Chapter 7

Nonfuel Minerals†

Oil and gas resources are not the only mineral assets of the OCS. An abundant variety of nonfuel mineral deposits have also been identified. Examples include sand and gravel in the New York bight, Beaufort Sea, and in areas offshore of California and Hawaii, placer deposits containing chrome, gold, platinum, titanium, and other heavy minerals, phosphorites along the southeastern U.S. margin and the coast of Southern California, manganese nodules on the Blake Plateau, cobalt crusts in areas around Hawaii, and marine polymetallic sulfides (MPS) in the Gorda Ridge area. Although these OCS nonfuel minerals are currently of only minor economic importance (as compared to OCS oil and gas resources), interest in them has grown markedly in recent years, and efforts have begun to clarify procedures for their exploration and development. Like their hydrocarbon counterparts, OCS nonfuel minerals are managed by the Minerals Management Service. However, most OCS nonfuel minerals are not commercially exploitable at present.

Nonfuel minerals on the OCS remain unworked except for the limited development and production of sulfur and associated salt deposits in the Gulf of Mexico. Due to geologic and economic uncertainty, the primary policy issue with respect to these minerals is one of generating information and allocating discovery and exploration effort between public and private interests.

Worldwide, the contribution of marine nonfuel minerals to minerals supply is very small compared with the more conventional onshore sources of the same commodities.[1] In the United States, OCS nonfuel deposits eventually might provide additional resources for at least 26 materials (although the magnitude and timing of these additions still require serious study). For most minerals, a period of exclusive production from successively costlier onshore deposits can be expected until a cost level is reached at which the least-cost marine deposits—as with hydrocarbons or sulfur—join into total production. Beyond that point, the respective shares of total output coming from onshore and marine sources would depend on how much additional output could be obtained from each source at incrementally higher cost levels.

Increasing attention has been paid to OCS nonfuel minerals, as evidenced by recent congressional hearings and studies of marine nonfuel minerals policy.[2] Given the cur-

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rent economic potential of marine nonfuel minerals, the reasons for this attention are not immediately apparent. However, the discovery and growing understanding of new forms of ocean minerals, such as marine sulfides, certainly fuels interest and reinforces an optimistic outlook for long-run minerals supply.

STRATEGIC MATERIALS

The availability of certain nonfuel minerals (designated "strategic" or "critical") as a supplemental source of metal commodities has been an important national policy goal to past federal administrations. In 1983 the Reagan administration reemphasized this goal, with particular focus on the potential resources of some of these minerals in the ocean. When President Reagan proclaimed an Exclusive Economic Zone (EEZ) for the United States, he said that "recently discovered deposits there [in the Exclusive Economic Zone] could be an important future source of strategic minerals."[3] Concerns for strategic minerals are reflected also in the name of the Minerals Management Service office, the Office of Strategic and International Minerals, which promotes the development of marine nonfuel minerals on the Outer Continental Shelf and within the EEZ.

Much disagreement exists about exactly what materials are or are not "strategic." A recent careful attempt to analyze this issue narrowed a long list to four "first tier" commodities: chromium, cobalt, manganese, and the platinum group metals. All four are potential OCS nonfuel minerals. The primary interest groups are government agencies with responsibility for supplying the national defense structure in times of crisis.

As a component of national minerals and materials policy, the management of OCS nonfuel minerals must be considered in the context of other factors that condition mineral supply. If there is some benefit to reducing the risk of economic disruption from variations in supply, the costs of encouraging marine mineral development should be compared to the costs of maintaining stockpiles, encouraging onshore mineral development, sponsoring basic and applied research into substitute minerals, recycling, and mining beneficiation technologies, and conservation. In 1985 the U.S. Office of Technology Assessment concluded that options based on substitution, conservation, or production from alternative conventional sources are superior to marine mining as approaches to reduced import dependency.[4]

ORGANIZATIONS AND JURISDICTIONS

Under the general authority of several broad policy mandates, the Department of the Interior is responsible for encouraging private research and development in domestic mining, metallurgy, and critical materials, both onshore and offshore. Under the specific authority of OCSLA section 8(k), the Department has promoted OCS nonfuel mineral development since an early sale of OCS lands for phosphorite minerals off the coast of Southern California in 1961. When the oil platform blowout occurred in the Santa Barbara Channel in 1969, public concerns about the external effects of industrial activity in the oceans helped to delay plans for leasing OCS lands for nonfuel minerals development.

However, in 1974 the Department's Bureau of Land Management (BLM) published a draft environmental impact statement with details on the proposed disposal of OCS lands for phosphorite and sand and gravel resources. Public reaction to the draft was mostly negative, and the BLM postponed its effort.

