Proceedings of the 1987 Exclusive Economic Zone Symposium on Mapping and Research: Planning for the Next 10 Years

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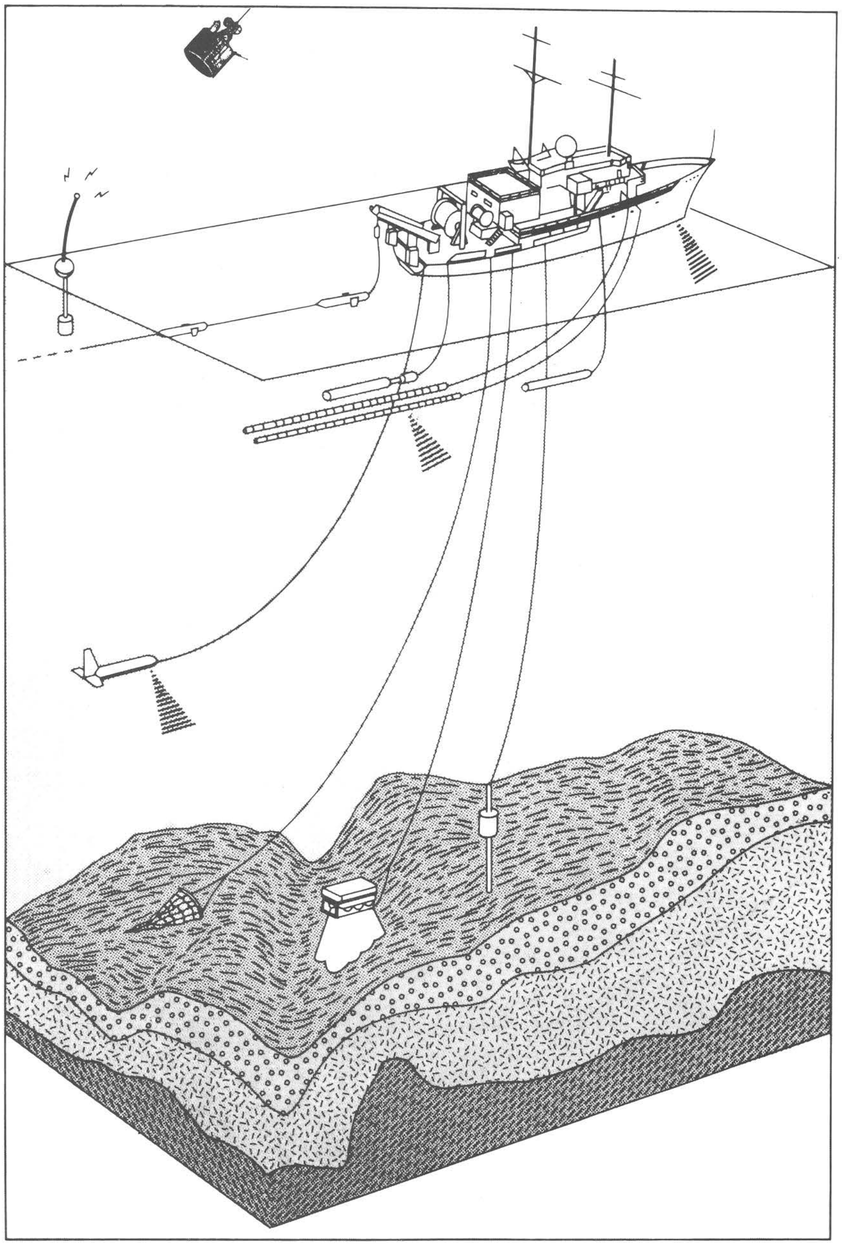

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MILLINGTON LOCKWOOD, National Oceanic and Atmospheric Administration, and
BONNIE A. McGREGOR, U.S. Geological Survey, EDITORS

Sponsored by the USGS–NOAA Joint Office
for Mapping and Research in the EEZ

Meetings held at the USGS National
Center, Reston, Virginia,
November 17–19, 1987

Department of the Interior
U.S. Geological Survey

Department of Commerce
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CONTENTS

Proceedings of the 1987 Exclusive Economic Zone Symposium on Mapping and Research: Planning for the Next 10 Years

Millington Lockwood *and* Bonnie A. McGregor, *editors*

Introduction and Symposium Summary

1987 EEZ Symposium Co-chairpersons:
Gary W. Hill, U.S. Geological Survey
Millington Lockwood, National Oceanic and Atmospheric Administration

This was the third in a series of biennial symposia dedicated to the implementation of a National program of research and mapping in the Exclusive Economic Zone (EEZ). It was held November 17–19, 1987, at the U.S. Geological Survey's National Center in Reston, Virginia. The meeting was convened under the auspices of the USGS–NOAA Joint Office for Mapping and Research in the EEZ. This Joint Office was formed in 1986 to establish a means of coordination and communication among the various entities—Federal, State, academic institutions, and the private sector—who have a responsibility or a need for mapping and research in the Exclusive Economic Zone. Sponsors of the meeting were the U.S. Geological Survey, Minerals Management Service, and the Bureau of Mines in the Department of the Interior and the National Oceanic and Atmospheric Administration in the Department of Commerce. Appendix 1 is a copy of the symposium program and agenda.

BACKGROUND—NEED FOR A NATIONAL PLAN

Mapping and research on the seafloor adjacent to the United States has been a National effort, involving primarily the Department of Defense, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, certain academic institutions, and private industry, the latter primarily for the exploration for oil and gas on the continental shelf. Within the USGS and NOAA these activities were accelerated in 1983, following the issuance of the EEZ Proclamation by President Reagan. The intent was to expand the exploration already begun on the continental shelf to the frontier regions of the EEZ. Only through increased exploration will the Nation realize the benefits this new territory has to offer.

The ocean has played a key role in our Nation's history. Fisheries, transportation, and defense are examples of national issues where the ocean has been a major factor. Energy and mineral resources, the disposal of wastes, multiple use opportunities, international boundary determinations, technology, and national defense applications are issues (or opportunities) that will continue to play an increasingly important role in our efforts to secure and maintain the quality of the American lifestyle and our international leadership. A well-developed comprehensive mapping and research program will provide much of the knowledge essential to meet this challenge. Advancements in technology, for example, high-speed computers, satellites, and new measurement systems, coupled with an awareness of the "earth system," allow us to build on past efforts in the EEZ. From this technology information base we can design and conduct a National EEZ program consisting of studies involving the geologic framework, seafloor processes, and nonliving resources of an area as large and as complex as the EEZ in a relatively short time frame.

To be successful the program must combine the expertise and technology found in government, academia, and the private sector. The program should have clearly defined goals and be coordinated with other ongoing activities in the ocean. It cannot be accomplished in a haphazard or isolated manner, and it must be based upon a carefully

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thought out long-range plan. The main purpose of the 1987 EEZ symposium was to determine the essential elements of this plan.

GOALS OF THE 10-YEAR PROGRAM

The goal of the National EEZ Mapping and Research Program is to describe the framework and understand the processes—geological, geochemical, and geophysical—that interact at and within the seafloor of the EEZ and that contribute to the development of the seafloor and continental margins and to the formation of the various nonliving marine resources on and within the seafloor. Specific objectives are to characterize and evaluate the seabed and subsoil of the EEZ in a timely manner by understanding the geological framework and processes related to this frontier; identifying marine energy, mineral, and other nonliving resources; understanding causes of seafloor geological hazards; determining sedimentary basin evolution; defining geomorphic and sedimentologic processes; and developing baseline information, which would allow activities involving use of the EEZ to be carried out in a timely, efficient, and environmentally sound manner.

The strategy for developing the program is based on the identification of scientific objectives, within the context of national issues, in order to focus the direction toward a 10-year goal. Previous symposia, workshops, and studies by national advisory groups suggested that the program be structured around regional areas (Alaska, West Coast, Gulf of Mexico, East Coast, and Islands) and three ocean resource categories (oil and gas, hard minerals, and other seafloor uses). Additionally, one element of the program will concentrate on technology for seafloor exploration.

STRUCTURING THE NATIONAL PROGRAM—CONSTRAINTS AND LIMITATIONS

To be successful in meeting the program's goals we must, of necessity, limit the activity to those which can be clearly identified as relevant to the program's objectives. To accomplish this, certain limits or constraints have been placed on the design of the program. These limiting factors include:

1. Geographical area defined as coast to 200 mi offshore with the primary emphasis on the outer shelf, slope, and continental rise. Areas of special interest are those not extensively studied in the past.
2. Program goals and objectives that have been established so as to be accomplished within a 10-year time frame, generally restricting the program to current (available) technology with limited operational improvements.
3. Emphasis is on the seafloor relative to geologic framework, processes, and resources. Much of the water column and biological aspects have been eliminated from consideration except as they relate specifically to the seabed or can be conducted as ancillary projects in conjunction with the primary mission.
4. Mapping and research should stress exploration, scientific interpretations, and investigation of the unknown frontier regions of the EEZ, utilizing the "telescope" approach—reconnaissance-scale efforts (regional), focusing down to site-specific studies of individual (local) features.
5. Wide involvement of user groups in program design, rapid turnaround of results, cooperative (government, academia, industry) projects, preparation of products and data bases for multiple uses (maps, atlases, and interpretative reports).
6. Program management philosophy is one of coordination, cooperation, and communications, rather than centralized control.

1987 EEZ SYMPOSIUM

The meeting began with overview presentations by spokesmen for ongoing national activities in the EEZ. These included the Department of the Interior, the National Oceanic and Atmospheric Administration, the National Science Foundation, the Oceanic Society, the Congressional Office of Technology Assessment, and the Amoco Oil Corporation. The keynote speaker for the meeting was Dr. James Baker, President of Joint Oceanographic Institutions, Inc., and President of the Marine Technology Society. The second day of the symposium consisted of nine individual (concurrent) workshops dealing with regional issues and specific ocean use activities (oil and gas, hard minerals, and seafloor uses), and one workshop panel dealt exclusively with exploration and mapping technology. During the final day of the symposium, workshop chairmen presented the major findings from their sessions during a 3-hour summary session.

Approximately 300 people attended all or some of the sessions of the meeting. Attendees represented the Federal sector (57%), private sector (23%), universities (10%), State agencies (8%), and foreign countries (2%). A complete listing of symposium attendees is included in appendix 2. Exhibits showed (1) the results from USGS surveys utilizing the GLORIA wide-swath side-scan sonar system, (2) an extensive display of NOAA's strategic assessments capabilities, (3) results of Minerals Management Service's regional State/Federal task forces in Hawaii and Washington/Oregon, and (4) seafloor surveys from private industry and academic researchers.

The primary purpose of the EEZ symposium was to provide scientific and technical advice from national experts in order to identify and analyze the currently available data and review program goals. In order to keep the meeting focused and to have attendees properly prepared, each workshop participant was given written guidance (see appendix 3). Workshops were asked to identify gaps between current knowledge and the program's goals. The topics each workshop dealt with were (1) geologic framework, (2) geologic processes, and (3) seafloor resources, hazards, and uses.

Each of the workshop panels was asked to address the following:

1. Analyze current programs and data relating to the state of knowledge in each topic area.
2. Identify gaps between current knowledge and program goals through the following procedure:
   a. Develop specific objectives for each program component in a region or ocean use category.
   b. Enumerate gaps between current knowledge and 10-year objectives for each component.
   c. Answer the following questions as they relate to the geological framework, processes, or seafloor uses:
      (1) What specific information do we need and for what purposes?
      (2) What are the attributes of these data and information sets?
      (3) What are the constraints to acquiring these data?
      (4) What is a viable strategy to acquiring and managing these data and information sets?
      (5) What are the consequences of not gathering these data?

SUMMARY OF SYMPOSIUM RESULTS

Each of the panels met for a day to discuss the above questions and developed a consensus from the individuals within each workshop. The full panel reports are contained in their entirety in this volume; however, a few of the more pertinent findings, issues, and recommendations are summarized generically below.

Mapping and Research

1. Reconnaissance-scale data sets and maps are an essential element of ocean exploration. These include bathymetry, morphology, seismic reflection profiles, gravity, magnetics, and bottom samples. Improved maps utilizing modern technology are needed for most areas of the EEZ. Except for areas of the continental shelf, in studies for oil and gas exploration, reconnaissance-scale data sets for the EEZ do not exist.
2. On the basis of available reconnaissance data, we should begin to expand our understanding of the seafloor into the third dimension by using a "corridor" approach (for example, identify a 30- by 200-mi corridor across an island arc to define, in detail, the framework, processes, and resources).
3. Although the deep water of the EEZ is a frontier area, the nearshore and coastal zones are an integral part of the EEZ and are important economically and also are the areas most likely to have resource potential in the immediate future. Nearshore areas must be part of a national research and mapping program.
4. Selected "spot," or ground truth, surveys should be carried out as a way to calibrate existing GLORIA, SeaMARC, and other seafloor imagery data and to begin to identify specific resources.

Technology Development and Implementation

1. The high cost of ship support requires that maximum use be made of underway platforms. Additional sensors (for example, gravity), especially those operating in a passive mode, should be standard on all EEZ survey ships.
2. An intermediate-scale reconnaissance survey technique should be evaluated for use in certain frontier areas following the GLORIA surveys as a means of further delimiting the geological framework prior to site-specific investigations or surveys by the multibeam swath-survey systems.
3. Further development should be undertaken to determine the feasibility of developing a cost-effective unmanned (robotic) rock drill suitable for use in water depths of 4,000 m on hard, irregular substrate like cobalt crusts.
4. Full implementation of the Global Positioning System and subsequent use by all investigators in the EEZ will ensure that positional accuracy is adequate for registration of all data sets and subsequent detailed investigations and studies.

Information Management

1. The vast amount of data that are being and will be collected in the EEZ require that as much as possible be digital. This digitization will facilitate the use, distribution, and permanent archiving of the data.
2. The accessibility of bathymetric data to all users is critically important. The restriction on the dissemination of NOAA's swath mapping data and maps should be reexamined in light of economic security and national independence, in addition to national security considerations.
3. An examination should be made of the data held by the Minerals Management Service and the geophysical

exploration industry to determine a way whereby certain aspects of these data (for example, the upper 1 second of multichannel seismic reflection data, or bathymetric, gravity, and magnetic data at reduced resolution) could be made available to the public.

Coordination and Policy Considerations

1. A comprehensive plan including design, implementation, and coordination options is critical to the success of a national program.
2. Advice of other Federal agencies, State Governments, academic institutions, and private industry should be sought to assure that the information needs of all users of the EEZ are incorporated into the plan.
3. Communications and coordination between Federal, State, and local agencies, academic institutions, and industry should continue to be encouraged and fostered within a national plan.

ROLE OF THE USGS–NOAA JOINT OFFICE FOR MAPPING AND RESEARCH IN THE EXCLUSIVE ECONOMIC ZONE (JOMAR)

The results of the symposium will serve as the main elements of the 10-year national plan. The individual workshop reports include details of mapping and research needs by geographical region and by specific ocean use category. The proceedings, along with other relevant sources of information (for example, National Academy of Engineering Marine Board's study on seafloor utilization, National Science Foundation's Engineering Directorate proposals, Coastal States Organization's recommendations regarding States' activities in the EEZ), will serve as the source material for a 10-year mapping and research plan. This plan, which will be prepared by the staff of the JOMAR (see illustration in appendix 1) in cooperation with the user community and other governmental agencies and organizations will serve as guidance for activities in the EEZ over the next decade.

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PART 1: INVITED SPEAKERS

The Need for Mapping and Research of the Seabed-Subsoil of the EEZ

James W. Ziglar
Department of the Interior

It is a pleasure for me to welcome all of you to this symposium on the Exclusive Economic Zone. As Assistant Secretary for Water and Science, I'm usually known as the Department of the Interior's water development advocate. I do, indeed, spend a significant amount of my time on such issues as financing water projects or ground water research. But the other half of my title, "Science," i.e., the geology and mining and minerals research being carried out at the Survey and the Bureau of Mines, is the part of my job I find most stimulating. In fact, the opportunity to direct part of the Federal Government's overall strategic and critical minerals program was one of the greatest attractions the Water and Science post held for me. I have always believed that America needs a strong defense capability, as well as a stable economy, and you simply can't have either of them without a strong minerals industry. There is no question in my mind that the EEZ will be playing an important role in providing the minerals and materials our Nation will need in the future.

When I was confirmed as Assistant Secretary for Water and Science, I spent a good deal of time being briefed by the scientists at the USGS and Mines on all of the different minerals programs they were working on. I must admit that up until that time, most of my knowledge about mining and mineral resources was based on what I had learned in the 1960's while working on the Hill and what I personally had seen in southern Africa and minerals producing areas in the U.S. When I thought of minerals, I thought of underground mines or large open pits. I hadn't really considered the potentials which the newly declared Exclusive Economic Zone might offer. The briefings I received opened a whole new arena for me. The researchers I heard were convinced that the ocean offered great potential. Their enthusiasm was contagious.

It was not long after those briefings that I had an opportunity to see first hand why these people were so excited about what they are doing. The British ship *Farnella* docked not far south of here for a few days during its mapping mission of the East Coast EEZ in cooperation with the USGS. When 50 people are willing to make it out to Reston at 6 a.m. on a Saturday morning to take a 6-hour round-trip bus ride to Norfolk to visit a research ship, that tells you something. Most of you are probably conversant with the sonar process used by the *Farnella* and its crew, and the resulting mosaics from the *Farnella* which are printed and bound. The EEZ atlases are impressive. But, if you really want to be impressed, I'd recommend a visit to the *Farnella*. Actually seeing how the information is gathered and taking a look at all the data in raw form help you appreciate how much work goes into processing these maps of America's newest frontier.

We do know a lot about a few select areas of our ocean territory. The Minerals Management Service and others have done great work gathering geological and environmental data around the sites that are proposed and ultimately selected for offshore drilling. Still, until the results from the USGS sonar mapping process began pouring in, we knew very little about the geography of the deep-water ocean floor. With the help of the *Farnella*, we've discovered that a lot we thought we knew about the ocean floor was not quite right.

I've taken a quick look at some of the scientific highlights that have come out of this mapping work. We've found new volcanoes, canyons, and fields of sand and mudwaves. For a policy maker and nonscientist like myself, the response to all of those discoveries might be "so what?" While this information might make fascinating reading in Scientific American or National Geographic, why should the Federal Government be out trying to figure out what the ocean looks like when "everybody knows" it's empty? Although we're in the initial phases of this exploration, we've already found some very good answers to the question of "so what?"

Last year, for example, the USGS announced that initial analyses of mineral samples collected from the seafloor off the Pacific coast indicated the potential for what could be a world-class polymetallic sulfide deposit of zinc, lead, copper, silver, and gold. The ore concentrations in initial samples demonstrate that the EEZ can indeed provide minerals that may be necessary in the future.

Polymetallic sulfide deposits that were formed in some prehistoric oceans are being mined on dry land today. It is the understanding we have been able to gain from those deposits that led us to the Gorda Ridge in search of "fresh" sulfide deposits. Now, the knowledge we gain offshore may help us better understand how these deposits are formed and provide new knowledge about minerals exploration on land. The benefits of ocean exploration are not limited to discovering new finds offshore.

One of the members of my personal staff has also spent time on a multiagency research vessel in the South Pacific investigating the cobalt-enriched crusts that have been located as a result of our increased emphasis on exploration of the EEZ. Besides coming back with a terrific tan, he also returned with a collection of mineralized crusts that are rich in cobalt. Because the manganese crusts appear to be easily removed, and because they lie in fairly shallow water, they seem to offer greater potential for recovery than the well-known manganese nodules from the deep ocean floor. Also, because these crusts lie within our EEZ, rather than in international waters, the legal, political, and policy problems should be less complex.

I guess an average American would be excited to hear that we've found gold offshore California. For me, a domestic find of cobalt and manganese is much more exciting.

As I earlier said, I am particularly interested in the national security issues that are associated with our country's supply of minerals. Cobalt and manganese are both essential ingredients in many of our Nation's defense systems—not to mention the role they play in the overall economy. But, because we have only low-grade deposits of these minerals on land, we've had to rely on overseas sources for them. Some of those sources are unstable, and some of them are unfriendly. Locating domestic sources, even if we currently do not have the technology to develop those resources, is an important step in improving our security situation. For this reason alone, I believe our EEZ program has already made substantial contributions to the good of the Nation.

I might mention, our current lack of technology is not being ignored. I've seen some fascinating research being done by the Bureau of Mines in Salt Lake City involving relatively new technology that appears to offer some promise for ocean minerals. The Bureau of Mines is increasing its efforts to investigate innovative, high-tech mining potentials, and I'm pleased to see that the Acting Director, Dave Brown, will be speaking on your program.

I am confident that our offshore minerals programs will contribute to a strong future. One of the reasons for my confidence is the successful offshore energy recovery programs that are currently being conducted. I've already mentioned MMS's offshore leasing program. It's definitely been a success for this country. A reasoned look at the full record will show that both economically and environmentally, our nation's offshore energy program is sound.

Energy resources are not all that are being developed offshore today. Construction materials, such as sand and gravel, already are being mined offshore. Land resources for these materials are being depleted, especially near some of our growing coastal cities. Other resources, such as sulfur, and, of course, salt, also are being produced from our ocean territory.

Ocean mineral resources are a reality today. They will be a necessity tomorrow. The USGS has estimated that, in the next 50 years, we will need to produce as much raw fuel and nonfuel mineral resources as we produced in the first 200 years of our history. Many of those resources will come from offshore waters.

Much of the progress we have made in understanding the ocean and its resources has come as the result of cooperation between industry, academia, and government agencies. This is certainly true of the EEZ mapping program. The joint office recently formed between NOAA and USGS is a major and practical step forward in ensuring the maximum possible cooperation in the basic research and mapping efforts on the EEZ. The recommendations of past conferences like this one have shaped the success we have had so far. I hope your commitment to contribute to our nation's future EEZ programs remains strong. With the continued dedication of our citizens, I believe we can indeed provide the resources that will be required to meet the challenges of a new century.

The Exclusive Economic Zone: Resources for the Future

D. James Baker
Joint Oceanographic Institutions, Inc.

INTRODUCTION

I would like to thank Gary Hill and the USGS–NOAA Exclusive Economic Zone (EEZ) Coordination Office for inviting me to talk to you. Secretary Ziglar has given us an eloquent statement of the need for mapping and research on the seabed and subsoil of the EEZ, and he has nicely set the stage for the rest of the afternoon's talks. The agenda reflects the complexity of the issues, and I'm looking forward to hearing the afternoon's talks.

BACKGROUND

In March 1983 President Reagan proclaimed the sovereign rights and jurisdiction of the United States and confirmed the rights and freedoms of all States, within an EEZ. Within the Zone, the United States is to have sovereign rights for the purpose of exploring, exploiting, conserving, and managing natural resources, both living and nonliving, of the seabed and subsoil and the superjacent waters and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents, and winds, and jurisdiction with regard to the establishment and use of artificial islands, and installations and structures having economic purposes, and the protection and preservation of the marine environment.

What is the background to the Reagan Proclamation? Forty-two years ago President Truman proclaimed U.S. jurisdiction over the natural resources of the seabed and the subsoil of the continental shelf adjoining the United States. Honduras, in 1951, established a 200-mi "resource protection zone," the first such EEZ. The United States implemented the Truman Proclamation by passage of the Outer Continental Shelf Lands Act under President Eisenhower in 1953. This unilateral action led to an international agreement in 1958 whereby all coastal nations acquired the rights to explore and exploit natural resources within their continental shelves. Of course, the question of the difference between the jurisdictional outer continental shelf and the geologically defined continental shelf has never been fully resolved. When the geologic continental shelf extends more than 200 mi from the coast, interesting problems can arise. The Law of the Sea Conference, concluded in 1982, established yet another definition of the continental shelf, which helps to resolve ambiguities, but since we and a few others are not signatories, problems remain.

The Ocean Drilling Program ran into such a problem recently when requesting clearance off Sri Lanka. There the site was more than 500 mi offshore, but this is territory that Sri Lanka claims. We protested in turn to our own State Department, who refused to help on the basis that we are trying to make a similar claim off Alaska and hence did not want to set a precedent! So the Law of the Sea Conference complexities continue.

Not only has mineral leasing on our Outer Continental Shelf been authorized since 1953, but fisheries have been managed within a 200-mi Conservation and Management Zone since 1976 under the Magnuson Act. Thus only the mineral deposits in areas within 200 mi of the coast but beyond the continental shelf edge—the least accessible part of the EEZ—have been added to the resource base of the United States with the establishment of the new EEZ.

But although the proclamation was primarily a codification of existing agreements and laws, it focused interest and attention on the offshore ocean. The Federal Agencies, industry, the scientific community, and the public have all been involved in defining that focus during the past 4 years. The most recent summaries come from three key reports:

- July 1987 OTA Ocean Frontier Project and Report on Marine Minerals: Exploring our New Ocean Frontier
- April 1987 Coastal States Organization and Report on Coastal States and the U.S. Exclusive Economic Zone
- June 1986 NACOA report on The Need for a National Plan of Scientific Exploration for the Exclusive Economic Zone

RESOURCES HELD IN TRUST

In defining the focus, the OTA report put it best: the most important aspect of the Reagan Proclamation is that the resources within the EEZ, whether on the seafloor or in the water column, whether living or nonliving, whether hydrocarbons or hard minerals, are declared to be held in trust by the U.S. Government for the American people. The Coastal States Organization report summarizes these resources: the 200-mi EEZ encompasses roughly 80 percent of the world's fisheries resources, most of the offshore hydrocarbon deposits, and many potential hard mineral resources, and describes the role of the coastal States. The NACOA report addresses specific elements and issues of a national scientific exploration plan for the EEZ. We will be hearing more about each of these from later speakers. The point I want to make here is that the U.S. EEZ is the largest and probably most valuable in the world.

GLOBAL CHANGE AND THE EEZ

Today we hear much about global change and the need for understanding and predicting the effects of mankind on our environment. Increasing carbon dioxide in the atmosphere, the hole in the ozone, and acid rain are all examples of problems that must be studied on a global scale. Grant Gross will present the science of the EEZ in a global context to us shortly.

I submit that exploring, understanding, and using the EEZ present another, equally important, but even more difficult set of issues. Moreover, the practical consequences make the need for a national program even more urgent. As with the national and international efforts to understand global change, we need a strong national and international effort to describe the EEZ's of the world. And we need to understand the connections between the EEZ and the global marine environment. For example, the distribution of marine phosphate deposits in the EEZ depends on oceanographic events of global extent. The extraction of energy from the Gulf Stream near Florida could have significant effects on the climate of Europe, by changing the global heat flux.

What is the urgency? We hold in trust, in the EEZ, the resources that we will need in the future. Petroleum, fisheries, hard minerals, pharmaceuticals, and renewable energy resources are all there. As our population grows and as we try to maintain a high standard of living for all our people, and as we try to maintain a competitive posture economically with the rest of the world, we will turn increasingly to this new resource base. Will we be ready to exploit it in a way that is consistent with long-term use and health of our environment? This can only be answered if we have a long-term plan that involves all the players. These include scientists, resource developers, and the public. We need to plan ahead—a lesson we can learn from the Japanese. The plan must recognize new developments, the most obvious of which is high technology.

HIGH TECHNOLOGY

High technology will play a key role in the exploration and development of the EEZ. We have already seen an enormous explosion in the detail and amount of data that can come from modern multibeam echosounding systems linked with high-speed computers. We can resolve details below the seafloor with new seismic techniques. Acoustic technology allows us to measure ocean currents and to monitor fish populations. New mooring technology allows us to directly monitor chemical and particle fluxes in the ocean. But high technology should not be applied simply to exploration and development. There are opportunities to apply high technology to the reduction of pollution, one of the major problems of use of the EEZ.

SATELLITES

The technology is not limited to in-situ measurements. Satellites, although widely known for their ability to provide instruments with a platform for a global view of ocean processes, also are revolutionizing the regional and coastal view of the ocean. Operational satellite data on sea-surface temperature are being used to monitor river discharge in the Gulf of Mexico and to prepare eddy forecasts for offshore oil exploration and production. The Coastal Zone Color Scanner has given us a whole new view of the complexity of coastal processes and the ability to measure and monitor biological and sediment concentrations simply not possible before. Coastal El Nino effects on biological production have been beautifully delineated.

Part of our EEZ is ice covered seasonally, and part of it, north of Alaska, is covered year-round. The motion, structure, and age of the ice data will be a regular operational product of several satellites operated by the United States, Canada, Europe, and Japan. This will be an important input to the exploration of the EEZ.

DATA MANAGEMENT

Data management is another issue that must be considered. The new seismic, acoustic, and satellite techniques generate far more data than we have ever seen before. We see rapidly increasing computing needs for data manipulation. Yet at the same time, we have seen a tenfold improvement every 7 years in computing power. Data storage with optical disks is becoming a reality: two compact disks can store a complete description of the entire 2 billion acres of the EEZ with one measurement every 300 m, or 1,000 ft. Or a long time series for a smaller regional area could be easily accessible.

THE INTERNATIONAL ASPECT

Resource management in the U.S. EEZ is now a domestic issue. But the way in which we handle the exploration raises many international issues. As exploration for mineral resources, particularly petroleum, extends seaward, the United States will face more confrontations with countries whose borders are contiguous. We are currently involved in disputes with Mexico and Canada over fishing and mineral rights. The U.S. efforts to classify EEZ information, although justified on a national security basis, tend to lead other countries to deny scientific access to their EEZ's. There is an international trend now to classify EEZ data regardless of its usefulness for economic or defense-related purposes. For example, India has classified all of its sea-level data, simply because the Soviet Union does the same thing. Since the United States is the major player in international waters in ocean science, this is an issue that needs resolution.

A second point is that with new remote sensing techniques it is now becoming possible to map certain aspects of the EEZ, such as surface biology, and the gravity and magnetic field, without requiring permission of the host country. As these techniques become more precise, it will be more and more difficult to justify the classification of data. This is a problem that will be upon us soon.

CONCLUSION

In summary, the effective management of the EEZ is essential to the future economic growth and security of the United States. We hold these resources in trust for the future, but we must know what is there and how it can be exploited. We must learn how we can exploit mineral resources without affecting fisheries. We must also learn how to conserve these natural resources.

We are making a start in the assessment of the EEZ. But the problems that are identified come back to an old issue in the United States: the need for national ocean policy leadership. In spite of many reports, and many attempts to develop this leadership, we still lack a clear national ocean policy adequately coordinated with State policy. We need to develop a government/industry/academic coalition to provide this leadership and to handle our ocean programs in a cost-effective way. It is possible to do this. The United States needs a comprehensive plan for management of the EEZ and clear guidelines for national leadership and authority. This workshop will be an important step in this direction.

The Needs of Users of EEZ Mapping and Research

J. Steven Griles
Department of the Interior

When the President signed the Exclusive Economic Zone (EEZ) Proclamation in 1983, he nearly doubled the area of U.S. jurisdiction. Vast new areas were made available for exploring, developing, conserving, and managing living and nonliving marine resources. That was a tremendous day for America. Now we must look forward from that impetus. Under the Outer Continental Shelf (OCS) Lands Act, the Department of the Interior (DOI) has a mandate to move forward in an expeditious manner to explore and develop marine mineral resources. We, as a Nation, need these resources to improve our national security, to reduce our trade deficit, and to reduce our reliance on foreign energy supplies. In today's political atmosphere, that mandate could not be more important. Our dependency, as a Nation, on imported oil imposes great risks not only to our national security but also to our economy. Recent events in the Persian Gulf should remind all Americans of the tenuous status of oil supplies from that area. It is vitally important for this Nation to increase its domestic oil and gas production and to begin to exploit the mineral resources of the EEZ.

I would like to digress from the EEZ for just a moment to a related issue that we in the DOI know as ANWR. ANWR is the acronym for an area on Alaska's North Slope designated as the Alaska National Wildlife Refuge. According to geologists from the U.S. Geological Survey (USGS), Bureau of Land Management (BLM), and Minerals Management Service (MMS), ANWR has the potential to be our largest remaining domestic oil and gas reserve. The DOI, including the Fish and Wildlife Service (FWS), is very excited about this potential and is working diligently on plans to open this area to exploration and hopefully production while protecting its sensitive wildlife for future generations. If you have an interest in America's future, you should learn more about ANWR. We in the DOI hope to make the critical oil and gas resources of this remote area available to all Americans. I mention ANWR because that area and the EEZ currently offer this Nation its greatest hope of discovering secure supplies of oil and gas and other minerals in the future.

We believe that Federal lands are a critical source of oil and gas and minerals for this country. Federal lands administered by MMS and BLM currently account for more than 30 percent of our domestic supply of natural gas, more than 16 percent of our oil, 20 percent of our coal, 80 percent of our lead, 60 percent of our potash, and 45 percent of our sulfur. Many other critical minerals are mined on public lands managed by agencies of the DOI. Under the OCS oil and gas program, the DOI has offered more than 89,000 tracts (approximately 482 million acres) on the Outer Continental Shelf for lease. Approximately 10 percent of the area offered has been leased for use by America to reduce its dependency on foreign oil. At the end of 1986, active oil and gas leases on the OCS occupied 26 million acres. About 7.4 million barrels of crude oil and condensate and 73.8 trillion cubic feet of natural gas have been produced from Federal OCS leases. Revenues from these leases have totaled $84.8 billion. The DOI is, in fact, a major component of the U.S. energy and mineral economy, and a major, *major* environmental regulator. The DOI Bureaus under the Assistant Secretary for Land and Minerals Management (MMS, BLM, and Office of Surface Mining Reclamation and Enforcement (OSMRE)) are responsible for all of the appropriate goals of good stewardship:

- making energy and mineral resources available
- achieving fair market value for the resources
- assuring the maintenance of environmental quality

As I mentioned earlier, our efforts on the EEZ under the OCS Lands Act have been substantial. In addition to our oil and gas leasing, we have also issued leases for phosphate and sulfur and salt. We anticipate sales in the near future for sulfur and salt and sand and gravel.

With the help of some of the people in this audience and the advice of some of the agencies represented here, Bureau of Mines, USGS, National Oceanic and Atmospheric Administration (NOAA), and others, we can make our EEZ programs work in a cooperative manner. That is the purpose of this symposium—to find better ways to cooperate in the exploration, development, conservation, and management of resources in the EEZ. The DOI has a responsibility to obtain and use the information necessary to ensure that it fulfilled the goals of good stewardship on the EEZ. We need the geological information to ensure that we manage the mineral resources for the benefit of all Americans. We need environmental information to ensure that exploration and development activities do not significantly damage the ecosystems of the EEZ. It is the responsibility of all concerned parties to ensure that the best information is available to decision makers as we move forward with our efforts.

In the spirit of the President's declaration on federalism, the MMS is working closely with several coastal States to study the potential for leasing and mining marine minerals off their shores. To date, the MMS has established five Federal/State task forces involving eight coastal States. Participating coastal States are Hawaii, California, Oregon, Georgia, North Carolina, Louisiana, Mississippi, and Texas. We expect to announce a new task force soon. We are aware of increasing interest in the mining of offshore resources such as sand and gravel and cobalt-rich crusts. We believe that our cooperative effort with the coastal States is the first step—a mandatory step—to assure that the principals of federalism are incorporated into the process.

The MMS's offshore hard minerals program is being developed on a case-by-case basis. In our current approach, we focus on specific mineral commodities and geographical areas. We study in detail with representatives of the affected States and interested industries the commercial development potential. We have only begun the process, and there is a need for steady progress within the program to ensure that we can have safe and environmentally acceptable development.

One of the major issues at this early stage of the program is how to best invest the public's financial resources. I believe that these resources are best used for site- and commodity-specific analyses rather than broad-scale inventories of baseline studies of resources across large areas of the EEZ. The development of these specific analyses should be a cooperative government/industry effort. State and Federal agencies should be involved in requiring and evaluating all available information on leasing and development opportunities. We need to develop a cooperative effort. We should realize that we are initiating a program which has available to it a vast amount of geological and environmental information. Much of this information was developed to support oil and gas leasing efforts on the OCS and can be used in analyses for offshore minerals development.

Since the President's EEZ Proclamation, interest in the EEZ has grown. This symposium is an indication of a growing interest in developing our offshore minerals leasing program. I'm certain that the future offers many challenges to such an effort. I believe that such a program must continue to satisfy a substantial share of this Nation's oil and natural gas requirements, as it does today. I also believe that we can take this infant marine minerals program and through the site- and commodity-specific analysis and Federal/State cooperation develop a mature and productive program.

In closing, I have some questions that should be addressed by the panels of this symposium. I hope the panels can focus some attention on these questions:

- How do we manage effectively this added jurisdiction given to us by the President?
- What is the most cost-effective use of Federal Government, private sector, and economic resources to achieve the maximum benefit both short and long term to the Nation?
- How do we encourage and ensure that user needs are addressed by the research programs?
- How do we educate the public to the real benefits and costs of a marine minerals program?

This symposium has an opportunity to initiate some strategic planning for the long-term future of this country. I wish you all the best of luck with your symposium and your subsequent activities. It was my pleasure to be with you this afternoon.

