim. Thus it is possible that there is some overlap among claims and a comparison of the total number may overestimate the actual number of technological concepts. Ernest Purser, Patent Examiner, Patent and Trademark Office, personal communication, 24 February 1984.

21. Both Lockheed and Union Miniere may have been interested in packaging their inventions to make them more marketable. See discussion in section III.

22. Some previous patent searches were conducted using certain PPFs as search keys. For example, the Office of Technology Assessment and Forecast search, n. 10, located seabed mining patents only for Deepsea Ventures, Kennecott, Lockheed, and Inco.

23. Takahara, n. 5.

24. U.S., Department of Commerce, National Technical Information Service, Industrial Patent Activity in the United States, Part 2, NTIS Patent Information Series (Washington: April 1981). This document is a listing of entities that received at least three U.S. patents during the period 1969 to 1980.

25. Balderston et al., n. 19, 201.

26. Broadus and Hoagland, n. 1, 541.

27. Broadus, n. 3. Also see: Tilton, n. 4, 64-79 for a description of "cyclical volatility" in mining industries.

28. James Leppink, Supervisory Patent Examiner, U.S. Patent and Trademark Office, personal communication, March 1983.

29. Slade, n. 4, notes that price cycles in nonferrous metal commodities are too long to be related to aggregate economic activity. She estimates a period of ten years for the cycle of one one of the nodule metals, copper.

30. See, e.g., the exploration license applications of the consortia, n. 10.

31. The creation of generic and more specific categories of technology is not novel and is merely a means of simplifying a complex problem for ease of comprehension and description. The Patent and Trademark Office has its own method of classification of inventions into the very broad categories of mechanical, chemical, or electrical patents. These categories are broken down into various classes, which are then further broken down into subclasses. U.S., Department of Commerce, Patent and Trademark Office, Manual of Classification (Washington: 1983). Krutein has demonstrated another method of categorizing patents into "general categories" of exploration, mining, lifting, processing, and other. Krutein, n. 10, p. 28.

32. Vertical integration "in the static sense . . . describes the extent to which firms in fact cover the entire spectrum of production and distribution stages." Motivations for vertical integration include the reduction of costs and the increase of control over a firm's economic environment. Scherer, n. 8. Completely vertically integrated mining companies are involved in the following functions: "exploration and development, mining, milling and concentrating, smelting, refining, manufacturing and sales." Fredrick C. Kruger, "Environment, Structure, and Organization of the Mineral industry," William A. Vogely, ed., Economics of the Mineral Industries, 3rd edition (New York: American Institute of Mining,

Metallurgical, and Petroleum Engineers, 1976). In seabed mining, recovery and metallurgical processing would replace all functions between exploration and manufacturing.

33. Because seabed mining consortia appear the most vertically integrated in a generic technological sense, generic categories have been subdivided in an attempt to show differences in technological focus among the consortia. Some caveats are in order, however. It has been much easier to differentiate between recovery patents than between metallurgical process patents. In many cases, patents cover technologies in more than one specific category; therefore, it has been impossible to assign numbers of patents to each category. Finally, because patent abstracts from the "Official Gazette" were the primary reference source for this comparison, in certain cases specific categories, which may have been described in the full patent, might have been excluded.

34. See generally: Philip B. Grote and Jerome Q. Burns, "System Design Considerations in Deep Ocean Mining Lift Systems," Marine Mining 2 (1981): 357-383. Active firms ideally would select the most effective specific technology within a generic category for use in seabed mining. If patent protection already exists for that technology, however, then firms either would obtain a license on that technology or choose the next most effective unprotected substitute. This could contribute to a convergence upon one specific technology.

35. See, for example, U.S., Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean Minerals and Energy, Deep Seabed Mining Draft Environmental Impact Statements on Issuing Exploration Licenses to OMA, OMI, OMCO, and KCON, 4 Vols., (Washington: May 1984).

36. Takahara, n. 5.

37. P. Le Gouellec et al., "Bilan Global des Activités Françaises dans l'Exploitation des Nodules: Objectifs du Programme Gemonod," Presented at 2nd International Seminar on Offshore Mineral Resources, Brest, France: Centre Océanologique de Bretagne, March 1984.