In 1975 the Department established an Ocean Mining Administration (OMA) to coordinate its ocean mining efforts, including marine geological research activities conducted by the Department's U.S. Geological Survey (USGS) and studies on the environmental effects of manganese nodule metallurgical processing by the Department's Bureau of Mines (BOM). The Ocean Mining Administration was short-lived. It spearheaded the Department's support of domestic deep seabed legislation in the late 1970s, until the Deep Seabed Hard Mineral Resources Act of 1980 gave primary management authority over deep seabed minerals (specifically manganese nodules) to the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce. In 1979 the USGS published a Program Feasibility Document on a proposed OCS nonfuel minerals program recommending a prototype lease sale. This recommendation went largely unheeded for three years during a change in administration.

Existing Authority: OCS Lands Act

In 1983 the Department of the Interior created the Office of Strategic and International Materials (OSIM) within the Minerals Management Service. OSIM was directed to proceed with activities leading to the disposal of OCS lands for nonfuel mineral development. Based upon the guidance of an interagency task force, the Minerals Management Service began to construct a regulatory regime to carry out the provisions of Section 8(k) of the OCS Lands Act. The agency planned three tiers of regulations directed at prelease exploration, leasing, and postlease activities.

As part of its new responsibility, OSIM implemented an innovative concept known as the federal-state "task force" (used earlier in the leasing of public lands onshore for oil shale and geothermal resource development). These task forces have been aimed at bringing coastal state managers into the leasing process at an early stage. The hope of the Minerals Management Service is that this process might reduce later delays associated with the intergovernmental aspects of the OCS disposal process. The specific activities of each task force have varied from case to case. Thus far, the task forces have been funded to conduct a range of activities from economic feasibility studies to oceanographic research, to public hearings, and to the drafting of environmental impact statements. The states of Alabama, Alaska, California, Georgia, Hawaii, Louisiana, Mississippi, North Carolina, Oregon, Texas, and Washington (as an observer) already participate as members of the task forces.

Legislative and Regulatory Initiatives

The enactment of the OCS Lands Act in 1953 was an exercise of the constitutional authority of Congress to dispose of public lands. (Although OCS lands are not true "public lands," Congress defined them in the act to be subject to U.S. jurisdiction, control, and power of disposition as discussed in Chapter 1.) The brief, nonspecific paragraph of the act that relates to the disposal of OCS lands for nonfuel mineral development leaves a considerable amount of discretion to the secretary of the Interior to set the terms and conditions of an OCS nonfuel mineral lease. One of the only specific requirements is that leases must be sold on the basis of competitive cash bonus bidding at an auction. Not surprisingly, industrial interests have been opposed to this disposal method. The Minerals Management Service reportedly has considered modifications to the traditional bonus bidding method utilized for the fossil fuels, but these considerations have not yet been widely published.

In large part because of the efforts at the OSIM to construct a regulatory system for nonfuels that would dispose of OCS lands competitively, an alternative legislative initiative has been pursued. In 1986 and 1987 identical bills were introduced in successive sessions of the Congress to change the disposal method found in the OCS Lands Act to an exploration licensing system.[5] The proposed system would include a "preference right" to a development-production permit in the event that a deposit of commercial potential is discovered. The current legislative proposal has been called the National Seabed Hard Minerals Act. In a general sense, this proposal is a throwback to one of the earliest methods of mineral disposal—the location-patent system of the 1872 Mining Law used on the federal public lands of the western United States. Significant differences can be found in the current proposal, of course, including the right to an exclusive exploration license and the possibility of a royalty charge upon production. The proposed National Seabed Hard Minerals Act has been drafted much more closely along the lines of the Deep Seabed Hard Mineral Resources Act (the legislation governing the allocation of entitlements to manganese nodules beyond national jurisdiction).

Multiple Agency Management

Jurisdictional ambiguities (geographic and regulatory) are a common feature of the management of OCS nonfuel minerals. This fact is well recognized by participants in the process but seldom has been subject to serious academic analysis. Such ambiguities can be expected in any situation when one agency has general management responsibility where the resources are found, but another agency manages the specific resources that might be extracted.

In the case of nonfuel minerals found on the OCS and on the deep seabed, at least two federal agencies, the Minerals Management Service and the National Oceanic and Atmospheric Administration, have statutory authority to regulate exploration and exploitation. Although there is an apparent clear division of responsibility at the continental shelf "boundary," the actual division is in fact uncertain. The creation of the Exclusive Economic Zone, which extends 200 nautical miles from the coastal "baseline," further clouds the jurisdictional issue. The Solicitor's Office of the Department of the Interior has published an opinion that concludes that the Interior Department has the authority to manage nonliving resources of the EEZ in areas that extend beyond what might be considered as the geographical continental shelf.[6] Yet, there has been no official delimitation of the OCS.