Ocean Science and Engineering

M. Grant Gross
National Science Foundation

In 1987, the National Science Foundation (NSF) began the Global Geosciences Program to support research on the processes which regulate the habitability of our planet. Such research cuts across all the earth sciences, involving the solid Earth, the ocean, the atmosphere, and especially the polar regions. One of the principal benefits of this activity will be an improved ability to predict and assess changes affecting the Earth. Such predictions are likely to be developed and used first in the coastal ocean, which includes the Exclusive Economic Zone (EEZ).

Let me begin by discussing NSF's research support. NSF provides about two-thirds of the support available to university-based oceanographers, geologists, and meteorologists for basic research. NSF-supported projects are not directed at solving specific problems. Instead our support focuses on improving our understanding of the ocean, its life, and the marine environment. However, many of the results of these projects contribute to answering practical questions, as resource identification and development. Indeed, many argue that such investments in basic research are necessary to maintain and improve the Nation's growth and productivity.

Second, NSF support does not focus specifically on the EEZ. But we do support many projects that deal with the margins of the ocean basins. We refer to this ill-defined region as the coastal ocean. Unlike the legally defined EEZ, the coastal ocean has very indefinite boundaries.

Research activities necessary to provide this level of understanding and predictive capability extend across traditional disciplinary boundaries. Physical oceanographers must work closely with biologists, chemists with geologists. Otherwise we will never be able to understand how the coastal ocean works.

The reason NSF instituted the Global Geosciences Program is because of the availability of new capabilities afforded by satellite observations of the Earth and the ability of supercomputers to process the vast amount of data involved. NSF, together with National Aeronautics and Space Administration and Office of Naval Research, has been working to insure that these new capabilities are available to university-based scientists and to train scientists and engineers in their use.

While the focus of Global Geoscience is worldwide, much of the research will be done in the U.S. coastal ocean. Here are some examples.

- One of the recent exciting discoveries has been the improved understanding of the role of the mid-ocean ridges. They are the site of processes involved with plate movements, a major area of heat release from the Earth's interior, and an area of mineral formation. As you all know, one of the most accessible mid-ocean ridge provinces lies off Washington and Oregon. A National Research Council-sponsored workshop has recommended research on mid-ocean ridges in the 1990's. Some of the work recommended will likely be done in this area. If so, university-based scientists will be joining work under way by scientists from National Oceanic and Atmospheric Administration and USGS.
- An international effort involving scientists from the United States and France is planned to investigate mid-ocean ridges in the Atlantic and the Pacific. This project is an outgrowth of FAMOUS (French-American Mid Ocean Undersea Study) of the 1970's, which first demonstrated the utility of using research submersibles to study mid-ocean ridges.
- Submerged continental margins are yet another example of studies that will likely be carried out largely in the coastal ocean. This activity has not yet matured to the level of the RIDGE study. A workshop will be necessary to formulate the major science questions in this area.

Some of the needed research instruments and techniques are available. Others must be developed. This topic will require joint planning and implementation by two traditionally separate scientific communities—sea-going geophysicists and land-based geologists.

Let me turn to ocean drilling. The new drilling vessel—the JOIDES RESOLUTION—has nearly completed a circumnavigation of the world ocean. It is now drilling in the western Pacific. Ocean drilling has involved many scientists. Some are in this room: some from the USGS, and many from other countries. We have had international participation in ocean drilling since the mid-

1970's. Our international partners include Britain, France, Germany, Japan, Canada, and the European Science Foundation, a consortium of 12 European nations.

The Ocean Drilling Program (ODP) involves extensive long-range planning. The first agenda for ocean drilling was established by the Conference on Scientific Ocean Drilling (COSOD), held in 1981. Many of the objectives set forth by COSOD–I, as it was called, have been drilled in the past 4 years. To prepare for possible future ocean drilling, COSOD–II was held in Strasburg in August 1987. The report is expected to be available early in 1988.

An important area highlighted in COSOD–II is the study of submerged continental margins. This has long been realized by scientific drilling ships that did not have the ability to drill and control a well if it encountered oil and gas. New approaches are being developed by ODP that will make it feasible to drill on submerged continental margins. It is still too early to identify targets for such drilling. But it is obvious that many will lie within the coastal ocean.

Global Geosciences emphasizes large initiatives. Large-scale processes necessarily involve large projects. Among these are the study of ocean circulation, called the World Ocean Circulation Experiment. This study will use ocean-sensing satellites to study the shallow-ocean currents. In addition, it will use more than 7 years of ship time to observe the deep ocean. From this will emerge the first complete description of the ocean currents. This new map will be comparable to the weather maps you see every day in your newspaper or on your television. Finally we will be able to replace the current maps compiled by Maury in the 19th century from logbooks of sailing ships.

Another project is the Global Ocean Flux Study. Satellites provide a wealth of information about distributions and growth of marine organisms in surface waters. When these organisms die and sink to the bottom, they transport organic matter. They also cause other chemical processes in the deep ocean. Up to this time we know little about their distribution. Widespread deployments of sediment traps to collect falling particles will be combined with knowledge of the production in surface waters to decipher how primary production and particle interactions control the chemical composition of ocean waters. These projects require more organization and coordination than single-investigator-initiated activities. About one-third of the support for these initiatives will provide the core activities that insure that appropriate collections and analyses are made. The remaining two-thirds supports projects that have traditionally been the backbone of NSF-supported projects in U.S. universities.

Other areas that have been identified as possible future initiatives include:

- Coastal ocean dynamics and fluxes,
- Land/sea interface, and
- Global ecosystem dynamics.

Let me close with a brief look at the efforts that NSF is making to improve the capabilities of the Nation's ocean science community in technology and engineering. The Ocean Drilling Program includes support to develop new instruments for electric logging of the boreholes to provide data between the sampled intervals and to develop drilling techniques needed for drilling on the continental margins.

Another new component of NSF's support activities is expanding support for ocean engineering. The traditional areas of support for ocean technology are combining with the new Ocean Engineering component of the Engineering Directorate to announce expanded opportunities for work in ocean engineering in the Nation's universities. This announcement should be available within the next few months, after this year's budget situation is clarified.

In summary, NSF funds a wide variety of activities in the Nation's coastal waters. In addition, it is also supporting developments in ocean engineering and technology. This is a big job and involves many agencies and individuals.

Technology, Competitiveness, and the Federal Role in the Exclusive Economic Zone

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INTRODUCTION

Technology is considered to be the key to exploration and exploitation of minerals within the EEZ. While this axiom is generally irrefutable, seldom is the feasibility of developing new technology or deploying existing technology a barrier to ocean exploration or development. Rather, the limiting factors tend to be whether the capital and operating costs of developing a seabed mineral deposit or a potential petroleum discovery can be offset by the value of the extracted resource and still allow a financial margin for profit, risk, debt service, and the recovery of capital costs. Many factors can affect the profitability of seabed mining operations, including the size of the initial capital investment for the mining system, operating costs and other fixed and variable costs, rate of mineral recovery, extent and quality of the mineral deposit, market value of the mineral commodities, stability of minerals markets, and long-term trends in consumption and demand for the commodities.

The establishment of the U.S. EEZ in 1983 generated enthusiasm and curiosity about the prospects for discovering minerals on the seafloor within this newly acquired public domain. This enthusiasm was shared by academicians, exploration geologists, government agencies, entrepreneurs, and politicians alike. Like the similar hysteria that surrounded the mid-Pacific deep seabed ferromanganese nodules in the 1960's and the 1970's when speculation about fortunes to be made in seabed mining were rife, soon after issuance of the EEZ Proclamation, special interests made exaggerated claims of the potential for vast mineral wealth lying on the ocean floor.

Blame for such exaggerations is shared by academic researchers seeking more Federal research funds; Federal agencies hoping for larger budgets and expanded programs; politicians putting a political twist on EEZ programs to fight a "resource war"; and some in the private sector looking for a safe haven after the economic prospects for deep seabed nodule mining collapsed. Consideration of national needs and a balanced public policy to deal with EEZ took a quantum leap from an innocent curiosity and enthusiasm about the minerals that may lie in the seafloor, to self-serving assumptions about certainty of the potential for mining commercial minerals. Consequently, during the past 4 years important public policy questions have been overlooked in a premature rush to establish mineral leasing regulations, interspersed with bickering over agency turf.

OPPORTUNITY FORGONE

Almost 5 years after laying claim to this new offshore province the United States has neither a national strategic plan and program for systematically exploring and assessing EEZ resources nor yet any manifestation of intent to make a financial or intellectual commitment to do so. Neither the Executive Branch nor the Congress has objectively considered the extent of the national interest in seabed minerals and what the roles and responsibilities should be among the private, public, and academic institutions regarding exploration and development of the EEZ. After the political assets for proclaiming the EEZ were realized, politicians and the Federal agencies returned to "business-as-usual" with only minor, incremental efforts to explore the EEZ added to existing agency programs. Even those modest initiatives have suffered in the face of budget cuts and fiscal austerity. A poorly conceived and flawed initiative to establish a Federal mineral leasing program remains the major thrust in the EEZ.

Until more is understood about the location, extent, and characteristics of offshore minerals within the EEZ, the economic future of seabed mining is mere conjecture. It is apparent from the literature that our knowledge of the location, extent, and quality of seabed minerals is sketchy at best. Because so little is known about the volume in place and the mineral content of seabed deposits, most of those that have been discovered thus far should be more properly considered "mineral occurrences" rather than "resources," since the latter is considered to be potentially economically recoverable. Thus, the evaluation of the commercial potential of U.S. EEZ hard minerals faces a dilemma.

Before the economic potential of seabed mineral deposits can be evaluated, the capital cost and operating costs of a mining venture must be determined. Before the private sector will undertake an expensive feasibility study and develop seabed mining technologies, it must know a great deal about the areal extent, depth, tenor, amount of overburden, topographical, and physical characteristics of the mineral deposit. Before underwriting an expensive prospecting and delineation project, the industry must have sufficient exploration data to identify potential mining sites worthy of future consideration.

Faced with this "chicken and egg" situation, it is clear that the Federal Government must assume the major responsibility for minerals exploration in the EEZ, and certainly more than it has been willing to shoulder thus far. It is unlikely that the private sector will invest in extensive exploration because of the depressed economic condition of the minerals industry, the absence of government assurances that successful exploration will lead to an exclusive property right to minerals that are discovered, and the extremely high cost of offshore exploration and prospecting. For practical purposes, there is no U.S. ocean mining industry, and market forces cannot be relied on to stimulate reconnaissance, exploration, and prospecting by private investors at this time.

Several factors make analysis of the commercial potential of seabed minerals difficult: (1) little is known about the extent and grade of the mineral occurrences that have been identified thus far in the EEZ; (2) without actual experience or pilot operations, mining costs and the unforeseen operational problems that affect costs cannot be assessed accurately; (3) unpredictable performance of domestic and global economies add uncertainty to forecasts of minerals demand; (4) changing technologies can cause unforeseen demand for minerals and materials; and (5) past experience indicates that methods for projecting or forecasting mineral demand fall short of perfection and are sometimes incorrect or misleading.

WORLD MINERAL ECONOMY: A HOUSE OF CARDS

There is nothing unique about minerals recovered from the seabed that sets them apart from land-based minerals, whether foreign or domestic. Mineral commodities are traded in international markets; thus, seabed minerals must compete with both foreign and domestic onshore producers, and possibly with foreign offshore mines in the future as well.

Demand for mineral commodities is related to the demand for goods and agricultural products. These markets are tied directly or indirectly to general economic trends and are notably unstable. With economic growth as the "common denominator" for determining materials consumption and hence minerals demand, the economic uncertainties facing the United States and the world at large make it difficult to forecast future demands from which to gauge the economic potential of seabed minerals.

Downturn in the world minerals industry began in the early 1980's as a result of a long-term trend toward miniaturization, consumption of less metal-intensive goods, slackened growth in the consumption of consumer goods and capital expenditures, a sluggish world economy suffering from the after-effects of high petroleum prices, and expanded mining and processing capacity in both the developing and industrialized nations as a result of materials demand projections in the 1970's that proved wrong. As a result, minerals prices have remained low during the 1980's and will probably remain so until demand absorbs the unused mineral production capacity.

The U.S. industry, in particular, has found it difficult to compete with foreign producers. Until recently, production costs in the United States have been well above the world average. Overvalued currency (high value of the dollar) during 1981–86 also may have contributed to making U.S. production less competitive. However, even with the current lower valued dollar with respect to other currency, the minerals industry has shown little real evidence of recovery. Among the minerals commodities known to occur in the EEZ, domestic producers of copper, phosphate rock, and zinc have been particularly hard pressed by foreign competition.

To survive the low mineral commodity prices of the 1980's, the domestic industry has undergone a significant shakedown and restructuring. While the surviving firms may emerge as stronger competitors, their ability and willingness to invest in risky ventures such as seabed mining are likely to be limited.

STATE OF THE U.S. MINERALS INDUSTRY: LITTLE STOMACH FOR RISK

Apart from the impact that the depressed state of the domestic minerals industry may have on investment in risky seabed mining ventures, capacity for processing minerals in the United States has been severely reduced through plant closings. This could affect the economic feasibility of seabed mining if plant capacity for processing the recovered minerals is not available in the future.

For example, the U.S. ferroalloys industry is now nearly extinct. There are no domestic reserves of either manganese or chromium for producing ferromanganese and ferrochromium that are used in steel; therefore, the United States must import all of these alloying elements. U.S. ferroalloy producers have lost domestic markets to cheaper foreign sources. Ore-producing countries find it advantageous to manufacture finished ferroalloy for export to the United States rather than ship ore, thereby gaining the value added. As a result, the form of U.S. chromium and manganese imports has changed during the last decade from predominantly chromite and manganese ore to mostly ferroalloys and finished steel.

In 1973, the United States ferrochromium capacity was about 400,000 short tons (contained chromium); by 1984, domestic capacity had shrunk to about 187,000 short tons—a decrease of about 54 percent. U.S. capacity is expected to shrink further, to perhaps 150,000 short tons by 1990. In 1984, only two of the six domestic ferrochromium firms were operating plants, and those only at low production levels or intermittently.

Decline of domestic ferroalloy production capacity will likely make the United States nearly totally dependent on foreign processing capacity in the future. This means that even if chromite or manganese ore could be successfully recovered from the seabed within the EEZ, the ore would have to be shipped abroad for processing. It is unlikely that a new domestic ferrochromium plant would be built to process seabed chromite, since it is doubtful that it could compete with existing producers.

Competitiveness problems are also developing in the phosphate industry. Although the United States has historically led the world in phosphate rock production (30 percent of world production in 1986), its leadership is currently being threatened by cheaper North African sources of phosphate, principally from Morocco. Some industry analysts consider it nearly a certainty that Morocco will displace the United States as world leader in the near future.

The domestic phosphate industry is facing significant land use and environmental problems and diminishing ore grades that have resulted in increased production costs, thus exacerbating the problems of meeting low-cost foreign competition. While offshore phosphorite deposits may show promise for competing with the beleaguered U.S. onshore producers, it is highly unlikely that a seabed mining firm could successfully compete in the world phosphate rock market.

Attention has been focused recently on the demise of the U.S. manufacturing sector and the loss of its competitive position to foreign producers. The economic and technologic linkages between manufacturing and mining suggest that domestic producers in both sectors are in for even more serious problems in the future. The domestic minerals industry has not benefited significantly from the periodic upturns in the economy between the recessionary trends that have marked the Nation's economic pattern since 1981. The lag in the mineral industry's response to general economic trends raises questions concerning its ability to recover and flourish in the future, much less its potential for expanding into new ventures in seabed mining.

STRATEGIC AND CRITICAL MINERALS: IS THE SEA A POTENTIAL SOURCE?

Several minerals used widely in manufactured goods that are considered to be vital to the U.S. economy and national security are known to occur or may occur in the EEZ. Included among these are chromium, cobalt, manganese, and the platinum-group metals for which the United States is nearly wholly dependent on foreign sources of supply. These materials are considered strategically important because of their use in high-technology and military applications. Originating mainly from sources in southern and central Africa, chromium, cobalt, manganese, and the platinum-group metals are vulnerable to supply interruptions, and therefore are stockpiled by the Federal Government in the National Defense Stockpile. Other critical materials derived from minerals in the EEZ, although not considered as vulnerable to supply interruptions as the first-tier strategic materials, are also stockpiled. These include titanium, copper, nickel, silver, lead, and zinc.

Some observers have speculated that seabed minerals within the EEZ might provide a more secure source of supply for some of the critical and strategic materials for which the United States now relies on foreign producers. While EEZ minerals might provide a cushion in the event of an interruption of normal supplies, mining and processing facilities would have to be subsidized or operated by the government to ensure the availability of standby production in such an emergency. Such would be the case for heavy-mineral chromite sands in the Pacific Northwest and cobalt-rich ferromanganese crusts on the flanks of the Pacific Islands.

The absence of domestic production facilities for ferrochromium and ferromanganese discussed previously adds to the difficulty of using EEZ minerals as an emergency source of supply for chromium and manganese. Low-grade, subeconomic chromite and cobalt deposits that occur onshore in the United States also might be considered an emergency source of these strategic materials. No significant occurrences of the platinum-group metals have yet been identified in the EEZ, although onshore deposits are known to exist adjacent to Goodnews Bay in Alaska. In the event of hostilities, reliance on seabed minerals for a secure supply of critical materials, such as cobalt or manganese, would require the protection and defense of at-sea mining activities on the open ocean, and the projection of sea power to protect shipping lanes.

NEEDED: COMMITMENT TO A FEDERAL ACTION PROGRAM

At this time in the evolution of an EEZ exploration program to learn more about the public assets that may lie in the seafloor, what is needed is *more* Government involvement and *more* Government investment rather than less, as some have argued on ideological grounds. Reconnaissance and exploration for EEZ hard minerals is as much the responsibility of the Government today as was the exploration of the western territories in the 1800's, or more recently in outer space. It is improbable that any major private commercial initiatives will be launched to explore the EEZ for its mineral potential, although some commercial interest may focus on certain nearshore shallow-water placer deposits. Exploration costs are immense, results have little market value, and there are no assurances that the value of the knowledge gained by a private firm will be recovered through the exercise of private property rights in the mineral resources it may discover. It is *not* an activity likely to be undertaken in response to market forces. Furthermore, much of the information obtained about seabed minerals through exploration will have academic value and should be made generally available to the public without proprietary restrictions.

Both the Department of the Interior's promulgation of regulations under the authority of the Outer Continental Shelf Lands Act and the legislative proposals for establishing an EEZ hard-minerals mining regime are, in my estimation, premature for several reasons. First, the economic condition of the domestic minerals industry, coupled with chronically depressed world markets for mineral commodities, makes the prospects for development of EEZ minerals remote indeed. Second, too little is known about the nature and extent of the resources and the technologies necessary to recover them to formulate a rational leasing and regulatory regime. Third, the remoteness of likely serious industry initiatives in developing seabed minerals will allow sufficient time for further evaluation of elements of seabed mining legislation to ensure that once formulated, the EEZ seabed mining legislation will provide a sound and fair leasing system for both the industry and the public. Fourth, Federal and State mineral leasing regimes must be developed concurrently and consistently to ensure a degree of uniformity and predictability for mining ventures that span State and Federal waters.

Instead of frittering away time and resources on attempts to formulate EEZ seabed mining legislation and regulations based on inadequate knowledge with little need or demand for such a mining regime, the Congress and the Executive Branch could better direct their efforts to devising and implementing a systematic mineral research, reconnaissance, and exploration program aimed at improving our knowledge about seabed minerals and the environment in which they exist.

While there is little question that either new standalone seabed mining legislation or an additional title amended to the Outer Continental Shelf Lands Act is ultimately needed to encourage exploration and possible minerals development by the private sector in the EEZ, expansion and improvements in the government reconnaissance and exploration programs are *more important* and *more urgent* than mineral leasing legislation at this time.

Credit is due where credit is deserved. The creation of the joint U.S. Geological Survey-National Oceanic and Atmospheric Administration Office for Coordination of Mapping and Research in the EEZ is an exceptional example of interagency cooperation between the Department of the Interior and the Department of Commerce that has the potential for improving the mutual effectiveness and productivity of EEZ programs. The Minerals Management Service's several State-Federal task forces aimed at coordinating EEZ hard minerals activities is another seemingly worthwhile initiative to the extent that task forces foster cooperation between the coastal States and Federal agencies.

Such efforts to coordinate Federal EEZ activities are good as far as they go, but they fall woefully short of providing the comprehensive focus needed to integrate the full range of government activities with those of the States, academic institutions, and the seabed mining industry. With the large number of actors involved in collecting EEZ information (both inside and outside the government), it is important that their efforts be focused and coordinated through a national exploration plan—yet no such planning process currently exists.

Faced with a similar planning and coordination problem in Arctic research, Congress enacted the Arctic Research and Policy Act of 1984. The act established an Interagency Arctic Research Policy Committee composed of the ten key agencies involved in Arctic research. A parallel organization, the Arctic Research Commission, was concurrently established to represent the academic community, State and private interests, and the residents of the Arctic and to advise the Federal Government.

The Federal Interagency Arctic Research Policy Committee and the Arctic Research Commission are charged with developing a 5-year Arctic research plan which includes goals and priorities. Budget requests for funding of Arctic research for each Federal agency under the plan are to be considered by the Office of Management and Budget (OMB) as a single "integrated, coherent, and multi-agency request." The Arctic Research and Policy Act does not authorize additional funding for Arctic research. Each Federal agency designates a portion of its proposed budget for "Arctic research" for the purpose of OMB review.

Congress has opted for a similar solution to coordinate multiagency research activities in acid precipitation. Title VII of the Energy Security Act of 1980 established an Acid Precipitation Task Force, consisting of responsible Federal agencies, national laboratories, and public members. The Task Force was assigned responsibility for developing and managing a 10-year research plan.

Research funds requested by the Federal agencies (comprising each agency's acid precipitation research budgets) are combined annually into a National Acid Precipitation Program that is submitted to OMB as a unit.

Both the Arctic Research and Policy Act and Title VII of the Energy Security Act may serve as prototypes for focusing, planning, budgeting, and coordinating Federal exploration and research activities in the EEZ. Neither act has proved too expensive, nor has either unduly encroached on the economy, jurisdiction, or missions of the individual agencies. Both approaches include participation from the general public and the private sector in developing research plans.

Although long-range plans and broad-based cooperation among those with a stake in EEZ minerals would likely improve the performance of the current research, reconnaissance, and exploration program, an additional long-term commitment of government funds and resources is needed to ensure timely exploration of the EEZ. EEZ mapping activities conducted by the National Oceanic and Atmospheric Administration and the U.S. Geological Survey have received modest but fairly consistent funding in the past. However, geological and geophysical exploration is pathetically underfunded and current programs are well below critical levels. Both mapping and geological exploration are needed to assess seabed minerals resources, and these activities must be brought into parity if a balanced EEZ exploration program is to be realized.

Under the current atmosphere of budget brinksmanship that prevails in the Congress and the White House, the prospects for long-term financial commitments and program continuity is probably a will-o'-the-wisp. But if the pursuit of an effective EEZ exploration program is to amount to anything more than high-flown political rhetoric, substantial commitments to additional government expenditures must come forth.

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Mapping of the Seafloor—Progress and the Plan

Paul M. Wolff
National Oceanic and Atmospheric Administration

Good afternoon. Today I'm going to talk about NOAA's EEZ seafloor mapping program. First, I'll outline NOAA's cooperative efforts with the Department of the Interior (DOI), including the development of an interagency agreement between NOAA and DOI's U.S. Geological Survey (USGS), and the establishment of a joint office to coordinate mapping activities, develop joint products and long-range plans, and conduct workshops and symposia related to EEZ mapping and research. Then I will discuss the bathymetric survey systems and associated hardware now in use and planned for the near future, and plans for operation of the NOAA fleet of research vessels in support of EEZ mapping. Next I will discuss the data archival, processing, and dissemination systems in use and future plans. Finally, I will review the geographic coverage of our mapping activities since the 1983 Proclamation and our plans for the next few years.

Of course, seafloor mapping is only one of several ways NOAA responds to the EEZ Proclamation. Others include:

- Conducting a wide variety of environmental analyses and assessments;
- Producing specialized data atlases and inventories in support of management planning and decision making;
- Conducting or supporting research through the Sea Grant and Undersea Research offices;
- Conducting fisheries research and management programs; and
- Managing and distributing data and information products through the National Geophysical Data Center.

If you care to learn more about NOAA's programs other than mapping, I encourage you to visit the exhibit area where a number of NOAA products and services are displayed. NOAA employees will be there to answer your questions and explain our display.

COOPERATIVE ACTIVITIES WITH THE INTERIOR DEPARTMENT

NOAA's bathymetric mapping program has been coordinated closely with the programs and requirements of DOI for a number of years, starting well before the 1983 EEZ Proclamation. Priorities for new survey and map coverage are developed in conjunction with USGS and the Minerals Management Service (MMS) to support DOI's minerals leasing programs with geologic and hazard assessment information and to support the complementary research and mapping efforts of both DOI and NOAA. This cooperative relationship has continued and become stronger since the EEZ Proclamation.

After a period of interagency planning based on the 1983 EEZ Proclamation, in 1984 NOAA and USGS developed a Memorandum of Understanding establishing the responsibilities of each agency for mapping of the EEZ. USGS works closely with NOAA to establish priorities for EEZ survey coverage, and the two agencies annually review those priorities.

To further facilitate interagency cooperation, USGS and NOAA recently established a joint EEZ program office located here in Reston with the marine offices of USGS. That office coordinates periodic assessments of survey priorities, develops long-range plans, and conducts workshops and symposia such as the program we are participating in today. A primary function of the joint office will be to coordinate USGS and NOAA activities with the needs of other agencies, academia, and the private sector. Also through the medium of the joint office, USGS and NOAA are working on joint product development, to take maximum advantage of the capabilities and equipment of both agencies.

NOAA's SURVEY SYSTEMS AND FLEET OPERATION PLANS

In 1984, after having developed a coordinated program plan in cooperation with USGS, NOAA started the field work needed to systematically map the EEZ from the 150-m-depth contour seaward. The mapping plan developed with USGS combines the capabilities of the two agencies, taking advantage of two types of survey equipment—the GLORIA long-range side-scan system being operated by USGS, and multibeam swath bathymetric survey equipment on NOAA ships.

Since the EEZ Proclamation, GLORIA surveys have been completed for the west coast, east coast, Gulf of Mexico and Caribbean EEZ, and parts of the EEZ off Hawaii and Alaska. The GLORIA system provides excellent images of broad areas, while NOAA's multibeam swath systems provide exceptionally good bathymetric data. The two capabilities, taken together, permit rapid, broad reconnaissance coverage to identify areas of potential interest, and much more precise bathymetry for those areas. Also, by using data from both systems, remarkable topographic depictions of the seafloor can be generated.

Since 1984, NOAA has conducted multibeam bathymetric surveys covering about 40,000 nautical mi^2 of the seabed of the EEZ (of a total area of about 3.4 million nautical mi^2), largely off the west coast and the coast of Hawaii. Most of the surveying has been conducted by using the NOAA ships *Surveyor* and *Davidson*. A multibeam system was added to the *Discoverer* in 1985, but, due to commitments to other projects, the *Discoverer* has only surveyed about 5,000 nautical mi^2 of the EEZ.

Two types of bathymetric survey systems are in use on NOAA ships. The *Davidson*, based in Seattle, is equipped with the Bathymetric Swath Survey System (BSSS), built from the Hydrochart system. BSSS is designed for use in waters of up to 650 m in depth, with a swath width of 2.5 times water depth. However, to conform to IHO standards of accuracy, which call for soundings accurate to within 1 percent of water depth, data are used only from an effective swath width of 1.5 times water depth for most surveys. A new system accurate to about 1,000 m is to be installed on the *Whiting* in September 1988. The *Surveyor* and *Discoverer* are equipped with Sea Beam, a 12-kHz deep-water system with an effective swath width of about 75 percent of the water depth. A third Sea Beam was installed on the *Mt. Mitchell* this year and has recently been certified as operational. The tables below outline general information on NOAA's multibeam ships:

Ship name	Normal survey area	Length (LOA) (in ft)	Multibeam system design depth (in meters)
Discoverer	Pacific, Bering Sea	303	600–11,000
Surveyor	Pacific, Bering Sea	292	600–11,000
Davidson	Pacific	175	150–600
Mt. Mitchell	Atlantic, Gulf of Mexico, Caribbean	231	600–11,000
Whiting	Atlantic, Gulf of Mexico, Caribbean	163	150–1,000

Other equipment on, or soon to be added to, the multibeam ships is shown in the following table:

	Discoverer	*Surveyor*	*Davidson*	*Mt. Mitchell*	*Whiting*
3.5kHz seismic system	×	×		×	
Satellite commun.	×	×		×	
GPS	×	×		×	
CTD system	×	×		×	
XBT system	×	×	×	×	×
SEAS	×	×	×	×	×
Rosette sampler	×	×	×	×	
Gravity meter.		×			

Also important to sounding data quality and usefulness is the accuracy of associated navigation systems. The goal is to achieve better than a 50-m circular error in positioning. All of the NOAA survey fleet is equipped with either Raydist or ARGO, calibrated by Mini-Ranger or by the Global Positioning System (GPS) when available. When GPS is available on an around-the-clock basis, it is expected to become the major navigation system. The use of GPS also will allow operations with more precise navigation farther from shore and in more remote areas of the EEZ.

Projections for operation of NOAA ships for survey coverage over the next 5 years are based on the assumption that about 25,000 nautical mi^2 per year can be mapped if the five NOAA ships equipped with multibeam systems work a total of about 600 days per year on EEZ mapping. It also is assumed that the *Discoverer*, now assigned to operations with the U.S. Navy for about 100 days per year, will be available to NOAA for about 100 days per year of EEZ survey work starting in 1989. If other ships with multibeam systems were available from sources such as the UNOLS fleet, greater coverage would of course be possible.

Before leaving this topic, I would like to point out that NOAA actively seeks to maximize use of its fleet by combining multiple tasks or projects on a single cruise. We regularly support other projects on a not-to-interfere basis as related to the primary mission, including ancillary projects conducted by our ships' personnel, piggyback projects conducted by additional scientific personnel from other agencies and organizations, and cooperative projects with other organizations (often funded partly or fully by the cooperating organization and performed on the basis of availability of NOAA resources). Types of projects which can be performed in conjunction with multibeam surveying include collection of various kinds of data (for example, meteorological, XBT, CTD, magnetic data, or water samples using Nansen or Nisken casts), marine mammal and bird observations, bottom sampling or coring, and others.

DATA MANAGEMENT AND PRODUCT PREPARATION AND DISSEMINATION

All of NOAA's swath mapping systems are set up to acquire data and conduct preliminary data processing in the field, at 1:50,000 scale, with the output being a set of selected, corrected soundings. With Sea Beam, a swath-by-swath contour plot can be produced, although present computer capacity does not allow a large map area of adjoining swaths to be gridded and contoured in the field. BSSS produces a more conventional field sheet with soundings, but no contours. Plans call for upgrade of shipboard computer systems to allow gridding and contouring of entire field sheets in the field. Final gridding and contouring of all data now are done at the EEZ Project Office in Rockville, Maryland.

Present shipboard data acquisition and processing equipment includes the PDP 11/34 and PDP 11/84 computers. Plans call for this equipment to be upgraded to VAX or equivalent in the near future, as funds become available.

After data and reports have been sent to the EEZ Project Office in Rockville, 1:50,000-contour plots are generated from a fixed *x-y* grid using the Universal Transverse Mercator (UTM) projection. Data are processed on a CYBER 170–815 super minicomputer. Peripherals consist of two mass-storage units capable of handling 474 million bytes, five terminals, and one 4125 Tektronix graphic terminal with plotter. Development of a DEC Micro VAX II computer system continues, with the objective of complementing and, if feasible, replacing the CYBER 170–815.

Contours suspected to be anomalies are inspected and compared to associated real-time graphic profiles for authenticity. Data anomalies are identified and removed. When more powerful shipboard computers are available, 1:50,000-scale contouring will be done aboard ship and resolution of anomalies will occur in the field. A processing report is submitted along with contour plots for review and acceptance, and several sheets are merged into a 1:100,000-scale base map produced as both digital and hard copy products. Selected contours from the digital data set are used to prepare depth curves for NOAA's nautical charts.

Development of color-filled bathymetric contour maps and preparation of other specialized products are under way.

The primary data products to be produced from the digital data base of soundings, on a referenced geographical grid, will be survey sheets at 1:50,000 and bathymetric base maps at 1:100,000 scales, high-resolution analog 3.5-kHz records, digital data sets on a fixed geographic grid, selected contours for nautical charts and bathymetric fishing maps, and limited geographical area large-scale maps and three-dimensional views of the seafloor.

Additional specialized products and services could include customized surveys and maps of specific sites and bottom features; special surveys for navigation safety; technical papers and presentations related to the EEZ program, surveying and processing methods, instrumentation, and data interpretation; cooperative investigations and research projects; gridding and contouring programs; customized data bases; and others.

Data archives presently are maintained at the EEZ Project Office in Rockville and include digital archives ("original" raw data tapes and "modified" parameter table and survey summary files) as well as printed copy (electronic control calibration, position plot, selected sounding plot, 3.5-kHz profile analog record, 12.0-kHz center beam record, single swath contour plot, and descriptive report). Data are archived by ½-degree blocks constituting individual 1:100,000-scale map areas. In northern latitudes off Alaska, map size will be adjusted to encompass 1½-degree blocks due to convergence of meridians, but digital data will be archived by ½-degree blocks. Selected data also will be incorporated into the Navigation Information Data Base of the new Automated Nautical Charting System II.

Eventually, as classification is removed, it is intended that raw data be archived at NOAA's National Geophysical Data Center (NGDC) in Boulder, Colorado, to permit users to have access to unprocessed data. In the interim, plans are under way to microfilm original hard copy records, convert digital data to a denser and more compact medium, and develop procedures for optical storage using either the WORM (write once, read many) or CD–ROM (compact disk-read only memory) technology. Procedures are being developed to extract the trackline and centerbeam data to be forwarded to the NGDC and for use in future editions of the GEBCO bathymetric map series.

The final aspect of the data management process will be to adopt an international data exchange format. Survey area locations are being incorporated into the NGDC GEODAS data base so the locations of existing multibeam survey coverage will be known.

GEOGRAPHIC COVERAGE OF NOAA's MAPPING ACTIVITIES

As I mentioned earlier, the EEZ covers about 3.4 million nautical mi^2. So far, since 1984, NOAA has surveyed about 40,000 nautical mi^2 of the EEZ, off the Pacific coast of the contiguous United States, and off the coasts of Alaska and Hawaii.

In the relatively near term, specifically from now through 1992, our program plan calls for mapping of about 25,000 nautical mi^2 per year and assumes that the five

NOAA ships with multibeam equipment will conduct survey operations a total of about 600 days each year. Areas identified for mapping during this period are off the west coast, Alaska, Gulf of Mexico, and east coast. Of course, if additional multibeam-equipped ships become available, the rate of mapping can be increased.

The long-range goal of NOAA's program is to map the entire area of the EEZ from the 150-m-depth contour to the 200-mi limit. Needless to say, the pace of the process will be driven by needs and demands of data users, and at the same time limited by competing demands for NOAA's resources.

Information Needs to Develop Technology to Recover the Mineral Resources of the EEZ

David S. Brown
U.S. Bureau of Mines

The EEZ is one of the last great mining frontiers in the world. Exploration and development is the lifeblood of the mining industry. Its health in the country in large measure will determine the quality of life for the generation and succeeding generations and how safe we will be in an increasingly hostile world. The range of products that come from the crust of the Earth including the EEZ is enormous, and their uses and values are dramatically altered and changing as we move into a high-tech world economy.

The products we extract from the Earth give us the power to sustain and enrich our lives. There are risk and cost associated with finding resources, extracting them and processing them, fabricating them into useful products, and disposing of the wastes. Because of rapidly advancing and changing technologies, we are also experiencing changing material requirements—a dynamic and exciting type of change. We have moved from a metals economy to a materials economy. We are increasingly driven by the design requirements of the manufacturing rather than the availability of resources. It is important that we understand these changes—to meet the information and research requirements that they impose. We need to inventory the mineral values of our public lands including the EEZ with not only the near term in mind but also the long-pull requirements that are going to drive the high technology of the future.

The minerals industry in the United States has gone through depressionlike conditions in recent years and is now hanging on by its fingernails. All of the advantages that the industry has enjoyed over the generation are no longer there. Increasingly we go up against State enterprises, and higher qualities than are those that remain in the country. But the industry is adapting to the global market: the restructuring, the nationalization, the cost cutting are producing results.

The reorganization of the Bureau also responds to the change. The structure is simplified and more streamlined. Program coordination and integration will be better.

The Bureau has had a longstanding interest in offshore mining. We have embarked on major new initiatives, innovative mining and processing techniques. The near-term information needs for development of recovery technologies in the EEZ include physical characterization of ores for mining and the chemical and mineralogical characterization for purposes of improvements in processing. We are gathering detailed information on those sites that appear to have great promise, and we are characterizing crustal samples. We are looking to improve the sampling techniques through use of dredges, chain bags, and other devices. We are evaluating processing techniques to recover cobalt, manganese, and nickel from the crustal deposits. We are encouraged by the work done on onboard flotation separation processing. Our economists have conducted reconnaissance studies of sands and gravels which are showing significant potential for near-term development. We have studied platinum-group metals and gold recovery from Alaskan placers.

