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The Future of Hard Minerals Mining on the New England Continental Margin

James D. Eger
University of Rhode Island

THE FUTURE OF HARD MINERALS MINING ON THE NEW ENGLAND CONTINENTAL MARGIN

JAMES D. EGER

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FORWARD

"The ocean is a desert with its life underground and a perfect disguise above."

America
"A Horse with No Name"

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I. INTRODUCTION

As man's needs for all commodities increase with the rapid worldwide increase in technological development, new sources for these commodities must be sought. In the United States, shortages of many materials are already being experienced, and the health of our economy is dependent on the continued supply of these vital materials. In order to supply our needs for minerals, intensified and improved exploration methods, improved technology allowing utilization of lower grade ores, synthetics and substitutes, government sponsored research programs, and new exploitable areas all must be developed.

Because of their proximity, their newness (in terms of exploration and exploitation), and their romance, the oceans are an attractive location for new searches for minerals. However, the oceanic environment is completely different from the land environment and requires new and more expensive techniques for exploration and recovery of minerals. For oil and gas, the returns from offshore are clearly worth the increased risks and costs of development. For hard minerals on the continental margin, however, the benefits are not as clear cut, and the lack of exploitation of these minerals to date is indicative of this problem. For the purpose of this study, hard minerals will include only those occurring at or near the seabed. Underground minerals mineable by use of land-based tunnels, such as coal, are not considered.

This study will look at the current situation affecting hard minerals mining on the New England continental margin by considering the existing resources, jurisdictional framework, exploration and exploitation technology, economic criteria, environmental effects, and the management situation. From this information, conclusions regarding future trends in the offshore hard minerals mining industry in New England will be made.

II. STUDY AREA

A. Location

The study area is confined to the continental margin directly adjacent to the New England States not including Long Island Sound. It is bounded on the west by the 70°50' W longitude line, which is roughly the southward extension of the Connecticut - Rhode Island border, on the south and southeast by the southern edge of the margin off Georges Bank, and on the east and northeast by a line extending landward along the axis of Northeast Channel until it intersects the U.S. - Canada median line, and then along the median line to shore (Figure 1). In regards to this northeast line, negotiations between the U.S. and Canada to determine their offshore boundary in this area are as yet unresolved, and the line chosen for this study approximates the possible boundary most favorable to the U.S.

B. Definition of Terms

Geological and legal definitions of seafloor provinces are often different, and discussions using these terms are often confusing because of these discrepencies. Because this study is primarily concerned with questions concerning

FIGURE 1

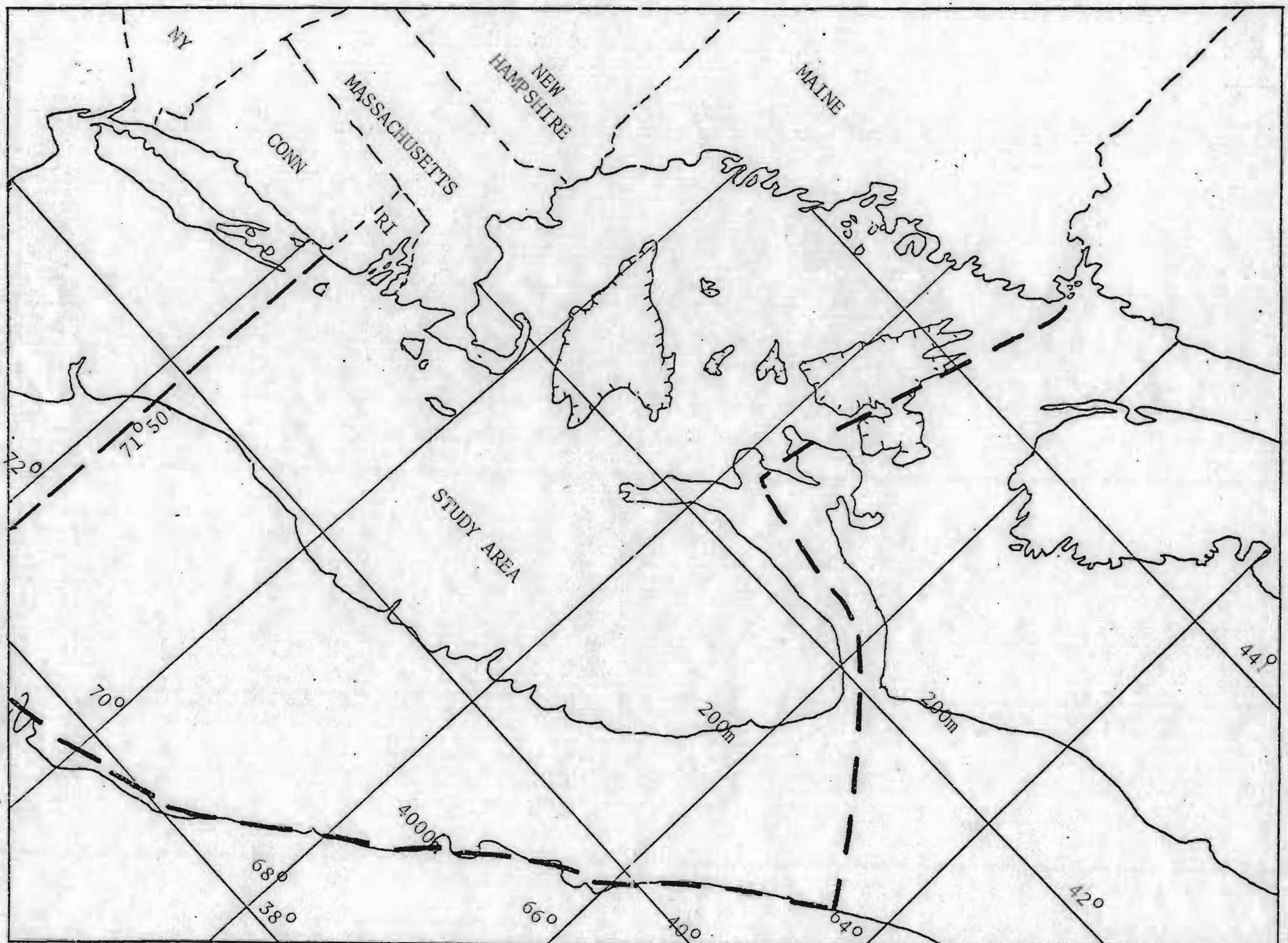

Figure 1. Study Area, bounded by 71°50' W Longitude, base of continental margin (chosen at 4000 meters), and hypothetical U.S. - Canada offshore boundary.

physical resources, the geological definitions indicated below, which are adapted from a paper by K. O. Emery,[1] will be used throughout this paper (see Figure 2).