Because of the preliminary state of knowledge about most OCS nonfuel minerals, a major share of management activity in the nearterm will necessarily involve programs of scientific research. Management ambiguities may be difficult to unravel for the many promotional, research and development, and data collecting and handling responsibilities of the Commerce and Interior departments. Agency roles and responsibilities overlap significantly in this area. NOAA and the USGS have recognized the need to coordinate individual and overlapping agency responsibilities for research in the water column, beneath the ocean floor, and on the ocean. Moreover, these two agencies have established a liaison office and have agreed to complement each other's activities in a bathymetric survey of the EEZ. In spite of such advances in mutual understanding, the Commerce and Interior departments may continue to share jurisdiction. Furthermore, preliminary indications show that, in several cases, those private firms that are already dealing with the National Oceanic and Atmospheric Administration on manganese nodule development are the same firms that have shown interest in potential OCS nonfuel resources.

Where areas containing potentially valuable natural resources are subject to multiple agency management and associated ambiguities, the pace of resource development can be subject to two offsetting effects. Multiple systems of rules covering a single resource or activity can impose additional costs that postpone the time when a resource will be explored and developed. This is especially true in a case such as marine nonfuel minerals where significant uncertainties are present about the physical operating environment. Private firms can be reluctant to commit investments in exploration (much less to establish long-term development plans in an uncertain legal environment). On the other hand, if the resource can be independently explored and developed by separate parties, each may accelerate its own development activities in order to discover and recover as much as possible before their competitor (the well-known "common pool" effect).

Under certain conditions, however, some jurisdictional overlap and managerial rivalry can be beneficial, enhancing both the quality of policymaking and the flow of information to interest groups such as private firms, environmental groups, and states. Especially in the early stages of an evolving legal regime, private interests who are contemplating investment in resource development may find enhanced access and greater range of influence on agency decisions when more than one agency is centrally involved in the process. Where the allocation of public funds and the selection of research projects depend critically (as they do for marine hard minerals) on scant scientific knowledge, it is especially important that resource managers have both up-to-date scientific information and balanced appreciation of its significance. Multiple agency management responsibility might enhance flexibility in the face of uncertainty and provide increased scope for combinations of agency strengths and specialties. Because a complex (and still poorly defined) variety of functions will be necessary to convert OCS nonfuel resource potential into a flow of economic supplies, premature monopolization of all these functions by a single agency could sacrifice the benefits of multiple agency management at a time when they seem most essential.

DESIGNING AN OFFSHORE NONFUEL MINERAL SYSTEM

All minerals have geologic and end-use characteristics that are distinguishing features. Several government studies and laws have recognized these features and, based on observed differences, have recommended the need to manage nonfuel minerals in a different manner than hydrocarbon minerals. It has been stated frequently by those engaged in the policy debate over management systems for offshore nonfuel minerals that differences in industrial structure and technology between the hard minerals industry and the oil and gas industry require an entirely different set of offshore access provisions. This concept was incorporated in the proposed National Seabed Hard Minerals bill virtually without discussion and certainly without adequate elaboration. The differences most often referred to are:

1. Investors face more uncertainty and greater risk in marine nonfuel minerals exploration.
2. Technology for marine hard minerals exploration and development is less developed than for marine hydrocarbons.
3. The oil industry has more experience in searching for minerals beneath the surface, and exploration success in marine hydrocarbons can be converted more readily into production.
4. Marine hard minerals may require more extensive drilling or testing and a longer period of development without benefit of revenues than for hydrocarbons.
5. The hard mineral mining industry has fewer financial reserves than the oil industry and is unable to pay large, front-end cash bonuses.

The implication drawn from these differences by prospective ocean miners is that a competitive bidding system for access and development entitlements (particularly one based on up-front payments such as the OCS Lands Act) is inappropriate for marine hard minerals. Prospective ocean miners prefer the licensing system found in the Deep Seabed Hard Mineral Resources Act because it collects only a minor tax on production. The provisions described in the proposed National Seabed Hard Minerals Act promise somewhat greater financial consideration to the public in exchange for the right to explore.

An important policy issue associated with noncompetitive licensing is that licenses are not necessarily distributed to the most efficient explorer or developer. Instead, they are issued to the first in line at the "land office." If licenses can be assigned by one firm to another, then, except for additional negotiation costs, this poses no problem for economic efficiency.

Whereas noncompetitive licensing is capable of achieving economic efficiency, the public would not receive a financial return. However, there appears to be no tangible reason why licenses for OCS nonfuel minerals could not be issued competitively (as they must under OCSLA 8(k)) so that access is allocated to the most efficient producer. Due to the high degree of geologic uncertainty and the current low level of industrial interest, however, expected economic rents could be low or even nonexistent. And thus bids would also be low or nonexistent. To compensate for the lack of rents, methods other than bonus bidding—such as profit share bidding or work commitment bidding, among others—that allocate access competitively have been suggested. In general, these methods of access impose enforcement and other administrative costs that are not encountered in a license-permit system. Moreover, there may not be enough commercial interest to hold a competition for access.