The EEZ holds promise but also presents economic and technological hurdles. We plan to continue to work with our sister agencies to supply them with information and research data and to expand our cooperation with the private sector to better understand the technology gaps for the recovery of onshore and offshore minerals.

The Outer Continental Shelf Program: Status, Prospects, and Information Needs

William D. Bettenberg
Minerals Management Service

Good afternoon. I am pleased to be here today to talk about the Minerals Management Service's (MMS's) current activities on the Outer Continental Shelf (OCS) and to discuss our concerns, plans, and goals for future activities and how they relate to our changing information requirements. This symposium provides an opportunity to pause, look ahead, and ask ourselves "where are we now, where do we go from here, and what do we need to know to get there?"

The first step in planning for the future of OCS activities requires an assessment of our current programs. The MMS is responsible for managing the minerals estate of the OCS for the Department of the Interior. This activity includes the geologic, environmental, and economic evaluation and leasing of these mineral resources; regulation of their exploration, development, and production; and management of the revenues obtained from such leases.

Reliable supplies of oil and gas are crucially important to a stable economy and to national security, and the OCS provides and has the potential to continue to provide the United States with significant and dependable quantities of domestic oil and gas. Over time, the OCS will begin to meet a portion of our solid minerals needs as well, including some that are of strategic importance. The OCS contribution to domestic oil and gas reserves has markedly increased from 14 percent of the Nation's available supply in 1960 (or 8.5 BBOE) to 22 percent in 1985 (or 14.0 BBOE). Currently, OCS production accounts for about one-fourth of our country's natural gas production and one-eighth of our oil production. Benefits accrued to the country in terms of revenues from bonuses and royalties paid amount to over $80 billion over the past 35 years. But, our dependence on imported oil and gas continues to grow and impose economic costs. This growing import dependence diminishes our international strategic position. Imports of crude oil and petroleum products alone cost the United States $38 billion in 1986 and currently account for about 44 percent of our national supply. This nearly matches the all time high of 48 percent in 1977.

To help meet future requirements for oil and gas, we developed the Department's 5-year OCS leasing program for mid-1987 through mid-1992. The plan includes 38 lease sales scheduled in 21 of 26 OCS planning areas. We have already held the first of these sales in the Gulf of Mexico and have five scheduled next year in the Gulf of Mexico and north of Alaska. We are also well along in doing the environmental and other work necessary for sales offshore California, the Atlantic coast, and other Alaskan areas scheduled in 1989 and beyond. These sales will lead to exploration examining new areas or using new theories in our continuing quest to inventory the Nation's offshore oil and gas resources in the hopes that the cupboard of previously unexplored areas is not bare.

In order for the Nation to accrue major benefits under the 5-year plan, the MMS relies heavily on the wealth of information gained over the years and which continues to be gained by industry and the Federal Government.

Industry collects and owns vast amounts of proprietary data and information that are used for oil and gas leasing, exploration, and development. We obtain much of this information under prelease geological and geophysical permits and postlease drilling permits. Over the last 30 years, we have acquired nearly 1 million miles of Common Depth Point seismic reflection data for resource assessment and mapping. In addition, we have data on over 25,000 wells drilled in the OCS off the continental United States and Alaska. This amounts to the largest library of seismic and geologic data by far from the total OCS. The information is used in the identification and evaluation of areas having potential for oil, gas, and solid mineral resources, in developing scenarios to assess the potential impacts of exploration and development, and to aid in economic valuation of bids for fair market evaluation purposes.

Current trends in exploration in the Gulf of Mexico have moved to waters of the continental slope and even abyssal depths of the OCS (a legal term defined by the Congress). Conoco, for example, has begun production drilling in the Gulf of Mexico in 1,760 ft of water. At least seven of the blocks receiving bids in this past August's Gulf of Mexico sale were in water approximately 2 mi deep, suggesting new water depth drilling records are in store. Shell has just spudded a well in 7,500 ft of water in the Mississippi Canyon area offshore Louisiana which will set a new world water depth record. The MMS resource evaluation geologists characterize these tracts as containing large unexplored salt dome and ridge structures with complex features such as salt tongue overthrusts visible deep below the seafloor, on seismic lines. These giant structures in very deep water are in one of the few areas of the United States where many giant fields are still expected to be found.

Another area of the OCS with substantial potential is a continuation of the Monterey fractured shale trend northward from the Santa Maria Basin into central and northern California. Just with existing discoveries offshore California, we are in the process of tripling production there within about the next 5 or 6 years. The Atlantic and Alaska OCS remain frontier exploration areas which have had generally poor commercial results so far. However, we remain particularly optimistic about the potential of the Beaufort and Chukchi Seas north of Alaska, both of which will be offered next year. At this point, we have five producible wells discovered in the Beaufort Sea within 28 mi of Pump Station #1 at Prudhoe Bay. With these exploration results and the production start in the Endicott field in State waters last month, the prospect that the Beaufort Sea will play an important future role in helping meet the Nation's oil requirements looks reasonable. These represent the most important areas for information gathering for the current OCS program and likely the next.

Changing trends in information used in both our prelease and postlease activities are evident in results obtained through the MMS Environmental Studies Program. In the early years of the program, OCS environmental studies consisted primarily of baseline, general biological and physical oceanography studies, and regional studies of shallow geologic hazards. Prior to 1984, the MMS spent over $50 million each on baseline studies and on regional shallow hazards work. Since then the program has been restructured towards a more focused investigation of processes that influence oceanographic and biologic systems and issue-oriented topics. For instance, our expenditures for air-quality studies quadrupled in 1986, and we are devoting an increasing share of our resources to discerning the long-term cumulative effects of OCS oil and gas activities since we have been unable to detect much in the way of short-term adverse effects.

Overall, I would have to say that we are comfortable with the information we are obtaining and the combination of private and public sector processes for developing that information to meet our future requirements.

Since the President's Exclusive Economic Zone (EEZ) Proclamation on March 10, 1983, there has been a growing interest by the private sector in OCS mineral resources. In response to this interest, the MMS currently has activities in a number of offshore areas. To date, a total of five joint Federal/State task forces involving nine coastal States have been established to cooperatively study offshore mineral resource potential. These task forces include Hawaii for cobalt-rich manganese crusts, Oregon and California for polymetallic sulfides, Georgia for heavy minerals, North Carolina for phosphorites, and the Gulf of Mexico coastal States for sand and gravel as well as heavy minerals. The MMS is working closely with the States to study the potential for leasing and mining of these marine minerals. Since overspending on the Gorda Ridge project—which is scientifically but not commercially interesting at this time—we have shifted our focus to start these efforts with a close examination of commercial viability before being willing to proceed further.

An offshore hard minerals industry is expected to develop on a gradual, incremental basis, with the more easily accessible and identifiable resources likely to be the first to be developed. On the United States OCS, industry interest is currently focused on sulfur, sand and gravel, heavy-metal placers, and phosphorites. Recently, we have also had private sector geologic and geophysical permittees operating on four discrete areas for four separate sets of minerals. We have a sulfur and salt sale scheduled in the Gulf of Mexico early next year which will be the first OCS solid minerals sale in nearly two decades. Over the next 10–20 years, we can expect that a fledgling ocean mining industry will develop and that only a minute fraction of the EEZ will be developed. This is similar to the pace of onshore mining development, where, over the past several centuries, only a small percentage, less than one quarter of 1 percent, of the land area of the continental United States and Alaska has been mined. In a similar vein, only 1.3 percent of the acreage considered for oil and gas leasing has ever been drilled.

To assure that we wisely manage Federal resources, the MMS marine minerals program is being developed on a case-by-case basis. Using this approach, we hope to ensure that only specific mineral commodities with economic potential and within defined geographic areas are targeted for detailed study. With present recovery technology, most deposits of interest are typically on or close to the surface and are either deposited on the surface, bedded, or placers entrained in bedded material. As such, they are generally easy to characterize and not particularly difficult to find. Commercial viability is an entirely different matter. As a result, the longer term MMS effort will be focused on collecting key mineral resource information from the private sector.

In terms of broad information requirements for the OCS/EEZ, geological and environmental information gathered from oil and gas activities often can be transferred and used in the hard minerals program. This gives us a good base of information on which to build in some areas, but much less in other areas.

Our immediate requirements for site specificity coupled with the anticipated slow pace of development do not indicate a critical need or urgency to understand all or even much of the EEZ thoroughly in the near term. As in the case of onshore mining activities, only a tiny fraction of the U.S. area will need to be studied in depth the next few years. The entire country was not mapped, inventoried, or investigated before mining activities were undertaken or could proceed onshore. Instead, early geological surveys focused on the most promising mineral districts identified by prospectors seeking to make or hold claims. As district-specific basic research into mineral genesis was published, it relied heavily on the results of commercial endeavors, and, in turn, scientific information was used by private industry to expand their search for minerals at their own expense.

Certainly, research and mapping efforts can contribute to our understanding in a way that will lead to the discovery of additional resources both onshore and offshore. Attention, however, should be focused on those areas where development is more likely to occur. Ample lead time should be available to address studies in other areas of the EEZ in the future. This time should be used wisely to scope the research to be done and maximize the information that can be gained, optimizing on the use of scarce ship time and other research resources. Such an approach would maximize the return for the dollars expended. Generally, we should expect industry to lead the way. Our leasing and study interests and efforts should be largely based on a demand/pull approach of industry interest and commercial viability rather than a supply/push effort on the part of government to create an industry-absent commercial interest and viability. This should be a guiding principle in managing the scientific resources that will be used to investigate the EEZ.

In addition, there has been a steady evolution in technology and with it an improvement in the cost-effectiveness of obtaining, characterizing, and understanding the significance of information for use in offshore mineral development. There should be no expectation of a decline in this pattern. As a result, future technological developments should be expected to lead to significant cost reductions in exploration, research, and mapping efforts that can be accomplished when the information is really needed. I would recommend at this stage in the process that research on tools for improving our knowledge in a more cost-effective manner be given more emphasis.

The role of the Federal Government in research and mapping activities on the EEZ must also be addressed in the context of existing fiscal constraints. One place the Federal Government has a clear leadership role is in the preservation of appropriate roles for the private and public sectors. The Federal Government should encourage this fledgling industry but should not get into the business of subsidizing it, either directly or indirectly through massive exploration endeavors. Private companies currently maintain this responsibility for oil and gas, and in this sense, the same should be true for solid minerals. There is a need for understanding environmental and geologic processes of the OCS/EEZ, and the government has a role to play here, but the more appropriate course typically is for companies to finance the necessary exploration and site-specific studies.

Information Needs and Multiple-Use Decisions: An Environmental Perspective

Clifton E. Curtis
The Oceanic Society

It is a privilege to participate, today, in this third Biennial Exclusive Economic Zone (EEZ) Symposium. This Symposium's focus on mapping and research—looking towards the next 10 years—is of special interest to me and to the Oceanic Society. As one of my organization's guiding principles, we seek to promote scientific research, on many fronts, that advances our understanding of oceans and coastal areas, and the complex connections between people, other living creatures, and our surroundings.

Before turning to the specific topic of my presentation, I'd like to provide a broader context for my remarks—my bias, if you will. Today our oceans and coastal areas are threatened as never before. In the United States, and around the world, abuse, mismanagement, and destruction of coastal and marine resources are far too evident. And they are growing. We have seriously damaged some of our coastal waters, where marine life is most plentiful. Much less is known about long-term threats to the deeper oceans, but there are signs of damage there, too. New uses of the ocean—such as seabed mining in the EEZ and beyond, or deep-water oil and gas exploitation in the Arctic—need to be developed to ensure a nondestructive relationship between human and marine life. For such uses, our actions need to be grounded in a perspective of the oceans as a resource requiring respect, caution, and careful management.

While providing this broader context, however, I hasten to add that when I participate in a meeting like this that is dominated by marine scientists, I feel as though I'm "carrying coals to New Castle." You are the ones leading the charge in our efforts to better understand and use wisely our vital marine and coastal resources. Environmentalists, policy makers, and others are absolutely dependent on you to provide information and analyses that will help us make informed, wise decisions about how best to use—or not use—the oceans.

Information needs and multiple-use decisions—these are important, related components of sound marine policy making. Other speakers today, and the workshop discussions to follow, will focus in detail on information needs that are pertinent to a 10-year plan for research and mapping. At the same time, the realities of multiple-use decisions constantly underpin and impinge on all our views as to what information is needed. From my "environmental perspective," I'd like to offer a few brief comments and examples concerning these two components of marine policy making, as well as some suggestions for how these needs and decisions might best be met.

INFORMATION NEEDS

Despite the important discoveries and advances of recent years, in many important respects we are still at the front end of developing technologies for exploration and exploitation of hard-rock minerals in the EEZ and for oil and gas recovery in frontier areas of the EEZ such as the deep-water Arctic. Our intervention by exploitation, and even vigorous exploration, will disrupt the marine environment. Decisions to proceed with those activities must be accompanied by actions that will minimize the environmental risk and provide for suspension of operations where unacceptable harm appears.

As part of the basis for sound decisions, I'd like to list a few examples of information needs that are of special interest to the environmental community—needs that I have grouped in five different categories:

A. Oceanographic/physical information
   1. Nature and magnitude of seafloor currents.
   2. Upwelling systems—how will mining affect these systems and the life they support?
   3. What is the importance of the different kinds of seafloor alteration that will result from mining on coastline evolution?
   4. Ice flow velocity/dynamics.
   5. Effects of seafloor alteration on bottom currents.
   6. What is the role of hydrothermal vents in driving bottom currents and how will mining affect these systems?

B. Mineral/oil and gas resource assessments
   1. Resource assessment/geochemical properties of mineral deposits.

C. Sediment characteristics

1. Studies of seafloor geologic processes—landsliding, turbidity currents, erosion/scour, faulting, and sediment collapse. (The distribution and intensity of the processes are not known and cannot presently be predicted from available regional geological information. These processes, for example, could cause problems for the stability of oil and gas platforms.)
2. Settling characteristics of disturbed bottom sediments.

D. Marine organisms
   1. Ecology of deep-sea environments. (Deep-sea biota need to be identified and scientifically classified. Up to 80 percent of the animals obtained from the few samples recovered have never been seen before. It will be impossible to monitor change in the animal communities without a systematic survey of these populations.)
   2. An assessment of important breeding and nursery areas. What effects would mining/oil and gas recovery/waste disposal have on these areas of the benthic environment?
   3. Potential adverse effects of oil spills on ice-covered areas, and the problems of blowouts or tanker spills in hostile environments.
   4. Recolonization rates of benthic organisms.
   5. Studies of biota—primary and secondary production, life histories, reproductive behavior, limiting factors, feeding habits and habitats (for example, submarine canyons, hydrothermal vents, and seamounts have been shown to be very important deepwater habitats).
   6. Spatial and temporal characteristics of oceanic processes that affect the distribution of living marine resources.

E. Socio-economic factors (Although this is not considered "hard" science for characterizing the seabed of the EEZ, it is an essential component of multiple-use decisions.)
   1. For waste disposal uses, a determination of "need" as part of an objective evaluation of all waste management options.
   2. Effects of coastal staging grounds/support facilities/processing facilities on the social and economic systems of affected coastal communities.
   3. Risk assessment, including both risk estimation and risk acceptability analysis.
   4. State-level/public participation (effective opportunities for early and substantive involvement of the public in the decision making process).

Efforts to address these kinds of information needs will involve the panoply of interests and expertise that resides within the oceans community, at large. It is fairly obvious that DOI and NOAA have a special role to play, especially through such offices as the USGS/NOAA Office of Oceanography and Marine Assessments (OMA), and NOAA's Ocean Minerals and Energy Division. In addition, the academic community/scientific centers of excellence (including Sea Grant-supported institutions), the private sector/industry (such as Deep Sea Ventures), coastal States (including those that have participated in the Federal/State "task forces" established by MMS in relation to seabed mining), and the environmental community (such as the Oceanic Society and Natural Resources Defense Council) can contribute, with their respective strengths and interests, in gathering and (or) making available information that will enable us to better understand the EEZ.

MULTIPLE-USE DECISIONS

Seldom, if ever, do decision makers have the luxury of considering one proposed project or action in isolation. That situation may have existed a decade or two ago, but for any significant activity being considered today, there are a host of conflicting, competing considerations that must be weighed in the balance. Moreover, as we look towards the future, resource use conflicts will continue to increase.

For existing and contemplated EEZ ocean uses, there exists a mix of State, national, and international measures that are required as decisions are made regarding the protection, sustained use, and development of marine and coastal resources. Despite the significant improvement in environmental laws and regulatory requirements since the 1960's, and special mention of the importance of environmental concerns in the President's March 1983 EEZ Proclamation, as a general statement it is still the case that EEZ policies continue to deal with environmental considerations in an ad hoc, fragmented manner.

In a related vein, few opportunities exist for examining the effects of decisions in one marine-related sector on others. Intersectoral considerations are almost nonexistent, and long-range cumulative assessments of multiple activities are impossible.

Having expressed these concerns, however, I do believe that there are two Federal statutes, in particular, that have played an important role (and are likely to play an even more important role in the future) in resolving multiple-use concerns. These statutes are the National Environmental Policy Act (NEPA) and the Coastal Zone Management Act (CZMA).

The NEPA underscores the importance of thoroughly analyzing the environmental consequences of Federal actions, and alternatives, well before a final decision is made. As formulated by the courts over the past 17 years, the purposes to be served by environmental impact statements under NEPA are:

1. To provide the decision makers and the public with environmental information to help them make choices,

2. To allow courts to evaluate agencies' efforts to take into account the environmental values protected by NEPA,
3. To provide information to the public, encourage public participation, and require decision makers to consider public input, and
4. To insure the integrity of the decision-making process.

In order to serve these purposes, an agency must present enough information about its proposed action to allow for balancing of expected benefits versus environmental risks. If done in an adequate fashion, the NEPA process helps engender significant information and analyses underlying sound multiple-use decisions.

The CZMA established an important federal mechanism enabling coastal States to balance national needs for economic growth and resource protection with the demand for energy development, resolve multiple land-use conflicts in coastal areas, and devise protective measures for particularly vulnerable, valuable coastal resources throughout the country.

In this regard, there are numerous examples of multiple-use-related concerns imbedded in State coastal programs. These relate to activities or programs like hazard reduction and safety improvements, ports and waterfronts, fisheries and wildlife, public access, and tourism.

I'd like to briefly highlight three examples of mechanisms that have been used (or that should be used) in order to enhance the likelihood that effective, acceptable multiple-use decisions are made in relation to our EEZ. Each of these examples offers constructive ways to resolve important EEZ-related issues.

Waste Disposal

In July 1987 the Keystone Center in Keystone, Colorado, published a 200-page report titled "A Decisionmaking Process for Evaluating the Use of the Oceans in Hazardous Waste Management." The report was the result of a 2-year "policy dialogue" involving a core group of about 20 individuals who held a series of informal, consensus-oriented meetings.

The group devoted substantial time to developing two decision-making matrices for evaluating the potential use of the ocean: one for scientific-technical factors, the other for the social-economic factors. In important ways, the group felt that these two sets of evaluations should be carried out in parallel, rather than following the traditional approach of doing the scientific-technical work first. The social-economic factors addressed in that report—a "needs" determination, legal/regulatory constraints, cost/benefit analyses, and risk assessments—offer valuable tools for achieving sound multiple-use decisions.

EEZ Seabed Mining

In early 1986, an informal "Working Group" of private individuals from the mining industry, environmental organizations (including the Oceanic Society), and coastal States was created. The main goal of that group was and is to examine the DOI's regulatory efforts for EEZ hard-minerals mining and to assess the statutory framework needed for the mining of hard minerals in the United States EEZ.

These individuals decided to come together because of their belief that negotiations and discussions at the earliest possible stage will result in fewer problems and less confrontations further on down the road. The driving force behind the working group has been the shared view that the Outer Continental Shelf Lands Act is not the proper vehicle for the development of the hard-mineral resources of the EEZ. Because of the statute's emphasis on OCS oil and gas resources, it does not address the very great differences between offshore oil and gas development and hard-mineral mining, does not provide adequate environmental safeguards, nor does it ensure effective public and coastal State participation, or revenue sharing with affected States.

During the past 2 years, the Working Group has found substantial common ground in its views on EEZ hard-minerals mining. The group has documented its agreements, in part, through a ten-point list of consensus concepts which have been presented at congressional hearings. Those concepts include the following:

1. A new, stand-alone EEZ hard-minerals statute separate from the oil and gas regime of the Outer Continental Shelf Lands Act (OCSLA) must precede the issuance of any EEZ hard-minerals regulations;
2. The new statute should govern all mineral deposits on or below the seabed of the EEZ other than oil, gas, sulfur, sand, and gravel;
3. The new statute should apply to all geographic areas covered by the EEZ Proclamation;
4. The mining and environmental provisions and practices of the Deep Seabed Hard Mineral Resources Act should be the point of departure for the new statute;
5. The Federal Government should ensure the early preparation and implementation of a comprehensive and systematic research plan; and
6. The new statute should provide an effective Federal/State/local consultation process based on the consistency provisions of the CZMA, and should provide an equitable system of sharing EEZ hard-mineral revenues with coastal States.

Building on these consensus points, the Working Group has expressed its general support for legislation (H.R. 1260) which Rep. Lowry introduced earlier this year, while offering more detailed comments on recommended improvements to that bill to congressional staffers in recent months. While our group has addressed a number of issues, our top priority has been to stress the importance of developing a comprehensive research program. In this regard, the work product of this symposium can provide invaluable assistance in meeting that objective.

Oil and Gas Exploitation

As those of you involved with oil and gas exploitation well know, each of DOI's 5-year plans for offshore exploration and development has been challenged in the courts. Moreover, the U.S. Congress has established so-called "moratoriums" for some specific sites, prohibiting exploration and development that was otherwise authorized by DOI. A key factor in these judicial challenges and congressional actions has been the differing views as to how to best interpret Section 19 of the OCSLA, which provides for balancing of interests—including national energy, security, environmental, and coastal State interests (especially in relation to "consistency" of proposed Federal activities with those of the coastal States).

In an effort to overcome some of these differences, a special consensus dialogue or dispute resolution group was established to consider oil and gas drilling in certain offshore Alaska areas. Sponsored by the Institute for Resource Management, the group included several oil companies (Sohio, Texaco, and Chevron), Alaskan officials, fishermen, and environmentalists. As a result of their meetings, agreement was reached on what areas should be included, and those areas that should be excluded—including sensitive areas in or near the Bering Sea, such as the Pribiloff Islands and the Aleutian Chain. Unfortunately, the group's agreement was rejected by DOI Secretary Hodel earlier this year, and the jury is still out on whether leasing will occur in a manner that is consistent with the group's recommendations. More broadly, Secretary Hodel's rejection of that agreement puts a damper on similar negotiations for the North Atlantic, for example, that could help avoid the adversarial nature of interest group relationships there.

As each of these examples suggests, in varying ways, conflict-resolution mechanisms such as those I've described, and others, are being used more, rather than less, these days. Interest group differences will always exist, but my motive in choosing these three different, but similar, EEZ-related initiatives is to highlight the important role that nonconfrontational measures can play as we seek to better understand, protect, and wisely use this Nation's EEZ.

CONCLUSION

It is fairly obvious that, in many cases, we are lacking sufficient information to make informed decisions on the wise use of the marine environment. The information needs I listed previously, and others, should be met in order to provide decision makers with the necessary tools to avoid multiple-use conflicts. Towards this end, we can discuss ad infinitum the types and quantities of information that are needed. However, without the political will, the necessary funding to generate the information will not be provided. Perhaps one of the greatest contributions a gathering of marine scientists and other specialists, such as yourselves, can make is to communicate the importance and necessity of this type of research to the public and to the politicians. The Oceanic Society is, in its special way, trying to do this, and we look forward to working with you to achieve this and other objectives that will ensure the protection and wise use of this Nation's EEZ.

The Face of the Deep—Road Maps of Discovery

Dallas L. Peck
U.S. Geological Survey

The first international symposium on Geographic Information Systems is also taking place this week in Washington, and it has important implications for all of us here.

For those of you who are not familiar with Geographic Information Systems—or GIS—this technology at its elemental level is an effort to bring all of us and all of our divergent data together. And from that convergence we will not only be talking to each other, but we will be able to use each other's data to create better, more useful products and solve many complex and vexing earth-science problems.

In the area of marine geology, GIS technology is beginning to make its inevitable, indelible mark improving the way that data is captured, kept, manipulated, used, and reused. All of our GLORIA data are in digital format. We are experimenting with making these data available on compact disks, and distributing these compact disks in cooperation with NOAA.

NOAA is also helping us to develop software to index this massive file of data, and we are working with NASA's Jet Propulsion Lab to develop the software to handle the many manipulations that can be made of this vast data base. We will describe this work in detail Thursday afternoon for those of you that are interested and can stay. Our new continental margin map series is being prepared in a computerized format that allows us to literally create maps inside a computer, that are then ready to be printed. We have a terminal set up in the exhibits area to show you this capability.

The frontier efforts in GIS technology fit in well with the frontier aspects of the marine realm and, more critically, the realm of the U.S. Exclusive Economic Zone (EEZ). We knew from the time of the Proclamation of the EEZ that we had our work cut out for us to map and explore that 3-million nautical mi^2 extension of our national domain.

Setting priorities and getting on with that important task of mapping and research in the EEZ has been an important function of these biennial symposia. And we listen very carefully to what is said in these forums. From the first symposium came two critical recommendations: (1) we tackle the task of mapping the seafloor, and (2) we develop an effective mechanism for cooperation in EEZ mapping and research. And we have done just that. The USGS began its vigorous program to map the seafloor—using the side-scan sonar mapping device GLORIA—based on the recommendation from the first symposium. And this year, we have formed a joint office with NOAA to coordinate mapping and research in the EEZ—again a recommendation from the first symposium that we provide a means to coordinate Federal efforts in this area.

We plan on listening carefully again during this symposium—to hear your views and plans for where we go from here. The most important outcome from this symposium will be the framework for a 10-year plan for seabed and subsoil mapping and research in the EEZ. Together, I think we can develop that plan. And together, we can all benefit.

We have made exciting and stunning progress in discovering the face of the deep and in providing the first road maps that will point the way to the structures, resources, and dynamics of this great frontier. I'd like to highlight for you our accomplishments in mapping the EEZ. When we began the GLORIA mapping effort 4 years ago, we were facing a task of mapping—and discovering the resource secrets—of the unseen seafloor of more than 3-million nautical mi^2 of unknown territory—a third larger than the land area of the United States (see figure). The long-range side-scan sonar system, GLORIA, developed by the British Institute of Oceanographic Sciences, was selected as the mapping tool. The system is able to map a swath of seafloor 37 mi wide and can cover an area the size of New Jersey in a single day under optimum conditions.

We began our GLORIA mapping effort in the late spring of 1984 on the west coast—completing 250,000 mi^2 of sonar mapping by 1984. The atlas for the west coast, the first of the series, was printed in 1986 and showed us many surprising pictures of the seafloor. Dozens of previously unmapped volcanoes, many with well-formed craters, were discovered. We also accurately identified previously unmapped major faults, some on the order of 50 mi long. Giant submarine landslides and submarine channels that look like rivers hundreds of miles long crossing the seafloor were also identified. Cascadia Channel can be traced winding its way across the seafloor for over 350 mi from the

EXCLUSIVE ECONOMIC ZONE

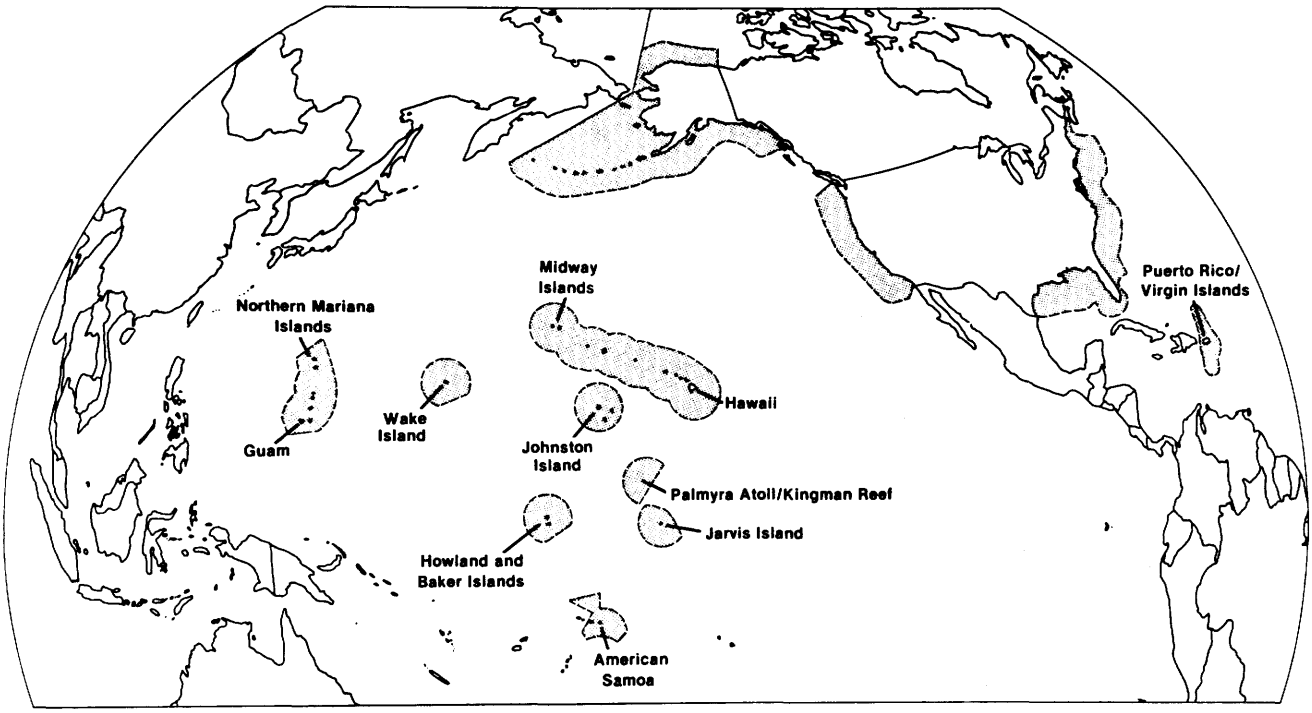

Photo credit: U.S. GEOLOGICAL SURVEY

coast of Washington, through the Blanco Fracture zone, and on to the west, outside the EEZ.

Our side-scan sonar mapping program is providing the regional perspective of the Juan de Fuca Ridge, to assess not only the geology but also the resource potential of the ridge and of the EEZ in general. We focused our research on the southern Juan de Fuca Ridge, looking at the submarine volcanic hot springs associated with the ridge's spreading center, where newly forming metallic sulfide deposits contain anomalously high quantities of copper, zinc, silver, and to a lesser extent, gold, iron, cadmium, and germanium. The hydrothermal vents that occur along the floor of such actively spreading ridge crests as the Juan de Fuca are an exciting resource frontier—where new mineral deposits are continually being formed. We are really just beginning to explore how many sulfide vents and determining how many mineral deposits exist along the 25,000 mi of the worldwide network of ocean spreading centers. This summer our geologists returned to a vast field on the Juan de Fuca Ridge and observed measurable growth on some sulfide chimneys.

With the completion of the west coast mapping, we moved on to the Gulf of Mexico and in 8 short weeks—and despite the winds and rains of two hurricanes—we mapped 150,000 mi^2. The atlas of the Gulf of Mexico was just released to the public 2 weeks ago. One of the most stunning features from the collection of mosaics from the western gulf is that of the Sigsbee Escarpment, the seaward edge of the salt-deformation province. The piles of debris that can be seen along the base of the Sigsbee Escarpment suggest that it is actively being eroded, in response to uplift of the sediments by salt intrusion. The extensively deformed continental slope in the northern Gulf of Mexico is an important deepwater frontier for oil and gas resources.

The dominant feature in the central Gulf of Mexico is the Mississippi Fan, constructed by sediments from the Mississippi River. In nearly 10,000 ft of water, we can trace the submarine channel that is the conduit for fan meandering over 250 mi across the seafloor. Evidence of dynamic debris-flow events transporting slurries of sediments vast distances are also obvious. The fan of the Mississippi is a modern analog as we develop oil and gas fields in ancient fans.

During the fall of 1985, we completed a survey of nearly 30,000 mi^2 of the EEZ territory off Puerto Rico and the U.S. Virgin Islands—bringing our total mapped miles of the EEZ to a little over 430,000 mi^2. The Puerto Rico Trench, the deepest point in the Atlantic Ocean, with a depth of over 24,000 ft, is within the EEZ. The north wall of the trench is broken into ridges and scarps, which may be caused by fracturing of the North American plate as it is bent going into the trench.

During a 4-month cruise in the spring of 1986, we completed 160,000 mi^2 of EEZ off the east coast from Maine to Florida. We found that from Cape Hatteras to Long Island, the continental margin is cut by several large submarine canyons and channels that cross the EEZ for over 100 mi. A vast dendritic pattern of canyons seaward of New Jersey merges on the continental rise to form a single large channel that extends across the EEZ. We thought that we already knew a lot about the Blake Plateau, but our sonar mapping showed us many new things. The seaward edge of the Blake Plateau is marked by an escarpment with over 12,000 ft of relief, which has been curved by ocean currents, aided by biological and chemical erosion. Cretaceous-age limestones crop out at the seafloor, forming the vertical escarpment. This limestone is part of the continuous reef trend that extends all the way from Mexico around the gulf coast and up the Eastern Seaboard, exposed here at the seafloor, but buried north of Cape Hatteras.

After 112 icy days in the Bering Sea, we had completed mapping of the EEZ around Alaska and north of the Aleutian Islands. Here we found that some of the largest submarine canyons in the world incise the continental margin of the Bering Sea. The Bering Canyon was found to have a channel that extends over 350 mi onto the abyssal plain on the floor of the Bering Sea. The submarine fan associated with Bering Canyon is believed now to be formed by sheet flow rather than channelized flow, which spreads sediments over a large region of the floor of the Bering Sea. The submarine fan of Bering Canyon has a different style of sediment distribution than the Mississippi Fan that we saw earlier.

The mapping effort around the Hawaiian Islands during 1987 added another 75,000 mi^2 to our growing total. Hawaii, too, had its share of surprises. We discovered two areas west of Hawaii with the thickest ferromanganese crusts ever reported—5 and 6 in thick. We found fluid lava flows covering over 400 mi^2 of seafloor, which confirms our supposed correlation between summit caldera filling and collapse with voluminous outpouring of lava on the adjacent seafloor. The side-scan images allow us to study the subaerial and submarine portion of the islands as a whole.

In just a little over 500 days at sea, the USGS mapped over 1 million nautical mi^2 of the seafloor of the EEZ—this represents about one-third of the total area of the U.S. EEZ. By 1991, with our present schedule, we will have GLORIA coverage in the EEZ around all 50 States.

The work accomplished thus far has been impressive. But there is more yet to be done. We will soon begin the verification studies, using the basic road maps of the EEZ that GLORIA provides to understand the mechanisms and the rates at which sediments are transported through submarine channels far from land. We will also be studying mineralization processes on the seafloor to learn more about how and where mineral resources are formed. From the GLORIA data, as presented in the atlas volumes that are being prepared for each region, and from the followup studies of that data, we will be able to provide other Federal and State agencies, as well as industry and the academic communities, with the information that they will need to move from the regional reconnaissance perspective of the GLORIA road maps to site-specific studies of areas of the EEZ.

The work that is being carried out now in the EEZ in the Federal Government, by private industry, and by State agencies and universities represents a massive effort that is of paramount importance to our Nation. Much as Lewis and Clark mapped and set the forces in motion for development of the West more than 180 years ago, the EEZ, which remains as the last terrestrial resource frontier, is being mapped, and the forces are now being set in motion for its development from the work in which we are all now engaged.

As I mentioned earlier, one of the important tasks that will be carried out during this symposium is the guidance by which we will reshape and direct our program in the EEZ for the next 10 years. Tomorrow's workshops will be the forum in which that guidance is provided. I am looking forward to those sessions, both as Director of the USGS and as a scientist who understands the value of our joint exploration of the EEZ.

I would like to thank our keynote speaker, Dr. Baker of the Joint Oceanographic Institutions, for his presentation today; and also to thank Steve Griles and Jim Ziglar from the Department of the Interior for their participation as well. And, of course, a special thank you to the Survey's co-sponsors for this symposium, the U.S. Bureau of Mines, the Minerals Management Service, and NOAA.

The EEZ Proclamation opened up the frontier of the EEZ for discovery. It also opened up new opportunities for cooperative exchange among the various agencies involved in the exploration of the EEZ. The presence of our speakers here this afternoon and the prestigious list of participants in our workshops tomorrow and on Thursday all point to the importance in which we hold the promises of the EEZ and the importance of our cooperation in unlocking the resource treasures of this, our Nation's last, great frontier.