<u>Continental Shelf</u>: The zone around the continent extending from the low water line to the depth at which there is usually a marked increase of slope to greater depth. The shelf edge marks this change in slope. The shelf edge ranges in depth from less than 60 to more than 500 meters, averaging 133 meters worldwide.

<u>Continental Slope</u>: The zone bordering the continental shelf extending seaward from the shelf edge down to depths of 1,200 to 3,500 meters at slopes averaging approximately 4-1/4°.

<u>Continental Rise</u>: The zone bordering the base of many continental slopes extending down to depths of 3,500 to 5,500 meters having a smooth slope averaging approximately 1/2°.

<u>Continental Terrace</u>: The combined continental shelf and continental slope.

<u>Continental Margin</u>: The combined continental shelf, continental slope, and continental rise.

The boundary between continents and ocean basins, which

FIGURE 2

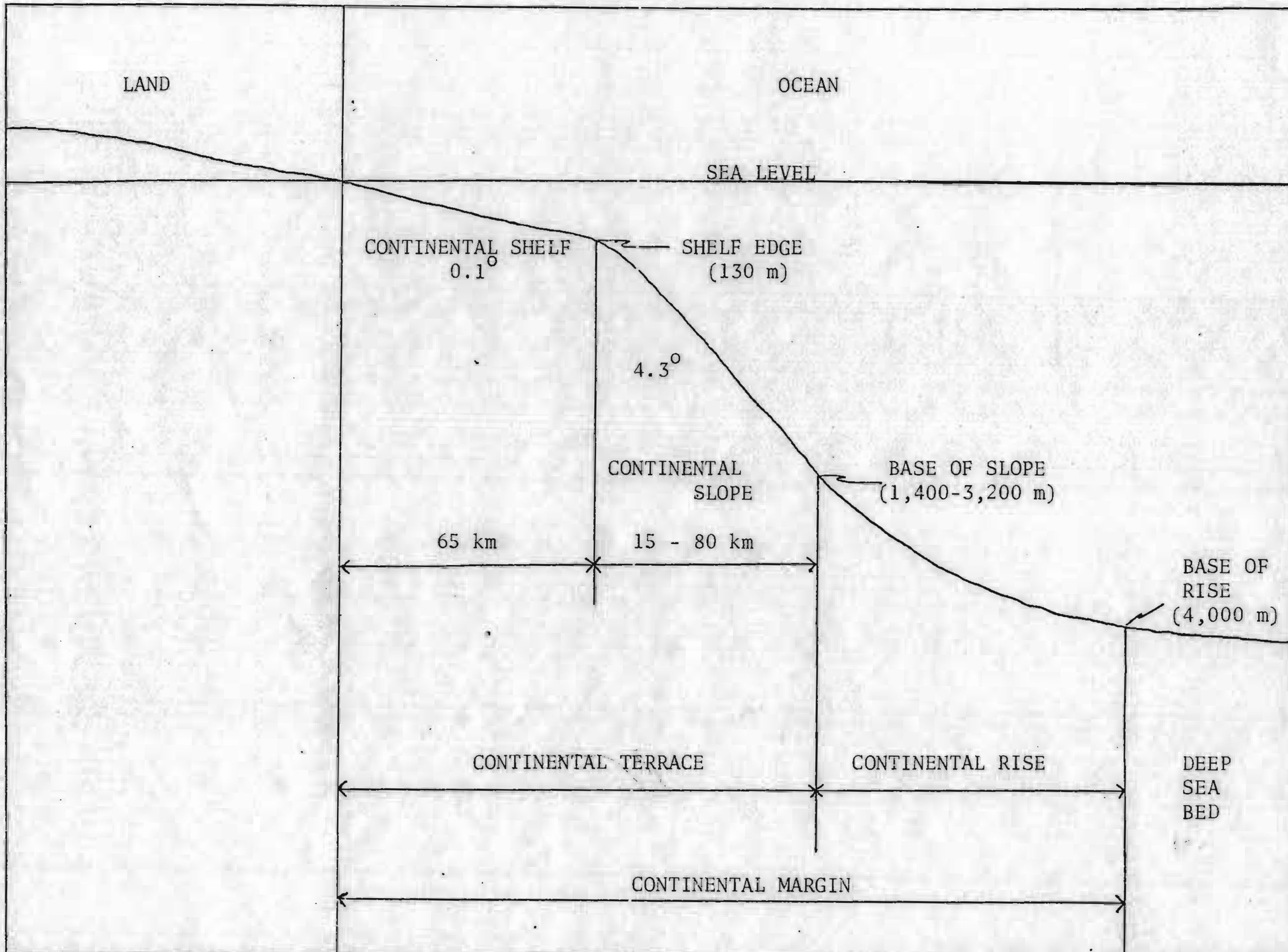

Figure 2. Profile of the continental margin; not to scale. From M.V. Adams, et al.[F1]

is marked by the change from lighter rocks high in silicon and aluminum whose specific gravity averages 2.7 to heavier rocks high in iron and magnesium whose specific gravity averages 3.1, occurs near the base of the continental slope.

C. Surficial Marine Geology

The distribution of surficial sediments on the continental shelf in the study area is the result of glacial and glaciofluvial processes which operated during the Pleistocene, and subsequent reworking by the Holocene transgression. In the Gulf of Maine, sediment eroded from onshore and offshore bedrock was transported and deposited directly by the continental ice sheet, leaving poorly sorted tills and gravels in some location and bare bedrock in others. The northern edge of Georges Bank (Figure 3) marked the southern limit of the ice sheet in this area. As the ice melted, large quantities of sand and gravel were distributed over the Bank by meltwater, with finer grained sediment carried out to sea to be deposited on the continental slope and rise. Some of the coarser material was also carried over the edge to be deposited in submarine canyons on the slope. South of Massachusetts and Rhode Island, sediment eroded from the New England upland and coastal plain formations was distributed