From the perspective of the resource manager who expects rapid technological change and uncertainty, several guidelines seem important for allocating the OCS nonfuel mineral lands. Achieving congressional objectives for nonfuel minerals may require maintaining a high degree of adaptability, diversifying to avoid commitment to a single outcome. However, as knowledge of OCS nonfuel minerals grows, and if the mineral resource potential proves sufficient to generate a stronger market for access, then the nonfuel OCS management may become more similar to that for oil and gas.

In the nearterm it may be beneficial for the resource manager to have the authority to make small changes in a disposal system to adjust to variations in economic conditions over time as well as new emphases in public goals. This kind of adaptability might be implemented at different levels and in alternative ways such as:

1. Individual access. The adjustment of terms and conditions of property rights on a case-by-case basis. Although this could incur substantial administrative costs, the small number of expected leases in the near future suggests that such a system might be administratively feasible.
2. Dual system. Multiple disposal methods might be employed for the same minerals across space or time, based upon the model found in the 1920 Minerals Leasing Act. This Act established a dual system in which solid minerals (e.g., phosphates, sulfur, salt) are leased competitively in "known geological structures" but are leased on a first-come, preference-right basis in areas where geological structures are unknown. The most recent version of the National Seabed Hard Minerals Resources Act, H.R. 2440, contains language that would allow the establishment of a dual system.
3. One system with marginal adjustment. One disposal method might be employed with marginal adjustments over time (as exemplified by the oil and gas provisions in the OCS Lands Act). Terms and conditions could be modified from time to time on future disposals to respond to changing market conditions.
4. Interim system with a sunset clause. This would entail a system like the proposed National Seabed Hard Minerals Act that would expire after a number of years (or perhaps after one round of licensing). Faced with virtually the same issues for nonfuel minerals on the U.S. public lands, the Public Land Law Review Commission recommended an "interim system" in 1970 and placed a premium on adaptability.

An important point is that adaptability is not equivalent to the exercise of discretion over access already granted through a lease or some other agreement. Adaptability can be incorporated into a disposal system for OCS nonfuel minerals without an increase in managerial discretion and its associated uncertainties.[7] Adaptability involves the adjustment of basic disposal methods such that the probability of achieving policy goals through future OCS land disposals is increased. The limits of adaptability may soon be tested for the nonfuels case under the provisions of the OCS Lands Act. It appears that the act could be more adaptable for the oil and gas minerals than for the nonfuels. Likewise, until the 1989 version as H.R. 2440, the legislative proposal (National Seabed Hard Minerals Act) did not appear to be any more adaptable than the OCS Lands Act in the sense described here.

POTENTIAL OCS NONFUEL MINERAL RESOURCES

Comparative Costs

In the placid, shallow waters of protected bays or estuaries that typically are under the control of the states, dredging costs for loose materials, such as sand and gravel, placer minerals, or phosphate, may be comparable to those onshore. Indeed, this is little more than an extension of conventional onshore production. For more exposed, high energy (weather and waves) offshore environments, much greater costs can be expected. Mining costs tend to be case-specific, but industry sources suggest that seabed dredging for these materials would cost three–five times more than inland dredging.

When a mining technology is more costly than another for a given level of ore, it still can be competitive if the ore grade is rich enough to compensate with higher metal yield or if the deposit is large enough to spread fixed costs over greater levels of output. For example, although average offshore drilling and equipping costs tend to be three–four times larger than onshore costs for oil and gas, the very large size of producing offshore deposits allows them to be competitive. Similarly, other marine deposits would have to offer compensating grade or size premiums to be competitive. Under some local conditions with locational or deposit-size advantages in delivered cost, offshore sand and gravel materials overcome the usual cost differential.

Mineral Types, Reserves, and Resources

From a general standpoint, OCS nonfuel mineral prospects can be classified into shallow coastal and deepsea deposits. Table 7-1 presents descriptive statistics comparing onshore and offshore production, estimated revenues, and resource estimates for nonfuel deposits with potential marine sources.

Shallow coastal deposits are the first general class of marine nonfuel minerals. These deposits are generally found in waters less than 200 meters and include the following six mineral types: sulfur, sand and gravel, calcium carbonate, marine placers, phosphorite deposits, and lode minerals.