38. Broadus and Hoagland, n. 1, 556-557. See also: Arthur D. Little, Inc., Technological and Economic Assessment of Manganese Nodule Mining and Processing, Prepared for U.S. Department of Interior, Office of Minerals Policy and Research Analysis (November 1979); John Reason, "Deepsea Mining: A New Maritime Industry," Surveyor 12 (1978): 2-7; and OMA's exploration license application, n. 10.

39. Broadus, n. 3.

40. Ocean Mining Associates, n. 10.

41. For an explanation of substitution in patent activity in other industries see: Roger L. Beck, "Patents, Property Rights, and Social Welfare: Search for a Restricted Optimum," Southern Economic Journal 45 (October 1976): 1045-55. Other patent strategies, especially fencing-in, are described by Scherer, n. 8, pp. 450-453.

42. For example, see the following patents by Deepsea Ventures: "Water Flow-Deflecting Shield for Dredge Suction Nozzle," US4171581 (23 October 1979); "Suction Nozzle Dredge Head," US4178704 (18 December 1979); "Steerable Ocean Floor Dredge Vehicle," US4208813 (24 June 1980); "Steerable Ocean Floor Dredge Vehicle," US4249324 (10 February 1981); "Dredge Head with Mechanical and Pumping Action," US4311342 (19 January 1982); "Dredgehead Having Forward Water-Deflecting Means Comprising Two Transverse Elements," US4319414 (16 March 1982); "Means for Controlling Feed of Particulate Material into Airlift Pipe," US4319782 (16 March 1982); "Remotely Steerable Dredge Vehicle," US4327505 (4 May 1982); "Dredging Apparatus Including Suction Nozzles," US4346937 (31 August 1982).

43. Broadus and Hoagland, n. 1, 558-559. See also: John E. Halkyard, "Deep Ocean Mining—Current Status and Future prospects," Ocean Industry (May 1979): 49-51; "Kennecott Researching Ocean Mining," Engineering & Mining Journal (September 1971): 38-42; Richard C. Tinsley, "Activities and Economies of Existing Manganese Nodule Mining Consortia," Proc. of Oceans '79 (September 1979).

44. Kennecott, "Process and Apparatus for Mining Deposits on the Sea Floor," US3456371 (22 July 1969); Kennecott, "Process and Apparatus for Transporting Mined Deposits from the Sea Floor," US3765727 (16 October 1973); Kennecott, "Sea-Bed Mining System," FRG2302940 (2 August 1973).

45. See, for example, the following Kennecott patents: "Solvent-in-Pulp Extraction of Copper and Nickel from Ammoniacal Leach Slurries," US3950487 (13 April 1976); "Recovery of Metal Values from Manganese Deep Sea Nodules Using Ammoniacal Cuprous Leach Solutions," US3983017 (28 September 1976); "Elevated Pressure Operation in the Cuprion Process," US3988416 (26 October 1976); "Metal Carbonate Recycle to Reduction Circuit in the Cuprion Process," US4018866 (19 April 1977); "Cuprion Process Start-Up Control," US4107262 (15 August 1978).

46. Kennecott holds patents in the United States, West Germany, Canada, Great Britain, South Africa, and Australia. Additionally, Frame, n. 12, 106, notes that there exist two more reasons for patenting overseas: "to encourage foreign participation in a joint venture" and as a negotiating tool "to extract concessions" from institutions in a foreign country.

47. Broadus and Hoagland, n. 1, 559-560; also see: "Few Innovations in Offshore Technology on View at Germany's Interocean '76," Engineering & Mining Journal (August 1976): 37-39; "Converted Drillship Will Begin Deepsea Mining Test in October," Ocean Industry (June 1977): 79-85; "Pilot Test of Manganese Nodule Recovery Begun," Meerestechnik: Zeitschrift des Vereins Deutscher Ingenieure für Meeresforschung und Meerestechnik 9 (1978): 47-50; Arthur D. Little, Inc., n. 38.

48. The patents cited specifically are: Earl & Wright, "Deep Sea Mining Method and Apparatus," US3672725 (27 June 1972); Preussag, "Apparatus for Recovery of Magnetizable Materials from the Sea Bottom," US3776593 (4 December 1973); Preussag, "Grabhead for Collecting Samples from Seabed," FRG2444167 (1 April 1976); Preussag, "(Spring Activated Grab Sampler?)," FRG2462197 (1976); Preussag, "Free Falling Grab for Underwater Sampling," FRG2462291 (2 December 1976); Howaldtswerke-Deutsche Werft, "Ship and Pier for Extraction of Valuable Materials from the Sea Bed," US3975841 (24 August 1976); Salzgitter, "System

for Gathering Solids from the Ocean Floor and Bringing Them to the Surface," US4052800 (11 October 1977); Sumitomo Metal Mining, "Apparatus for Recovering Minerals, in Particular Manganese Nodules, from the Bottom of the Water," US4042279 (16 August 1977).