Workshop 1: Scientific Mapping and Research to Characterize the EEZ—Alaska

Panel Co-chairpersons:
Michael S. Marlow, U.S. Geological Survey
Douglas A. Wolfe, National Oceanic and Atmospheric Administration

INTRODUCTION

The Alaskan Exclusive Economic Zone (EEZ) has an enormous area of approximately 4.8×10^6 km^2, or about 60 percent of the total EEZ area that is associated with the contiguous United States and Alaska. The Alaskan EEZ is composed of diverse geologic elements and supports a rich and productive assemblage of biological resources. For purposes of mapping in the U.S. Geological Survey (USGS) Continental Margin Map Series (Peck and Hill, 1986), the Alaskan EEZ is divided into 8 areas (of the 20 for the entire United States, including Hawaii). The Minerals Management Service (MMS) has further divided these areas into a current total of 14 planning areas for exploration and potential development of oil and gas reserves on the Alaskan Outer Continental Shelf (OCS) (fig. 1). For this presentation, however, the offshore Alaskan EEZ will be discussed as three regions: the Gulf of Alaska and Aleutian Island Arc, the Bering Sea, and the Arctic region north of the Bering Strait. The tectonic elements of these regions are diverse, ranging from the actively subducting margin in the western Gulf of Alaska and the eastern and central Aleutian Arc, through the actively transforming margins of the eastern Gulf of Alaska and western Aleutian Arc, to the formerly active margin of the Bering Sea as well as the rifted and totally passive Arctic margin.

A large number of major sedimentary basins occur within the Alaskan EEZ (fig. 2). In the Bering Sea the EEZ extends to the 1867 U.S.-U.S.S.R. Convention Line and includes the deepwater Aleutian and Bowers Basins.

The purposes of this report are:

1. To outline scientific objectives for characterizing and evaluating the mineral, energy, and other nonliving resources of the seabed and subsoil of the Alaskan EEZ and for understanding the geological framework and processes in which and by which those resources are formed and
2. To identify the consequent research and mapping activities needed to support effective development and use of those resources.

Although the research program developed in this report focuses primarily on nonliving resources, it is recognized that any eventual development of those resources must be carried out in an environmentally sound manner, with due regard for resource-use conflicts that may arise, for example, with interests such as transportation, commercial and subsistence fisheries, or threatened and endangered species. These concerns are being addressed by the Information Needs for Seafloor-Seabed Utilization Panel (Silva and others, this volume) and will not be discussed here.

This report presents a brief introduction to the diverse environmental characteristics and major geological and structural features within each Alaskan region. Existing programs and data coverage in each area are discussed relative to the outstanding problems and needs in each region. Programs are then outlined and recommended for acquiring and managing additional information needed for effective exploration of the Alaskan EEZ.

AREA DESCRIPTIONS

The Gulf of Alaska and Aleutian Island Arc

The Gulf of Alaska region is geologically very dynamic. Located at the juncture of the North American and subducting Pacific crystal plates, the region exhibits a large amount of seismotectonic activity, manifested by ground shaking, tsunamis, and submarine slumping. The Gulf of Alaska is bounded by the south coast of Alaska, which is arcuate and extends for hundreds of kilometers, from the Alaska panhandle on the east side of the Gulf to the Alaska Peninsula on the west. To the west of the Alaska Peninsula, the North Pacific Ocean is bounded by the Aleutian Arc. Altogether this EEZ area is about 2.2×10^6 km^2. This coastline is the most complex in the State and contains a large variety of geomorphological features, dominated by the presence of rugged mountains. Many of the volcanic mountains in the Alaska and Aleutian ranges are active and have erupted in historical times, including Augustine in lower Cook Inlet, Katmai at the base of the Alaska Peninsula, and Pavlof on the southwest end of the peninsula.

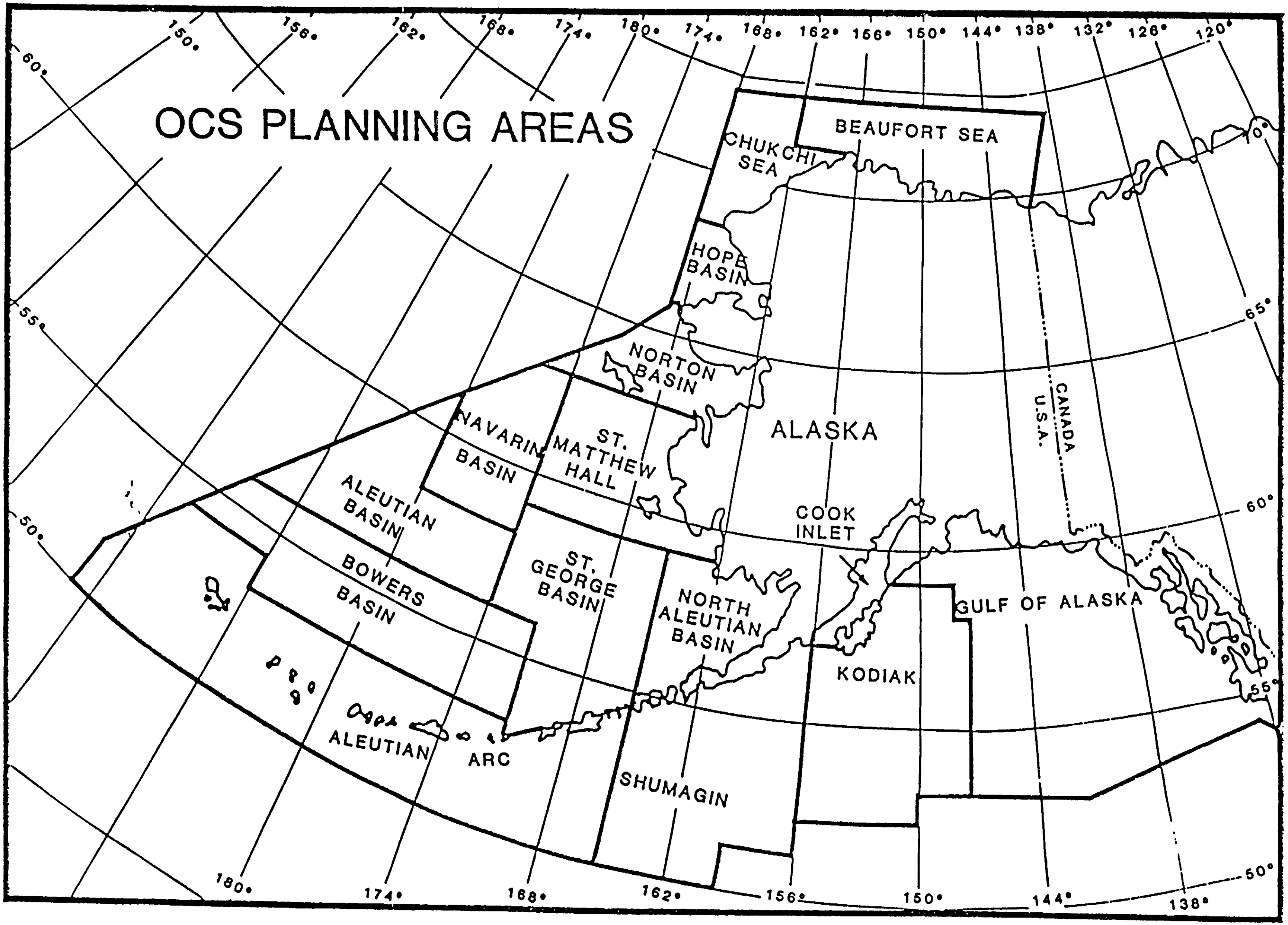

Figure 1. Planning areas under consideration by the U.S. Minerals Management Service for potential oil and gas development on the Outer Continental Shelf of Alaska.

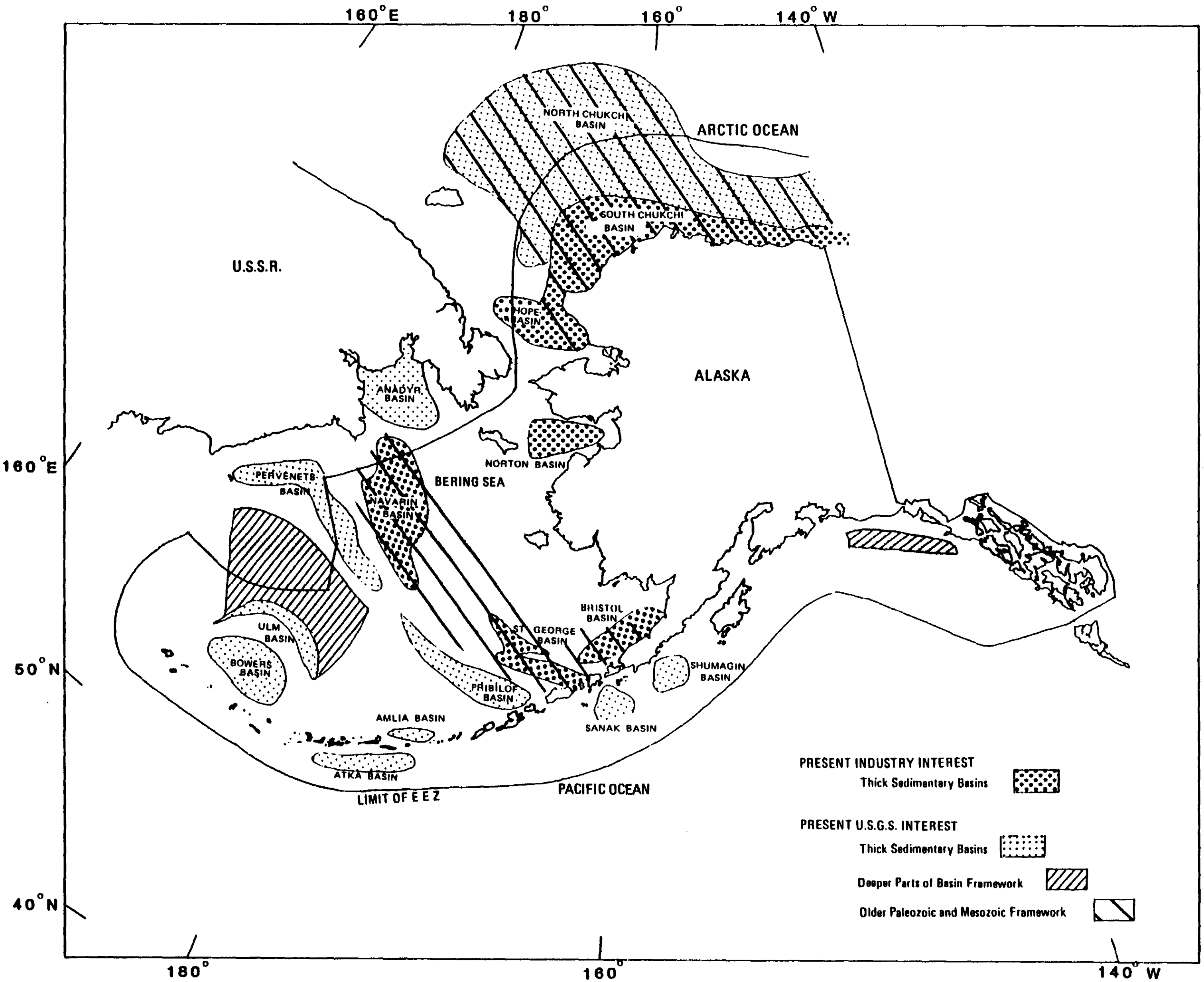

Figure 2. Locations of major basins within the EEZ of Alaska and adjacent areas (modified from Klitgord and Watkins, 1984).

Coastal plains are few in the Gulf of Alaska region. The only flatlands of any significant extent occur on the east side of Cook Inlet and between Dry Bay and Yakutat. The coastal segment extending from Cross Sound in southeastern Alaska westward to Prince William Sound is typified by unprotected shorelines and has only three embayments of consequence: Lituya, Yakutat, and Icy Bays. Prince William Sound is in essence an inland sea, being a complex of islands and fjords relatively sheltered from the open gulf. The rocky coastlines of the Kenai Peninsula and Kodiak Archipelago are indented by numerous fjords and embayments. Cook Inlet is a large, shallow estuary, some 250 km long and from 25 to 100 km wide. The south coast of the Alaska Peninsula is steep and rugged. Bays are numerous along the peninsula, as are islands along its western half.

The continental shelf in the Gulf of Alaska is narrow in comparison to the shelf in the Bering and Chukchi Seas. Some 100 km wide in the vicinity of the Fairweather Ground south of Yakutat, the shelf narrows to about 10 km off Bering Glacier, then widens to about 150 km in the vicinity of Kodiak before progressively decreasing in width toward the tip of the Alaska Peninsula. The shelf is dissected by numerous sea valleys and troughs, a number of which appear to be glacial in origin. Major topographic highs include the Fairweather Ground southeast of Yakutat, Portlock and Albatross banks off Kodiak Island, and emergent features such as Middleton Island in the northern gulf and the many islands in the western gulf.

The climate in the Gulf of Alaska is maritime, characterized by heavy precipitation, cool summers, and relatively warm winters. Due to the mild climate prevalent in the outer Gulf of Alaska, sea ice does not form in winter. However, the more rigorous climatic conditions and shallow water in parts of Cook Inlet promote ice formation, typically north of the Forelands and along the west side of the inlet, for about 2 months during the winter. Much of the snowfall deposited on the mountains along the Gulf coast feeds icefields, piedmont glaciers, and valley glaciers. Many glaciers and icefields extend to near the coast and some enter tidewater and are localized sources of icebergs, for example in Icy Bay and near Columbia Glacier in Prince William Sound.

Major storms are commonplace in the Gulf of Alaska. They are most intense in winter, when the storm tracks frequently lie along and south of the Aleutian Islands and Alaska Peninsula. Storms generally move eastward through the region and stagnate in the eastern gulf. In late summer and fall, by contrast, many storms move into the Bering Sea. High coastal winds also occur as episodic, katabatic events, flowing downward through mountain passes and river valleys and sometimes extending 30 km offshore. They are commonplace at the Copper River Delta and Dry Bay in the eastern gulf and near Cape Douglas on the west side of Cook Inlet.

Streams associated with the coastal mountains are mainly short and often of the glacial outwash type: typically of steep gradient, braided, and carrying high sediment loads. Only the Alsek and Copper Rivers penetrate through the coastal mountains from the interior and enter the Gulf of Alaska. Coastal waters turbid with glacial rock flour prevail in the eastern gulf westward to Prince William Sound, and in much of Cook Inlet. Elsewhere in the gulf the waters are relatively free of sediment. Tides in the gulf of Alaska are mixed, predominantly semidiurnal, with amplitudes averaging 3 to 5 m but attaining as much as 10 m at the head of Cook Inlet.

The Gulf of Alaska is rich in biotic resources. Diverse fish communities and marine mammals such as sea otters and harbor seals are associated with widespread kelp beds. Salmon, crab, herring, and halibut form the basis for domestic fisheries in the region, while foreign fisheries target on ground fish. Coastal and shelf waters also support large populations of birds and marine mammals.

Major goals of geologic studies in the Gulf of Alaska have included detailed investigation into the tectonic processes and geologic history of both convergent and transform margins or the transition between these margin types. Past research in the gulf has focused on the regional geologic framework, the processes active in subduction zones, and hydrocarbon generation along transform and convergent margins. In the western half of the Gulf of Alaska (west of 148°W.) no exploratory wells have been drilled for petroleum. Development of possible hydrocarbon resources may be adversely affected by the high seismicity of the margin beneath the gulf. The allochthonous Yakutat block is colliding with the continent below the eastern Gulf of Alaska, and investigations are continuing into the processes within this collision zone and into the structural transition that connects the collision zone with the adjacent subduction zone. Marine geologic and geophysical data show the structure of the Yakutat block, and in the future, these data may suggest the location boundaries of other tectonostratigraphic terranes.

To the west of the Gulf of Alaska, the Aleutian Ridge forms much of the northern rim of the Pacific Ocean. The island-crested ridge extends roughly 2,200 km westward from the tip of the Alaska Peninsula to near Kamchatka, 1,700 km of this length being part of the United States EEZ (fig. 3). The ridge, which divides the Pacific Basin from the Bering Sea Basin, defines an areal expanse of the EEZ of about 800 km $\times$ 1,700 km, or 1.4×10^6 km^2 (400,000 nautical mi^2). Geomorphically the ridge averages 160 km in width, and the ridge relief is a spectacular 9,300 m, measured from the floor of the Aleutian Trench at 7,300 m below sea level to the volcanic summits of Umnak Island.

The vast bulk and diverse geomorphic form of the Aleutian Ridge record important North Pacific tectonic events and crust-forming processes. Volumetrically large masses of sedimentary deposits have accumulated over the

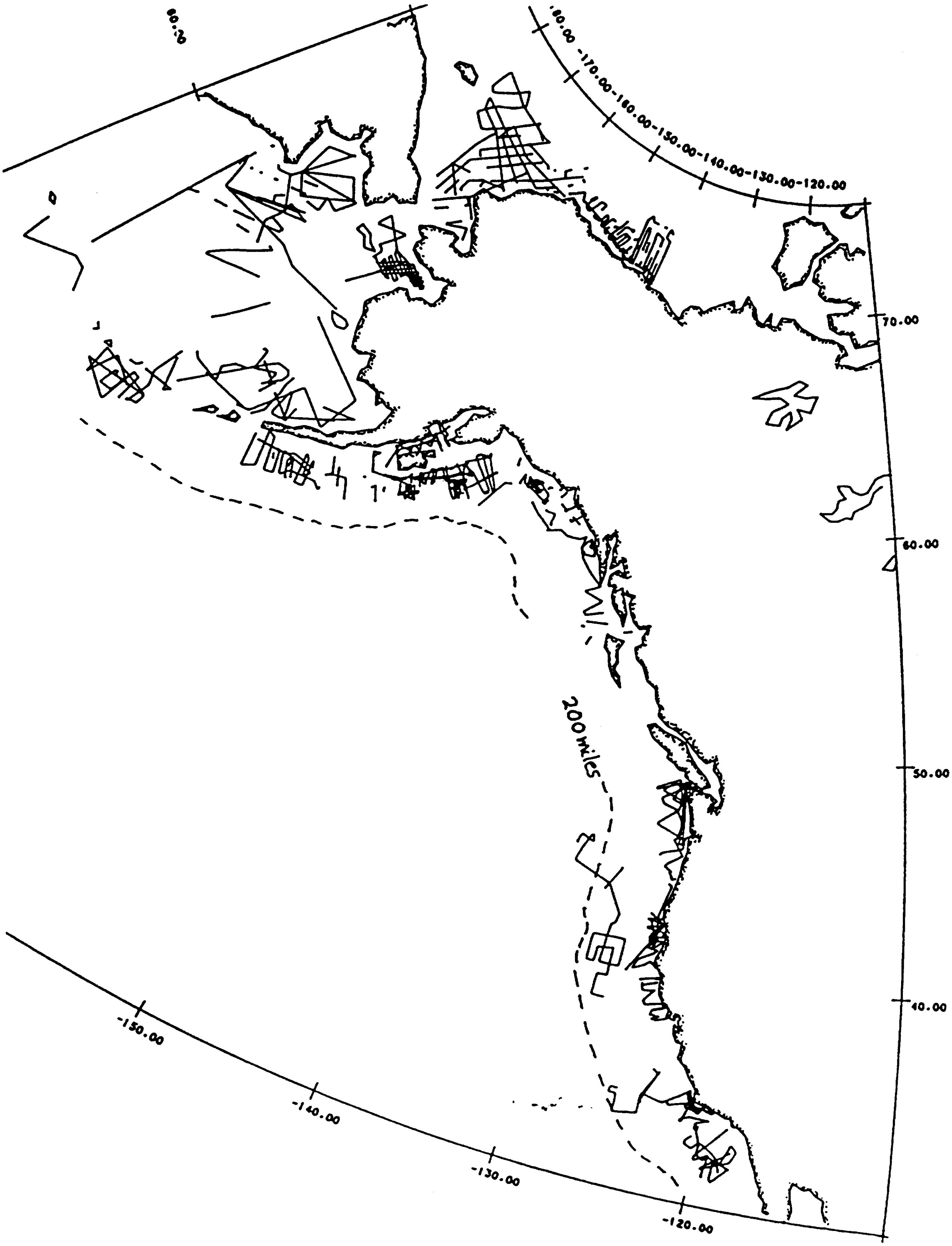

Figure 3. Tracklines for existing geophysical information available from the U.S. Geological Survey for the west coast of North America and Alaska.

submerged flanks of the ridge and in crestal or summit basins. However, only a limited amount of reconnaissance seismic reflection data are available to study these deposits and their resource potential. The combined line-mileage of multichannel seismic reflection (MCS) profiles collected over the Aleutian Ridge is roughly 3,000 km. Eighty-five percent of these tracks are confined to the ridge's 300-km-long Adak-Amlia sector (172°–176°W. long; fig. 4). Single-channel reflection profiles are also mostly confined to this ridge sector, as are samples of submerged outcrops. Thus, for the remaining 1,400 km of ridge length, only 400 km of MCS data and a few hundred pounds of rocks are available for study. Owing to this paucity of research-quality MCS and other related geophysical data, and offshore rock samples, the geologic history of the Aleutian Ridge is poorly known and the resource potential of the Aleutian Island Arc region is, accordingly, even less understood.

Bering Sea

The eastern Bering Sea, with about 2×10^6 km^2 of EEZ area, borders the western coast of Alaska and extends approximately 1,500 km from the Aleutian Islands to the Bering Strait. Seasonal contrasts are extreme: during winter over half of the sea surface is covered with ice; during summer, sea surface temperatures may become almost temperate, exceeding 16°C in the eastern portion of Norton Sound.

The strong westward flow of the Alaska Stream provides the waters that penetrate into the Bering Sea through deep passes in the Aleutian Islands. In the eastern part of the sea, three fronts (regions of enhanced horizontal gradients of properties) separate the water overlying the shelf into distinguishable domains with distinctive hydrographic and stratification properties. Shelf circulation is generally sluggish and characterized by the presence of nonstationary eddies.

Advances and retreats of the ice edge are correlated with fluctuations in sea and air temperatures, surface winds, and regional meteorological events. Ice formation usually begins in mid-October and may persist in some areas through June, although the retreat of the ice edge begins in April. In extreme years ice may extend as far south as Unimak Island; generally the southern limit is from northern Bristol Bay to the vicinity of St. George Island in the Pribilof Islands.

The continental shelf in the eastern Bering Sea is very broad, extending over 640 km offshore in the northeastern sector. More than 44 percent of the Bering Sea is covered by the shelf, with the 200-m isobath approximately dividing the sea in half. This extensive shelf area supports high abundances of commercially valuable fish and shellfish and large populations of marine mammals and seabirds.

North of Bristol Bay the coastline flattens out into the broad, deltaic lowlands of the Yukon and Kuskokwim Rivers. Here, intertidal areas are often wide and storm surges extend as far as 40 km inland. Although this section of the Bering Sea is dominated by the sediment-laden waters of the Yukon and Kuskokwim Rivers, so-called clearwater areas occur between the major distributaries. The clearwater areas have recently been pinpointed as being among the most biologically productive areas in the central portion of the eastern Bering Sea coast.

Norton Sound, in the northeastern Bering Sea, is a rather isolated body of water; its hydrography and circulation are dominated by local wind and atmospheric patterns. Recent evidence indicates that the outer part of Norton Sound is distinguishable from the inner by persistent oceanographic features. The water of the outer sound is dominated by a northerly flow between the sound and St. Lawrence Island. Nearshore regions of Norton Sound are subjected to regular scouring by seasonal ice.

The eastern Bering Sea supports a rich and diverse biota. The bulk of the commercial fishery resources, principally king crab, snow crab, and salmon, occurs in the southern portion of the region. Nineteen species of cetaceans and eight species of pinnipeds occur in the eastern Bering Sea. The Pribilof Islands are the primary breeding ground for most of the world population of northern fur seals, while the northern Bering Sea and southern Chukchi Sea are the feeding grounds for about 95 percent of the world population of gray whales. Several species of seals and walrus are commonly associated with sea ice and depend upon it as a substrate for their breeding and molting. Bowhead and beluga whales also winter along the ice edge or in ice-infested areas. In addition, the bird populations in the eastern Bering Sea compose one of the richest avian faunas on Earth. These birds depend upon the exceptionally high productivity of the Bering Sea waters for maintenance of their dense populations.

The Beringian continental margin extends about 1,500 km northwest from the Alaska Peninsula to the U.S.S.R. (fig. 2). The outer part of the margin is underlain by a series of linear basement ridges and extensional sedimentary basins, which contain up to 15 km of Cenozoic and possibly late Mesozoic strata. Oceanic crust of Cretaceous age and 3 to 10 km of overlying Cenozoic sedimentary rocks are believed to lie beneath the Aleutian Basin, adjacent to the margin.

The assessment of the resource potential of the Beringian margin is predicated on the understanding of the geologic processes that formed hydrocarbons and other minerals along the margin. Possible commodities on the margin and Bering shelf include oil and gas, heavy metals such as platinum and gold, and sand and gravel. Many other minerals may exist offshore, but they await exploration and discovery. Appraisal of the resource potential of the margin requires interdisciplinary studies of terrane accretion, basin

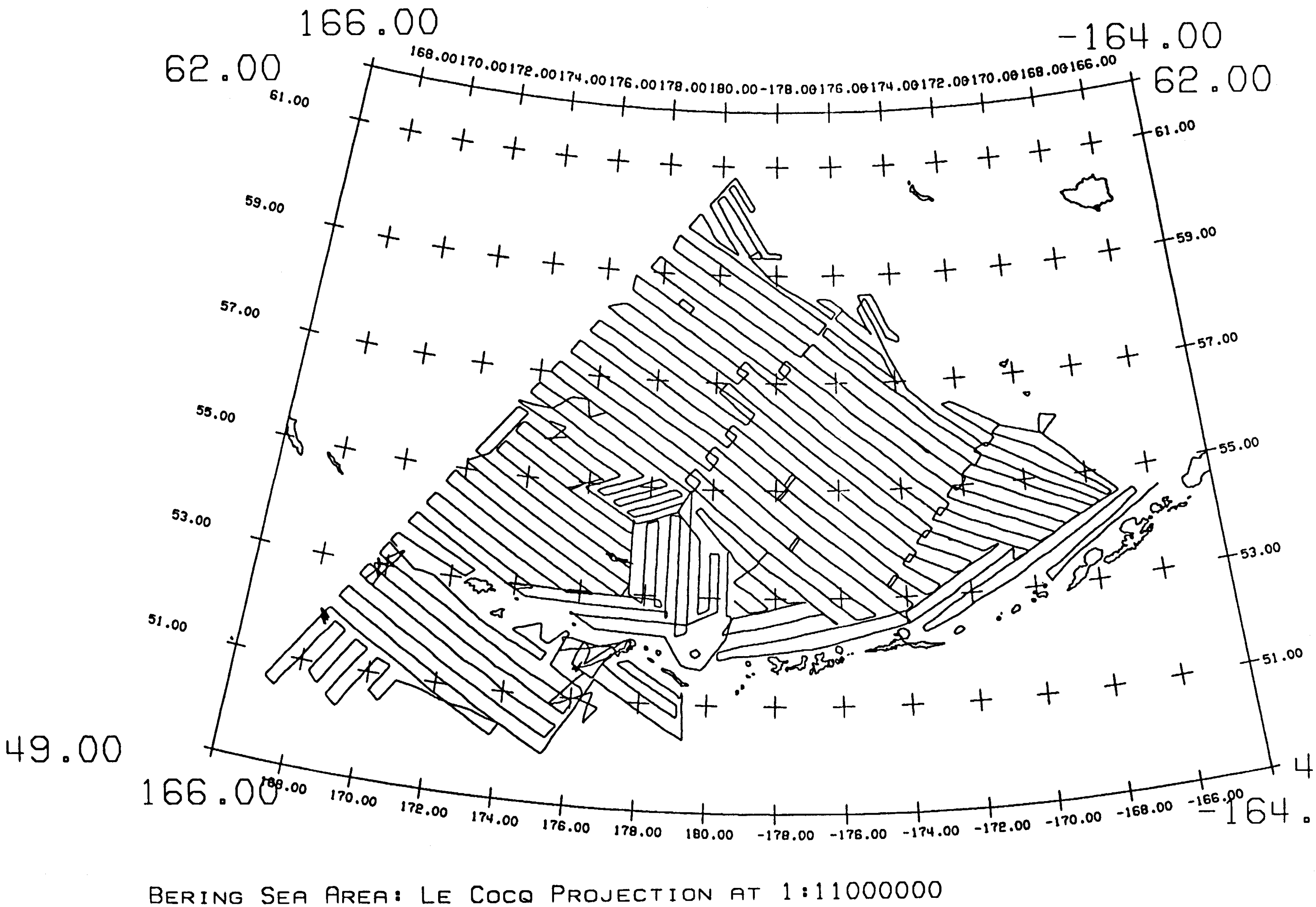

Figure 4. Tracklines for GLORIA data in the deep portion of the Bering Sea.

formation, deep crustal structure, and margin collapse to assess the tectonic history of this portion of western North America. The deepwater region beyond the margin (the Aleutian Basin) is unexplored with respect to resource potential. Only reconnaissance single-channel seismic reflection and GLORIA surveys have systematically covered the basin, except for a couple of widely spaced multichannel seismic reflection lines.

Arctic

The American sector of the Arctic Ocean extends from the Bering Strait (66°N., 168°W.) to Demarcation Bay (69°N., 141°W.). This region of the EEZ, about 660×10^3 km^2 in area, comprises portions of the Chukchi and Beaufort Seas and is bounded by over 1,000 km of coastline.

The Chukchi Sea is a shallow marine basin with water depths of less than 100 m extending several hundred kilometers offshore. Its circulation is influenced by ocean currents flowing predominantly northward and carrying relatively warm Alaskan coastal water into the region. These northward coastal currents combine with a westward drift along the southern margin of the Arctic ice pack to establish a broad counterclockwise summer circulation in the Chukchi Sea.

The Beaufort Sea has a relatively narrow continental shelf extending 50 to 100 km offshore. The adjoining Canada abyssal plain is more than 3,000 m deep. Circulation patterns in the Beaufort Sea are generally dominated by the circulation patterns of the Arctic Ocean. Ocean currents flow westward between Mackenzie Bay and Point Barrow under the influence of the clockwise Arctic gyre. These waters are generally colder than those in the Chukchi Sea, although recent studies have indicated that a narrow band of warm, brackish water flows along the coast with the prevailing westward currents. This band is usually 1 to 4 km wide and periodically attains temperatures up to 10° to 12°C, as compared to offshore water temperatures of well below 5°C.

In both the Beaufort and Chukchi Seas lunar tides are very small, reaching a maximum of 1.3 m at Kotzebue. Wave heights and storm surges pose more severe hazards in the Chukchi than in the Beaufort Sea, primarily due to the longer reaches of open water in summer and fall.

The Beaufort Sea coast is predominantly low-lying wetland tundra dotted by numerous thaw lakes. Offshore islands determine the nature of much of the nearshore physical and biological environment along the Beaufort coast. These islands effectively moderate the influence of polar pack ice where they occur, and in the few weeks of summer, partially separate the cold, saline waters of the open Beaufort from the warmer, brackish waters near shore. Some of these islands are true barrier islands, bounding shallow lagoons (for example, Jones Islands and Simpson Lagoon), while others lie farther offshore, with deeper waters between them and the mainland (for example, Narwhal Island and Stefansson Sound). The islands themselves, and the mainland coast, where unprotected by these islands, are subject to considerable erosion by wave action.

The coast of the Chukchi Sea is more complex than the Beaufort coast. It has sections of higher relief, such as dry tundra meeting the sea at a bluff, and occasional cliff faces, as at Skull Cliffs and Cape Lisburne. In these bluff and cliff face regions there are no barrier or other offshore islands. Elsewhere, however, extensive lagoon and semi-protected embayment systems exist in association with islands, spits, and bars.

Ice dominates the entire Arctic OCS area. Sea ice cover is close to 100 percent for 9 to 10 months each year and freezes up to 2.4 m thick in one season. Multiyear ice, up to 4 m thick, and icebergs with drafts of as much as 50 m are present. Landfast ice forms during the winter, extending from less than 1 km to as much as 50 km offshore. The ice pack moving westward past the Alaskan coast shears against the landfast ice, forming an extensive pressure ridge system. Pressure ridges and hummocks may exceed 10 m in height and are matched on the underside by ice keels several tens of meters deep. The sea floor of the continental shelf is scoured by dragging ice keels that form deep gouges. Ice gouges of indeterminate age have been found as far out as the 50-m isobath, though they are more numerous in shallower waters, especially along the ice shear zone. The ice season is somewhat shorter in the Chukchi Sea than in the Beaufort Sea, but ice conditions and ice hazards are more severe in the Chukchi. The extent of landfast ice along the Chukchi coast between Barrow and Cape Lisburne is much narrower than along the Beaufort coast. Thus, with the exception of Kotzebue Sound, severe ice conditions are encountered much closer to the coast.

The presence or absence of ice profoundly affects the occurrence of fish, birds, marine mammals, and other biota in the Arctic. During the period when ice cover is minimal, most of the annual primary production occurs and biological utilization of the area is high. Anadromous fish move seaward from their overwintering areas in rivers and are joined by large populations of waterfowl and shorebirds that also feed heavily in the barrier island areas and the band of warmer, brackish water along the coast. During the ice-free period, bowhead whales, beluga whales, and several species of seals also frequent the nearshore areas of the Arctic Ocean. In ice-covered periods, by contrast, primary production virtually ceases and the large populations of fish, birds, and marine mammals generally disappear.

The Chukchi Shelf is a broad, flat, shallow, submerged portion of northern Alaska's Arctic coastal plain that is equal in area to all of Alaska north of the Brooks Range. A reconnaissance grid of USGS MCS data (line spacing on average about 50 km) has been obtained in seasonally ice-free waters, but the data are of variable quality. Data quality and spacing, and the limits imposed by working only in ice-free waters, have left major regional geologic, tectonic, and economic questions unanswered in the Arctic region.

ACTIVITIES—PAST AND FUTURE

Much of the explorational work in the Alaskan EEZ has focused on the identification and evaluation of potential reserves of recoverable oil and gas in Outer Continental Shelf areas and on assessment of the potential environmental impacts of developing those resources. Geophysical survey work has been carried out primarily by the USGS and by private industry. NOAA's Outer Continental Shelf Environmental Assessment Program (OCSEAP), with funding primarily from the Minerals Management Service, has supported major research efforts on (1) geological and ice-related hazards to OCS oil and gas development, (2) the physical oceanographic and circulation regimes of Alaskan OCS areas, and (3) the distributions and sensitivities of living marine resources, including endangered species, potentially vulnerable to impacts that might result from oil and gas development. These programs and other related efforts are described briefly below.

Geological Framework and Environmental Studies by the USGS

Since 1965 the USGS has conducted numerous oceanographic expeditions to the Alaskan EEZ, often in cooperation with other Federal Agencies such as NOAA, the U.S. Navy, and the U.S. Coast Guard (USCG). Tracklines of many of these cruises are summarized on figure 3. Many of the data sets are available from the NOAA National Geophysical Data Center in Boulder, Colorado. Several of the USGS cruises have been cooperative endeavors with Canada and Great Britain. An extensive bibliography of USGS reports and publications on Alaskan work is appended.

Gulf of Alaska.—Seafloor geologic hazards studies of the continental shelf in the Gulf of Alaska between Prince William Sound and Dixon Entrance were conducted between 1974 and 1980. The high-resolution seismic reflection data and seafloor sediment samples allowed delineation of large areas of seafloor instability in areas of rapid sediment accumulation. These areas are largely on the inner shelf seaward of important sediment sources such as the Copper and Alsek Rivers and the Malaspina and Bering Glaciers.

The triggering mechanisms of the seafloor slides and slumps, which were mapped on the shelf and slope and in the adjacent bays and fjords, include large storm waves and frequent strong earthquakes. Several earthquake faults have surface or near-surface offset, suggesting recent movement. The seaward extension of the Fairweather Fault extends from Cross Sound to Dixon Entrance and connects with the Queen Charlotte Fault. Together these faults form the boundary between the Pacific and North American plates.

GLORIA imagery plus acoustic, magnetic, and gravity profiles were collected across a small segment (TACT area) of the continental margin in the northern Gulf of Alaska in 1986. The remainder of the deepwater portion of the EEZ in the Gulf of Alaska will be insonified by GLORIA in 1988, 1989, and if necessary, 1990. Follow-up "ground-truth" cruises are also planned and include sampling, bottom camera and TV, and more detailed seismic reflection profiles plus high-resolution side-scan and submersible dives.

The current research program in the gulf is divided into four overlapping categories: hydrocarbon resources; neotectonics, including geohazards and sea-floor utilization studies; geologic framework; and crustal structure. Studies of neotectonics will be based heavily on swath-mapping bathymetry and partly on MCS data, whereas studies in the hydrocarbon and geologic framework categories will require mainly MCS data and results from geologic sampling, which may include shallow drilling. Crustal studies can be accomplished by using MCS, large-airgun refraction, as well as gravity and geoidal and possibly two-ship seismic data.