1. *Sulfur* has been recovered commercially off the coast of Louisiana since the early 1960s. Sulfur is used as a chemical reagent and in the production of fertilizer. Salt-capped sulfur domes are mined using the Frasch process of injecting hot water to melt the sulfur and air pressure to force the melt to the surface. Salt is recovered nearby and used to make a brine solution that acts as a drilling fluid in sulfur extraction. Because salt is also an OCS nonfuel mineral, the rights to salt deposits are often sold together with sulfur rights. Offshore sulfur production is now limited to a single operation, producing approximately $36 million in revenues annually. The recovery of waste sulfur from pollution control equipment may replace Frasch sulfur entirely by the year 2000. Since 1953 only six lease sales have been held for sulfur minerals on the OCS (Table 7-2). The most recent sale, held in February 1988, attracted $15 million in high bonus bids on 14 tracts in the Gulf.
2. *Sand and gravel* are produced within the jurisdiction of coastal states by small dredging operations for construction aggregate. For decades, deposits of these

Table 7-1
Descriptive Statistics: Offshore Nonfuel Minerals

U.S. Marine deposits	Material commodity	(A) U.S. Marine production[a] (MT×10³)	(B) U.S. Mine production (MT×10³)	(C) Estimated average price ($/MT)	(D) (A)×(C) Marine revenues ($×10⁶)	(E) (B)×(C) U.S. Revenues ($×10⁶)	(F) (D)×100/(E) Marine share of U.S. revenues (%)	(G) U.S. Marine reported speculative resources (MT×10³)	(H) U.S. Identified onshore resources (MT×10³)	(I) (G)×100/(H) U.S. Speculative marine resources compared to U.S. identified resources[b] (%)
Sand and gravel	Sand and gravel	3,000	865,900	3	9	2,598	1	665,778	65,000,000	1
Shell	Calcium carbonate	14,000	(1,400,000)	6	84	(8,400)	1	large	very large	small
Sulfur	Sulfur	381	11,200	105	40	1,176	3	27,125	1,000,000	3
Barite	Barite	—	343	31	—	11	—	2,087	90,720	2
Phosphorite	Phosphate rock	—	40,000	24	—	960	—	4,615,000	9,250,000	50
Mineral placers	Rutile	—	—	364	—	—	—	12,156	7,801	156
	Ilmenite	—	—	49	—	—	—	180,537	87,091	207
	Titanium	—	16	12,236	—	196	—	—See: Rutile, Ilmenite—		
	Zirconium	—	—	182	—	—	—	25,039	12,207	205
	Hafnium	—	—	231,483	—	—	—	250	127	197
	Yttrium	—	—	35,020	—	—	—	3,450	28,123	12
	Thorium	—	1	35,850	—	1	—			
	Chromite	—	0	42	—	0	—	30,158	9,979	302
	Gold	—	1	10,600,000	—	800	—	1	8	10
	Platinum	—	—	9,000,000	—	—	—	1	9	1
Crusts	Platinum	—	—	9,000,000	—	—	—	2	9	22
	Cobalt	—	0	25,353	—	0	—	42,267	1,270	3328
	Nickel	—	1	5,026	—	5	—	22,684	13,880	163
	Manganese	—	0	141	—	0	—	1,128,751	66,770[c]	1691
Massive sulfides	Copper	—	1,170	1,475	—	1,726	—	—	382,000	—
	Zinc	—	210	893	—	188	—	—	65,000	—

[a] U.S. marine production occurs predominantly in the territorial sea.
[b] Reported grades may be incomparable (particularly in the case of estimated crust resources).
[c] Very low grade manganese, less than 20 percent wt.

Source: P. Hoagland III and J. Broadus, "*Seabed Material Commodity and Resource Summaries,*" Woods Hole Oceanographic Institution, WHOI-87-43, 1987.

Table 7-2
Gulf of Mexico OCS Sulphur and Salt Lease Sales

Year	Tracts bid on	Tracts leased	Total bonus (million $)
1954	5	5	1.2
1960	1	1	.1
1965	50	50	33.7
1967	8	1	.0
1969	38	4	.7
1988	14	14	15.1

Source: Minerals Management Service.

materials have been mined for their use as construction aggregate or for beach nourishment. In countries such as England, the Netherlands, and Japan, marine sources make a major contribution to total sand and gravel supplies. In the United States, these sources still account for only about 1 percent of total production, but the potential is large.

In 1987 the U.S. Bureau of Mines completed a study commissioned by the Minerals Management Service of the prospects for offshore production of sand and gravel in the United States.[8] The study suggested that "significant potential" may exist for the development of sand and gravel off New York and Boston in the nearterm. At present, production is accomplished by pumping or dredging, often tens of kilometers offshore. Practical recovery depths are less than about 50 meters. High transport costs limit these construction minerals to local market areas, with great geographic variety in price among markets.

In 1983 the Minerals Management Service initiated steps toward the leasing of OCS lands for sand and gravel resources off Alaska. The oil and gas industry had expressed an interest in these deposits because of their potential use as a material for the support of production platforms in the icy Arctic region. However, due to slumping oil prices, industry interest in Arctic production waned, and the sand and gravel sale was cancelled.