49. AMR, DOMCO, Sedco, and Inco, "Agreement and Amendment to Joint Venture Agreement of February 20, 1975," Art. II, 2.2(b), Art. IX, 9.4 (iii) (14 November 1975), found at Sedco, Form 10-K Annual Report to Section 13 or 15(d) of the Securities Exchange Act of 1934 (Washington: Securities and Exchange Commission, 1981).

50. See n. 48; Sumitomo Metal Mining, "Recovering Manganese Nodules Obtained from Ocean Bed--By Sledge Using Water Pump to Drive Minerals into Collection Chamber," FRG2643041 (14 April 1977); "Method and Apparatus of Surveying Nodular Targets on the Seafloor," US4319348 (9 March 1982); "Process for Treating Manganese Nodules," US4029498 (14 June 1977).

51. Broadus and Hoagland, n. 1, 557-558. See also: Richard C. Tinsley, "Mining of Manganese Nodules: An Intriguing Legal Problem," Engineering & Mining Journal (October 1973): 84-87; "'Hughes Glomar Explorer' Begins Sea Tests of Mining Systems," Ocean Industry (March 1974): 32-34; "Ocean Minerals Recovered from Floor of Pacific by OMCO," Maritime Reporter (1 August 1978); "Glomar Explorer Grooming for Deepsea Mining Tests," Ocean Industry (July 1978): 66; "Glomar Explorer Will Test Sea-Bed Mining Device for Nodule Recovery," Engineering & Mining Journal (August 1978): 31, 33; B. Rintoul, "Ocean Minerals Outlines Mining Plans," Offshore (October 1978): 121-132; Conrad G. Welling, "The Massive Technology for Ocean Mining," Stockton's Port Soundings (September 1980): 8-11.

52. Lockheed Missiles and Space, "Ocean Mining System and Process," US4232903 (11 November 1980).

53. Lockheed Missiles and Space, British Patent Application 2112834A.

54. Shell Oil, "Underwater Locating Device," US3222634 (7 December 1965); Shell Oil, "Submarine Dredging Apparatus," US3706142 (19 December 1972).

55. Shell Oil, "Process for Extracting Copper, Cobalt, and Nickel Values from Aqueous Solution," US3703573 (21 November 1972); Shell Oil, "Extraction of Copper Values from Aqueous Solution," US4173616 (2 November 1979).

56. Baggermaatschappij Bos & Kalis, "Transport System for Seabed Minerals," FRG2355416 (16 May 1974). Baagermaatschappij virtually disappears as a distinct corporate entity of Boskalis in 1979. Royal Boskalis Westminster Group, Annual Report 1979 (Papendrecht, The Netherlands).

57. CSMRI also has been conducting research on nickel laterite metallurgy for SOHIO, the parent of Kennecott. Larry Cox, Colorado School of Mines Research Institute, and Dr. Yarar, Colorado School of Mines, personal communications, 15 June 1983. CSMRI also has worked for OMCO on the environmental effects of metallurgical processing. See: Individual draft environmental impact statement for OMCO, n. 35.

58. Benjamin W. Haynes, Stephen L. Law, and Riki Maeda, "Updated Process Flowsheets for Manganese Nodule Processing," Information Circular 8924 (Washington: U.S. Bureau of Mines, 1983).

59. Broadus and Hoagland, 560-561. See also: David W. Pasho, "The French Association," Internal Report 1976-10, Energy, Mines and Resources Canada (October 1976); Gerard Piketty "France: Deepsea Operations and Mining Techniques," Ocean Industry (April 1980): 350-356; J.P. Lenoble, "Travaux du Groupe Français pour la Recherche et l'Exploitation des Gisements de Nodules Polymétalliques de 1970 à 1981," (January 1982).

60. See the following patents by SGCEM: "Sea-Bed Mining Floating Dredge," FRG2331489 (10 January 1974); "Hydraulic Dredging Apparatus," US3829160 (13 August 1974); "Hydraulic Dredging System and Method for Collecting and Removing Material from Deep Sea-Beds," US3908290 (30 September 1975).