FIGURE 3

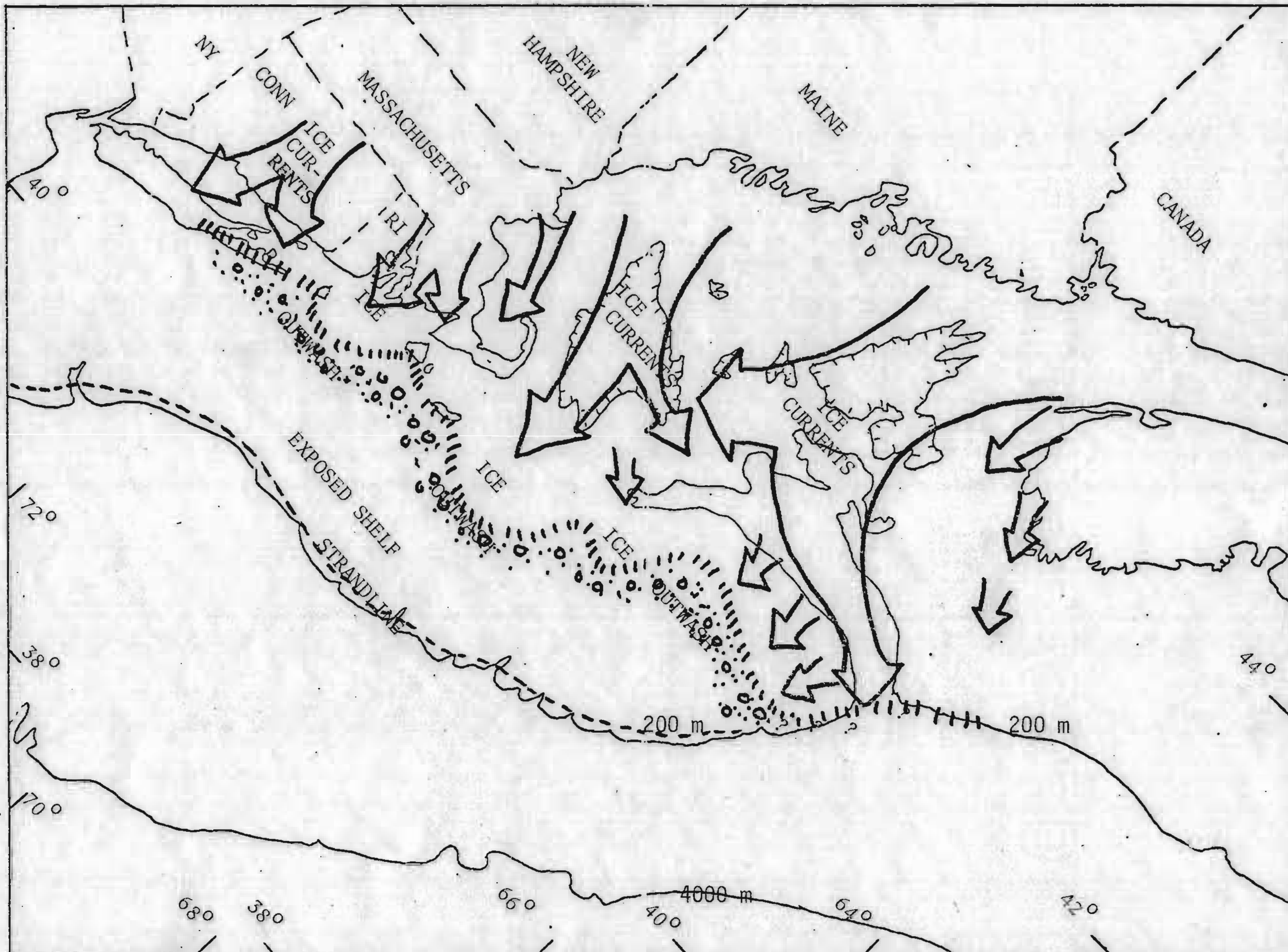

Figure 3. Southern limit of glaciation in the study area. After Schlee.[F2]

as outwash and fluvial deposits. Reworking by the Holocene transgression has produced lag gravels on banks and till-like gravels in hummocky areas in the Gulf of Maine, scattered patches of rounded gravels partially covered by sands on Georges Bank, and scattered patches of gravel partially covered by sand south of Massachusetts and Rhode Island.[2] Despite the reworking most of the coarser sediment in the Gulf of Maine is poorly sorted, with gravel, sand, silt and clay present in varying amounts, while gravel on Georges Bank and Nantucket Shoals is better sorted and rounded, and contains more quartz.[3] Sediments in shallow water (20 meters and less) are still subjected to reworking.[4]

Heavy minerals found in the area include garnet, staurolite, monazite, andalusite, and titanite, which are usually associated with coarser sediment, and amphiboles, epidote, augite, and altered grains, which are more common in fine grained sediments. The mineral composition of the sediment is determined primarily by source, but sorting weathering and diagenetic processes are also important.[5]

III. HARD MINERALS RESOURCES

Continental margin hard mineral resources can be placed in these general categories: manganese nodules, heavy minerals (placers), phosphorite, and aggregates (sand, gravel and shell). A brief description of the origin of these types of mineral deposits is given below.

A. Manganese Nodules

Manganese nodules contain concentration of iron, manganese, cobalt, nickel, and copper.[6] In order for manganese nodules to accumulate in appreciable quantities these metals must be present in sea water in sufficient quantities and sediment accumulation must be slow so that the surface of the nodule does not become buried, precluding further growth. On the Atlantic continental margin of the United States, manganese nodules occur only on the Blake Plateau off the southeastern coast where the rate of sediment accumulation is slow due to strong bottom currents. On the New England continental margin manganese nodules do not exist as a resource.

B. Heavy Minerals

Heavy minerals are those minerals whose specific gravity is significantly higher than that of average crustal minerals. Because of their high specific gravity heavy minerals can become concentrated by separation from average sediment which is subjected to high energy wave and current action. Because the formation of heavy mineral deposits depends on winnowing of lighter sediments in high energy conditions, the best environment for formation of these placers is the beach and nearshore zone. Consequently, relict strandlines on the continental shelf, occupied during periods of glacially lowered sea level still stands in the Pleistocene, are favorable areas for future heavy mineral exploration. The formation of low energy placers composed of fine grained (silt and clay size) heavy minerals is not well understood.

In New England the potential for offshore heavy minerals mining is low. Inundation of the New England shelf with glacial and glaciofluvial sediments has kept the winnowing process from producing any heavy mineral deposits of appreciable size because of the large supply of new sediment. Small concentrations of titanite and monazite occur in southern Cape Cod Bay, but it is doubtful that these deposits will be mined.

C. Phosphorite

Phosphorite is found on many continental shelves and slopes throughout the world.[8] As the world demand for fertilizer increases, phosphorite becomes an increasingly important resource. Its price is a reflection of this increased demand. From 1966 through 1972 the price of phosphorite held constant at $4.91 per ton, but in 1975 its price had jumped to $39.50 per ton. This marked increase in price may allow some offshore phosphorite deposits to be mined competitively with onshore deposits.

Formation of phosphorite is largely restricted to areas of upwelling currents in low latitudes. Some occurrences are related to uplift and weathering of older, phosphorite bearing strata. Phosphorite is found in surficial sediments from Long Island eastward onto Georges Bank, mostly in water depths $<$ 200 meters.[9] It comprises only 1 to 2% of the sediment as compared to the $\sim$30% content of deposits currently being exploited. It is highly unlikely that phosphorite mining on the New England continental margin will ever take place.