3. *Calcium carbonate* is recovered primarily in the form of the mineral "aragonite" and is used in cement, glassmaking, and foundry applications. (Shell, mentioned above with other aggregates, is also a form of calcium carbonate.) In 1986 the Minerals Management Service issued a prelease prospecting (geological and geophysical) permit for "carbonate sands" on the OCS lands off the Florida Keys. Calcium carbonate is mined onshore in the form of limestone (of which vast deposits exist). Limestone is used as a construction material (as either "crushed" or "dimension" stone) and also to produce lime for steelmaking, water purification, and pollution control. The U.S. Bureau of Mines classifies some organically generated forms of calcium carbonate (such as precious coral and pearl) as types of gemstone. Exploitation of these organically generated mineral forms are considered a fishery and a precious coral fishery exists off the coast of Hawaii.
4. *Marine placers* include deposits of light-heavy minerals such as chromite or titanium oxides (ilmenite, rutile, leucoxene) and other "associated" minerals (zirconium, monazite containing yttrium, thorium, and other rare earths) and heavy-

heavy minerals like native forms of precious metals or tin. Again, with the sponsorship of the MMS, the Bureau of Mines conducted engineering and cost studies of a chromite placer off the coast of Oregon, titanium placers off the coasts of Virginia and Georgia, and a gold placer off the coast of Alaska.[9] Only the gold placer is being worked (although there has been some recent prospecting efforts on the others). Off Nome, Inspiration Mining Company is presently recovering gold from an offshore placer deposit within the Alaskan territorial sea. A small portion of this deposit may extend beyond Alaskan jurisdiction onto OCS lands. Marine placer minerals so far reported do not seem to exhibit a much larger size or higher grade than their onshore rivals, and Emery and Noakes have shown that strong physical constraints generally will limit the distribution, grade, and accessibility of marine placers.[10] Table 7-3 compares two estimates of the costs for developing and producing the Nome deposit.

5. *Phosphorite* deposits are found off the coast of Southern California, North Carolina, and Florida. The potential for phosphorite development off the U.S. Atlantic Coast near North Carolina has generated recent interest, and a jointly sponsored state and federal effort has been directed at examining the commercial potential

Table 7-3
Nome Gold Placer Costs

	Bureau of Mines (January 1987)	OTA
Deposit kind	Gold Placer	Gold Placer
Grade	0.6 gram per yard^3	0.35 to 0.45 gram per yard^3
Size	35,000,000 yard^3	80,000,000 yard^3
Distance to shore unloading point	0.5 to 5 miles	0.5 to 10 miles
Maximum dredging depth	80 feet	90 feet
Annual mining capacity—tonnage dredged	1,632,000 yd^3	4,500,000 yd^3
Mining system	Used seagoing bucket line dredge with full gravity processing	Used seagoing bucket line dredge with full gravity processing
Mining system operating days	150	150
Shore processing plant	Minimal for final cleaning of gold concentrates	Minimal for final cleaning of gold concentrates
Capital costs (million $)		
Dredge		5
Plant and other		10–15
Total	$9.1	15–20
Direct cash operating costs $US per yard mined	2.00	1.55
Comments (OTA'S)	Technically feasible and appears economically profitable	Technically feasible and appears economically profitable

Source: Office of Technology Assessment, *Marine Minerals*, 1987.

of deposits there. The only lease sale held to date for OCS nonfuel minerals other than sulfur/salt has been for phosphorite deposits off the coast of Southern California in 1960. These leases were relinquished shortly after the sale ostensibly because of the existence of unexploded naval ordnance at the site. Some interest has been shown in the development of new borehole mining methods that may enhance access to subseabed phosphates, but this also favors expansion of deep rival resources onshore.

6. *Lode minerals* include deposits such as the barite of Castle Island, Alaska. Barite, or barium sulfate, is used as a weighting agent in oil and gas drilling fluids. Until 1980 barite was produced from Castle Island within the waters of the state of Alaska. The Castle Island mine—a particularly rich deposit—was mined out above sea level from 1966 to 1969. Subsequent exploration work by the Inlet Oil Company discovered subsea reserves of approximately 2 million metric tons, and the mine was continued below sea level, effectively turning it into a marine deposit. The need for barite is tied closely to drilling activity in the oil and gas industry and the Castle Island mine is not currently in production. Lode deposits of the OCS lands are unknown and will probably be difficult to discover.

Deepsea deposits are the second general class of nonfuel minerals, including cobalt-enriched ferromanganese crusts on the flanks of seamounts between 1,000–4,000 meters in depth, marine sulfides precipitated around hydrothermal vents at crustal spreading centers found between 2,000–2,500 meters, and certain deposits of marine phosphorites found on seamounts between 1,000–4,000 meters. At this stage, attempts to characterize potential mining costs for marine sulfides and cobalt crusts are speculative at best. No technologies are known for breaking, sorting, and lifting these hard-rock deposits at such great depths, and only the most preliminary mining concepts have so far been presented. No method is known by which the crusts can even be selectively extracted in quantity without also extracting much barren substrate material, and practically nothing is known about the thickness (size) of the sulfide deposits. Development of techniques, such as a hard-substrate drill, to overcome these shortcomings is a priority in seabed minerals exploration.