Bering Sea.—Geologic hazards in the southern half of the Beringian continental margin in the Bering Sea were investigated in the 1970's and the northern half of the margin in the 1980's. The main seafloor hazards mapped on the outer shelf of this frontier petroleum area are shallow (less than 250 m subsea depth) acoustic anomalies interpreted to be caused by gas in the sediment. Biogenic methane was dominant, but thermogenic hydrocarbons were detected. Hydrocarbon anomalies observed on seismic reflection profiles obtained on the lower slope and rise are attributed to gas hydrates.

Evidence for seafloor instability was observed on nearly all seismic-reflection records collected on the Beringian continental slope. The types of mass movement mapped ranged from small debris flows and slides a few meters thick and tens of meters wide to massive slide or slump blocks hundreds of meters thick and several kilometers in areal dimension.

Newly collected GLORIA imagery (1986 and 1987) shows the ubiquitous nature of sediment instability on the slopes surrounding the Aleutian Plain. The Beringian margin, Aleutian Arc, and Bowers Ridge slopes all show abundant evidence of erosion and transport by mass-movement phenomena. Sheet flow is prevalent in the northern part of the Aleutian abyssal plain, whereas GLORIA imagery of the southern half of the plain shows domination by turbidite sedimentation.

GLORIA imagery has been obtained for the entire deepwater portion of the Bering Sea. The data are being processed for inclusion in an atlas. Follow-up cruises are needed to the Bering Sea to "ground-truth" the GLORIA and associated geophysical data.

Arctic.—The USGS has worked on environmental problems of the Alaskan Arctic since 1970, supported for several years by NASA's ERTS–1 project and for 10 years under the sponsorship of NOAA's OCSEAP. Except for several cruises on coast guard ice breakers and on NOAA vessels, most of the work has been done from small USGS vessels or from the winter ice cover. The main research tools employed over the years include high resolution seismic systems, fathometer, side-scan sonar, underwater TV, vibrocorers and box corers, grab samplers, scuba equipment, and remote sensing.

Maps prepared by the USGS for the Arctic region include those for sediment distribution and thicknesses, ice gouges, strudel scours, and ice movement and zonation. Much of the USGS research has been on unique ice-related processes and hazards. The Arctic shelf is shallow, has little relief out to the break at 60 m, is blanketed by a very thin cover of sandy Holocene sediment, and everywhere is impacted and plowed at different repetition rates by massive ice keels. Although not sediment starved, ice-related processes seem to prevent sediment accretion and even lead to erosion. In the Beaufort Sea, relict ice-bonded sediment occurs at shallow depths out to at least the middle shelf. Very little is known about offshore permafrost in the Chukchi Sea, but it apparently is not widespread.

Future environmental work in the Arctic should attempt to define precisely how, and how fast, ice is moving sediment as a key to understanding the future dispersal of pollutants in ice-covered waters. Electric resistivity techniques should be developed for mapping the top and the bottom of ice-bonded sediment, and such techniques should be applied to better define offshore permafrost. This in turn would provide a better understanding of the distribution of gas hydrates known to occur on the shelf and slope. Future work should also deal with the problem of extensive slumping on the continental slope. Studies of slumping, diapirs, possible pingos, and canyons would best be accomplished by the use of Sea Beam and by developing an under-ice GLORIA capability.

Additional MCS data are also required to define the deep structure of the North Chukchi Basin, which is interesting for both the basin tectonics and petroleum potential, and the character of the almost unexplored Chukchi continental borderland. These investigations require an icebreaker, and a jointly sponsored U.S. Navy-USGS investigation of the borderland is planned for 1988 using a Coast Guard Polar-class icebreaker. In addition, selected conventional and deep-penetration MCS profiles should be acquired to supplement existing data in the Chukchi and Beaufort Seas.

Industry Studies

Private industry has been actively collecting geophysical and sample data from the Alaskan EEZ since the 1960's. Initially, this activity anticipated lease sales held in the 1970's and 1980's, and it is ongoing. Several Continental Offshore Stratigraphic Test (COST) and exploratory wells have been drilled, but except for the North Slope, no significant hydrocarbon discoveries have resulted from exploration to date. Except for the COST well data, the industry data are generally proprietary and not available to the public.

GLORIA Surveys

In 1986, the U.S. Geological Survey began systematically collecting GLORIA and other geophysical data from the Alaskan EEZ as part of a cooperative program with Institute for Oceanographic Sciences (IOS) of Great Britain. At the end of 1987, some 50,000 km of trackline data had been collected (fig. 4). GLORIA images are being digitally processed for those EEZ areas deeper than 200 m in the whole Bering Sea and along the western Aleutian Arc. The eastern Aleutian Arc and the Gulf of Alaska will be covered in 1988 and beyond. The Arctic will not be covered because of shallow water and ice cover.

OCSEAP Studies (NOAA and MMS)

In 1972, the Minerals Management Service (then BLM) began a greatly expanded program of marine environmental studies in support of exploration and development of OCS oil and gas nationwide. In Alaska the MMS program was initiated in 1974, through an interagency effort with NOAA, as the Outer Continental Shelf Environmental Assessment Program. From 1975 to 1984 the OCSEAP included major geological and geophysical study components, carried out largely by the USGS and the Geophysical Institute of the University of Alaska. These studies focused primarily on potential geohazards associated with OCS oil and gas development, including (1) definition of the seismicity of the Alaskan OCS regions, especially in the northern Gulf of Alaska and Aleutian areas and in the vicinity of the Seward Peninsula, (2) identification of areas with unconsolidated or gas-charged sediments and potential for sediment instability or slumping, (3) mapping of submarine permafrost distributions, (4) identification of areas susceptible to ice scouring, and (5) mapping the distribution of near-surface sediment types. Additional data on surficial sediments have also been gathered in conjunction with distributional studies on benthic fauna.

In addition to the geohazards studies, OCSEAP has supported major efforts in meteorology, physical oceanography, and ice motion throughout the Alaskan OCS and has acquired extensive data on the seasonal distributions of living marine resources potentially vulnerable to impacts from the development of OCS oil and gas reserves. These data will be invaluable also for estimating the potential environmental risks associated with development of other categories of mineral resources from Alaskan EEZ regions.

Nearly all OCSEAP studies are well documented, both by original reports from the Principal Investigators (table 1) and by regional synthesis reports. In addition, OCSEAP has produced major regional environmental summaries for the Bering Sea (Hood and Calder, 1981) and for the Gulf of Alaska (Hood and Zimmerman, 1986). A complete bibliography of all OCSEAP publications and reports is also available (U.S. Department of Commerce, 1986). Geological and geophysical data from OCSEAP studies are available from NOAA's National Geophysical Data Center, while other data types (oceanographic, chemical, biological) are available from NOAA's National Oceanographic Data Center. These latter data types can be accessed also through the Alaska Office of NOAA's Ocean Assessments Division in Anchorage.

Strategic Assessment Program (NOAA)

The Strategic Assessment Branch (SAB) of NOAA's Ocean Assessments Division conducts comprehensive, interdisciplinary assessments of multiple resource use throughout the Nation's EEZ and adjacent coastal areas. One major SAB product is a series of regional data atlases of the EEZ. The atlases contain regional thematic maps that present interdisciplinary technical information to policy makers in a consistent and comprehensible form. The Bering, Chukchi, and Beaufort Seas Data Atlas will be published in early 1988; and the West Coast and Gulf of Alaska Data Atlas is scheduled for late 1988. Each data atlas brings together four general types of information relevant to decision making: (1) physical and chemical characteristics of resources and their surrounding environment; (2) biological characteristics, including species distribution, abundance, life history, and habitat; (3) economic characteristics, including resource extraction and production activities; and (4) environmental quality, including pollutant discharges and hazardous materials disposal. The Bering, Chukchi, and Beaufort Seas Data Atlas will contain 108 maps. These maps synthesize and present the best available information on important characteristics of the Arctic region. This regional atlas emphasizes living marine resources with over 80 maps in this category. In addition to maps on biological, physical, and economic aspects, this atlas also contains thematic maps depicting Native subsistence activities in a variety of Alaska coastal habitats. An explicit assessment of the content and quality of the information underlying each map is portrayed in the atlas.

A national atlas folio series, also under development by SAB, presents comprehensive information on the use and health of the coastal waters of the United States. This series presents a national coastal and oceanic perspective and framework for environmental quality research, assessment, and monitoring. The first 5 of the 20 themes to be mapped are currently available: (1) estuarine systems, (2) NOAA's National Status and Trends Program, (3) dredging activities, (4) ocean disposal sites, and (5) oil production. Subsequent maps will include hazardous waste sites, commercial ports and shipping routes, operational discharges of petroleum hydrocarbons from ships, harvest-limited shellfishing areas, Federally funded marine pollution research, marine mammals, and fisheries management areas.

Table 1. A sampling of recent Principal Investigator final reports from NOAA's Outer Continental Shelf Environmental Assessment Program (OCSEAP)

	OCSEAP Final Reports
47:	Molnia, B.F., 1982, Erosion, deposition, faulting and instability of shelf sediments: Eastern Gulf of Alaska, 638 p.
48:	Hampton, M.A., 1983, Geotechnical framework study of the Kodiak Shelf, Alaska, 94 p.
	Lee, H.J., and Schwab, W.C., 1983, Geotechnical framework, Northeast Gulf of Alaska, 452 p.
49:	Latham, G.V., Dorman, H.J., and Ibrahim, A.B.K., 1980, Coordinated ocean bottom seismograph measurements in the Kodiak Shelf area, 28 p.
	Lahr, J.C., and Stephens, C.D., 1983, Earthquake activity and ground shaking in and along the eastern Gulf of Alaska, 54 p.
	Frohlich, C., and Donoho, P., 1982, Measurement and location of earthquakes in western Alaska, the Gulf of Alaska, and the Bering Sea, 48 p.
	Jacob, K.H., and Hauksson, E., 1983, A seismotectonic analysis of the seismic and volcanic hazards in the Pribilof Islands-Eastern Aleutian Islands region of the Bering Sea, 232 p.
	Pulpan, H., and Kienle, J., 1984, Seismic risk studies, western Gulf of Alaska, 65 p.
	Kienle, J., and Swanson, S.E., 1980, Volcanic hazards from future eruptions of Augustine volcano, Alaska, 139 p.
52:	ERTEC Western, Inc., 1983, Seafloor geologic hazards on the northern Aleutian Shelf, 342 p.
	Phillips, L., Barnes, P., Reimnitz, E., and Hunter, R., 1985, Geologic processes and hazards of the Beaufort and Chukchi Sea shelf and coastal regions, 477 p.

U.S. Arctic Research Planning Activities

Under the mandate of the Arctic Research and Policy Act of 1984 (P.L. 98–373), the Interagency Arctic Research Policy Committee (IARPC) has prepared a U.S. Arctic Research Plan (IARPC, 1987) that outlines and discusses major research needs for the U.S. Arctic region (defined for purposes of the plan to include the entire Alaskan EEZ area north of the Aleutian Chain). One aspect of stated U.S. Arctic policy is to support sound and rational development in the Arctic region while minimizing adverse effects on the environment. Research needs identified by the IARPC (1987) to support this policy goal include mapping of energy and mineral resources both onshore and offshore and understanding the basic structural and functional aspects of marine ecosystems in terms of both productivity of renewable resources and their potential vulnerability to impact from development activities. The purpose of mentioning this Arctic planning activity here is merely to note the obvious parallels with the EEZ planning effort as it pertains to Alaska and to call for appropriate coordination between the two activities.

RECOMMENDATIONS

In each of the five regions within the Alaskan EEZ, we suggest a series of studies and measurements made along area transects, or swaths. These transects would be corridors some 20 to 30 km wide and extending at right angles across the major structural elements in each region. Although specific locations have not been formulated, for these swaths in each area, they should extend from beyond the edge of the EEZ to the beach, where they would connect with existing onshore geologic data or cross sections.

Along each transect, the objectives are to derive:

1. A three-dimensional cross section of the regional framework (more than one transect may be necessary in each of the regional subdivisions of the Alaskan EEZ);
2. The characteristics of geologic processes and hazards within the corridor that are representative of the region; and
3. A reconnaissance estimate of the resource potential of the region.

Each transect would require the use of two ships working together to obtain three-dimensional deep crustal structure from seismic reflection and refraction data including Expanding Spread Profiles (ESP). Both ships would then operate separately to obtain the following data:

1. Geopotential: gravity and magnetic profiles;
2. High-resolution seismic reflection profiles (0–1,000 m subbottom);
3. Bathymetry;
4. Sample information involving:
   a. Coring (20 m)
   b. Dredging
   c. Grab sampling; and
5. Bottom photographs and sonographs.

Following the collection and analysis of the transects, a systematic drilling program should commence to provide "ground-truthing" of the geophysical data. At least one hole should be drilled in each transect and should collect the following:

1. Continuous cores;
2. Basement samples if possible; and
3. A series of down-hole logs.

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Workshop 2: Scientific Mapping and Research to Characterize the EEZ—West Coast

Panel Co-chairpersons:
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Donald A. Hull, State Geologist, Oregon

INTRODUCTION

The Exclusive Economic Zone (EEZ) of the west coast of the United States has complex geology and rugged topography with a relatively narrow continental shelf and a steep slope. The geologic framework of the continental margin zone of the West Coast EEZ is divided into three basic types, each with characteristic morphology, tectonic style, sedimentary cover, and, to a lesser extent, associated mineral deposits. These types are the actively deforming continental borderland of southern California, the transform margin of central California, and the active subduction zone from northern California to Washington. In addition, this EEZ sector is the only one around the 50 States that also includes an oceanic spreading-ridge environment. The West Coast EEZ is an area of significant and increasing oil and gas production and recent hard-mineral discoveries. It is also a zone of upwelling where ocean currents bring nutrients to especially productive fisheries.

The West Coast EEZ is currently characterized by relatively limited mapping coverage and incomplete knowledge of the basic geologic framework, especially in deeper water areas west of the continental shelf. The limited knowledge of geology is a serious impediment to meaningful appraisal of mineral resources and geologic hazards. It is clear that the geologic processes in this portion of the EEZ have resulted in the formation of important mineral resources; however, a meaningful quantitative appraisal of the resources is not possible given the state of current knowledge.

A recent report entitled "International Role of U.S. Geoscience" issued by the National Research Council (1987) notes that there are three major problems with respect to seabed resources. First, many of the accumulated data have not been adequately synthesized, compiled, and interpreted. Second, more detailed studies of selected areas within the EEZ and in other areas are needed to provide a base for resource assessment. Third, more cooperative research programs are needed to develop better relationships with other countries. The NRC report noted that foreign seabed-research programs are more directly related to their particular resource interests than are U.S. Government-supported activities. Much of the U.S.-sponsored oceanographic research is directed at broad scientific problems rather than being focused on the more practical aspects of EEZ exploration and resource evaluation.

DESCRIPTION OF AREA

Certain sectors of the West Coast EEZ have been relatively well surveyed as a result of the proximity to major oceanographic research laboratories rather than through coordinated mapping programs. In addition, parts of the Outer Continental Shelf (OCS) are very well known, specifically those areas that have been leased for oil and gas exploration. Although many of the industry data from the OCS activities are proprietary, some of the OCS regions were studied systematically as part of geologic framework and environmental studies for the U.S. Government. Federal Government-funded studies are publicly available, for example, as Environmental Impact Statements and Open-File Reports. Government agencies, together with university researchers, provided the bulk of the publicly available geologic framework and hazard assessment data now available (only for selected OCS areas) within the EEZ. The deeper water parts of the West Coast EEZ, most of the total area under consideration, have been the objective of two systematic, regional mapping efforts. In 1984, the U.S. Geological Survey surveyed the entire EEZ area by using the GLORIA side-scanning sonar system (EEZ SCAN 84 Scientific Staff, 1986). This imagery provided for the first time a map of all geomorphic features within the EEZ. In 1984, NOAA began a coordinated program to map the EEZ using the Sea Beam and other swath-mapping sonar systems to provide detailed bathymetric maps (10-m contour interval maps are achievable with these systems). Both these programs were in response to the President's Proclamation of the EEZ in March 1983. The rate at which the West Coast EEZ can be mapped is such that several decades of effort will be required.

NOAA and the USGS have established a cooperative mapping program to help direct the choice of areas surveyed to regions of national interests and agency program priorities. The West Coast EEZ is the locus of a variety of recent and current scientific studies specifically directed to resource questions. An example is the coordinated investigation of biologic and geologic resources on Gorda Ridge, an oceanic spreading center offshore of northern California and southern Oregon. A Federal-State technical task force has directed the expenditure of $1.2 million from 1984 to date to investigate polymetallic sulfide deposits and associated biologic communities. The Gorda Ridge studies program will continue, and a dive program is planned for 1988 with support from the U.S. Navy.

A second example of specific investigations in the West Coast EEZ is a preliminary review by Oregon State University oceanographers of the marine placer occurrences that contain variable amounts of chromium, titanium, and other strategic metals.

STATE OF KNOWLEDGE

The current state of knowledge for the West Coast EEZ should be examined in two steps before specifying any 10-year program goals. The first concern is whether the data exist to define the geologic framework and processes affecting the EEZ and to evaluate both resource potential and environmental hazards of the EEZ. Although we may understand the geologic framework at a "plate-tectonic-processes" scale, we clearly do not have bathymetric or geologic maps at a scale useful for resource exploration or definition of potential hazards. The second step is to determine how well we understand any particular sector of the EEZ in light of a desire to map and recover mineral resources. We are asking whether certain resource areas may be well enough known to propose site-specific efforts (the highest "magnification" in a telescope approach) that can be carried out simultaneously with EEZ characterization studies elsewhere. Except for certain areas of the continental shelf, the answer is clearly that we do not.

Data must be compiled before an efficient 10-year mapping program can be defined. For much of the West Coast EEZ area, nonbiologic oceanographic data and comprehensive bibliographies were assembled for all but the southern California sector about 10 years ago (Chase and others, 1975; Wilde and others, 1976, 1977, 1978, 1979). These data compilations, completed before any EEZ proclamation, cover most of the West Coast EEZ but are not specific to it. They represent the cooperative efforts of the USGS, Department of Energy, University of California, and all oceanographic institutions along the west coast. Obviously, these (or similar) data compilations would have to be updated before defining extensive resource mapping programs for the West Coast EEZ.

The data compilations noted above were not intended to provide interpretations. A more detailed review of the data available, along with limited geologic framework interpretations, is available for the Washington and Oregon continental margin (Kulm and others, 1984). This atlas is not specific to the EEZ but includes all of the EEZ area offshore of the two States. Publication of a compilation of the entire California continental margin geology for the offshore area only has begun and will include a series of seven sets of maps (four map sheets to each area to show geology, geologic hazards, gravity, magnetics, earthquake epicenters, fault plane solutions, and data sources) (Kennedy and others, in press; Greene and Kennedy, in press). These maps, unfortunately, do not cover the entire EEZ but the map series is a good approach for basic framework studies that need to be completed for the entire West Coast EEZ.

An example of mineral resource inventory is a map of offshore mineral resources prepared by the College of Oceanography at Oregon State University and the Oregon Department of Geology and Mineral Industries (Gray and Kulm, 1985). A geologic bibliography and a map index also have been prepared for the area offshore of Oregon (Peterson and others, 1985).

A publication due out by the end of 1987 provides both a review of the geologic framework and sedimentary processes within the West Coast EEZ and also an evaluation of the mineral resource potential of the area (Carlson and Nelson, 1987; Clague and Holmes, 1987; Clarke, 1987; Clifton and Luepke, 1987; Embley and others, 1987; Howell and others, 1987; Koski and others, 1987; Kvenvolden, 1987; Lister, 1987; Loebner and others, 1987; McCulloch, 1987; McLean and Wiley, 1987; Morton and others, 1987; Snavely, 1987; Vedder, 1987).

The definition of a 10-year program for the West Coast EEZ must await geologic evaluations of this and other reports due to be released by early 1988. The most significant of these later publications expected is Volume N of the Decade of North American Geology from the Geological Society of America.

These two major syntheses of the geology of the West Coast EEZ should be considered only as flagships of a series of reports now in production that bear directly on the questions of EEZ exploration and possible exploitation. (Many of the individual reports of these volumes are known to this panel's co-chairs by title only, so we could not utilize the information for this workshop report.)

The Strategic Assessment Branch of the National Oceanic and Atmospheric Administration (NOAA) is currently developing the West Coast of North America Strategic Assessment Data Atlas. It is the fourth in a series of data atlases synthesizing the best available information on important characteristics of the Exclusive Economic Zone and adjacent coastal areas of the United States. The data atlas will contain approximately 150 maps at a scale of

1:5,000,000, with accompanying text, organized into six chapters: physical environments (15 maps); biotic environments (7 maps); living marine resources (70 maps); economic activities (20 maps); environmental quality (20 maps); and jurisdictions (7 maps). The atlas will reflect extensive collaboration with regional experts in government, universities, and private institutions. A preliminary edition consisting of 50 of the 150 thematic maps that will appear in the final atlas will be available in early 1988.

In summary, the current state of knowledge of the West Coast EEZ is inadequate to identify the extent of mineral resources or define geologic hazards. Within the next year, however, syntheses of existing data and (as a minimum) reconnaissance-level evaluations of the geologic processes and mineral resource potential will be available to help focus a 10-year program. The exciting discoveries of cold methane vents on the slope offshore of Oregon and extensive sulfide deposits in Escanaba Trough on Gorda Ridge, both in 1986, are two examples that should help emphasize that long-term program goals defined in this workshop need to be reevaluated on a regular (frequent) interval.

ADDITIONAL INFORMATION NEEDED

A variety of additional data is needed to define the basic geology of the West Coast EEZ. During the next 10 years, it will be important to focus available funds on selected segments of this large area in order to characterize the geologic framework and processes. We prefer an approach that is based initially on the selection of segments of this broad EEZ for initial investigations. The segments would be 100 to 200 km wide and extend from the onshore coastal region to the seaward limit of the EEZ. The segments could be selected to be representative of various distinctive tectonic regimes such as the California continental borderland, the area of active subduction off Oregon and Washington, and the transform margin of central California. Areas within the West Coast EEZ outside the selected segments could be mapped in a systematic fashion guided by need for resource, geologic hazard, or geologic framework data.

Bathymetric Mapping

Bathymetric mapping is fundamental and necessary. The need for such maps was recently evaluated for the area offshore of Oregon (Ireland, 1985). Specifically, for the Oregon continental margin for water depths greater than 200 m, maps at a scale of 1:250,000 with a contour interval of 50 m were judged to be necessary. Areas with a water depth less than 200 m should be mapped at a scale of 1:100,000 and a contour interval of 10 m, except for the nearshore areas extending west from the coast a few miles, which should be mapped at a scale of 1:24,000 with a contour interval of 2 m. Thus, the scales and map boundaries for bathymetric maps would be a logical extension of onshore topographic mapping programs. The selection of map projections and scales needs to be coordinated with users and suppliers of data; for example, U.S. Geological Survey interests will require 10 m in contour intervals for all of the EEZ. The relative priority of completing bathymetric map coverage versus various types of imagery (for example, side-scan sonar such as the SeaMARC systems) needs to be reevaluated as the surveying tools evolve.

A 10-year program for mapping the West Coast EEZ will require improved bathymetric compilations, preferably produced by using multibeam swath-mapping sonar systems capable of providing 10-m contour intervals. The highest priority will be for the edge of the continent itself, where mineral exploration is likely to occur first. Thus, the continent and shelf/slope areas should be mapped at a scale of 1:250,000. Mapping of the deeper water parts of the EEZ generally will not be required within the 10-year time frame and map compilation at 1:500,000 will probably suffice.

Compilation of geologic data including seafloor substrate, engineering properties, and seismic activity is needed to provide base maps for resource studies and geohazard evaluation. These maps should be at the same scales used for the bathymetric maps noted above, with 1:250,000 scale being used for the shelf to base of slope areas. These geologic data compilations could be patterned upon the set currently being constructed for the California margin (Greene and Kennedy, in press).

The maps developed in the program will provide information that is useful to biologists and scientists studying the living marine resources of the region. Knowledge of the distribution of bottom sediments, for example, is valuable in examining the seasonal migrations and movements of a variety of fish, invertebrates, and mammals along the west coast.

In looking ahead to future detailed exploration and commercial development of seabed mineral deposits in the EEZ, it seems reasonable to suggest that permanent geodetic monuments be implaced on the seabed at widely separated sites. The monuments would be useful for accurate locations of lease boundaries for exploration or exploitation.

The geologic framework of the EEZ can best be understood by selecting segments for concerted investigations. These segments, as a minimum, should be selected to characterize the three main types of West Coast EEZ provinces: subduction (northern California to Canadian border), transform-simple (central California), and transform-complex (continental borderland off southern California). Each segment should have a finite width, perhaps one degree of latitude, and be subjected to a variety of coordinated and systematic geologic and geophysical surveys. The segments would extend from the westward limit of the EEZ and be continued onshore to tie into the landward extension of similar geologic environments.

Constraints

The primary constraints to availability of these data sets are funding, classification due to defense sensitivities, technology limitations, and the proprietary nature of much of the information collected by the private sector.

The funding limitations relate principally to the high cost of operating vessels for the extended periods needed to systematically map, sample, and survey the large areal extent of the EEZ. Other costs related to data processing and distribution are significant. The major portion of the Federal mapping budget in the United States, however, has been directed towards defense and space agencies; thus, civilian mapping needs suffer as a result.

In recent years, the National Security Council has required detailed bathymetric data to be classified because of the possibility that the data could be used by a foreign government for submarine navigation.

There are additional constraints resulting from limited availability of technology. A recent Office of Technology Assessment (OTA) report has described the need for technological advances (U.S. Congress, OTA, 1987).

The direct sampling of some seabed minerals is an available technology; however, utilization is constrained by the small number of available research submersibles such as ALVIN and SEA CLIFF. Other sampling technologies, for example, drilling of hard-rock mineral deposits, have not yet been adapted to routine use on the seafloor in deep waters.

A principal reason for limited availability of necessary data sets in the EEZ is the current national system of selecting oceanographic projects based on scientific priorities rather than national needs in the EEZ.

The understanding of the geology of the West Coast EEZ can be enhanced by an improved mechanism for cooperation between the private sector and research organizations. For example, the exploration for petroleum and natural gas resources has generated voluminous seismic data; however, these data are treated as proprietary for an extended period of time. Similarly, there are limited mechanisms for sharing of cuttings and cores from offshore oil and gas wells. A period of between 2 and 5 years for proprietary treatment of data and samples should be implemented to balance the national interest in understanding the EEZ while protecting private-sector investment.

Long-Term Consequences

Serious long-term consequences will result from failure to adequately map and study the West Coast EEZ. The primary result will be reduced exploration for mineral resources. The unexplored and less explored sedimentary basins in the United States lie principally offshore. The major portions of these unexplored offshore sedimentary rocks that may contain potential for petroleum and natural gas are within the EEZ. Thus, the national dependence on imported energy minerals may be accelerated by any failure to understand the geology of the EEZ.

A second consequence will be the continued dependence on imported strategic minerals at a time when supplies from traditional suppliers in southern Africa may be in jeopardy.

A third result may be a lesser understanding of tectonic processes and the attendant seismic hazards. For example, the active subduction zone under Oregon and Washington requires study within the EEZ as well as onshore. In excess of 80 percent of the population of these States resides within 100 mi of the coast. The fundamental nature of the subduction process in this area is the key to appraisal of seismic hazards in the northwest States.

Strategy

The preferred strategy for acquisition, interpretation, and dissemination of data from the EEZ is a coordinated national program with a single lead agency for individual work elements; for example, the responsibility for preparation of bathymetric maps might best reside in a single agency, in this case, NOAA.

A common Geographic Information System (GIS) framework should be established which will allow overlay of bathymetric, geologic, and mineral information developed by DOI and cooperating agencies with living marine resource and oceanographic/atmospheric information developed by NOAA. Original data sets, as well as data synthesis and analysis, should be made readily available to States and to State-Federal task forces established to coordinate research and management. A GIS for the west coast should be oriented to management of ocean activities by State and Federal agencies as well as to collection, maintenance, and update of information.

A State-Federal task force should be the mechanism for investigation and management of specific mineral deposits in the EEZ. These task forces have proven effective for coordination of exploration and should provide for continued joint management of actual development activities. Where necessary, these task forces should ensure coordination between research and exploration related to mineral deposits and exploration and environmental studies related to oil and gas. Thus, States should be encouraged to initiate formation of a task force and enter into cooperative agreements with appropriate Federal agencies to ensure that State management needs are met.

The preparation of a complete set of bathymetric maps for the West Coast EEZ should be undertaken as the initial step in a 10-year program. The next sequential step would be preparation of a set of geological and geophysical maps along segments of the EEZ using a variety of existing and newly collected data. These maps could be prepared jointly by the U.S. Geological Survey and State geological organizations as a logical extension of the current cooperative program for onshore geological and geophysical mapping (COGEOMAP). This work can be tied to the existing GLORIA side-scan imagery, which not only reflects morphology of the seafloor but also, through the character of the backscattered acoustic data, indicates differences in seafloor substrate. The 10-year period will likely be insufficient for the mapping much more than segments of the West Coast EEZ. A final step in the 10-year program would be a crustal-drilling program based on previous mapping along the selected segments. The scientific drilling would be designed to add a third dimension to the geologic mapping and constrain interpretations based on geological and geophysical data.

A logical strategy for EEZ data development involves improved cooperation between the military and civilian organizations. The excellent cooperation in the Gorda Ridge minerals program, during which the Navy's Submarine Development Group One supported Gorda Ridge Technical Task Force efforts with the SEA CLIFF submersible and deep-towed side-scan sonar system, is a notable recent example of the benefits to be realized from joint military-civilian research.

Another strategy to address the lack of funding is a direct reinvestment of a modest portion of EEZ revenues back into the research and development activities so as to enhance the data development that will likely result in further resource definition.

Finally, enhanced international cooperation will help to accelerate EEZ-data development. In recent years, German, Russian, and Japanese vessels and scientists have begun to explore the U.S. EEZ. The coordination of these efforts will lead to improved knowledge.

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Workshop 3: Scientific Mapping and Research to Characterize the EEZ—East Coast

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The Atlantic EEZ area consists of the continental shelf, slope, and rise (Uchupi, 1968; Emery and Uchupi, 1972, 1984). The continental shelf is essentially the submerged part of the continent, underlain by sedimentary basins and less dense continental crust. The slope marks the topographic transition to the North American deep ocean basin. The rise and adjacent abyssal plains at 3,000–4,000 m water depth are underlain by denser oceanic crust formed over the past 140 million years as a part of the separation of Africa-Europe and North America. The shelf shows variation in form based on its past history. On the Gulf of Maine–Georges Bank region off New England, the area has been extensively sculpted by glaciers during the last ice age. The gulf is veneered with till and outwash in a series of swells and depressions that cover the area. Georges Bank is covered on its northern third by extensive sand shoals, formed of glacial outwash and shaped by vigorous tidal currents. Southwest of the Georges Bank–Nantucket Shoals area, and continuing to Cape Hatteras, North Carolina, the shelf is mostly flat, is sand covered, and characterized inshore by extensive fields of sand ridges. Relict river channelways are preserved crossing the shelf off major rivers like the Hudson or estuary mouths such as the Delaware Bay and Chesapeake Bay. Most of the sedimentary cover is reworked detrital debris originally carried to the shelf by an extensive system of rivers when sea level was much lower and the shelf was exposed.

South of Cape Hatteras, though the shelf is still flat, the character of the sediment type changes as carbonate detritus becomes dominant in the warmer water. Interrupting the transition to the deep sea off Florida and Georgia is the Blake Plateau, a deepwater plateau in water depth of 700–1,000 m that extends north of the Bahama Banks. The plateau has been eroded by the Gulf Stream to create a broad series of swales and drifts along the western side of the plateau. In effect the plateau is an extensive submerged carbonate platform that had reefs along its eastern side in the Early Cretaceous. Its eastern boundary is a steep (near-vertical) escarpment, which drops to over 5,000 m, and the Blake basin.

Other deepwater features on the Atlantic slope and rise include the New England Seamounts, an easterly trending chain of extinct submerged volcanoes that extend 1,000 km to the east off southwest Georges Bank. Also built across the rise are the Hudson fan and the extension of the Hudson submarine canyon. North of the Blake Plateau is Blake Outer Ridge, a constructional feature that extends out from the northern Blake Plateau to 4,000 m. Farther north, the continental slope is indented by numerous submarine canyons that formed when the sea level was lower and sediment input from rivers was closer to the shelf edge.

STATUS OF RESEARCH ON THE ATLANTIC EEZ

Bathymetry

The abundance of soundings in the Atlantic EEZ (Uchupi, 1968, fig. 2) ranges from more than 40 soundings per 10 km^2 (for inshore and coastal areas) to less than 5 soundings per 10 km^2 (for offshore outer shelf and deepwater areas). These soundings, mainly collected on smooth sheets by the U.S. Coast and Geodetic Survey (now NOAA—National Ocean Service), plus surveys collected by oil companies, have been issued in small-scale bathymetric maps (Uchupi, 1968; Belding and Holland, 1970; Emery and Uchupi, 1984) to cover the entire Atlantic EEZ. Larger scale, more detailed bathymetric sheets exist for selected parts of the continental margin as issued by NOAA at a scale of 1:250,000 with a bathymetric contour interval of 2 m and by coastal institutions for selected areas of the shelf-slope-rise (McGregor, 1987, unpub. data; Newton and Pilkey, 1969). The bathymetric data used in these maps vary from lead line soundings and sonic profiles that came into widespread use before World War II to limited Sea Beam surveys using an array of transducers of the 1970's and 1980's (McGregor, 1987, unpub. data). The swathlike imaging of the seafloor by a Sea Beam survey gives us our first real portrayal of deep sea topography, an important first key to the origin of the seafloor. The means of locating survey lines have also changed in a major way, from celestial navigation prior to World War II through Loran to the satellite navigation system of the present. Contour intervals have varied, depending on the scale of the map, from 1- to 2-m contour intervals at a scale 1:250,000 to 20- and 200-m contour intervals at a scale of 1:1,000,000 (Uchupi, 1968) to a 400-m contour interval (scale 1:4,000,000) for the entire Atlantic (Emery and Uchupi, 1984). A small-scale (1:50,000) bathymetric map at a 10-m contour interval was published by Kirby and others (1982) for the Toms Canyon area of the continental slope seaward of southern New Jersey.

Sampling of Seafloor Sediment

Sampling of the seafloor in the Atlantic margin out to 2,000 m was summarized by Uchupi (1963). He reviewed prior sediment studies over the previous century and emphasized the relict nature of the sedimentary cover north of Cape Hatteras and the low rate of deposition on the continental shelf. Authigenic and calcareous sediment prevail south of Cape Hatteras. Beginning in 1962, the USGS began a cooperative study with Woods Hole Oceanographic Institution (WHOI) under K.O. Emery. As a result of this 10-year program, several thousand grab samples of the seafloor were collected out to 3,800 m water depth and up to 300 mi seaward of the coast. The results of the cooperation are mainly chronicled in the USGS Professional Paper 529 (see Schlee and Pratt, 1970; Schlee, 1973; Hollister, 1973; Milliman and others, 1972). Maps from this series extend out to 4,000 m water depth, though the coverage of samples in extreme deep water is sparse (coverage of 1 sample per 100 km^2, Hathaway, 1971).

These maps show a sand-covered shelf veneered sporadically with gravel in the northern latitudes that gives way in deeper water to finer grained, more calcareous (planktonic-benthonic foraminifera) sediment with rafted coarser debris. As with bathymetry, far fewer samples have been collected in deep water. For the sample collection scheme of the USGS-WHOI program up to 1971 see Hathaway (1971, figs. 2–4).

Several notable data compilations have been made, mainly in shelf areas. The New York Bight series published by the Sea Grant program of New York State is a 32-chapter monograph on all aspects of the New York Bight Shelf area, edited by D.F. Squires. The Coastal Engineering Research Center (U.S. Army Corps of Engineers) published an extensive set of reports that assessed the sand resources of the inner Atlantic shelf between New England and Florida. (Duane and Stubblefield, 1988, and references cited therein).

Small-scale studies of deepwater areas have been carried out by observations from submersibles coupled to closely spaced sonic profiles and corehole data in the Toms Canyon area off New Jersey (Hampson and Robb, 1985) and in Oceanographer Canyon off Georges Bank (Valentine and others, 1984). Inshore surveys were made of coastal New England to provide more detailed bathymetry and sediment textural patterns (Schlee and others, 1973; Folger and others, 1975).

Coring and Drilling in the East Coast EEZ

Shallow and deep drillhole data in the Atlantic margin were summarized as of 1972 by Emery and Uchupi (1972, chapter 3) and still later by Ewing and Rabinowitz (1984), by Uchupi and Shor (1984), and by Bryan and Heirtzler (1984) as a part of the Ocean Margin Drilling Program–Regional Atlas Series and by Emery and Uchupi (1984, chart 4) for the entire Atlantic Ocean. For exploratory holes on the U.S. Atlantic margin, drilled in the 1970's and 1980's, Wiese (1986) summarized the drilling activity mainly on the New Jersey shelf (34 wells) and other Atlantic shelf areas up to 1986 for the Minerals Management Service. Except for several DSDP (Deep Sea Drilling Program) legs (11, 93, 95) and one ODP (Ocean Drilling Program) leg (102), holes in the deep seafloor are very few. The deep sea stratigraphy is based on drillhole results (approximately 31 DSDP holes—all off the middle Atlantic and the Southeastern United States) in the deepwater areas. These wells (Poag, 1985; Jansa and others, 1979) have provided the basis for North American basin stratigraphy. Several key seismic horizons have been identified and mapped (by using seismic reflection profiles), and a detailed history has been constructed from the drillhole results (Jansa and others, 1979; Poag, 1985; Dillon and others, 1985; Tucholke, 1987).