D. Aggregates

i. Shell ($CaCO_3$)

Calcium carbonate is important in a number of industries, including construction, road building, and agriculture. Because of its low value/ton, transportation costs can have a significant effect on price, and local supply is desirable. For this reason dredging of oyster shell has taken place in some coastal metropolitan areas where nearby land sources of calcium carbonate are not available, making the lagoonal and estuarine oyster shell deposits economic.

Emery[10] has noted large oyster shell deposits in relict sediments on the continental shelf south of Boston. The exact size and extent of these New England deposits is not known. Even if they are large, their distance from shore could increase the cost of recovery so much that they would not be mineable. Land sources will continue to supply New England needs for $CaCO_3$ for the forseeable future.

ii. Sand and Gravel

Sand and gravel constitute the most common resource of the U.S. Atlantic continental shelf. The distribution and origin of sand and gravel on the New England continental shelf has been concisely discussed by Schlee[11] and Schlee and Pratt[12] as well as numerous other investigators (Figure 4).

Sand is found on the shelf throughout the study area

FIGURE 4

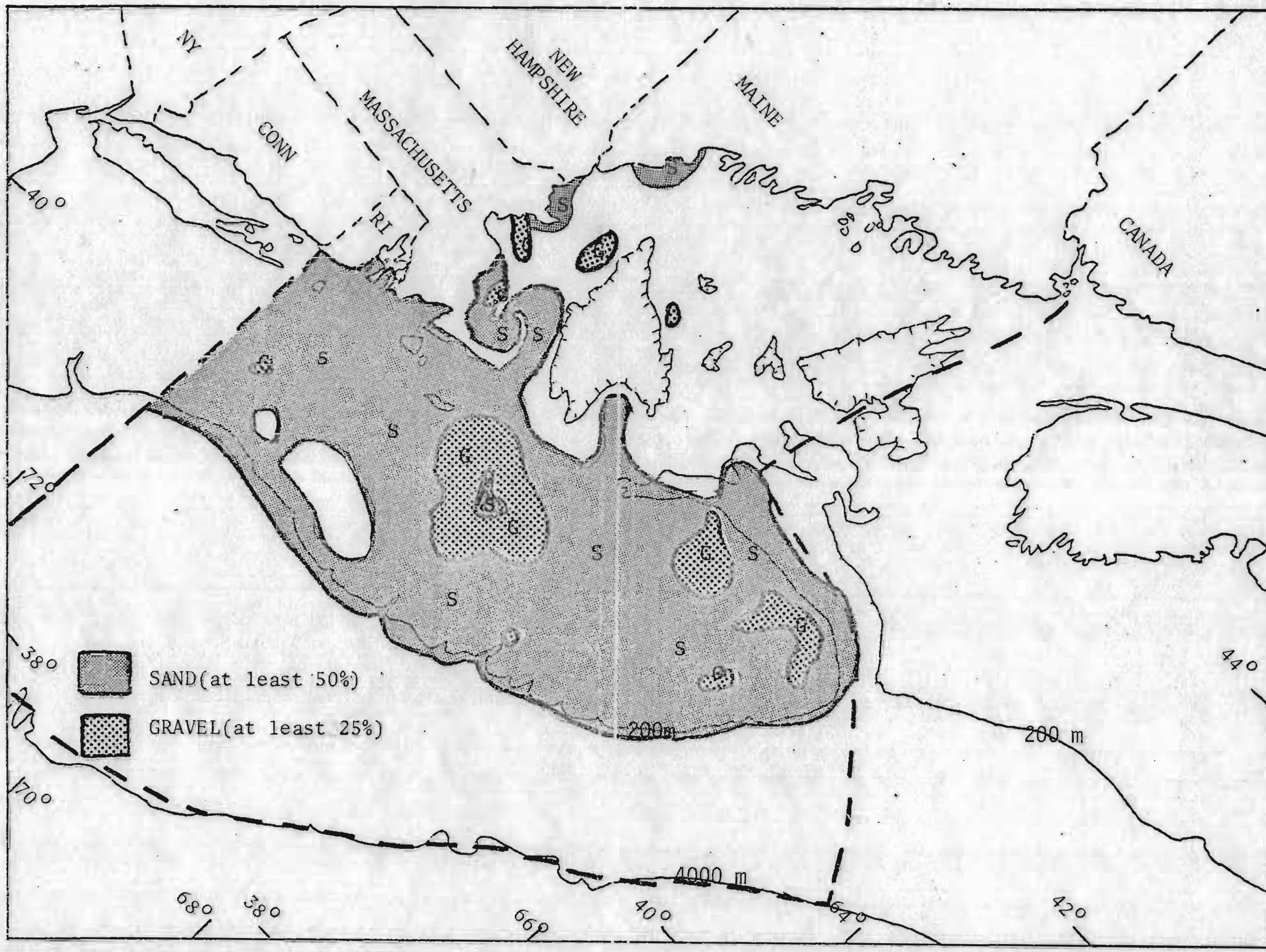

Figure 4. Distribution of sand and gravel in the study area. After Schlee.F3

with the exception of the deeper parts of the Gulf of Maine. On the rest of the margin (slope and rise) finer grained sediments predominate. From Nantucket Shoals eastward across Georges Bank sand forms an almost ubiquitous surficial cover, with coarser sand found in the shoal areas. Gravel is found at the surface in Northeast Channel, east of Nantucket Shoals near Great South Channel, in two locations on the northeastern end of Georges Bank, Massachusetts Bay near Plymouth and near Boston, and in small patches throughout the region. Detailed exploration is necessary to determine the exact extent, depth, and grain size distribution of these deposits.

Estimates of the volume of mineable sand and gravel deposits in the western part of Massachusetts Bay have been made by the Raytheon Company and by Lassiter.[14] Lassiter developed a probabilistic model for estimating the volume of sand and gravel resources in this area using constraints such as silt content, minimum percentage of sand and gravel, and minimum deposit thickness. Using a 20% by volume maximum silt-clay content as the cutoff for mineable deposits and refining this with the "subjective judgement" of experts, Lassiter estimated that there are 273 million cubic yards of mineable sand and gravel in western Massachusetts

Bay. Decreasing the allowable silt-clay content to 5% by volume lowers this estimate by approximately half. The Raytheon survey estimated that 196 million cubic yards of mineable sand and gravel exist in this area. Georges Bank and the Nantucket Shoals area contain billions of cubic yards of mineable sand and gravel. However, deposits in these areas are too far from major urban markets to be presently considered as economic resources.

IV. TECHNOLOGY

This section will briefly discuss the methods used in mining the offshore hard minerals discussed in section III. Since the most promising hard minerals resources in the study area are the aggregates, attention will be focused on techniques for recovery of these minerals.