"Resource" estimates have been reported for cobalt crusts in certain areas of the central Pacific, but these are based largely on very limited sampling or hypothetical grade-concentration combinations.[11] Cobalt crusts occur on the OCS near Hawaii and other Pacific territories of the United States. They also occur on the current-swept Blake Plateau off the Eastern Coast of the United States.

The highest quality (grade and density) manganese nodules are located beyond U.S. jurisdiction between the Clarion and Clipperton fracture zones on the Pacific seabed. Several U.S. firms hold exploration licenses in this area, issued under the authorization of the Deep Seabed Hard Minerals Resources Act. Lower quality nodules are found within the U.S. EEZ. High densities of nodules (but of low quality) are found on the Blake Plateau off of the southern Atlantic Coast of the U.S. These lower quality nodules are merely mineral "occurrences" whose economic significance is minor at best.

For marine sulfide deposits, geological and geochemical inference provide virtually the only basis for estimates of potential quantities in-place because of the extremely limited number of observations (approximately 50 sites have been sampled to date) and the absence of data on deposit thickness. Some speculative extrapolations of minerals in vent deposits on the midocean ridge based on geochemical deposition models have been attempted.[12] In 1983 the Minerals Management Service considered the disposal of lands for purported marine sulfide resources on the OCS near the Gorda Ridge (an active seafloor spreading center off the coasts of Washington and Oregon). A draft environmental impact statement for the Gorda Ridge received negative comments particularly because of its lack of resource information (sulfide deposits were not discovered on the ridge until 1986). To date, marine sulfides have been discovered on the OCS only at the Gorda Ridge.

Exploration and Technological Advance

For most OCS nonfuel minerals, traditional sampling and dredging technologies would probably be used to explore for and recover the minerals. Basic search strategies for OCS nonfuel mineral exploration are presented in Table 7-4.

During the 1960s and through the early 1980s, much effort was spent in the development of technologies for exploration and development of manganese nodules.[13] In contrast, technologies for finding and working nearshore deposits (like sand and gravel) and placers are in a relatively mature stage and have not experienced the same degree of recent technological advance. A summary of relevant dredging technologies is presented in Table 7-5.

In the long run, continuing basic and applied marine scientific research provides an "input subsidy" for potential seabed material resources. Oceanographic knowledge already has been used successfully in locating onshore occurrences of marine phosphorites, and there is some expectation that observation of marine sulfide deposits eventually will help locate commercial sites onshore. There is increasing reliance on scientific theory to target search for onshore deposits, and continuing study of marine deposits may help focus this search.

Table 7-4
Search Strategies

Approximate range to deposit	Method
10 kilometers	Long-range side-looking sonar Regional sediment and water sampling
1 kilometer	Gravity techniques Magnetic techniques Bathymetry Midrange side-looking sonar Seismic techniques
100 meters	Electrical techniques Nuclear techniques Short-range side-looking sonar
10 meters	Near-bottom water sampling Bottom images
0 meter	Coring, drilling, dredging Submersible applications

Sources: Adapted from P.A. Rona, "Exploration for Hydrothermal Mineral Deposits at Seafloor Spreading Centers," *Marine Mining*, 4, No. 1, 1983, 20–26.

Table 7-5
Dredging Technologies

Type	Description	Present max dredging depth	Capacity
Bucketline and bucket ladder	"Continuous" line of buckets looped around digging ladder mechanically digs out the seabed and carries excavated material to floating platform.	164 feet	Largest buckets currently made are about 1.3 yd^3 and lifting rates 25 buckets per minute (1,950 yd^3/hour with full buckets).
Suction	Pump creates vacuum that draws mixture of water and seabed material up the suction line.	30 feet	Restricted by the suction distance unless the pump is submerged.
Cutter head Trailing hopper	Mechanical cutters or high pressure water jets disaggregate the seabed material; suction continuously lifts to floating platform.	50–300 feet	Many possible arrangements all based on using a dredge pump; the largest dredge pumps currently made have 48" diameter intakes and flow rates of 130 to 260 yd^3/min of mixture (10 to 20% solids).
Airlifts	Suction is created by injecting air in the suction line.	10,000 feet	Airlifts are not efficient in shallow water. There may be limitations in suction line diameter when lifting large fragments.
Grab:			
Backhoe/dipper	Mechanical digging action and lifting to surface by a stiff arm.	100 feet	Restricted by the duration of the cycle and by the size of the bucket; currently largest buckets made are 27 yd^3.
Clamshell/dragline	Mechanical digging action and lifting to surface on flexible cables.	3,000 feet	The largest dragline buckets made are about 200 to 260 yd^3/hr; power requirements and cycle time increase with depth.