In the slope–outer shelf areas, more emphasis has been on dredging to sample rock outcrops to work out a shelf-slope stratigraphy (Weed and others, 1974). In this area, the section is abbreviated with pronounced unconformities and sequences of rocks as old as Early Cretaceous exposed in the bottoms of submarine canyons. In a few areas, correlations have been attempted through the slope area based on core and submersible samples (Valentine, 1981; Poag, 1985; Hampson and Robb, 1981) tied to seismic sections in the area.

Geophysical Profiling

The most comprehensive stratigraphic record for the Atlantic EEZ is based on seismic reflection profiles collected over the past two decades. Distinctive reflectors can be traced over several tens of thousands of kilometers on these profiles. The pre-Cretaceous stratigraphy of the continental rise was best defined by Klitgord and Grow (1980), and for younger seismic stratigraphy (Cretaceous and younger) Tucholke and Mountain (1979), Poag (1985), Schlee and others (1985), Schlee and Hinz (1987), and

Tucholke (1987). Sufficient studies have been performed in the North American basin to define a deep sea stratigraphy and name units (Jansa and others, 1979), on the basis of DSDP drilling results and seismic reflection profiles so as to provide continuity among widely scattered drill sites. A compilation of the seismic reflection profile coverage for the Atlantic shelf-slope-rise area is given by Uchupi and Shor (1984), by Ewing and Rabinowitz (1984), and by Bryan and Heirtzler (1984) for the Ocean Margin Drilling Atlas and by Emery and Uchupi (1984, Chart III-A) for the entire North Atlantic. Though we have emphasized reflection stratigraphy in this review of geophysical data, it is important to realize that many studies have focused on deep crustal structure through the Atlantic margin (Hutchinson and others, 1982; Grow and others, 1983; Grow, 1981) based on gravity and magnetics as well as multichannel seismic reflection profiles. In addition, a multiship-multichannel line has been run across the mid-Atlantic continental margin off New Jersey as a part of the LASE (Large Aperture Seismic Experiment) (Gamboa and others, 1985) to look at the detailed velocity structure associated with a buried paleoshelf edge—a feature of considerable economic-resource interest.

Direct Imaging

A new method of direct imaging of the deep North Atlantic seafloor was first used in 1979 and again in 1987 in the form of GLORIA (Geologic Long Range Inclined Asdic) sonographs. The results of the first survey have been published as part of a larger survey (Dillon and others, 1985) or as surveys of the continental slope off the mid-Atlantic (Twichell and Roberts, 1982) or Georges Bank (Scanlon, 1984) or off North Carolina (Cashman and Popenoe, 1985). The GLORIA system allowed viewing of the major depositional systems (fans, areas of slumping, major distribution channelways) covering over thousands of square kilometers of the seafloor. The GLORIA EEZ surveys are being published as atlases (for example, EEZ SCAN 84 Scientific Staff (1986) and the EEZ SCAN 85 Scientific Staff (1987) for the Pacific and Gulf of Mexico, respectively). The atlases show the seafloor images and interpretations of the features plus seismic sections along the traverses. These mosaics are a basic building block of the study of the EEZ because they provide broad areal coverage of the depositional fabric of the seafloor. The mosaics are basic to understanding seafloor sediment distribution and associated processes active during the Pleistocene and Holocene. In addition, more limited area surveys have been made of the upper Mississippi fan (Kastens and Shor, 1985) and of the Wilmington Canyon area (McGregor and others, 1982). The Sea MARC I system used by McGregor and others is a mid-range side-scan sonar device that can survey a swath up to 5 km wide, depending on the distance the fish is towed above the bottom.

Detailed Bathymetry

As is true for land exploration and research, a necessary first-level tool for marine studies is a high-quality bathymetric map. There are two commercial swath mapping systems manufactured in the United States: one for deep water (more than 300 m), called Sea Beam, and one for shallow water (30–650 m), called BS^3 (Glenn, 1970; Perry, 1985). The Sea Beam system acoustically surveys a swath $0.8 \times$ water depth, and the BS^3 surveys a swath $2.5 \times$ water depth. Depth accuracy is stated to be 1 percent of depth for both systems. Little of the Atlantic shelf and EEZ has been mapped with swath systems.

Commodity Review

Hard Minerals: Over time, there have been varying levels of research or commercial-driven studies directed at several commodities on the U.S. east coast continental shelf and EEZ. These commodities are sand and gravel, heavy minerals, manganese nodules, and phosphates.

Sand and, to a much lesser extent, gravel seem to be nearly ubiquitous on the continental shelf north of Cape Hatteras (for example, Schlee, 1964; Duane and Stubblefield, 1988, and references cited therein). While much less plentiful and more calcareous in nature south of Hatteras to the Florida Keys, sand does occur intermittently and in sometimes significant volumes (Duane and Stubblefield, 1988). Density of data on which estimates of character and volume are made is very much greater inshore than offshore, beyond 3 nautical mi. Much of this information has been developed as a consequence of research projects carried out by the U.S. Army Corps of Engineers, the U.S. Geological Survey, and the National Oceanic and Atmospheric Administration. The U.S. Bureau of Mines (1987) did some preliminary economic studies, concluding that sites off Boston and New York City have the highest commercial potential. This conclusion echoes that of De Lois and Wallace (1982) that mining of sand offshore of the greater New York metropolitan area would be profitable. De Lois and Wallace (1982) point out that economies of scale are key to profitable marine mining.

Identified resources of phosphorite are large, and one of the major provinces is within the U.S. EEZ, from offshore North Carolina south to Florida (Riggs, 1984). In a detailed study of the North Carolina continental shelf, Riggs and others (1985) estimate 4.5×10^9 metric tons of concentrate could be recovered. Broadus (1987), estimating that marine phosphorite resources represent less than 10 percent of total world onshore resources, concludes that there is little near-term need to exploit the marine deposits.

Research relating to the occurrence and character of manganese nodules and crusts on the Blake Plateau began in the 1950's and continues (Manheim and others, 1980). Results of research have been well summarized in a report to the USGS by the Charles River Group. The concentration of copper, nickel, and cobalt is low in these nodules and crusts. Nevertheless, the Blake Plateau occurrence is a potential resource for manganese. In fact, the Blake Plateau was the site of the first successful mining of manganese nodules when, in 1970, the R/V *Deep-Sea Miner* dredged nodules from approximately 800 m of water (Siapno, 1987).

Heavy-mineral placers have been the focus of a variety of studies of differing scope. Analyzing samples obtained on a 10-km grid on the continental shelf from Nova Scotia to Florida, Ross (1970a,b) and Milliman and others (1972) noted some samples with anomalously high heavy-mineral content. Presently, Berquist and Hobbs (1986), in an assessment of heavy minerals in the inner continental shelf offshore of Cape Charles, Virginia, concluded the concentrations were sufficient to justify further research. Their research, with the target species titanium, is now being extended south toward the border with North Carolina. Many of the samples used in these studies are surficial, although recent studies make use of vibratory coring devices. The U.S. Geological Survey is also conducting research on heavy minerals on the Virginia shelf (Escowitz, 1987, personal commun.). In 1974, Noakes and others reported on possible heavy-mineral deposits on the inner continental shelf off Georgia. Recently, the Minerals Management Service granted an exploration permit to DuPont and Associated Minerals, USA, for heavy minerals beneath waters in Federal jurisdiction offshore of Georgia (Woolsey, 1987, personal commun.). Titanium-bearing sands offshore Virginia and Georgia were in the subject of a study on economic potential by the Bureau of Mines (1987). In this report, the Bureau identified conditions necessary for economically feasible mining.

Presently, there are no commercial marine mining operations off the U.S. east coast, in either State or Federal waters.

Process Studies

The last phase concerns process studies in the East Coast EEZ. Most of these have taken place on the continental shelf (inshore areas), much less so in the deep ocean. Many inferences on the types of processes thought to have acted in an area over the past few hundred or thousand years have been made by study of the character of acoustic profiles (Emery and others 1970; Emery and Uchupi, 1984; Schlee, 1973). The trouble with this approach is that the profile is a composite picture of events that have shaped the seafloor over an undefined length of time. Mainly through an inspection of the physiography, Emery and Uchupi (1984, Chapter 2, Chart XA) list the processes they think are shaping the continental margin.

Actual observational studies are rare but have been made by Butman (in press; 1986a,b) for the southern part of Georges Bank, Lydonia Canyon, and Oceanographer Canyon. These studies show currents strong enough in the submarine canyons to resuspend fine-grained sediments at the canyon heads. Similiar studies of the mid-Atlantic Bight and slope areas southwest of Georges Bank have been made by Hamilton (1984), Csanady and others (in press), and Butman (in press) as part of the Continental Shelf Research SEEP volume to be published soon. The SEEP studies showed that near-bottom currents faster than 20 cm/sec (0.4 kt) occur frequently over the Outer Continental Shelf but are rare at depths of 500 m and 2 km over the slope. A descriptive compilation of marine processes has been made by Stanley and Swift (1976) for the shelf-slope-rise. Except for coastal areas, the studies mainly focus on offshore morphology, sediment texture, and bedform geometry. These and other studies suggest that internal waves of tidal, or shorter, period formed along thermoclines and warm core eddies may generate localized, elevated, near-bottom velocities at the shelf break.

For deepwater areas, a good summary of what we know of dynamic sedimentary processes has been given by Tucholke (1987) in a published summary of the U.S. Atlantic continental slope and rise compiled for MMS by Milliman and Wright (1987). Tucholke discusses the importance of debris flows, mass movements, and turbidity currents in the Atlantic slope-rise area but is mainly descriptive. No one has really documented any of these processes in situ, except for the 1929 Grand Banks slump, which progressively broke transatlantic cables (Heezen and Ewing, 1952) well north of the U.S. EEZ. The Wilmington deep sea fan has been described by Cleary and others (1985), and Cacchione and others (1978) have described the Hudson Canyon. On the basis of four submersible dives, Cacchione and others found evidence of current scour and sediment movement in 2,900–3,000 m in water depth in Hudson Canyon.

The paucity of actual measured current-meter observations and the dearth of morphology, core, and sediment textural studies over limited areas of the deep seafloor point up the essential first step—namely to overlay the maps and partial maps from inferred process studies on to the GLORIA mosaics for the East Coast EEZ and see what processes correlate with what mosaic patterns and what the interplay of geostrophic current deposits and mass wastage debris is. How much of an imprint do earlier active episodes of sedimentation (for example, the Pleistocene) make on the seafloor?

GAPS IN OUR KNOWLEDGE ABOUT THE EAST COAST EEZ

Geologic Framework

The broad geologic framework for large-scale features like the Baltimore Canyon trough (Grow and others,

1983) and the continental rise wedge (Tucholke, 1987) are fairly well known mainly because of the large number of seismic reflection profiles collected over the shelf area and because of the intense interest in the trough by oil companies and by academic institutions (Tucholke and others, 1982). The continental rise wedge has not been subdivided areally to the degree the shelf has. Only two DSDP holes (105 and 536) have been drilled through the entire section to the basement. Hence, knowledge about the deep-sea stratigraphic section is severely limited, a condition ODP at one time hoped to remedy by drilling ODP hole 603, due east of Cape Hatteras. The site was eventually cancelled because of time constraints. But a complete section is still needed, as is more detailed mapping of the buried paleoshelf edge. It is in this area that the pinch-out of organic-rich black shales of Cretaceous age takes place. What is the nature of the pinch-out, and have these units acted as source beds to any of the flanking structures of the buried paleoshelf edge complex? Shell Oil Company drilled this structure in 1983–84 and encountered minor noncommercial gas shows. Their drilling program revealed much about the complex (Karlo, 1986) but only a limited amount about the seaward flanking facies. Most knowledge comes from DSDP hole 603, in 4,633 m water depth, 270 mi east of Cape Hatteras where Legs 93 and 95 encountered 268 m of deep-sea turbidite sands of Early Cretaceous age. Again, what are the areal distribution and source rock potential of these units?

The bathymetry in the Atlantic rise area is only partially known through widely spaced surveys on small-scale maps. A published complete Sea Beam survey of the area is needed to see the morphology of fans, deep-sea channelways, lower rise hills, sediment drifts, and debris aprons. We hope that the current negotiations between the Navy and NOAA will result in free and open release of this type of survey. It seems ironic that we are willing to sell such devices to friendly nations like France, who can publish the results of their surveys but seek to restrict use of this high-technology system in our own waters.

Also needed for the slope-rise area is a sampling program keyed to the main depositional features seen on the newly acquired GLORIA mosaic. As a start, the existing samples should be plotted on the mosiac so that gaps in coverage can be spotted and additional samples can be obtained. With this type of correlation we should be able to construct for the first time a process-oriented sediment map. The followup to this type of map will be a compilation of the high resolution seismic profiles to see how the major depositional features (fans, slumps, sediment drifts) show up on the profiles. There are a number of questions associated with this topic: Are they only ephemeral surface features, or have they been around for a while? If so, what is their definition by seismic characteristic?

Small-Scale Features Under the Continental Shelf

These features (folds, faults, grabens, horsts, reefs, rollover structures) have been mapped in most detail by the oil companies or by MMS staff. Here the profiles are closely spaced and gridded to bring out potential exploratory structures as they relate to particular lease blocks. In the deep sea, small-scale structures need to be detected and mapped, but these are more likely to be the interest of oil and mining companies intent on leasing an economically important area. Smaller features like the Charleston Bump, Blake Outer Ridge, or New England Seamounts will probably continue to be of interest to academic and to individual government scientists just as could separate ODP drilling transects.

Study of smaller sedimentologic features like the Hudson fan or the Carolina trough salt domes may be more likely the cooperative effort of academic and governmental scientists as the interest arises. Shallow structure of offshore sedimentary deposits again will likely be a cooperative effort between university and governmental investigators. Much will depend on whether the deposit is a potential sand-gravel or placer deposit or a mineable manganese pavement.

The deepwater studies for economic deposits will likely be done by the companies who hold the leases, as in the past. On the continental rise there has been an almost complete lack of the type of detailed surveys that usually precede leasing. Doubtless, we and academic institutions will continue to map major depositional structures of research interest. Perhaps some of the topical studies of a fan, a field of salt diapirs, or a sediment drift will kindle interest by companies in their search for exploitable structures.

Geologic Processes

Though most of the actual bottom-current observations have come from the shelf, these studies have been widely spaced and targeted at specific lease tract areas (Knebel and others, 1976) or estuaries and major segments of the shelf (New York Bight). Many of the studies attempted to focus on circulation and sediment budgets and shallow stratigraphy for selected inshore areas (O'Hara and Oldale, 1980; Meade, 1969).

On the slope, a few studies have been made in widely spaced canyons and a few canyon dives in submersibles. But, the lack of milestone studies is on the continental rise. As already pointed out, inferences about the forces acting there have been made on the basis of sediment patterns, bottom photographs, and shallow seismic stratigraphy. HEBBLE (High Energy Benthic Boundary Layer Experiment) studies are lacking, such as were made off Nova Scotia (Hollister and McCave, 1984). Laine (1978) studied abyssal circulation in the North American basin by using acoustic profiles, cores, and DSDP drill sites. Through intense study of a 2 km × 4 km rectangle of the seafloor, the HEBBLE study showed that the deep seafloor is impacted periodically by abyssal storms which stir up the bottom and groove mud beds. We strongly recommend similar type studies in specific areas selected in part on the GLORIA mosaic, to get at the strength, duration, and type of bottom currents acting there. This type of a process study is an important precursor to any exploitation of the rise area in order to gain an idea of the forces acting there—forces which could adversely affect a mining process and disperse unwanted pollutants.

PROCESSES AND FRAMEWORK AS THEY PERTAIN TO NONLIVING RESOURCES

A combination of academic, governmental, and industry studies is needed to gain a detailed understanding of the areas of thickest sediment accumulation under the rise, the position of pinch-outs of organic-rich stratigraphic units, locations of folds, diapirs, faults, and buried channel systems, and heat-flow values adjacent to buried and exposed seamounts.

Except for the Shell Oil Company efforts on the lower Atlantic continental slope (1,527 to 2,116 m water depth) petroleum exploration has never been attempted in water as deep as that on the continental rise. Obviously, the price of the commodity will need to rise before interest is again evident in the Atlantic continental margin. For hard-mineral exploration, again, the price for the commodity will need to rise and a clear set of regulations to cover the offshore areas will need to be promulgated in response to an interest in the selected areas by the mining companies. Government and university scientists can continue to do broad-gauged studies in the deep sea, which will in a general way address the objectives mentioned above, but the companies will need to focus more narrowly on economic targets for future leasing.

RECOMMENDATIONS FOR THE ATLANTIC EEZ PANEL

The 17 members of the Atlantic panel represented a broad cross section of governmental, academic, and industry views on the Atlantic margin. Basically we considered future study of the continental shelf from a commodity (sand and gravel) use viewpoint and future study of the slope and rise (deepwater part of the EEZ) from a research view, realizing that the deepwater areas probably do have resource and multiple use potential, though exploration would be farther in the future and dependent upon results of research. We have not formulated a detailed step-by-step plan for EEZ study but instead offer recommendations to focus on the next series of steps needed to promote development of the area. This will provide the kind of data needed for Federal and State planners in the regulation and study of offshore areas.

1. To continue the issuance of high-quality bathymetric, geologic, and environmental maps at varying scales and for varying purposes of selected areas of the continental shelf. The main driving force for the maps is the anticipated development of offshore sand, gravel, phosphorite, and heavy-mineral placer deposits. Obviously, such an undertaking will need to be cooperative between governments, industry, and academic institutions to provide the many-faceted types of maps each is best able to produce and will find most useful. The scales of such maps would range from 1:24,000 to 1:100,000 and could be contoured at as low as a 1-m interval. Environmental studies should seek to measure the direction and strength of bottom currents on the shelf floor plus the magnitude of impact from extreme events, either seismically or atmospherically driven, such as winter storms and hurricanes that move through the area. We want (1) to see in advance how these currents act when a water column or benthic plume is created as a part of shelf floor dredging for sand and gravel and (2) to verify any change, or lack thereof, as a consequence of dredging.

   In the slope-rise area the emphasis shifts more to one of basic research, specifically the "ground truthing" of the recently collected GLORIA data. The sand, gravel, phosphorite, and heavy-mineral placer deposits, their areal distribution, and deposits from the many different kinds of processes evident on the GLORIA mosaic need to be checked and the examination and description of core and spot samples keyed to textural changes apparent on the mosaic. From such a project could come much more realistic geologic and environmental/processes maps for the floor of the deep sea, such as much improved maps and interpretive views of the type of processes moving sediment into the deep sea, their relative importance, and their geometry. From such a process emphasis on the GLORIA mosaic we can pick the best areas to locate Sea Beam bathymetric map requirements and process type studies in the deep sea that highlight downslope mass-wastage sediment transport, slump, geostrophic sediment movement, and Gulf Stream bottom transport. By focusing on processes studies, future projects should be able to determine the best locations for waste disposal in the deep ocean, depending in part on whether the objective is for dispersal or for burial. The evaluation of the type of processes acting there should also aid in assessing the possibility of resource extraction, such as manganese nodule (pavement) mining or oil and gas drilling.

2. The panel recommended development of a task force among Federal, State, industry, and appropriate special interest groups to facilitate development of offshore placer-sand-gravel mining in the coastal area between Virginia and Massachusetts. The task force would promote regulations in order to encourage development and would identify and locate the kinds of data needed by State planners charged with leasing in State waters. These data include, but are not limited to, geologic maps to portray shallow stratigraphy (less than 0.1 second) and outcrop and environmentally sensitive data.
3. The panel recommended wider use of existing data storage systems and libraries. In assessing any part of the shelf, one inevitably needs to know what types of data are in one of several central repositories, such as the National Geophysical Data Center (NGDC-NOAA-Boulder) or the National Oceanographic Data Center (NODC-NOAA-Washington, D.C.) to evaluate a specific problem (for example, impact of mining on a certain subsurface aquifer system). A more widespread effort is needed to get investigators (State, Federal, academic) to file data from their surveys in a central repository, where it can be used by other nonconflicting investigators interested in the same area. NGDC currently serves such a function for geophysical profiles of varying types for Federal-academic data. Planning for similar repositories covering a broader range of user groups and encompassing a wider variety of data types is strongly recommended for the Atlantic area.
4. A higher priority should be given to coastal studies by Federal programs in the EEZ than presently exists. The National Science Foundation currently is placing the emphasis of its oceanographic programs on past climate changes as reflected in deep sea sediment. NOAA is collecting bathymetric data in selected areas of the deep sea and on the continental shelf. More effort is recommended for State, academic, and Federal scientists to chart the multi-use impacts of storms, coastal development, dumping of toxic and nontoxic wastes, and siting of offshore structures for the inner coastal shelf. Because of its proximity to large population centers along the east coast, this is the area that will need more study in the future to ensure adequate information for potential users and regulators.

Constraints

In line with instructions for future plans in the Atlantic EEZ, the panel discussed and was concerned about the following potential problems.

1. Declining numbers of skilled/educated personnel to study the East Coast EEZ.
2. Classification of swath-type bathymetric data by the U.S. Navy. A main effort by NOAA in the EEZ is in the collection of Sea Beam data by four ships dedicated to this effort. To have most of this data classified thwarts the effort to chart the bathymetry by a new, improved technique. Ways have to be found to "sanitize" the data sufficiently to satisfy the Navy's objections yet adequately portray the morphology of the seafloor.
3. Several members of the group expressed concern about the impact of a recently issued proposal permitting research of academic institutions (Texas A & M) for the continental shelf area by MMS. The concern deals with a possible constraint to future research if the rules are put into effect.
4. Data collection limitations: an incomplete system of Global Positioning System (GPS) satellites for precise navigation, the low towing speeds by certain geophysical gear, and need for large-volume samplers to sample selected suites of heavy minerals in placer investigations.

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Workshop 4: Scientific Mapping and Research to Characterize the EEZ—Gulf Coast

Panel Co-chairpersons:
James M. Coleman, Louisiana State University
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INTRODUCTION

The Gulf of Mexico basin (fig. 1) is the largest semi-enclosed depositional basin in the United States and has been the site of extensive hydrocarbon exploration and exploitation since the 1940's. Since the Late Jurassic, the drainage basin of the Mississippi River system has been delivering sediments to the Gulf of Mexico (Worzel and Burke, 1978). Mesozoic and Cenozoic deposits are estimated to have attained a total thickness in excess of 15 km (Martin and Bouma, 1978; Bouma and others, 1978). Thus the river system has been operative over relatively long periods of time, constantly feeding sediments to the receiving basin and building a thick Tertiary and Quaternary sequence of interfingering deltaic, nearshore, coastal-brackish-water, and marine sediments, which have prograded the coastal plain shoreline seaward. Through time, the sites of maximum deposition, or depocenters, have shifted within the gulf coastal plain, forming a relatively thick Tertiary and Quaternary sequence of clastic sediments. The zone of maximum thickness trends roughly east-west near the present-day coastal plain of Louisiana and Texas. Rapid subsidence associated primarily with sediment loading and salt and shale diapirism (fig. 2) has been responsible for unusually thick localized sedimentary accumulations.

The modern depositional pattern in the gulf basin, where terrigenous deposits dominate on the northern and western shelf areas and carbonates occur on the broad platforms of the eastern gulf, has persisted since the Late Jurassic–Early Cretaceous (fig. 3). It was then that the terrigenous clastic influx from tectonically elevated northern and western continental interiors began to overwhelm the mainly carbonate environments that encircled the gulf during Jurassic times (Garrison and Martin, 1973). The bulk of the sediment was delivered to the northern margin of the gulf during the Cenozoic and prograded the shelf as much as 300 km from the margin of the Cretaceous platform deposits to the present shelf edge. This progradation rate is exceptionally high, averaging 5 to 6 km of shelf edge progradation per million years (fig. 3). Such rapid progradation contrasts sharply with that of the eastern margin of the United States, where the average is measured in fractions of a kilometer per million years.

The Quaternary deposits of the gulf basin are unusually thick: up to 3,600 m have accumulated beneath the present shelf in offshore Louisiana and Texas, and up to 3,000 m have accumulated in the deep gulf basin in the vicinity of the present Mississippi Fan. On the continental slope, many of the Quaternary sediments have been deposited in salt withdrawal basins (intraslope basins) and sediments often accumulate to considerable thicknesses. Much of this thick Quaternary sedimentary sequence has been controlled by the relatively high-frequency fluctuations in climates associated with glacial advance and retreat within the Mississippi River drainage basin.

DESCRIPTION OF REGION

Northern Gulf Basin

The subaqueous late Wisconsin and Holocene sediments of the gulf basin display a high degree of variability and record varying process controls. The continental shelf off west Florida is primarily carbonate, which gradually merges into the relict sand sheet that fronts most of peninsular Florida, Alabama, and Mississippi. Studies by Gould and Stewart (1956), Doyle and Sparks (1980), and Doyle (1981) along the west Florida shelf show that facies patterns tend to parallel the adjacent coastline. Coarse carbonates (grainstones) mixed with quartz sands are typical of the nearshore parts of the shelf, whereas these facies grade into carbonate mudstones near the shelf edge. Off the Mississippi delta and western Louisiana, the shelf is variable in width and relatively complex in its pattern of sedimentation. The broad shelf off Texas displays little topographic relief and consists mostly of relict sediments.

The continental slope of the gulf basin is a region of relatively gentle gradients interrupted by a complex series of basins and highs (salt and shale diapirs); it is blanketed with fine-grained pelagic and hemipelagic sediments that

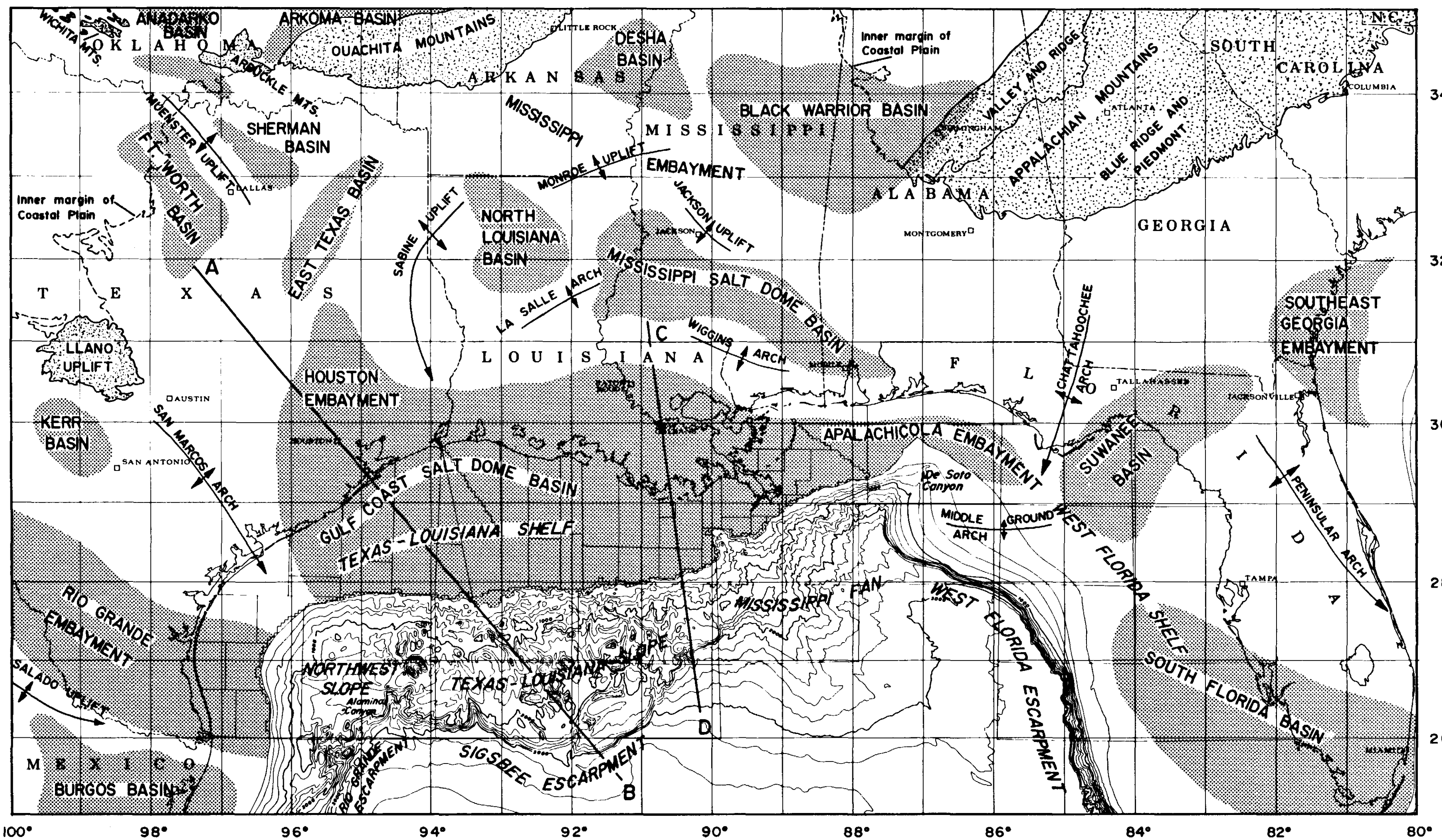

Figure 1. Physiographic and geologic provinces and subsea topography of northern Gulf of Mexico. Contour interval, 200 m; scale approximately 1 cm = 120 km. (From Martin, 1982, figure I–5.)

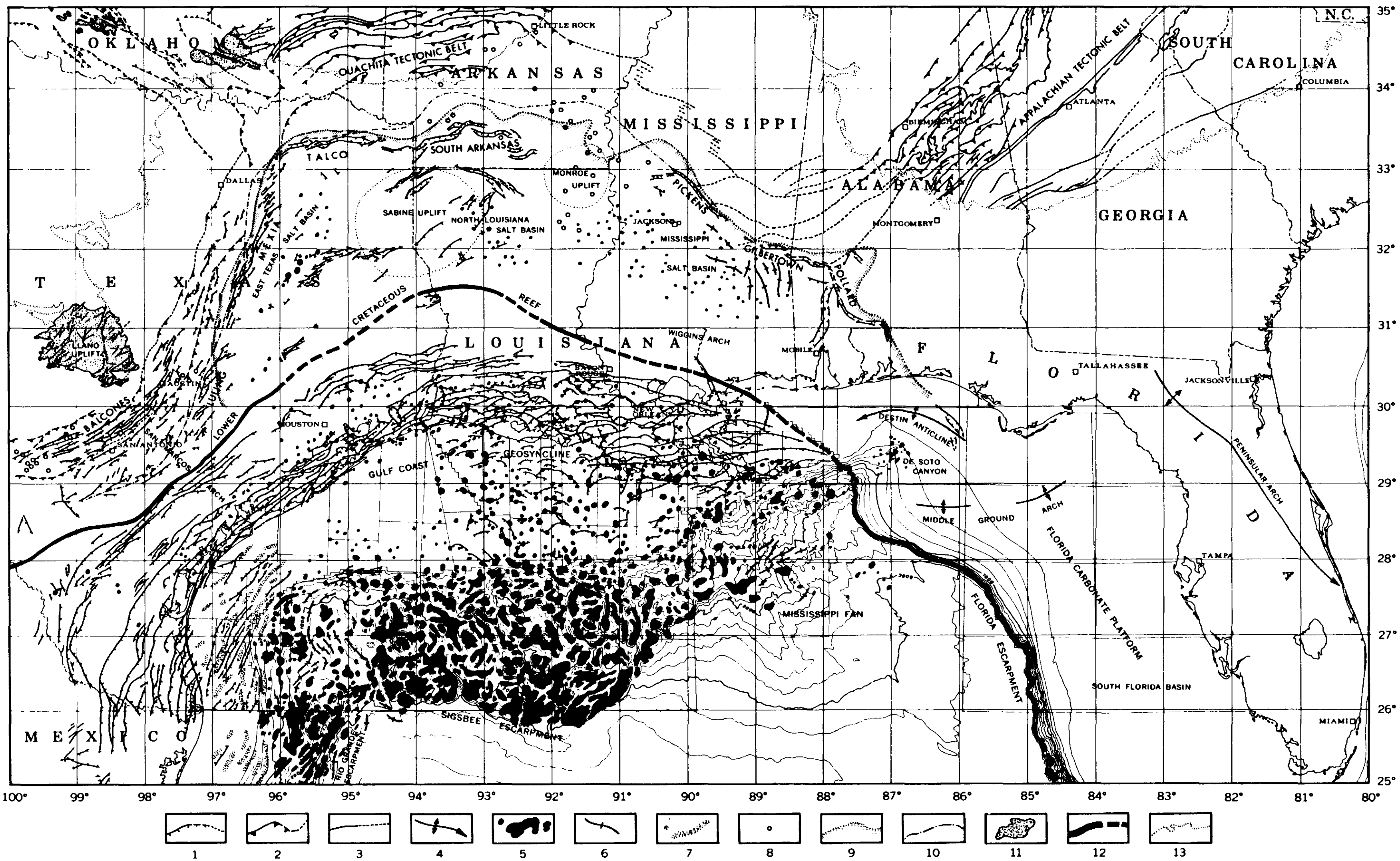

Figure 2. Tectonic map of northern Gulf of Mexico region. Explanation of patterns and symbols: (1) normal fault, (2) reverse fault, (3) fault of undetermined movement, (4) broad anticline or arch of regional extent, (5) salt diapirs and massifs, (6) salt anticlines and pillows, (7) shale domes and anticlines, (8) Mesozoic plutonic and volcanic rocks, (9) updip limits of Louann salt, (10) known downdip extent of buried Ouachita tectonic belt, (11) exposures of Paleozoic strata and Precambrian basement, (12) Lower Cretaceous shelf-edge reef system, and (13) inner margin of Cretaceous and Tertiary strata. Bathymetry in meters (200-m interval); scale approximately 1 cm = 120 km. (From Martin, 1982, fig. I–6.)

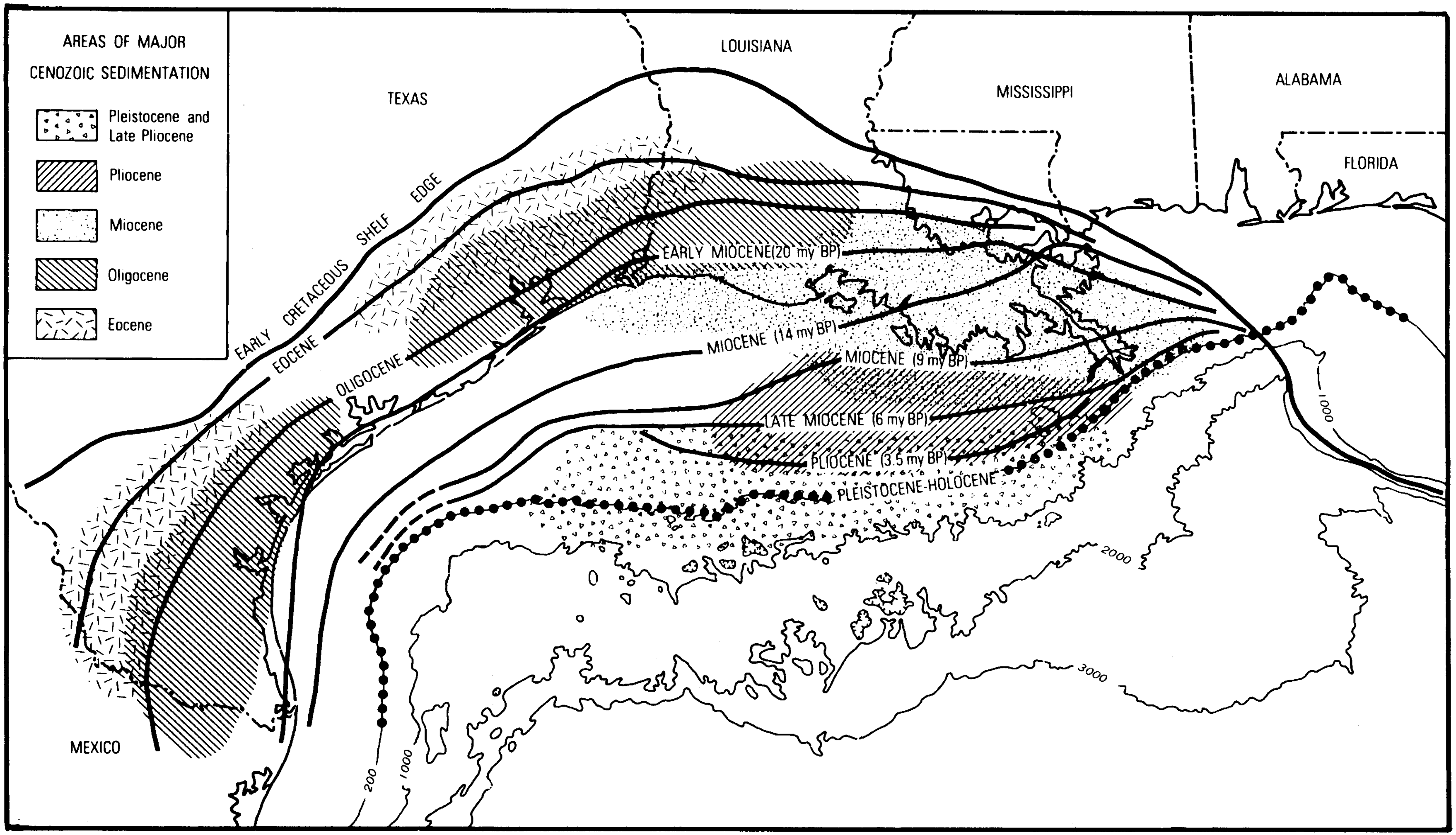

Figure 3. Sketch map showing paleoshelf edges in gulf coast basin and distribution of major Tertiary depocenters. (From Martin, 1982, fig. I–9.)

are interrupted by carbonate-rich sediments on topographic highs such as diapirs. The continental slope off Louisiana is characterized by the only major submarine fan in the gulf, the Mississippi Fan.