A. Exploration Methods

Initial reconnaissance surveying of an offshore area is done using geophysical methods such as reflection seismology. The signal source, which directs energy into the seafloor, is attached to a ship which traverses the area, usually on a predetermined grid. The signal receiver (hydrophone) is usually towed behind the ship and receives energy which, after penetrating the seafloor, has been reflected upward from a subbottom density interface. The travel time from signal emission by the source to signal reception by the hydrophone(s) (expressed in milliseconds for shallow sediments) can be used to determine the thickness of sediment to the interface. This reconnaissance surveying gives a general picture of the distribution and thickness of sedimentary strata in an area, and is used to locate areas of interest.

Grab sampling is another reconnaissance method in which a small amount of surficial sediment is collected from a number of locations and then analyzed. The samples discussed by Schlee for the northeastern U.S. shelf[16] were collected in this manner.

For more detailed investigations, a combination of exploration methods is usually employed. Closely spaced seismic reflection profiling of the type described above may be used initially. Shallow seismic refraction profiling methods, which indicate acoustic velocities in the sediment, can also be used.[17] Cores of various types and lengths are taken to substantiate seismic information and to provide material for direct visual and manual evaluation. The coring method most often used in unconsolidated sediments containing aggregates is vibracoring from jack-up drilling ships. In addition to depth limitations, the vibracoring method itself has shortcomings. The vibrations allow the corer to penetrate the sediment, but the corer tends to bounce off, and hence miss, the larger pieces of rock, resulting in an unrepresentative core. Other coring methods include jet coring and rotational drilling.

The major drawback to coring is that it is expensive and yields information only for the site that is cored.

Site to site correlations in unconsolidated deposits are difficult and are often unreliable. Therefore, much research and effort is going into developing improved geophysical methods for investigating offshore sediments.[18] Bottom photographs, bathymetric charts, and more specialized techniques such as resistivity and magnetic surveys are also used.

B. Mining Methods

Unconsolidated deposits such as sand and gravel, shell, and placers are mined by dredging. The typical dredging system consists of the following components: excavation, lifting, mining control, benefication, supporting platform, and disposal.[19] The characteristics of the individual deposit determine what excavation tool is used. Offshore dredging operations are greatly affected by motion, depth, and distance from shore, environmental parameters which require special design. Excavation and lifting can each be done by any of three methods: mechanical repetitive, mechanical continuous, and hydraulic continuous.[20] Platform and control components must be designed to provide stability and some flexibility. Benefication and disposal systems must be designed to provide efficient sorting and elimination of fines and efficient product transfer.

A theoretical offshore sand and gravel mining operation using a trailing suction hopper dredge is described below:

> "The trailing suction hopper dredge ranges in size from about 920 to about 9,000 metric tons (1,000 to about 10,000 tons). One or more high-head centrifugal pumps are used to dredge a slurry of solids from the seafloor through suction pipes. Dredging to about 37 meters (120 ft) below the water surface is commonplace; below that, jet assistance is utilized.
>
> "If the dredge is equiped with a swell compensator and articulated dredge pipe(s) most of the relative motion between the ship and the dredgehead can be accomodated. This prevents the transfer of the weight of the ship to the dredgehead and enables the dredge to work routinely in seas up to 2 meters (6 ft). An operator can assist the swell compensator in heavy seas by manually working the main winch controlling the dredge pipe, enabling the dredge to work in seas up to 6 meters (20 ft), although this is not commonplace.
>
> "The slurry, containing about 10 percent solids, is fed to the hopper(s) where most of the solids remain. The excess water flows overboard, along with the suspended fine particles. The dredge mines while in motion, creating numerous shallow trenches in the seafloor, each about 1 meter (3 ft) wide and 30 cm (1 ft) deep.
>
> "The size of the dredge is optimized on the basis of the market arrangements whereby 920,000 metric tons (1 million tons) per year can be utilized over ten years. Firm X decides to construct a 3,000 ton dredge and supply the one million tons per year commitment by using it virtually full-time.

"Firm X estimates that it can deliver the aggregate for 50 cents per ton. Its partner will pay $1.00 per ton, process the sand and gravel at a cost of .50 per ton, and deliver the materials to the market place for $2.50 per ton. While the United States average cost of inland processed sand and gravel is about one-half this, the high cost of truck delivery makes this figure highly competitive in certain urban markets.

"The mining cycle takes about 24 hours to complete, including five hours for loading at the mine site and transit to the processing plant, and three hours for unloading and return to the mine site. Operation is continuous except for about 10-15 percent down-time for maintenance and adverse weather.

"The dredge utilizes a coarse grid steel framework across the opening of the suction head to prevent large rocks from passing up the suction pipe. Coarser sizes are screened off and rejected after passing through the pump. At the other end of the particle size spectrum, fine material is washed overboard.

"The shore-based support facility for the dredge includes wharves, stockpiling, and processing facilities, as well as a treatment plant. Dry discharging of the dredge is accomplished by scraper-buckets coupled with over-the-side conveyor belts. With this system, scraper-buckets are rapidly hauled up ramps at the forward part of the hopper and then emptied into an elevated hopper, which feeds an over-the-side conveyor belt carrying the material ashore. Clay, salt, shells and other impurities are washed out by shore-side processing techniques, which then separate the material into a variety of sizes for blending as required by the market."[21]

It is important to understand that the above mining system is theoretical only. In order for a sand and gravel mining system to work in the U.S. its magnitude would have to be greater. At present the great majority of aggregate mined offshore is for fill material, primarily in beach nourishment projects.

A hopper dredge with a 6,000 cubic yard capacity costs approximately $25,000,000. In order for a dredge this size to operate profitably, far more than 1 million cubic yards per year would have to be dredged, and a mining project of the size discussed above could not keep such a dredge occupied full time.

C. Effect of Technological Advances

The science of mining hard minerals on the continental margin is still in its infancy. Because conditions in the oceanic environment are very different from those encountered on land, many new mining techniques are required. In general, improved navigation and charting techniques are needed to pinpoint areas of interest. For placer deposits, more research into the methods of formation of placer deposits and improved sampling techniques are needed for aggregate mining, improved exploration techniques as well as advances in dredging methods are needed.

The major dredging difficulties encountered offshore are related to motion and depth.[22] Unconsolidated hard minerals on the continental margin can now be mined in water 92 meters deep, and mining in 200 meters of water may soon be possible.[23] However, the current practical limiting water depth is closer to 30 meters for most operations. Motion remains the most difficult problem. Flexible excavation and lifting systems are being developed, and the future may see enclosed dredging systems which can move across the seafloor independent of surface conditions and operate in depths as great as 4,000 meters.[24]

The effect of these advances will be to increase man's access to continental margin hard mineral resources, making offshore deposits more competitive with existing onshore hard mineral deposits.