61. SLN, CNEXO, and Tetra Tech, "Sea Bed Mining Machine," FRG2336800 (7 February 1974).

62. Centre National pour l'Exploitation des Océans, Rapport Annuel 1981 (Paris, France), pp. 36-39.

63. CNEXO and SLN, "Method and Apparatus for Continuous Underwater Mining Using Plural Ships," US3889403 (17 June 1975); see SGCEM patent at n. 60.

64. See the following patents by CEA: "Seabed Mineral or Ore Working Process," FRG2801708 (18 January 1977); "Submarine Nodule Pick-Up Machine," Fr2377521 (15 September 1978); "Method and Apparatus for Mining Nodules from Beneath the Sea," US4231171 (4 November 1980); "Apparatus for Mining Nodules Beneath the Sea," US4343098 (10 August 1982); "Submarine Vehicle for Dredging and Raising Minerals Resting on the Sea Bed at Great Depths," US4357764 (30 June 1983).

65. See SGCEM patents, n. 60.

66. Le Gouellec et al., n. 37.

67. Broadus and Hoagland, n. 1, 561-562; communications with several knowledgeable sources on patent activity in Japan; see also: DOMA, "Organization of the Deep Ocean Minerals Association," Brochure (Tokyo: 31 March 1981); Ambassade de France au Japon, "Le Japon et l'Exploitation des Nodules Polymétalliques," Note by Service Scientifique (18 August 1982); MITI, "Manganese Nodule Mining System," Provisional Agenda Item-TAG.5.1 for Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (Tokyo: November-December 1982).

68. Gauthier, n. 16.

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78. Linebaugh, n. 14.

79. Gold Mining Institute, n. 77.

80. Such an increase would be consonant with the recently more active position of the Soviet Union at the Law of the Sea Preparatory Commission. See supra, n. 10 and accompanying text. The adaptation of seabed mining technology from shallow to deep water may not present a significant technological problem for the Soviets. A.C. Vine, Scientist Emeritus, Department of Geology and Geophysics, Woods Hole Oceanographic Institution, personal communication, December 1984. It is possible that the solutions to other, more significant seabed mining problems (e.g., the separation of clay sediments from nodules) could be more easily addressed initially in a shallow water environment.

81. M.G. Krutein, personal communication, 9 May 1983.

82. Yoshio Masuda, Japan Marine Science and Technology Center, to James M. Broadus, Letter concerning Japanese large-scale R&D project (1 August 1983).

83. Howaldtswerke-Deutsche Werft, n. 48.

84. John R.H. Black, The Recovery of Metals from Deepsea Manganese Nodules and the Effects on the World Cobalt and Manganese Markets, Ph.D. Dissertation (Cambridge, Mass.: Massachusetts Institute of Technology, 1980).

85. Ibid.

86. Hubred, n. 10; Haynes, Law, and Maeda, n. 58; Benjamin W. Haynes and Stephen L. Law, "Predicted Characteristics of Waste Materials from the Processing of Manganese Nodules," Information Circular 8904 (Washington: U.S. Bureau of Mines, 1982).

87. Haynes, Law, and Maeda, n. 58.

88. Kennecott, "Manganese Nodule Pelletizing," US3942974 (9 March 1976).

89. General Mills, Inc., "Recovery of Metal Values," US3197274 (July 1965).

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16. Abstract (Limit: 200 words)

Patent issues are one way to observe the behavior of private firms and government agencies at a formative stage in an industry's development when, for strategic reasons, these participants are careful about disclosing details of their activities. The seabed mining industry is a good example of an industry in its formative stages. This industry has been characterized in large part by the research and development (R&D) of technology to recover minerals from deep ocean polymetallic nodules and to process them metallurgically into metal products. The nearly 400 seabed mining patents that have been granted worldwide are a rough measure of this R&D activity. Patent issues can reveal several interesting aspects of an industry: (a) the identity of participants; (b) the generic type of technology; (c) the technological concentration of patent holders; (d) the technological integration of patent holders; and (e) the timing of inventive activity. In some cases, industrial motivations and strategies may be inferred from these aspects. Moreover, seabed mining might be subject to the cyclical fluctuations of markets for the metals contained in polymetallic nodules. Patent activity could provide some insight into the nature of a possible seabed mining industry cycle.

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2. seabed
3. mining
4. minerals
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6. metallurgy
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