Morphology and Depositional Patterns in the EEZ

The submerged part of the northern gulf basin can be divided into several major regions or provinces (fig. 1): the northeastern and eastern gulf (offshore Florida, Alabama, and Mississippi), the central gulf (offshore Louisiana and Texas), and the western gulf (offshore west Texas and Mexico).

The sedimentation patterns and near-surface structure are poorly known for many of these regions; it is only in the north-central gulf where abundant data are present because of the large number of drill sites acquired for offshore petroleum platforms. The modern continental shelf and slope, especially in the north-central gulf, have been dominated by huge sediment yields of the Mississippi River and its shifting sites of deposition during the late Wisconsin and Holocene. Areas in the immediate vicinity of the deltas receive large volumes of sediment and seaward building of the shelf edge. Rapid subsidence associated with sediment loading, and vertical aggradation result. Areas removed from the site of active sedimentation accumulate only thin veneers of hemipelagic and pelagic sedimentation. In some instances, particularly along the eastern and southern margins of the gulf, carbonate deposition dominates. Another major factor controlling sedimentation patterns and modern shelf morphology has been changing sea levels associated with the advance and retreat of continental glaciers during the latter part of the Pleistocene and Holocene. When sea level is lowered, sites of active nearshore sedimentation migrate seaward, causing a rapid buildout of the shelf edge in front of the prograding delta lobes or causing exposure to subaerial erosional processes in areas removed from the sites of active deltaic sedimentation.

Continental Shelves

The morphology of modern continental shelves of the Gulf basin has been controlled primarily by sea-level fluctuations during the Pleistocene, as well as the location of the site of active sedimentation of the Mississippi River. Depositional environments on the continental shelf can generally be categorized as terrigenous in the northern and western shelf areas and carbonate on the broad platforms of the eastern and southeastern gulf. This pattern has persisted since Late Jurassic–Late Cretaceous time, when terrigenous clastic influx from tectonically elevated northern and western continental interiors began to overwhelm the mainly carbonate environments that encircled the gulf during the Late Jurassic (Garrison and Martin, 1973). Most sediment was delivered to the northern margin of the gulf during the Cenozoic and prograded the shelf as much as 300 km from the margin of the Cretaceous platform deposits to the present shelf edge.

Western Florida Shelf

The continental shelf in this region is extremely broad, often exhibiting widths of nearly 200 km. The surface is relatively smooth and displays little morphologic variability. Most of the sediment zones are oriented parallel to the shelf contours and are thus parallel to the present shelf edge. The shelf edge is rather abrupt in places, and the bottom gradient of the continental slope is extremely steep. However, this shelf-slope area is a modern example of a nonrimmed carbonate margin, which is much less steep than the typical reef-dominated, rimmed margin. The only major bathymetric relief on the western Florida shelf is formed by bedforms in the mollusk-rich sand and coralline algae ridges (Doyle, 1981).

Northeastern Gulf Shelf

The shelf break off westernmost Florida, Alabama, and Mississippi ranges in depth from 60 to 100 m and is characterized by a relict topography covered by a thin sand and mud sheet deposited during the last eustatic sea level rise. The shelf is rather narrow because of the large reentrant referred to as the De Soto Canyon. This large reentrant is not a true submarine canyon but is formed at the point where Tertiary clastic sediments lap against the carbonate facies of the northeastern gulf. The sediments underlying the thin Holocene sediment cover consist of fluvial sands and gravels deposited during the last low sea-level stand. Most of the inner shelf consists of a clean quartz-rich sand that was reworked numerous times during the changing sea levels associated with the late Pleistocene. Linear shoals, probably representing relict nearshore topography (beach and barrier systems), are present within this sand sheet. Small bedforms are actively migrating on the shelf, indicating modern-day reworking of these relict topographic features. The outer rim of the shelf consists of a lime-mud facies, a mixture of calcium carbonate, quartz, and terrigenous clays. Offshore of Mississippi and Alabama, the same lime-mud facies exists but contains several zones of carbonate buildups and inter-carbonate facies. The buildups occur in two depth zones, one at 65–80 m and one at 97–110 m water depth. The carbonate buildup zone is characterized by algal limestone pinnacles, some attaining relief in excess of 15 m. In the inner-reef areas, molluscan shell debris and other carbonate debris in a muddy matrix are the most common lithology. Separating the sand facies from the lime-mud facies is a transition zone consisting of calcareous muddy sands and silts.

Louisiana Continental Shelf

The shelf off Louisiana is highly variable in width, generally less than 20 km off the active mouths of the Mississippi River delta and in excess of 180 km off the western Louisiana coast. The narrow shelf in front of the Mississippi River is probably the most dynamic area in the submerged coastal plain of the gulf margins. Deltaic sedimentation has dominated the northern Gulf of Mexico basin since the Late Jurassic or Late Cretaceous; this sedimentation is the major mode of transport and deposition that has been responsible for the huge volume of sediment found in this basin. The Mississippi River delta not only is one of the most studied but is the most important supplier of sediment to the gulf basin. It is one of the world's largest deltas, with an area of 28,600 km^2, of which 4,700 km^2 (16 percent) is subaqueous.

The present deltaic plain is mainly the result of deltaic progradation and shifting delta lobes occurring since relative stillstand was reached in the Holocene. During the last low sea level (15,000 to 18,000 years ago), the Mississippi River was delivering sediment and forming deltas near the present-day shelf edge (Suter and Berryhill, 1985). As sea level began to rise, sediment yield to the coastline diminished, as most of the sediment was being deposited within the rapidly aggrading alluvial valley that had been deeply eroded during low sea levels. Alluvial valley infilling continued as sea level rose. By approximately 12,000 years ago, valley infilling was nearly complete, and deltas began to actively prograde. During the period of 18,000 to 12,000 years ago, the Louisiana shelf deposits record a relatively thin pelagic clay and a thin sandy shell horizon that mark this hiatus in deltaic development.

The subaqueous part of the Mississippi River deltaic plain consists of that area of the Gulf of Mexico, off the Mississippi River delta, that is below low tide level and actively receiving riverborne sediments. Major subenvironments generally radiate from the mouths of the distributary channels. Three major depositional environments are present: the distributary mouth bar, the delta front, and the prodelta. Sediment-laden, fresh river water debouches through the distributary mouth, spreading as a buoyant plume. Water velocity decelerates with distance from the river mouth, and coarser clastics rapidly drop out of suspension. Deposition of these coarser sediments produces the distributary-mouth bar, which, being in relatively shallow water, is subject to reworking by marine processes. These deposits also contain large quantities of transported organic matter, commonly referred to as "coffee grounds." The distributary-mouth bar deposits display well-developed crossbedding and cross-laminations, particularly climbing ripples. Farther offshore, deposition of fine sands, silts, and minor amounts of clay forms the delta front, or distal bar environment. These deposits display well-developed reverse-graded and normal-graded laminations. Farthest offshore, deposition is characterized only by fine-grained clays referred to as prodelta deposits.

Subaqueous slumping and downslope mass movement of sediments, although only recently recognized as normal processes, are very important to subaqueous morphology off the Mississippi River delta. Recent research has shown that low-angle slopes at the delta front are unstable and that large amounts of sediment are transported from shallow to deep water in a variety of ways (Coleman, 1976). Factors influencing the stability of bottom sediments include rapid deposition and sedimentary loading, biochemical degradation of organic material and methane gas production, underconsolidation of fine-grained deposits, and cyclic loading induced by passage of winter storms and hurricanes (Coleman and Prior, 1980).

Rapid deposition of the coarser distributary-mouth bar sands over the weaker prodelta clays leads to diapiric intrusions of clay into and through the sands. Such forms are usually called mudlumps or mud diapirs. Other instability forms include collapse depressions, peripheral rotational slides, mudflow gullies, depositional lobes, and shelf-edge slumps. Detailed descriptions of processes of failure, geometry, and distribution of these features can be found in Coleman (1976), Coleman and Prior (1980), and Prior and Coleman (1978).

The most common type of instability is the mudflow gully. Submarine failures result in a radiating pattern of channels, with seafloor relief in excess of 5 m, that crease the narrow shelf to the edge of the continental slope. It is estimated that as much as 50 percent of the sediment annually delivered to the river mouth is displaced seaward near the shelf edge by these instability processes. At the shelf edge, large-scale shelf-edge failures and growth faults control the shelf-edge morphology (Coleman and others, 1983).

West of the active Mississippi River delta, the shelf is extremely broad and mud covered, displaying little topographic relief. Holocene muds, which blanket the shelf, vary in thickness from a few meters to 10 m and were derived from the Mississippi River by the slow westward drift that characterizes this part of the northern gulf. Off central Louisiana, there are a few shoals, remnants of former deltas that formed during the Holocene transgression and are now stranded on the middle and inner shelf. These shoals consist of sands reworked from the transgressed delta facies. They form relatively low-relief structures and are generally thin, less than a few meters thick (Penland and Boyd, 1981). Near the shelf edge are a few carbonate banks, commonly associated with topographic highs created by diapirism, that formed during former low sea-level stands. Some of these banks display algal pinnacles that rise above the seafloor and display relief of up to 10 m. Large areas of the shelf edge are covered with carbonate-cemented sediments and shell lags. Beneath the Holocene blanket of hemipelagic muds rich in calcareous microfaunal tests are eroded channel systems that formed during the last low sea level as the channels of both the Mississippi River and coastal streams entrenched themselves in response to the lowered sea level (Suter and Berryhill, 1985). Offshore borings near the outer shelf indicate a considerable volume of fluvial and deltaic sands associated with these low sea level riverine systems. Sand thicknesses on the order of 70 to 100 m are present.

Offshore Texas Shelf

The shelf offshore of Texas is relatively broad and displays only minor topographic relief. Shelf sediments contain only a thin cover of Holocene deposits overlying an eroded late Pleistocene subaerial fluvial plain; in many instances, late Pleistocene sediments crop out on the seafloor. Entrenched stream channels similar to those off the Louisiana shelf are common across the shelf but have been completely infilled during the Holocene rising sea level stage (Suter and Berryhill, 1985). The shelf edge consists of a series of prograded late Pleistocene shelf-edge deltas (Suter and Berryhill, 1985) that formed in response to the lowering of sea level. Little information is available on types of sediment composing these delta lobes and the thicknesses of the sequences. Much of the shelf edge is characterized by crenulated topography, the result of sediment instability processes during the late Pleistocene and diapiric intrusion of salt and shale masses. Both deep-seated and shallow compaction faults are common across the shelf but show little topographic expression because of truncation during the last eustatic rise of sea level (Berryhill, 1980, 1981). Along the outer shelf edge, carbonate banks are common, similar to those off the Louisiana shelf. Those off Texas, however, do not tend to have much Holocene sediment cover. The most prominent of these carbonate banks are the West and East Flower Garden Banks off Galveston, Texas, which have developed into true coral-algal reefs. These reefs display active carbonate-producing faunal and floral growth. The reefs have developed on diapiric structures near the shelf edge. Many of the carbonate banks cap diapiric highs and were actively growing during the lowered late Pleistocene sea level; today, as a result of Holocene sediment cover or lack of sunlight penetration because of water depth, only a few display active growth.

Continental Slope

The continental slope of the gulf basin is a region of gently sloping seafloor that extends from the shelf edge, or roughly the 200-m isobath, to the upper limit of the continental rise, at a depth of 2,800 m. The slope occupies more than 500,000 km^2 of prominent escarpments, smooth and gently sloping surfaces, knolls, small-scale pinnacles, intraslope basins, ridge and valley topography, and submarine channels (Martin and Bouma, 1978). Martin and Bouma (1978) described nine distinctive subprovinces and many individual features (fig. 1). The factors that have controlled the present-day morphology include reef building on the Florida and Yucatan carbonate platforms; erosion, nondeposition, and faulting in the Straits of Florida and Yucatan Channel; diapirism and differential sedimentation on the slopes off Texas and Louisiana; tectonic uplift and diapirism in the Golfo de Campeche; rapid accumulation of terrigenous sediment of Pliocene and Pleistocene age in offshore Louisiana; and the folding of a thick blanket of sediment on the slope off eastern Mexico.

Louisiana-Texas Slope

The most complex province is the Louisiana-Texas slope, comprising a 120,000-km^2 area of knoll and basin seafloor. The average gradient of the slope is slightly less than 1°, but slopes greater than 20° are not uncommon around the many knolls and basins. Steep-sided knolls, enclosed intraslope basins, and canyonlike topography characterize the eastern two-thirds of the slope, whereas occasional knolls and low-relief noses mark the otherwise featureless slope of the western sector (Martin and Bouma, 1978; Bouma and others, 1978). The extreme topographic relief of the slope is a product of salt diapirism (fig. 2) and salt withdrawal beneath the basins. Intraslope basins, such as the Gyre basin, are flanked and commonly surrounded by salt domes and contain exceptionally thick sections of Tertiary sediments (Bouma and Coleman, 1986). The basins are directly related to the growth of adjacent salt spines, which blocked active submarine channels or coalesced to create seafloor expression in noncanyon areas.

The major characteristics of the Louisiana-Texas continental slope are shown schematically in figure 4, which depicts a typical outer continental shelf–upper continental slope setting. The shelf edge is commonly marked by a distinctive break in slope, but the geometry and gradients are dependent upon the presence or absence of several factors: faulting, diapirism, local low sea-level sediment accumulations (shelf-edge deltas), fluvial channels, the development of bioherms, or shelf-edge erosion. Figure 4 depicts a series of prograding inclined strata representing delivery of sediment to the shelf edge during lowered sea level. Because of rapid accumulation, these sediments show postdepositional and syndepositional features. Typically, growth faults tend to accentuate the shelf-edge break. Some of these faults extend through the near-surface sediments to the seafloor and have associated gas seeps, indicating their deep origin within the sedimentary sequence. Associated with some of the growth-fault

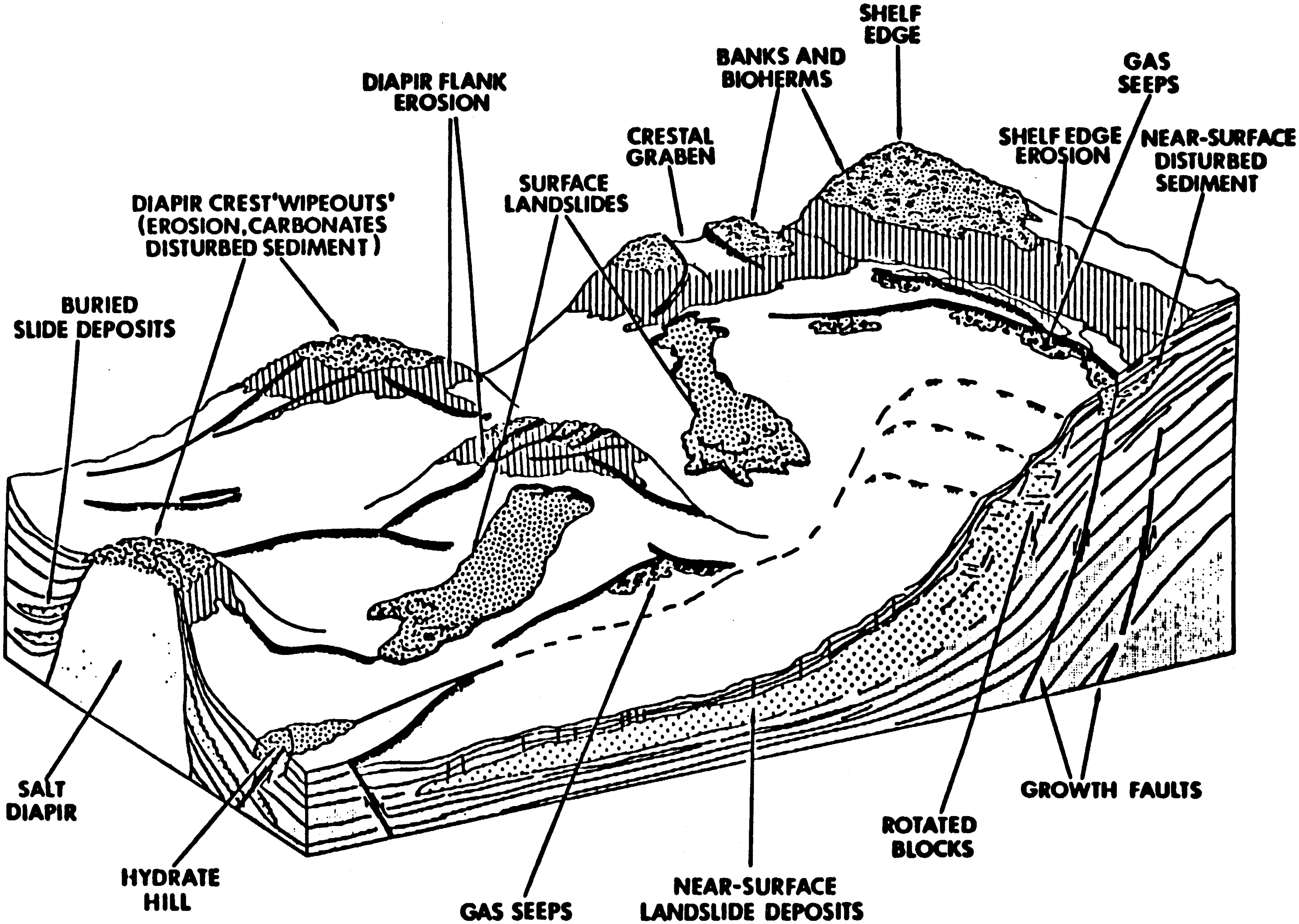

Figure 4. Schematic block diagram depicting the principal geologic feature associations on the Outer Continental Shelf and upper continental slope of offshore Louisiana and Texas. (After Coleman and Prior, 1987.)

systems are both large-scale and localized landslides. Sediments overlying such features typically display differential compaction or may inherit geometries from underlying landslide morphology.

Because of changes in sea level, banks and bioherms are common occurrences at the shelf-edge break and on top of upper slope diapiric spines. Their distribution at the seafloor depends upon sedimentation and erosion patterns during subsequent rise in sea level. Seafloor erosion on the shelf and shelf break often represents relict features but in some cases may be continuing to the present in response to oceanographic factors.

Diapiric ridges, spines, and intraslope basins are common features on the upper and middle continental slope. Their relief and surface expression are complex, being dominated by faulting associated with differential growth of the diapir. Complex fault patterns exist across the diapir's crest, often extending into adjacent basins and forming intricate and widespread fault systems. Such faulting provides pathways for gas migration, both thermogenic and biogenic, into the near-surface sediments. Chemosynthetic organisms, rapid diagenesis and cementation, and clathrate development are associated with these gas seeps, the latter exclusively with deep-source thermogenic gas. All these features can result in acoustic wipeouts on high-resolution geophysical data, and interpreting them (together with chaotic landslide deposits) is difficult. Erosion across the diapir crests often exposes older and more consolidated sediments, leading to highly diverse acoustic images. Growth of diapirs and associated oversteepening of their flanks can promote localized and large-scale, near-surface, as well as deeply buried, landslide features.

The Sigsbee Escarpment (fig. 1) is the most prominent feature at the base of the slope. This escarpment is nearly continuous along the entire base of the slope from the western gulf to De Soto Canyon. The scarp is the expression of the lobate frontal edge of the northern gulf diapiric province and is underlain throughout its length by a complex system of salt ridges, overthrust tongues, and steep-sided massifs (Humphris, 1978; Martin, 1978, 1984). The continuity of the escarpment is broken locally by diapiric outliers and large pronounced reentrants of several interlobal canyons such as Alaminos and Keathley Canyons.

The Mississippi Canyon and Fan mark the eastern boundary of the diapiric province and form one of the more prominent physiographic features in the northern Gulf of Mexico (fig. 1). The Mississippi Canyon and upper Mississippi Fan comprise the continental slope off the present shelf seaward of the modern Mississippi delta. The Mississippi Canyon is a broad submarine channel that formed by retrogressive slumping during the late Pleistocene and has been partially infilled during the Holocene rise in sea level (Coleman and others, 1985). The Mississippi Fan is a complex of overlapping fan lobes that were deposited during low sea level stands during the Pleistocene (Moore and others, 1978; Bouma and Coleman, 1985). At the base of the slope, in the upper part of the Mississippi Fan, sediments 2,400 m thick have been deposited in the past 2.1 million years. Drilling on the Mississippi Fan during DSDP Leg 96 (Bouma and Coleman, 1985; Feeley and others, 1985; Stelting and others, 1985; Coleman and others, 1985; Roberts and Thayer, 1985) indicated that the channel system was migratory in nature and contained a considerable quantity of coarse, terrigenous clastic sediment. The drilling in the lower fan indicated the presence of sheet sands of considerable thickness.

The Quaternary Mississippi Fan consists of several fan lobes, each having an elongate shape. These lobes are connected to an incised submarine canyon cut into the continental shelf and slope. The fan-lobe complex is basically composed of channel-overbank deposits that can be subdivided into four regions: (1) a canyon, probably formed by massive slope failure; (2) the upper fan, which terminates near the base of the slope (the main channel acts as a conduit for sediments delivered to the more distal parts of the system); (3) the middle fan, which is an aggradational unit with a convex upward surface and a sinuous aggradational channel (graveliferous and sand-rich deposits form the basal part of the channel and are capped by fine-grained sediments of the passive fill); and (4) the lower fan, which is also aggradational in nature and shows evidence of numerous small channels that have switched through time. Near the ends of each channel, broad sand sheets have been deposited. Late Pleistocene sedimentation rates were extremely high during glacial sea-level low stands and minimal during interglacial high sea levels. In the youngest fan lobe, during the late Wisconsin glacial stage, accumulation rates ranged from 12 m per thousand years for the middle fan to 6 m per thousand years for the lower fan. During the interglacial periods, sedimentation rates rarely attained a few tens of centimeters per thousand years.

The De Soto slope lies between the eastern limit of the upper Mississippi Fan and the West Florida Terrace. This section of the slope is relatively smooth and is underlain by a thick sequence of conformably bedded sediment that is deformed by minor monoclinal folds and isolated small salt domes. The most conspicuous physiographic element in this area is the broad valley formed by the depositional convergence of the terrigenous slope with the northernmost exposure of the Florida Escarpment.

Mississippi-Alabama-Florida Slope

The northern part of the continental slope off Mississippi, Alabama, and western Florida is relatively smooth and unbroken. Thick sequences of salt and shale are not present in this region, and the clastic wedge overlying the carbonate platform is relatively thin and undeformed. Small erosional gullies, possibly resulting from the late Wisconsin lowering of sea level or relatively minor mass wasting, crease this continental slope. The continental slope along the eastern margin of the Gulf of Mexico is extremely complex and is defined by a double reef trend; the shallower reef lies between 130 and 150 m, whereas the deeper reef trend ranges between 210 and 300 m water depth (Doyle and Holmes, 1985). Holocene and late Pleistocene sediments composed of foraminifera-coccolith ooze accumulate at an exceedingly rapid rate, averaging 30 cm per 1,000 years (Doyle and Holmes, 1985). At a depth between 1,000 and 2,000 m, the slope increases significantly, in places exceeding 20°, and forms the West Florida Escarpment. The escarpment is erosional in nature and is composed of sediments deposited in a shallow-water, back-reef, and lagoonal facies (Freeman-Lynde, 1983). On the upper slope, at a depth of approximately 500 m, a terrace, believed to be composed of outcropping Miocene sediments, is a prominent morphologic element. A series of gullies and small canyons crease the middle and upper slope. One of the most striking features of the west Florida upper continental slope is the irregular morphology associated with mass movement processes. The mass wasting features range from creep to massive slides to gravity-induced folds tens of kilometers long (Doyle and Holmes, 1985).

PAST ACTIVITIES AND RESOURCE POTENTIAL

Mapping in the EEZ

The Gulf of Mexico basin was a mature hydrocarbon-producing basin. In 1947, a fixed platform/drilling tender was spudded in 16 ft of water 12 mi off the Louisiana coast. This platform marked the beginning of active exploration and exploitation in Federal waters. As of December 1985, some 38 years later, 6,192 offshore tracts had been leased and 23,569 wells had been drilled. Drilling is now being conducted in water depths in excess of 7,000 ft (2,100 m). This offshore region is highly productive, and as of 1985, some 95 percent of the oil and over 99 percent of the gas produced from the Outer Continental Shelf came from the Gulf of Mexico.

In such a mature producing basin, a large amount of surface and near-surface data has been acquired. Thus, the Gulf of Mexico basin can be used as a model with which to identify those types of data acquisition that were useful or useless to both regulatory agencies and the industrial sector. This was the general approach that was used during the Gulf of Mexico workshop. The number of participants varied from 10 to 17 and included personnel from Federal agencies, State agencies, the private sector, and academia. Generally the discussions commenced with a review of existing data, followed by an evaluation of resource potential (State by State). The future needs for data acquisition were then addressed, and the final task was delimiting a series of recommendations.

Previously Acquired Data

Past data acquisition has been overwhelming. Federal agencies have collected in excess of 198,000 km of regional high-resolution seismic and side-scan sonar data (including the recent GLORIA survey) and over 12,000 km of mapping data in detailed grids on the leased offshore blocks. Industrial concerns, in response to Federal requirements, and in an effort to insure safety of their offshore facilities, have acquired over 1,500,000 km of high-resolution seismic data on a detailed gridded basis with leased offshore tracts. In addition, in excess of 20,250 km of regional high-resolution seismic data have been acquired on the continental shelf and continental slope. State agencies and academic research teams have acquired an additional 21,000 km of mapping data. Thus, within the EEZ in the Gulf of Mexico, in excess of 1,751,500 line km of data have been acquired to date. This probably represents the largest single collection of data along a continental margin in the world. Ground truth (drop cores and shallow foundation borings) has also been collected. In general terms, approximately 3,700 foundation borings have been drilled on the continental shelf, 200 borings on the continental slope, and in excess of 6,500 drop cores from the shallow sedimentary column. Unfortunately, many of these are site specific, and many areas of the gulf basin have not been sites of shallow subsurface data acquisition.

It was concluded that a large amount of data has been acquired in this mature basin but that a high percentage of the total data has been acquired in only a small percentage of the basin. Interpretation of this data has resulted in a generally good understanding of the sedimentary processes and basic geologic structure of the near-surface sediments in the gulf basin. The paucity of ground truth (core data) in the relatively deep water and complex bathymetric region of the continental slope and in certain areas of the continental shelf has been a detriment to a better understanding of the late Quaternary evolution of the basin and to aiding in the interpretation of the large volume of high-resolution seismic data. It was pointed out by several panel members that, even with this vast collection of data, numerous scientific questions remain unanswered.

Resource Potential

The panel discussed the potential for future resource development in the gulf basin. In terms of oil and gas, the continental shelf region of offshore Louisiana and Texas is a mature basin, and only deeper drilling offers any significant future resource. Enhanced oil and gas recovery will, however, be required in the future. In Mississippi, Alabama, and Florida, the continental shelf has had minimum exploration, and a few recent discoveries have been made that indicate that this region has some potential for future exploitation. The continental slope and deepwater basin in the Gulf of Mexico is presently a frontier area. Recent oil and gas discoveries in the Neogene sediments on the continental slope and in the deepwater basin have indicated that there is a considerable potential for future resource development. Reservoir sands are abundant within the sedimentary section. The area is characterized by extremely complex structure, varied surface relief, and deep water. A considerable amount of future mapping and ground truth data will be required to evaluate the near-surface conditions.

With regard to nonfuel minerals, the Gulf of Mexico can be considered to contain few potential resources of any great magnitude. Salt and sulfur have a very high potential for extraction from the shallow-seated salt diapirs on the continental shelf offshore Louisiana and Texas. Production from the caprock of several diapirs is presently being undertaken, but within State waters. A greater demand for these products would promote development in Federal waters.

Sand and gravel are present in the shallow waters offshore Mississippi, Alabama, and Florida but are generally absent or have considerable overburden off Louisiana and Texas. The well-developed offshore sands of the eastern gulf have considerable potential, but environmental problems would be severe because much of the shoreline is highly developed and draws a considerable amount of tourist trade. Shell and other carbonate resources have fair potential in the shallow waters off Louisiana, where shell dredging has been operative for a considerable time. Texas, Alabama, and Mississippi contain some shell resources in shallow Federal waters, but these resources do not appear to be of a major economic value. The carbonate reefal system of Florida contains vast quantities of commercial carbonates that remain a potential resource. In all cases, environmental problems are severe and will require considerable study before these resources can be considered as viable alternatives to similar resources on the mainland.

The potential for recovery of placer minerals is very low in Texas and Louisiana, but it is possible that there are minerals of some commercial value offshore of Mississippi, Alabama, and Florida. Shoreline deposits contain some heavy minerals, but so little is known of the characteristics of the offshore sand bodies that it is difficult to evaluate the future potential.

Some atypical resources, fresh water and abandoned wrecks, were discussed in general terms. In offshore Florida, there is an abundance of fresh-water springs, and there have been several inquiries as to the commercial development of this resource. Once again, few data are available with which to fully evaluate this resource. The shallow waters of the continental shelf off all of the coastal States have numerous shipwrecks, both of antiquity and more modern times. These presently serve as refuges for large communities of marine organisms, and future development into artificial reefs could have some commercial value.

ADDITIONAL DATA REQUIRED

On the basis of the vast quantity of data previously acquired in the gulf basin, the panel attempted to identify those data that will be required for future assessments. High-resolution seismic data are generally abundant in the gulf basin, but much of the data is associated with oil and gas exploration and concentrated in the offshore regions of Louisiana and Texas. There is a need for similar types of data on the continental shelves of Mississippi, Alabama, and Florida. Regional high-resolution seismic grids are generally available along the entire continental slope, but detailed data in some critical regions are not available.

One of the highest priorities of future data acquisition is accurate bathymetry in both the shallow and deep waters of the Gulf of Mexico. Only 10 to 20 percent of the gulf coast is covered by modern bathymetric surveys, and these data are primarily from the nearshore zones within State waters. These data are extremely important in pre-leasing evaluation by industry and for evaluation of potential hazards from a regulatory standpoint. In highly developed oil and gas regions, accurate bathymetry is required for pipeline routing and other offshore support facilities. Continued development of the EEZ in the gulf basin will result in an increase in marine traffic across the shallow waters. There will be a necessity to assess future navigation problems. Accurate contemporary bathymetry will be required in this region because it is prone to rapid change.

Accurate interpretation of the vast amount of high-resolution seismic data has been hampered by a lack of ground truth, especially in the deep waters of the continental slope and the shallow waters off Mississippi, Alabama, and Florida. Cores and shallow drillholes are required in order to determine the surface and near-surface lithology, chronology, and mass physical properties. The basin is highly variable as a result of sediment input from several different river systems. The large sediment yield from the Mississippi River and the extremely dynamic nature of this large clastic supplier have resulted in relatively thick sequences of extremely recent sediments that have not undergone normal compaction; thus, much of the region is highly prone to subaqueous sediment instability. Ground truth is required to evaluate potential hazards. This information is important because many regulatory decisions are being made solely on the basis of interpretation of high-resolution and side-scan sonar data.

The capability of evaluating lithology, geologic processes, and chronology solely from remotely sensed data is poor at best. Studies in areas where abundant ground truth data exist indicate that these relationships will require considerable improvement.

The panel recommended that reinstatement of collection of regional seismic grids, especially in the deeper waters of the continental slope, would aid in evaluation of geologic processes, geohazards, and multiple-use activities. The data should be acquired in digital form and properly archived so that they will be accessible to all researchers in the gulf basin.

The consequences of not acquiring these data sets are as follows:

1. Future oil and gas development would not be stopped, but future development would be impacted in the sense of potential regulatory aspects if based on poor data and interpretations.
2. Lack of data acquisition would severely reduce the evaluation of other potential economic resources on the shelf and slope of several offshore regions in the gulf.
3. Acquiring the data would significantly clarify and improve the regional understanding of the gulf basin and provide a solid basis for developing sound regulations and environmental impact evaluations.

In a discussion concerning the strategy of managing existing data, there was a lively debate as to who is the user, especially of data acquired by Federal agencies. Panel members felt that users of this acquired data should not be just the members of the Federal agencies and regulatory agencies but that State agencies, private industry, and academia should have immediate access to the raw data. Many members of the panel indicated definite problems with accessibility of raw data and long waiting periods before data are available for general distribution.

PANEL RECOMMENDATIONS

The final panel session revolved around the recommendations that should be considered in a 10-year goal. These recommendations are:

1. Better define the coordination between the Federal agencies acquiring the data and the end users (State agencies, private industry, and academia).
2. Give careful consideration to the accessibility of raw data and the archiving of previously collected data. The time between acquiring the data and its public release is far too long at present.
3. Acquire new data in a digital and standardized format so as to allow rapid access to the raw data. A standard digital format would be usable by numerous agencies rather than just the agency acquiring the data.
4. Investigate the possibility of setting up an archiving facility for ground truth data such as cores, mass physical properties measurements, and so on. Many data are presently lost because of lack of such a facility.
5. Recommend that future data acquisition in the Gulf of Mexico basin include three aspects: regional high-quality bathymetry, ground-truth data (cores and borings), and reinstatement of a policy to acquire regional 3×3-mi grids of high-resolution data, especially in the deepwater areas and on the continental shelves offshore Alabama, Florida, and Mississippi. Such a plan would insure a good data base on which to evaluate future economic potential, develop rational regulatory policies, and significantly advance our scientific knowledge on the Gulf of Mexico's continental margin.

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Workshop 5: Scientific Mapping and Research to Characterize the EEZ—Islands

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INTRODUCTION AND DESCRIPTION OF THE REGION

The region discussed in this section includes more than half of the U.S. EEZ and covers a broad range of physiographic settings and oceanographic conditions. However, the areas around U.S.-held islands have received only a very small percentage of the research and exploration effort devoted to date to all of the U.S. EEZ. Summaries of the key technical and economic issues of living and nonliving resource management in this region have recently been assembled by the U.S. Congress Office of Technology Assessment (U.S. Congress, 1987a,b).

We distinguish two geological classifications of islands in this group: island arcs, formed by uplift at convergent plate boundaries, and oceanic islands, formed at hot spots, spreading centers, or in other midplate volcanic processes. The specific contributions to the U.S. EEZ provided by these island regions are presented in table 1. Islands of the U.S. EEZ and their approximate EEZ areas are presented in table 2. General descriptions of the geological settings of these areas follow.

Island Arcs

Island arcs are typically arcuate belts of islands formed by volcanic activity and uplift resulting from the subduction of oceanic crust at convergent plate boundaries. They are commonly associated with back-arc spreading centers, zones of rifting, and active volcanism on the seafloor. U.S. island arcs of the Pacific, excluding those of Alaska, are Guam and the Northern Mariana Islands. Puerto Rico and the Virgin Islands (St. John, St. Croix, and St. Thomas) comprise the Caribbean island arcs.

The Caribbean.—Puerto Rico and the Virgin Islands form part of the Greater Antilles island chain in the northeastern Caribbean. Since the end of the Eocene, the tectonics of the region have been dominated by left-lateral strike-slip motion between the North American and Caribbean Plates (Burke and others, 1984). The islands lie within a complex, 300-km-wide deformation zone which occurs along the plate boundary and which is influenced by both extensional and compressional elements in addition to the dominant strike-slip motion (Sykes and others, 1982; Mann and Burke, 1984; Burke and others, 1984; Byrne and others, 1985).

The Pacific.—The Northern Mariana Islands and Guam are a classic island arc consisting of trench-forearc-volcanic arc/back-arc basin association and created by convergence between the Pacific (oceanic lithosphere) and Mariana Plates. The Mariana trough is a slow-rate back-arc spreading center.

Oceanic Islands

The islands considered in this group include the U.S. EEZ areas in the central Pacific region. The islands and seamounts in these areas were formed by hot-spot activity, as volcanoes at spreading centers, and from poorly understood volcanic episodes that occurred in the middle of the Pacific Plate. Brief descriptions of each distinct area are provided below. As will be discussed in the third section of this report, the principal nonliving resources in the oceanic islands group are expected to be associated with island flanks and seamounts. Therefore, the geological settings outlined in this section focus on island and seamount formation processes.