V. ENVIRONMENT

A. Physical Effects of Mining

Offshore mining will undoubtedly cause environmental changes in the immediate area of the mining site, and changes in a larger surrounding area may occur. The need for understanding the possible environmental impacts of a marine mining operation is clear.

Direct effects of marine mining on the environment include removal of substrate, introduction of fines into the water column, possible introduction of organics, toxins, and metals into the water column, possible burial of adjacent benthic organisms, possible alteration of bottom current paterns, and possible alteration of fish spawning patterns due to substrate removal.

Guidelines for offshore mining environmental studies do exist,[25, 26] and a number of studies were done in connection with the now defunct New England Offshore Mining Environmental Study for a site in Massachusetts Bay which was planned as a test sand and gravel mining operation. Among these projects were particle dispersion tests, benthic community studies, water movement studies, and phytoplankton productivity studies.

Harris[27] has suggested areas in which environmental research is needed, both in areas relevant to sand and gravel mining generally, and in relation to specific commercial dredging operations. General research suggested includes characterization of the geology and hydrology of sand and gravel deposits as well as bottom current regimes, studies into the chemistry and dispersion of fines, and determination of the ecological significance of the sand and gravel substrate in terms of fisheries spawning and feeding and benthic communities. For specific operations, prebaseline studies including geology, chemistry, current system, and fisheries ecology, followed by baseline, dredge monitoring, and follow-up studies are suggested.

As experience is gained, the development of the capability to predict environmental changes and long term effects is hoped for. Studies of the offshore mining industry in other countries such as the United Kingdom[28] can be helpful in achieving this goal.

B. Multiple use Conflicts

The presence of an offshore hard minerals mining operation may involve multiple use conflicts which would have to be resolved before mining could commence. These conflicts include shipping, recreational boating (especially for nearshore operations), aesthetics (also for nearshore operations), and fishing. Of these, the possible conflicts with the fishing industry are the most critical. In his discussion of possible sand and gravel resources in western Massachusetts Bay Lassiter provided overlays to show that the spawning areas of a large number of commercial species could be affected by a marine mining operation in this region.[29] It is important to realize, however, that a mining operation would involve a small area, and if the discharge of fines were kept small, effects of the mining operation on fisheries would be minimal.

C. Onshore Impacts

Onshore impacts of an offshore hard minerals mining operation would be limited to the shore facilities of the mining operation itself. This would consist of docking facilities and onshore processing and storage facilities. Because of marketing and distribution conditions, the onshore facilities would preferably be located as close to the center of the metropolitan area as possible. The harbor areas of Boston and Providence are already highly industrialized, and location of the plant in a properly zoned industrialized area would eliminate any problems of aesthetics. Offshore benefication and sorting of dredge material and small onshore settling ponds would insure that no fines or harmful organics, etc. would be released into the waters around the plant. With proper planning and design, the onshore component of an off-shore hard minerals mining operation would have no adverse impact on the environment.

D. Effect of Environmental Legislation

The Panel on Operational Safety in Marine Mining made a number of recommendations with respect to environmental protection and safety in Outer Continental Shelf mining, including the following:

> "The panel recommends that cooperative industrial and governmental research to identify the existing environmental conditions in potential outer continental shelf mining areas be intensified, and further, that research be conducted to identify the environmental effects, both short and long-term, of outer continental shelf mining; (that) environmental standards be formulated using the knowledge gained during monitoring of prototype operations; (that) industry be informed of pertinent environmental requirements in a timely manner through the formulation of sound regulations and environmental criteria; (and that)

an independent panel of experts be established to provide for adequate review of proposed scopes of work, and for evaluation of results of baseline and monitoring studies."[30]

Current state legislation with regard to marine mining is largely prohibitive, and environmental concerns are a major cause of this situation. The cost of environmental impact studies is very high, and if industry is expected to assume the burden of paying for detailed impact studies, the chances for marine mining on the New England continental margin in the future will be greatly reduced. Regulations and guidelines will have to be developed specifically for hard minerals mining to properly reflect the realities of this industry.

VI. ECONOMICS

A. Feasibility

There is no doubt that the demand for hard minerals will increase in the future, and that the value and desirability of land in metropolitan areas will increase also. Future land aggregate mines will be further from metropolitan centers, resulting in higher prices for hard minerals.

The current price for sand in the Boston area is $2.00 per ton, and for 3/4" gravel it ranges from $3.00 to $3.50 per ton. The gravel is produced by crushing rock, and naturally rounded gravel is difficult to obtain. Transportation by truck adds at least $1.00 per ton to the price.[31]

Brooks and Lloyd have reached some important conclusions regarding the economic feasibility of marine mining:

> "Like any piece of capital, the value of an ore deposit is the present value of the net cash flow recoverable from its exploitation. But for our purposes the question is whether the value will be high enough to attract both the investment funds from prospective mining firms and the necessary support from national governments, given...that mineral scarcity is unlikely to be a problem in industrial nations for the forseeable future and that alternative onshore sources of supply are available.
>
> "The oceans, after all, represent a kind of extensive margin on exploitation, just like

the opening of new lands to cultivation. It is usually necessary for both direct economic returns and broader socioeconomic forces to be operating in concert before exploitation of an extensive margin is undertaken. While the matter of direct returns from recovering non-fuel minerals from the oceans remains unresolved, there are enough firms interested to make it apparent that profitable operations are at least a reasonable possibility.

"Considering the socioeconomic forces, ...it is fair to say that they suggest most strongly that we must take account of the relationships of offshore minerals resources and to other offshore resources. If we treat marine minerals as independent resources, free for exploitation, we are likely to get into the same sorts of economic and social problems that have arisen on land.

"Our goal should be as economically efficient an ocean mining operation as possible. This means avoidance of concentration on either technologic efficiency or commercial profitability alone. The former implies too little consideration of other sources of supply, and the latter too little consideration for socioeconomic effects. If we can avoid either trap, and if we can also resolve the political problems that are bound to arise as ocean exploitation becomes feasible, the geologic capital lying in and on the bottom of the oceans may, in fact, become an efficient source of economic capital.[32]

B. Leasing

Leasing of submarine areas inside of the three-mile territorial sea is controlled by the individual states. Outside the territorial sea leasing procedures set forth in the Outer Continental Shelf Lands Act must be followed.[33] These procedures were derived in response to the then fledgling offshore oil industry, and as such the OCS lands Act is unsuitable for hard minerals leasing.

A number of alternative leasing plans for offshore hard minerals mining have been suggested[34] and one possible method is presented here.