Source: Office of Technology Assessment, *Marine Minerals,* 1987.

The rate of technical progress in exploration and discovery may be one area where seabed deposits are gaining on their conventional onshore rivals. Real discovery costs onshore have been rising (perhaps doubling in the past 30 years). Advances in deepsea exploration technology such as multibeam sonar, underwater photographic, and electronic imagery transmission, robotics, and deep submergence vehicles verified and refined the geophysical theories that had for several years predicted the occurrence of the hydrothermal marine sulfides deposits at oceanic crustal spreading centers. The theoretical results were largely independent of the search for commercial seabed mineral deposits as were the advances in exploration hardware. Technology developed to support offshore oil and gas operations has made a major contribution to the study of marine nonfuel minerals. Similarly, spillover benefits are also provided by investments for military and national security purposes such as the work financed by the *Glomar*

Table 7-6
Prelease Exploration Permits for Marine Minerals on the OCS

Year	Number of Permits	Permittee	Minerals Prospect	Approximate Location
1966	1	Marine Exploration	Gold Placers	Norton Sound, Alaska
1966	1	Ocean Science and Engineering	Gold Placers	Norton Sound, Alaska
1966	1	Newport News Shipbuilding and Drydock	Phosphorites	North Carolina
1967	2	Ocean Resources	Phosphorites	Southern California
1967	1	Bear Creek Mining	Phosphorites	Southern California
1969	1	Global Marine	Sand and Gravel, Heavy Minerals	New Jersey
1969	1	Ocean International	Heavy Minerals	Mid-Atlantic
1970	1	Deepsea Ventures	Manganese Nodules	Blake Plateau
1975	1	Radcliff Minerals	Sand	West Cameron, Louisiana
1986	2	DuPont	Heavy Minerals	Georgia
1986	2	Associated Minerals	Heavy Minerals	Georgia
1986	1	Technical University of Clausthal	Cobalt Crusts	Hawaii
1987	1	Inspiration Gold	Gold Placers	Norton Sound, Alaska
1987	1	Geomarex	Carbonate Sands	Florida Keys
Total	17[a]			

[a] This total does not include 32 permits issued from 1982–1987 to 7 companies in the Alaska OCS region concerning high-resolution geophysics or shallow geological investigations. These permits were directed, in part, toward sand and gravel resources that might be used for the construction of gravel islands or other support structures for offshore oil production facilities.

Sources: DOI, Program Feasibility Document: OCS Hard Minerals Leasing, 1979; R. Amato, Atlantic OCS Region; R. Kuzela, Gulf of Mexico OCS Region; D. Meyerson, Pacific OCS Region; J. Schearer, Alaska OCS Region.

Explorer submarine recovery effort of the mid-1970s and the recent navy sponsorship of the Argo/Jason system development at the Woods Hole Oceanographic Institution.

Information obtained through nonexclusive "permitted" private exploration on the OCS must be reported to the Minerals Management Service, the permitting agency. In particular, the Minerals Management Service holds all privately generated data and information obtained under nonexclusive geological and geophysical exploration permits confidential for variable 25–50-year periods. (Resource information must be made accessible to public managers upon request.) After these periods, resource information becomes available to the public. A list of permitted geological and geophysical investigations for OCS nonfuel minerals since 1960 is presented in Table 7-6. The confidential treatment of proprietary information is a sensitive issue to firms that explore on the OCS. (Recall from Chapter 3 the discussion of the billions of dollars spent on exploration and bidding as well as the conflicting effects of public versus private information.) Proposed OCS nonfuel mineral prospecting regulations contain a 20-year period during which resource information generated by private firms will be kept confidential.[14]

A wide range of OCS nonfuel minerals exist, and some already make contributions to national mineral supply. In comparison with hydrocarbon production and reserves, however, the economic importance of the OCS nonfuels is trivial. Considering the early stage of development for the majority of these minerals, even small steps taken to generate information could make important gains toward a fuller understanding of their resource potential. Management concerns, therefore, might usefully be directed at the rate and flow of information.

It is apparent that interest groups and public agencies alike have been involved in positioning themselves for the distribution of benefits that could flow to firms and managers from a working system for the disposal of OCS lands for nonfuel mineral exploration and development. To some degree, the activities of competing interests or agencies have helped to push issues surrounding the management of OCS nonfuels higher up on the nation's policy agenda than they might be if their position was based solely upon a sober analysis of the economic potential of these minerals. This increased public exposure has helped to expand the stock of knowledge about OCS nonfuels and may yet result in a more realistic appraisal of the likely potential and value of these minerals as public assets.

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