The mining operation would be divided into three components: exploration, development, and production. For the exploration phase, a firm would have two years in which to carry out exploration in an area composed of 36 lease blocks (5,760 acres/block). Annual rental would be $10.00 per acre. Following the exploration phase the firm would choose 9 blocks and have two years for development. This would be followed by the production phase, limited to 3 blocks. The lease would run for ten years, and annual rental would be $1.00 per acre. A royalty of 2% on revenues would be paid to the U.S. Government. Extentions on the time limits would be allowed.

Whatever leasing procedures are adopted for offshore hard minerals mining, the economic structure of the industry will have to be considered if mining is to ever take place.

VII. JURISDICTION

A. Truman Proclamation

The legislative history of marine mining on the continental margin of the United States goes back to 1945, when President Truman issued Proclamation 2667, better known as the Truman Proclamation on the Continental Shelf. This was the first formal U.S. claim of jurisdiction over the continental margin beyond the three mile territorial sea:

> "...and whereas it is the view of the government of the United States that the exercise of jurisdiction over the natural resources of the subsoil and seabed of the continental shelf by the contiguous nation is reasonable and just, since the effectiveness of measures to utilize or conserve these resources would be contingent upon cooperation and protection from the shore, since the continental shelf may be regarded as an extention of the landmass of the coastal nation and thus naturally appurtenant to it, since these resources frequently form a seaward extension of a pool or deposit lying within the territory, and since self-protection compels the coastal nation to keep close watch over activities off its shores which are of the nature necessary for utilization of these resources;...
>
> "Having concern for the urgency of conserving and prudently utilizing its natural resources, the Government of the United States regards the natural resources of the subsoil and seabed of the continental shelf beneath the high seas but contiguous to the coasts of the United States as appertaining to the United

States, subject to its jurisdiction and control. In cases where the continental shelf extends to the shores of another State, or is shared with an adjacent State, the boundary shall be determined by the United States and the State concerned in accordance with equitable principles. The character as high seas of the waters above the continental shelf and the right to their free and unimpeded navigation are in no way thus affected."[35]

B. Submerged Lands Act of 1953

The Submerged Lands Act of 1953 (Public Law 31) established State Jurisdiction over lands beneath navigable waters within State boundaries for the purpose of control and administration of the natural resources in this area.

"Sec.3. Rights of the States.-

(A) It is hereby determined and declared to be in the public interest that (1) title to and ownership of the lands beneath navigable waters within the boundaries of the respective States, and the natural resources within such lands and waters, and (2) the right and power to manage, administer, lease, develop, and use the said lands and natural resources in all accordance with applicable State Law be, and they are hereby, subject to the provisions hereof, recognized, confirmed, established, and vested in and assigned to the respected States..."[36]

C. 1958 Geneva Convention on the Continental Shelf

The 1958 Geneva Convention on the Continental Shelf gave international sanctity to coastal state sovereignty over continental shelf resources. Article I sets the limitations of coastal state sovereignty over the shelf:

> "For the purpose of these articles, the term 'continental shelf' is used as referring (a) to the seabed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters or, beyond that limit, to where the depth of the super-adjacent waters admits of the exploitation of the natural resources of the said areas; (b) to the seabed and subsoil of similar submarine areas adjacent to the coasts of islands."[37]

The "exploitability clause" has caused much debate over exactly where a coastal state's sovereignty ends. One suggestion, which would include all of the continental slope and a good part of the continental rise, would be determined by the boundary between the continent and the ocean basin, which can be determined by geophysical methods.[38]

The exclusivity of coastal State rights over continental shelf resources is affirmed in Article 2:

> "1. The coastal State exercises over the continental shelf sovereign rights for the purpose of exploring it and exploiting its natural resources.
>
> "2. The rights referred to in paragraph 1 of this article are exclusive in the sense that if the coastal State does not explore the continental shelf or exploit its natural resources, no one may undertake these activities, or make a claim to the continental shelf,

without the express consent of the coastal State.

"3. The rights of the coastal State over the continental shelf do not depend on occupation, effective or notional, or on any express proclamation.

"4. The natural resources referred to in these articles consist of the mineral and other non-living resources of the seabed and subsoil together with living organisms belonging to sedentary species..."[39]

D. Law of the Sea Conference

At this writing, the outcome of the Law of the Sea Conference is unclear. If a treaty is written there is a good chance it will include the creation of a 200 mile "exclusive economic zone," to be measured using the limit of coastal States' territorial sea as a baseline.

The effect on the hard minerals mining would be minimal because the areas of interest are already covered by existing conventions.

VIII. MANAGEMENT

A. Federal

The responsibility for managing continental margin mineral resources rests with the Department of the Interior. The Bureau of Land Management handles all lease sales on the OCS, while the U.S. Geological Survey does pre-lease sale evaluation and inspection of existing operations in the area. Since the 1953 OCS Lands Act is the definitive piece of legislation in this area, the fact that its primary concern was the offshore oil industry makes it obvious that new legislation is needed to deal with hard minerals mining on the outer continental shelf. The recommendations in the 1974 Draft OCS Proposals[40] are directed toward providing the legislation needed in this area.

As the offshore mining industry matures, the scope of mining operations on the continental margin will greatly increase. Therefore, the management capabilities of the Conservation Division of the U.S. Geological Survey, which manages mining operations in this area, will have to be expanded.

B. State

The 1972 Coastal Zone Management Act provides funding for coastal states to formulate plans for managing their coastal areas, and, subsequent to approval of states' plans, funds are provided for management of these areas. Therefore, State CZM offices would have responsibility of formulating guidelines for hard minerals mining in State waters, and in managing such operations. Of course, approval of plans in navigable waters will still be required from the Corps of Engineers.

In New England, it is hoped that the advent of coastal zone management will result in realistic guidelines for mining so that the existing prohibitions on offshore hard minerals mining can be lifted.

The situation in Rhode Island is a good sample of this type of prohibition. The Coastal Resources Management Council is granted authority over minerals extraction by Rhode Island state law.[41] The Councils regulations follow:

> "The mining and extracting of minerals, including but not limited to, sand and gravel from the territorial waters of the State of Rhode Island, whether by land-based or floating machinery, shall be prohibited until such time as sufficient technical and research data is shown to this Council to prove under what condition said extracting and mining may be carried out without adversely altering the marine environment or conflicting with other use of tidal waters.
>
> "This prohibition shall not extend to dredging tidal waters for navigational purposes, channel maintenance, or to beach replenishment. These activities, while requiring a permit from the

> Council, are not expressly prohibited even where excavated material is used or sold commercially.
>
> "The Council encourages and supports continued research into the environmental and economic impacts of aggregate mining in state waters. Upon discovery of new techniques, and as research findings indicate, the Council may modify its policy.
>
> "Land mining of minerals including but not limited to sand and gravel where related to or demonstrating a potential effect on a water area subject to this Council's jurisdiction is expressly prohibited in absence of a Council permit."[42]

Thus, while prohibiting normal commercial type mining operations for environmental reasons, the Council permits mining for beach nourishment projects which require large amounts of material in a short time.

This seems to be a bias against industry, for, as discussed above, any offshore sand and mining operation in this area would need a large market for fill material to make the output large enough to be viable. To put it another way, the Council is prohibiting what would be a minor part of a mining operation's output if market factors were allowed to determine the feasibility of such an operation.

IX. CONCLUSION

From the facts presented in this study and from the tenor of discussions at the NOAA sponsored marine minerals conference held in March, 1976, it is possible to postulate a scenario of events with respect to hard minerals mining on the New England outer continental margin:

- A test site will be developed for dredging of sand and gravel.
- The project will be subsidized by the Federal Government.
- The dredging will be closely monitored to determine environmental changes and effects in the project area.
- From the data, a model capable of predicting environmental changes caused by such an operation will be developed.
- Regulations will be developed and assigned to some regulatory agency.
- Development, made uneconomic by these regulations, will be precluded for some time.

Whether or not these events take place, the general situation is clear. Factors other than pure market considerations, such as environmental concerns and jurisdictional-management problems, will have a large part in determining whether or not the sand and gravel industry will move offshore in New England.

FOOTNOTES

[1]K. O. Emery, "An oceanographer's view of the Law of the Sea," Symposium on the International Regime of the Seabed (Rome, 1969), pp. 10-11.

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[3]John Schlee and Richard M. Pratt, Atlantic Continental Shelf and Slope of the United States - Gravels of the Northeastern Part, U.S. Geological Survey Professional Paper 529-H (Washington: U.S. Government Printing Office, 1969) p. H 1.

[4]Schlee, op. cit., pp. 7-8.

[5]David A. Ross, Atlantic Continental Shelf and Slope of the United States - Heavy Minerals of the Continental Margin from Southern Nova Scotia to Northern New Jersey, U.S Geological Survey Professional Paper 529-G (Washington U.S. Government Printing Office, 1970) p. G-1.

[6]John L. Mero, The Mineral Resources of the Sea (New York: Elsevier Publishing Co., 1965), p. 312.

[7]K. O. Emery and L. C. Noakes, "Economic Placer Deposits of the Continental Shelf," Economic Commission for Asia and the Far East Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas, Vol. 1 (New Your: United Nations, 1968), pp. 95-111.

[8]V. E. McKelvey and F. H. Wang, World Subsea Mineral Resources, U. S. Geological Survey Miscellaneous Geologic Investigations Map I-632 (Washington: U.S. Government Printing Office, 1969), 4 maps, p. 17.

[9]V. E. McKelvey, et.al., Potential Mineral Resources of the United States Outer Continental Shelves.

[10]K. O. Emery, Some Potential Mineral Resources of the Atlantic Continental Margin, U.S. Geological Survey Professional Paper 525-C (Washington: U.S. Government Printing Office, 1965), pp. C157-C160.

[11]Schlee, op. cit., pp. 1-9.

[12]Schlee and Pratt, op. cit., p. H 1.

[13]Schlee, op. cit., p. 6.

[14]J. B. Lassiter, J. E. Soden, and R. J. Powers, An Assay of the Marine Resources of Massachusetts Bay (Cambridge, MIT Sea Grant Program MITSG 74-26, 1974) pp. 1-58.

[15]The Economic Potential of the Mineral and Botanical Resources of the U.S. Continental Shelf and Slope (Washington Economic Associates, Inc., 1968), Draft p. VII-F-18.

[16]Schlee, op. cit., p. 3.

[17]James D. Eger, Experiments in Shallow High Resolution Seismic Refraction Profiling (unpublished Master's Thesis, University of Florida, 1975), 71 pp.

[18]John B. Herbich, Unpublished summary of NOAA sponsored research in technology development for sand, gravel and shell, at the NOAA Marine Minerals Workshop (Silver Springs, Maryland: March, 1976).

[19]M. J. Cruickshank, C. M. Romanowitz, and M. P. Overall, "Offshore Mining - Present and Future," Engineering and Mining Journal, (January, 1968), p. 84-91.

[20]Ibid., p. 90.

[21]Panel on Operational Safety in Marine Mining, Mining in the Outer Continental Shelf and in the Deep Ocean (Washington: National Academy of Sciences, 1975), pp. 29-32.

[22]M. J. Cruickshank, C. M. Romanowitz, and M. P. Overall, op. cit., p. 89-91.

[23]Panel on Operational Safety in Marine Mining, op. cit., p. ix.

[24]M. J. Cruickshank, C. M. Romanowitz, and M. P. Overall, op. cit., p. 91.

[25]R. M. Owen, Pre-Mining Analysis of the Marine Environment (Milwakee: Fourth Underwater Mining Institute, 1973), p. 26.

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[27]Larry C. Harris, Unpublished Summary of NOAA sponsored research in environmental assessment for sand, gravel and shell, at the NOAA Marine Minerals Workshop (Silver Springs, MD.: March, 1976).

[28]Harold D. Hess, Marine Sand and Gravel Mining Industry of the U.K. (Washington: NOAA ERL 213-MMTC 1, 1971).

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[30]Panel on Operational Safety in Marine Mining, op. cit., pp. xiv-xv.

[31]Source - informal quotations from local sand and gravel companies.

[32]David B. Brooks and Barbara S. Lloyd, "Mineral Economic and the Oceans," Proceedings of a Symposium on Mineral Resources of the World Ocean, ed. Elizabeth Keiffer (Kingston, University of Rhode Island Occasional Publication No. 4, 1968), pp. 29-30.

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[34]U.S., Department of Interior, Draft Environmental Statement: Proposed Outer Continental Shelf Hard Mineral Mining, Operating and Leasing Regulations (Washington: Bureau of Land Management, 1974).

[35]George A. Doumani, op. cit., Appendix 2, pp. 126-127.

[36]Ibid., Appendix 5, pp. 134-135.

[37]Ibid., Appendix 9, p. 162.

[38]Hollis D. Hedberg, "The National-International Jurisdictional Boundary on the Ocean Floor," Ocean Management, Vol. 1 No. 1 (March, 1973), pp. 83-102.

[39]George A. Doumani, op. cit, Appendix 9, pp. 162-163.

[40]U.S., Department of the Interior, op. cit.

[41]Rhode Island, General Laws, 46-23-6B(c).

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F.3 John Schlee, Sand and Gravel on the Continental Off the Northeastern United States, op. cit., pp. 4, 6.