The Hawaiian Archipelago

The baseline for this EEZ boundary consists of the emergent islands ranging to the northwest some 1,800 nautical miles between the island of Hawaii and Kure Atoll. These islands, as well as many seamounts and subsea elevations roughly aligned with them, are all believed to have been formed by hot-spot volcanism (Morgan, 1972). This process continues today on the northeast ridge of the Kilauea Volcano on the island of Hawaii and on the submarine volcano Loihi, located to the southeast of Hawaii

Table 1. Types of deposits, target resources, and physical settings

Deposit Type	Target Resources	Physical Setting
Placer	Gold, tin, platinum, chromite, rare earths, and construction aggregates	Insular shelves
Phosphorites	Phosphorous (fertilizer)	Atoll lagoons seamounts, islands
Precious coral	Corallium sp. and black coral	Island flanks, seamounts, and other current swept areas
Polymetallic sulfides	Silver, zinc, cadmium, gold, copper, molybdenum, lead, vanadium, barium, strontium	Spreading seafloor rift zones (submarine volcanoes)
Ferromanganese nodules	Nickel, copper, cobalt, manganese	Central Pacific abyssal ocean floor between latitude 18°N and 20°N
Cobalt-rich ferromanganese crusts	Cobalt, nickel, manganese, platinum, cerium, titanium, lead	Old seamounts and ridges
Hydrocarbons	Oil, natural gas, coal	Within and behind island arc systems
Molybdenum-rich manganese deposits	Molybdenum, manganese	Within island arcs
Manganiferous sandstone	Manganese	Within island arcs

(Malahoff and others, 1982). Geological ages for these islands and seamounts range from essentially 0 at Loihi to about 30 million years old (Ma) at Hancock Seamount on the northwest extreme (Jarrard and Clague, 1977; Epp, 1978).

Also within this EEZ region are over 50 seamounts that are not associated with this northwest-southeast trend and that are believed to range in age from 70 to 85 m.y. (Johnson and others, 1987). These Cretaceous ages are for most of these seamounts only estimates, and the processes that led to the formation of these seamounts are generally unknown.

Wake Island

Wake Island is thought to be a northern extension of the Marshall Island group (Clark and others, 1985) of Middle Jurassic (160 Ma) age. However, recent geochemical work (B.H. Keating, personal commun., 1987) suggests that Wake may actually be associated with the Line Island Chain.

Johnston Island

The EEZ around Johnston Island contains extensive seamount areas and may be the best prospect for manganese crust deposits of all the oceanic islands. Within this area is the apparent intersection of the Mid-Pacific Mountain trend and the Line Islands, and the geological ages of the included seamounts range from 80 to 120 Ma (Clark and others, 1985).

Line Islands (Palmyra Island, Kingman Reef, and Jarvis)

The formation of the Line Islands appears to be the result of at least two episodes of volcanism, one or more in the Late Cretaceous (70–100 Ma) and one in the Eocene (35–45 Ma; Keating, in press). The Palmyra/Kingman seamounts have been dated at greater than 90 Ma. Jarvis may be somewhat older (Clark and others, 1985).

Howland and Baker Islands

These islands are part of a small seamount chain running north-south. They are just to the north of the

Table 2. Approximate areas of the U.S. Exclusive Economic Zone for the Pacific and Caribbean Islands

Island(s)	Political Status	Length of* Coastline	Total area between* 0 and 200 nautical miles	Geologic Type
American Samoa+	Territory	75 (138)	125,000 (428,800)	Oceanic Island
Caribbean Puerto Rico Virgin Islands	 Commonwealth Territory	373 (690)	61,100 (209,600)	 Island Arc Island Arc
Guam	Territory	68 (126)	60,600 (207,900)	Island Arc
Hawaii Midway	State Possession	653 (1208) 7 (13)	697,000++ (2,390,700)	Oceanic Island
Howland and Baker	Possession	6 (11)	124,100 (425,700)	Oceanic Island
Jarvis	Possession	4 (7)	94,200 (323,100)	Oceanic Island
Johnston	Possession	4 (7)	131,000 (449,300)	Oceanic Island
Northern Marianas	Commonwealth	179 (331)	224,300 (769,300)	Island Arc
Palmyra Atoll - Kingman Reef	Possession	8 (15)	104,100 (357,100)	Oceanic Island
Wake	Possession	10 (19)	120,000 (411,600)	Oceanic Island
TOTAL % U.S. Total		1,387 (2,565) 12%	1,741,400 (5,973,100) 51%	

* In nautical miles; values in parentheses are in kilometers. Data from C.E. Harrington, National Ocean Survey.

\+ Includes Swains Island and Rose Atoll
++ Includes Midway Island

equator and were mined in the past for substantial guano deposits. Their age has not been determined (Clark and others, 1985).

American Samoa

The east-west-trending Samoan Islands are a very young island chain, mostly less than 5 m.y. in age (Keating, 1987). Included in the American possession are Tutuila, the Manua Islands, Swains Island, and Rose Atoll.

RECENT ACTIVITIES IN THE AREA

Island Arcs

GLORIA imaging of the EEZ of the eastern Caribbean region has been completed (EEZ SCAN 85 Scientific Staff, 1987). Accompanying the imagery are bathymetric, seismic reflection, and magnetic anomaly data collected along tracklines spaced up to 25 nautical mi (45 km) apart. Earlier studies (Meyerhoff and others, 1983) have identified two possible petroleum-bearing basins (North Coast Tertiary basin and the North Mona basin) along the fore-arc slope. Insular shelf surveys have located several suitable offshore deposits of construction materials. Planned activities include GLORIA ground-truth surveys near areas of possible major slumping along the insular slope and placer investigations along the northern shelf.

In the Northern Mariana Islands and Guam region there is evidence for mineral-producing hydrothermal activity in the Mariana Trough, a back-arc spreading center. Crust sampling on seamounts has recovered iron-manganese crusts with copper and molybdenum. A "Mariana transect" of the Deep Sea Drilling Project (Legs 59 and 60) drilled ocean plate, trench, fore-arc, arc, back-arc, and trough. Drilling may continue in the area during the early 1990's with the new Ocean Drilling Project (ODP).

Oceanic Islands

In the last 10 years, significant oceanographic research has been carried out by several countries to investigate the exploitation potential of marine mineral deposits and the general geology of this region. This work has included continuing efforts funded by the West German government and German industry (Halbach and others, 1982; Halbach and Manheim, 1984), several field efforts in the Hawaiian Islands, Johnston Island, and Line Islands area by the University of Hawaii (Dollar 1984; Helsley and others, 1985; Malahoff and others, 1985; Sager and Keating 1984), and extensive work by the USGS in many of the island EEZ areas (Hein and others, in press a; Manheim, 1986).

The above programs have looked in detail at the resource potential, geological setting, and potential environmental impact problems associated with cobalt-rich manganese crust deposits. Research on other potential nonliving resources in the central Pacific has been completed as well, including work on marine phosphate deposits (Rao and Burnett, unpub. data, 1987), sand and gravel resources near Hawaii (Dollar, 1979), and potential marine sulfide deposits (Malahoff and others, 1982).

STATE OF KNOWLEDGE AND 10-YEAR OBJECTIVES

State of Knowledge

We distinguish four general processes that seem to control the formation and distribution of nonliving resources and geohazards in the island EEZ areas: volcanic island-building processes, hydrogenetic processes that produce sulfide minerals, hydrogenetic processes that produce ferromanganese oxide deposits and certain marine phosphate deposits, and sediment transport processes, which profoundly affect all of the above as well as geohazard potential and the distribution of hydrocarbon resources.

The state of knowledge about each of these is briefly outlined here, with emphasis being given to the current limitations in our understanding.

Volcanic Processes

At least four kinds of volcanism have created the islands and seamounts in these EEZ areas. Island-arc volcanism, which is caused by the interactions between converging tectonic plates, is believed to be responsible for the formation of the Northern Marianas, Guam, Puerto Rico, and the Virgin Islands. Hot-spot volcanism, produced by relatively stationary mantle sources of magma erupting through moving oceanic plates, is probably responsible for the Hawaiian Islands and much of the Samoan Island chain. Spreading center volcanism, caused by persistent eruptions at loci associated with divergent tectonic plates, may be responsible for many of the seamounts in these areas. Reactivated volcanism, possibly caused by tensile forces acting on existing zones of weakness in oceanic plates, may be responsible for much of the mass of the Line Islands.

Detailed studies to understand both these constructional volcanic processes as well as the associated destructional processes (such as mass wasting of submarine flanks and volcanic caldera collapse) are needed to understand the island-building processes that control the distributions of the nonliving resources and geohazards.

Hydrothermal Systems and Sulfide Mineralization

The most promising sites within the island EEZ areas for sulfide mineralization lie in the Guam and Northern Marianas along the Mariana Trough. Hydrothermal systems have been identified on and near the back-arc spreading center near 18° N. Subsequent mapping, water column studies, and submersible dives (Hawkins, 1987) have identified several active sulfide-producing hydrothermal vent systems in this area. Analogy with other spreading centers suggests that similar mineralization potential should exist along the Mariana Trough from southwest of Guam to the northern end near 20°, a distance of more than 800 km. Except for a few sites where the detailed work has been conducted, this large region is essentially not surveyed.

Hydrogenous Processes and their Relation to Marine Ferromanganese and Phosphorite Deposits

Polymetallic oxides, which include deep-sea ferromanganese nodules and seamount crust accumulations, are believed to form primarily from the precipitation of iron and manganese oxides in seawater (for example, see Cronan, 1980). Crusts have been the subject of recent interest more so than nodules because of their abundance within the EEZ and their relatively high concentrations of the strategically important metal cobalt (Helsley and others, 1985; De Carlo and others, 1987a; Chave and others, 1986). These deposits generally form where metal oxides accrete on sediment-free outcrops on the slopes of seamounts. Slopes exposed to strong currents are generally devoid of sediments and particularly suited to crustal growth, whereas highly sedimented regions such as valleys between topographic highs are not (De Carlo and others, 1987b). Metals of potential economic value such as Co, Ni, and other trace elements including Pt are scavenged by the major metal-oxide surfaces and incorporated possibly by lattice substitution (Cronan, 1980). Slow growth rates (1–5 mm per million years) enhance the accumulation of certain minor and trace constituents by providing extended periods of time during which metal ions can be scavenged from the water column. An early paper by Cronan (1967) suggests an inverse correlation between cobalt content and growth rate.

Although the literature is replete with reports dealing with ferromanganese deposits, no quantitative mechanism that can satisfactorily account for these complex minerals has yet been published.

In the island EEZ areas, at least two distinct types of phosphate deposits have been identified: submerged, guano-derived deposits and relatively widespread hydrogenetic deposits, often associated with ferromanganese crusts (Cullen and Burnett, 1986). Recent work has shown that phosphatic phases are often admixed with the crusts or present as discrete layers (Halbach and others, 1983; De Carlo and others, 1987b). Very little is known regarding the combinations of factors that lead to these deposits.

Sediment Dynamics

Generally, the EEZ seafloor off most islands can be divided into three provinces: the shelf, the slope, and the abyss. More complicated classifications are necessary for areas where active tectonic processes, such as subduction and seafloor spreading, are occurring. The processes that control sedimentation and sediment type can be grouped into geological, biological, and oceanographic factors. The geological factors include regional tectonism, the morphology of the shelf and slope, sediment supply and type, and climate (Karl and others, 1983). Biological factors include primary productivity levels, the balance between coralline construction and terrigenous sediment inputs, and bioturbation (Rhodes, 1974; Jordan, 1978; Jumars and others, 1981; Kennett, 1982). Oceanographic factors include many kinds of advective and dispersive processes that mix, transport, and deposit sediments (Karl and others, 1983).

Because of the number of factors and their variable influence from site to site, it is pointless to define "typical" island environment sedimentary processes. Except for in a few specific sites, the relative contributions of these factors have not been assessed for the island systems. However, it is critical that the dynamics of island sedimentation are considered as complete systems, beginning with sediment input and coastal processes and culminating with abyssal depositional processes. Investigations constrained to only one portion of a sediment transport system are thus necessarily incomplete.

Sand and gravel are ubiquitous on beaches around many island shores and traditionally have been used for construction purposes. Sand mining has resulted in significant coastal erosion and loss of beaches that are major concerns for tourism and residential development. Future utilization and increased needs for these relatively shallow-water resources demand a comparable increase in coastal, near-shore, and shelf research.

Two key elements missing from most sedimentological investigations but of great practical interest are the geotechnical behavior of the sediment types being studied and their susceptibilities to transport by current action. An increase in the understanding of these processes is necessary in order to allow environmentally and economically sound exploitation of existing nonliving resources.

10-Year Objectives

Significant progress in the next 10 years toward better understanding of the general processes outlined above would greatly facilitate our ability to use and conserve our enormous island EEZ areas. The workshop group believes that such progress could most readily be achieved within the context of the following geographically focused objectives:

Island Arcs

1. Framework studies with special emphasis on oil and gas potential within offshore basins and on the quantification of sediment transport pathways from the coastline to the abyss.
2. Detailed surveys to obtain ground truth for the existing GLORIA images to determine the processes responsible for the formation of this unique structure and consequences relative to geohazards. Sedimentological and geotechnical studies should be included.
3. Continued insular shelf studies for placer minerals and construction materials.

Because active volcanism occurs along many of the Mariana Islands in areas subject to significant sedimentation, there is the potential for deposits of a number of nonliving resources, including oil, gas, Co, Ni, Cu, Au, Ag, Pt, Zn, phosphorites, and construction materials (table 1, fig. 1). The dynamic tectonic processes involved in all island-arc areas create numerous geohazards that need to be clearly identified, including faults and earthquake zones, volcanic centers, and areas subject to slope failures (fig. 2). Island settings are also prone to tsunamis, shoreline erosion, landslides, and volcanic ash falls. Research objectives needing to be addressed are:

1. Gathering of adequate data to assess the sediment thickness, potential petroleum source rocks, and possible reservoirs within the fore-arc and along the arc-axis platform.
2. Investigating the Mariana Trough, a probable site of hydrothermal venting, to determine the occurrence of polymetallic sulfide deposits.
3. Exploring the flanks of older seamounts and guyots, which may be favorable sites for cobalt-rich crust deposits.
4. Examining younger shallow seamounts for phosphorite and precious coral deposits.
5. Exploring insular shelf areas for placers and construction materials.

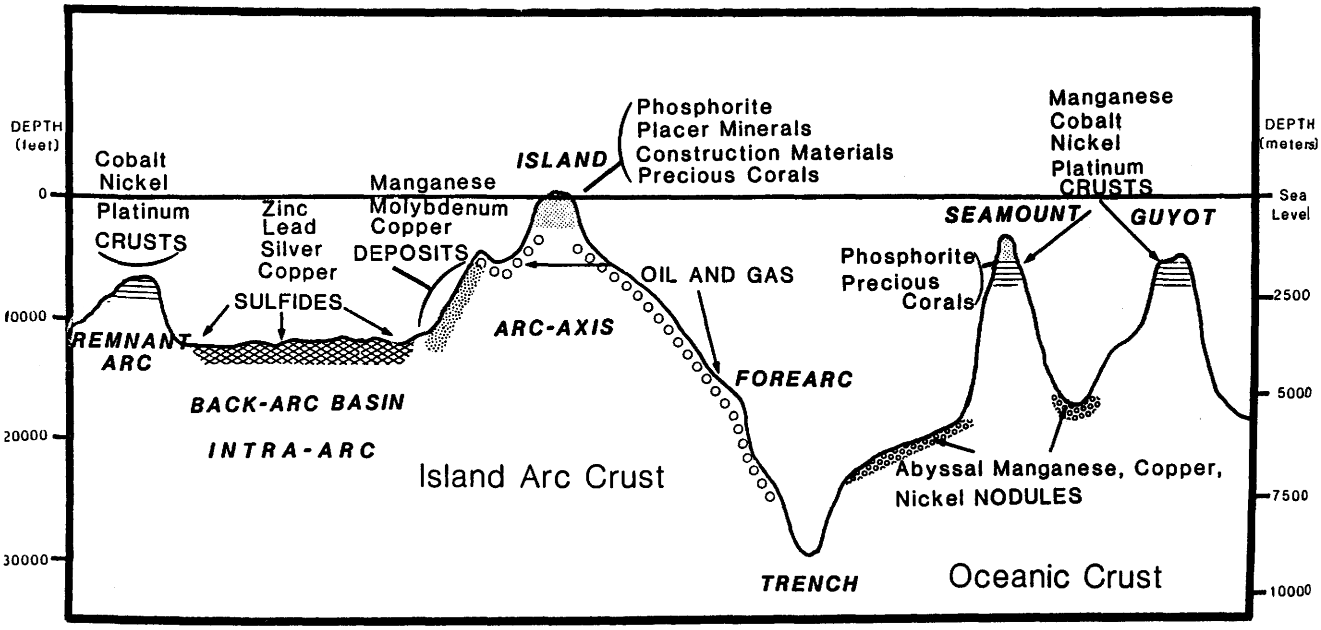

Figure 1. Potential resources associated with island arcs.

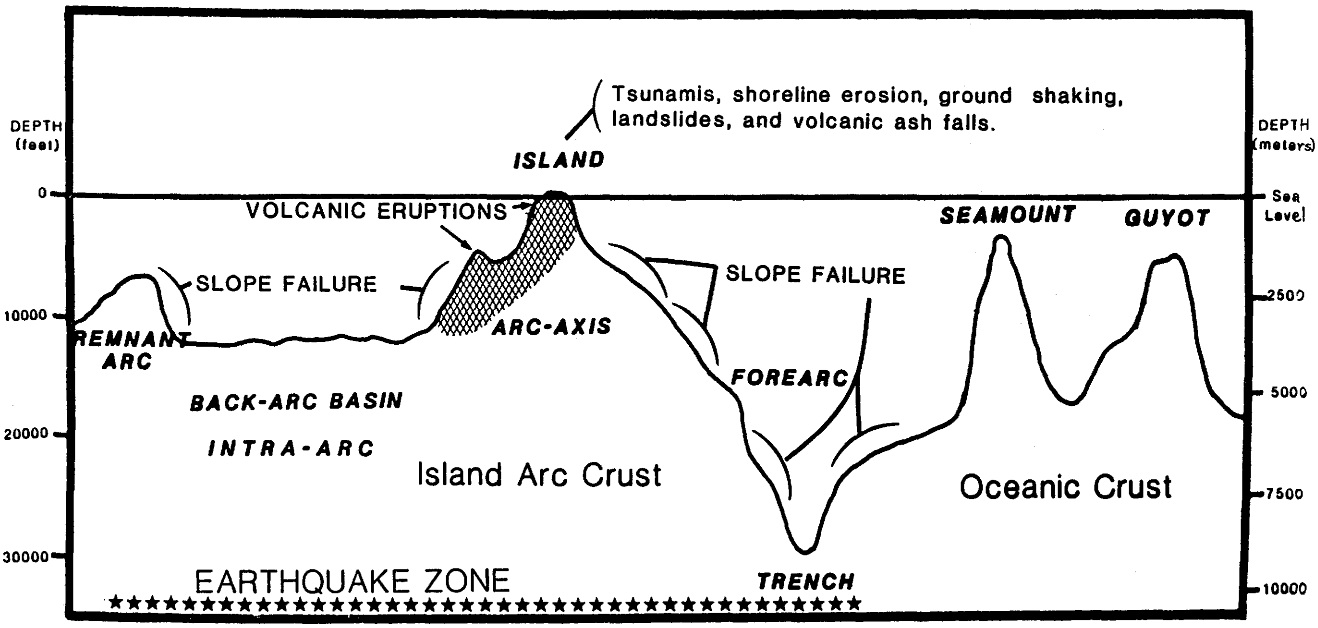

Figure 2. Geohazards of island arcs.

Oceanic Islands

As is apparent from the brief geological descriptions of these areas presented above, much remains to be learned about the geological histories of the Pacific oceanic islands and seamounts. Of these, only the Hawaiian Archipelago seems to have had a relatively straightforward tectonic history. As indicated in table 1 and figure 1, the apparent nonliving resources in these areas consist of phosphorites, manganese crusts and nodules, and construction materials. The formation mechanisms for phosphorites and manganese oxide deposits are not well known. Except for the Hawaiian and Johnston Island areas, very few resource data are available.

Geohazards in these areas are essentially the same as those noted for island-arc areas (fig. 2), except that for many of these intraplate island areas the risks of potentially dangerous seismic activity are generally lower. The clear-cut gaps in the data outlined above suggest the following research objectives:

1. Assembling all existing magnetic and gravity data for the central Pacific to test the various tectonic theories of formation for the U.S. EEZ in this region.
2. Conducting appropriate low-resolution mapping surveys in the areas with maximum resource potential where little or no regional reconnaissance has been performed to date.
3. Performing high-resolution acoustic and sampling surveys in representative areas to test formation hypotheses for phosphorites and manganese oxide deposits.

RECOMMENDATIONS

Data and Information Sets

Coastal Problems and Local Coordination

Near-shore and shoreline processes are clearly of paramount importance to the economy, ecology, and social fabric of the local jurisdictions in the island EEZ areas. We recommend active coordination of research and data acquisition with local jurisdictions and experts on: (1) coastal erosion problems and processes; (2) sand and gravel resource inventory and development; (3) coral reef resources, including recreational considerations, conservation for shoreline protection, and management of deep-sea coral resources; and (4) geohazards.

To facilitate these goals, educational training and development of island personnel through technical workshops and technology transfer programs are recommended.

Reconnaissance Mapping.—We recommend the collection of reconnaissance-scale side-scan sonar imagery, bathymetry, subbottom seismic reflection profiles, and gravity plus magnetic-anomaly data for the entire sections not surveyed of the island EEZ areas. Some of the island regions, because of the high relief and scales of features, may require somewhat higher resolution imagery than that provided by a general reconnaissance mapping program. Detailed bathymetric surveys are considered particularly important.

The regions of highest priority for this reconnaissance work are believed to be the Northern Mariana, Hawaiian, and Johnston Island EEZ areas.

Release of NOAA Data.—We recommend that the bathymetric data, collected by NOAA with the Sea Beam system in the EEZ, be made available for resource evaluation work and survey design through an efficient and orderly procedure that recognizes the legitimate security considerations involved.

Detailed Studies of Processes.—We recommend support for high-resolution mapping and sampling studies at specific sites to investigate basic processes relevant to island settings. Specific priorities for this kind of work include the following:

1. Sediment Dynamics. Studies of sediment dynamics and geotechnical properties, particularly of carbonate sediments, which assess suspended and bedload transport, mass wasting, slumping, and so forth. An understanding of these processes is crucial to such concerns as shoreline erosion, navigation, recreation, coastal pollution, and cable and pipeline routing. Specific areas recommended for this work are north Puerto Rico, Hawaii, and Palmyra Island.
2. Hydrogenetic Mineralization Processes on Seamounts. Studies of individual seamounts to assess the ferromanganese oxide and phosphate resources within the context of the existing geology, fine-scale topography, biology, and physical and chemical oceanography. Specific areas for this work should include Cross Seamount and the Johnston Island area.
3. Hydrothermal Mineralization Processes. Studies in different tectonic regimes to examine the processes that lead to the formation of marine massive sulfide deposits and the geochemical and biological effects of the hydrothermal systems involved. Specific areas for this work should include sites in and near the Mariana Trough as well as the Loihi Seamount off the Island of Hawaii.
4. Volcanic Island-Building Processes. Studies to examine the major constructional processes of volcanic islands, including hot-spot, island-arc, and poorly understood midplate volcanism, as well as associated destructional processes of mass wasting and erosion. Specific areas for this work should include Guam and the Mariana chain (for island-arc volcanism), Loihi (early-stage hot-spot construction), the Island of Hawaii (major constructional and destructional processes), and the Line Islands (midplate reactivation processes).

Constraints to Acquiring These Data

At present, funding is the principal constraint limiting data acquisition and interpretation. Adequate interpretation of the data and timely publication of the results should be a high priority. One approach to the possible reduction of this constraint is for the island governments to encourage cooperative programs with Federal agencies. The program could be framed around the local data or information needs and could include Federal training to permit direct participation by island residents in data collection and analysis. In this way the costs for high-priority work can more readily be shared and the processes of technology transfer can more effectively be implemented.

Consequences of Not Gathering the Data

So little is known of the island EEZ's that a rational and objective assessment of resources and geohazards is nearly impossible. The high potential for extensive strategic mineral deposits within U.S. EEZ seafloor areas requires a thorough and widespread investigation. In order for the island nations to make intelligent decisions regarding use of their seafloor, they need sufficient technical information.

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Workshop 6: Technology Needs to Characterize the EEZ

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INTRODUCTION

Current technology, in many respects, shapes the view that we have of the Exclusive Economic Zone (EEZ) and its potential. Indeed, much of the present interest in the EEZ is due to the fact that technology now makes it more practical than ever before to explore and exploit offshore areas. However, substantial improvements are both possible and necessary. Technology, and the strategy with which it is employed, will determine the pace and cost of exploration of the EEZ. The risk of exploitation of the EEZ will be, in large part, a reflection of gaps in technology or its application.

Many of the present exploration activities use modern technology in an optimal manner, but others do not. Order-of-magnitude improvements in the state of the art seem possible both in the technology for acquiring data and in the technology for managing and analyzing data. In most cases, the improvements can be realized through systematic development in a 10-year plan and do not require technological breakthroughs.

This symposium is aimed at providing a basis for such a 10-year plan. The overall goal of this plan, as stated in the Guidance for 1987 EEZ Symposium Workshops (see appendix 3), is to "describe the framework and understand the processes . . . which interact at and within the seabed and subsoil of the EEZ and that contribute to the development of the continental margins and the formation of various non-living marine resources on and within the seafloor." Specific objectives include:

1. Identify marine energy, mineral, and other nonliving resources,
2. Understand geohazards, basin evolution, and geomorphic and sedimentological processes,
3. Develop baseline information that would allow activities involving use of the seafloor or subsoil to be carried out in an efficient manner.

Other workshops at this symposium are to define the data needs that are implied by that goal and those objectives. These data specifications will be important in directing technology development. They are difficult to specify precisely, in part because of the inherent nature of exploration. During this exploratory phase, technological possibilities will have to be examined and matched with evolving perceptions of data needs.

PRESENT STATUS OF TECHNOLOGY

Seafloor Mapping

Bathymetry and Acoustic Imaging

Seafloor mapping is the initial activity in virtually any exploration strategy. For the past 60 years, the primary technique has been the use of acoustic echo sounders. Substantial areas of the U.S. EEZ (especially off Alaska and around the Pacific Islands) still have not been covered with any modern technology. Most areas have been covered only with single-beam echo sounders run on relatively widely spaced lines. In shallow water, survey lines have been closer, positioning more accurate, and effects of finite beam width less troublesome. Generally, in depths less than 50 m, existing data are sufficient to define seabed morphology over spatial scales down to 50 or 100 m. Off the continental shelf, accuracy and sounding density decrease and information on scales shorter than several kilometers is rarely available.

Present practice in shallow water continues to be the use of single-beam sounders, but often supplemented with side-scan sonar. Side-scan systems provide reflectivity images rather than quantitative depth information. They can provide area coverage over swaths of several hundred meters with resolution of less than a meter. Shallow-water systems are relatively inexpensive and can be operated from small boats.

Deepwater systems are larger, more expensive, and usually operated from large ships (Tyce, 1986). During the past decade, multibeam echo sounders have come into use for deepwater surveying. The best known of these systems, Sea Beam, covers a swath of 0.8 times the water depth with a resolution of 5 percent of the water depth. In 4,000 m of water, the swath width is more than 3 km and the spatial resolution across track is about 200 m. Recently, a number of competitive systems have been introduced (deMoustier, in press). The GLORIA, a long range side-scan sonar, is also being used to map the deepwater portions of the EEZ. The system can cover swaths of 45 km with a resolution of 100 m. For higher resolution in deep water, it is necessary to tow equipment near the bottom. Deep-tow and SeaMARC I are examples of this type of system. They provide resolution of the order of a few meters, over swaths from 2 to 5 km. Tow speeds, however, are limited to 1 to 2 knots.

The goals of development of new technology for seafloor mapping are improvements in resolution and area coverage rate (Andreasen and Pryor, in press). For shallow-water application, several airborne systems offer significant improvements. Laser "sounding" systems have reached operational status in Canada and Australia. In water depths of up to 35 m, these systems will provide resolution of the order of 10 m over swaths of 250 m at speeds of 120 knots. A U.S. Navy system, nearing completion, will combine a laser "sounder" with a multispectral scanner to provide coverage over a 700-m swath with 1-m pixels. A third type of airborne sensor uses very low-frequency electromagnetic fields. The approach has been demonstrated but it is still experimental. Resolution is not likely to be better than 30 m, and the swath width is limited to the footprint size, but the system can operate through ice cover and can provide information on bottom conductivity along with the depth measurements.

Interferometric side-scan sonar offers promise for application over a wide range of depths (Andreasen and Pryor, in press). This technique is similar to conventional side-scan systems but uses a second receiver so that the direction of echo arrival can be determined. Thus, it is capable of providing quantitative depth data over the same swath that a conventional side-scan image is obtained. The SeaMARC II system demonstrated the value of this combination in deepwater operation (Blackinton and others, 1983; Davis, 1986). It can cover a swath of up to 10 km with 10-m resolution. For intermediate water depths, the SeaMARC/S system can cover swaths of up to 1 km with 0.5-m resolution. In depths less than 60 m, the Bathyscan system can cover 200-m swaths with 0.5-m resolution. These systems have an advantage over alternatives in area coverage rate and resolution. Further improvements in accuracy and data processing techniques will make them fully competitive with alternatives. The technique works best over the same range of angles as conventional side-scan systems and may be combined with single or multibeam echo sounders to provide coverage near the vertical. SeaBeam systems have also been modified to provide image output similar to a side-scan system (deMoustier, 1986). This modification improves its effective resolution and provides information on the bottom composition through acoustic reflectivity.

Numerous other techniques have demonstrated promise in experiments. Included among these are multibeam side-scan sonar (in which multiple, parallel beams are formed to improve the effective resolution), synthetic aperture sonar, and acoustic holography. Image processing techniques are commonly applied to side-scan data (Chavez, 1986). Textural analysis can be used to classify bottom types and pattern recognition can aid in locating objects. Statistics of the amplitude of Sea Beam echoes have been demonstrated to be correlated with the abundance of manganese nodules (deMoustier, 1985). Quantitative analysis of backscatter imagery, particularly from multiple frequency systems, may support the type of resource assessment that is possible on land by use of satellite remote sensing.

Optical Imaging

Optical imaging is an important tool in mapping the seafloor at specific sites. Still photography provides the greatest resolution. Ranges of 30 to 50 m in clear water are possible, although 10 m or less is most common. Stereo photography was used in the HEBBLE project and several other studies to provide quantitative measurement of seafloor microtopography over scales from centimeters to meters (Akal, 1984).

Video systems have been developed to provide continuous records of submersible dives and to act as "eyes" to navigate towed, remotely operated vehicles (ROV's). It is now possible to obtain coverage of substantial areas. The video system on the ARGO uses low-light-level, silicon-intensified target cameras rated at ISO 200,000 (Harris, 1986). It can cover a 56-m-wide swath at an altitude of 35 m above the bottom and resolve features of the order of centimeters. The JASON vehicle, being built to accompany ARGO, is planned to have stereo color television "eyes." Fiber optics seem to offer the improvements in usable cable bandwidth that will be needed to implement this. Image processing and pattern recognition techniques have application to optical imagery just as they do to acoustical imagery.

Subseafloor Mapping

Magnetics

Magnetic data provide an indication of subsurface structure and are also important as an indicator of the age and evolution of the seafloor. Coarsely spaced lines of data (greater than 20 km) were adequate to play an important role in confirming the theory of seafloor spreading. Recently the scale of studies has focused down to smaller regions, and more detailed data (less than 5 km line spacing) have been sought for use with two- and three-dimensional analysis techniques (K.D. Klitgord, unpub. data, 1987). Total field measurements, done with proton precession magnetometers, are normal practice. Gradiometer techniques, which would eliminate some of the effects of temporal variation and improve sensitivity to closer magnetic sources, have recently been developed. MAGSAT has provided worldwide coverage. Regional surveys, with greater resolution and accuracy, are often done from aircraft. Surveys from surface ships, combining magnetic observations with bathymetric, gravity, and single-channel seismic measurements, are often done by academic vessels. Combining high-resolution bathymetric data with magnetic data permits inversion of the observed fields to infer source magnetization (Miller and Hey, 1986). The best resolution of surficial spatial variations in rock types and magnetization is based on data from sensors on deep-towed vehicles or submersibles.

Gravity

Gravity data provide an indication of intermediate to deep seafloor structure (Marcia McNutt, unpub. data, 1987). At long wavelengths, it has been used to characterize the state of isostatic compensation and, thus, define tectonic models. At shorter wavelengths, it has proven useful in defining salt domes and sedimentary infill for oil and gas exploration as well as magmatic processes at spreading centers. SEASAT provided worldwide coverage accurate to 6 mgals and was able to resolve wavelengths of 100 to 200 km. Accuracy, but not resolution, will be improved by the addition of unclassified data from GEOSAT, and data from the planned TOPEX and proposed Geopotential Research Mission (GRM) (National Research Council, 1985). Shipboard gravimeters are accurate to 2 to 8 mgals with resolution to 2 or 3 km. Accuracy is very dependent on navigational errors, which affect the Eotvos correction. Terrain corrections are best made when data are taken simultaneously with swath bathymetric measurements. Over 50 percent of the power in the gravity spectrum at wavelengths less than a few hundred kilometers is due to bathymetry. Airborne gravimetric measurements have recently evolved to near the same quality as shipboard measurements. Gravity gradiometer equipment is under development for all platforms from spacecraft to surface ships and submarines. Ocean bottom gravimeters have been routinely used on the continental shelf. Current developments are pushing toward full ocean depth capability and 10-μgal accuracy. For long-term geodynamic observations, a 1-μgal instrument can be considered to be sensitive to a 40-mm displacement of the seafloor (Marcia McNutt, unpub. data, 1987).

Single-Channel Seismic Profiling

Seismic techniques are the primary geophysical methods for acquiring information about geological structure and stratigraphy. Single-channel techniques suffice for most shallow penetration requirements. The depth of penetration increases with the power and decreases with the frequency of the sound source. Resolution improves as the frequency increases. Subbottom profilers (typically 3.5 kHz) provide the highest resolution and typically penetrate the uppermost 20 to 30 m of strata (Trabant, 1984). Boomer systems use frequencies down to 400 Hz and penetrate to approximately 40 m. Sparkers extend the frequency range down to 40 Hz, increase the power to 10 kJ (15 bar-meters), and penetrate to 500 m. Air guns and water guns can generate frequencies down to 20 Hz and penetrate to 1,500 m. Explosives can also be used as sources. The natural seismicity of the Earth—earthquakes and microearthquakes—can also act as sources for seismic analysis.

To improve horizontal resolution and penetration, subbottom profilers are often towed near the bottom in deep water. Nonlinear or parametric acoustics are also used in subbottom profilers on surface ships in order to improve horizontal resolution by forming narrow beams without sidelobes. Often, only rudimentary processing is done with analog circuitry and recorders. Deeper penetration systems often employ digital processing techniques, such as deconvolution, in order to improve vertical resolution. Multiple frequency operation is practical with shallow penetration systems. Quantitative analysis of backscatter from multiple frequencies can indicate the presence of resource deposits. The frequency dependence of backscattering from manganese nodule fields is different from that of nodule-free regions (Spiess, 1987). The Multiple Frequency Exploration System (MFES), built by Sumitomo, was judged effective in the search for manganese nodules (Porta, 1983). Refraction and wide-angle reflection techniques can also be accomplished with single-channel equipment. A separate ship or a sonobuoy is used as a receiver. These techniques are useful to determine subbottom velocity information.

Ocean bottom seismometers (OBS's) also are used as receivers for seismic work. Seismic tomography experiments have been conducted by using arrays of bottom instruments and explosive sources imbedded in the ocean floor (Thurber and Aki, 1987).

Multichannel Seismics

Multichannel seismic surveys became standard industrial practice during the 1970's. The essential goal of adding channels is to improve the signal-to-noise ratio of the seismic image. The present practice is to use streamers up to 5 or 6 km long, with 240 or 480 hydrophone channels, arranged into 25-m sections (NORPO, 1986). The signals are sampled at intervals of 1, 2, or 4 milliseconds for up to 10 to 15 seconds after the initial echo. The most effective sources are arrays of five to seven air guns displacing a total of approximately 10,000 in^3 at 2,000 psi. This generates a relatively flat spectrum from 5 to 125 Hz. Three-dimensional (3–D) analysis is a recent innovation, but, for some companies already, the majority of survey work is in support of such analysis (Clark, 1987). To acquire data for this type of analysis, survey lines are set very close together, from 25 to 100 m apart. The efficiency of data acquisition can be increased by towing two streamers rigged from booms at the desired separation. This type of work is expensive (approximately $1,000 per km (OTA, 1987)) and requires specially outfitted vessels.

Equipment must be tuned to the particular application. Oil and gas exploration requires optimizing the resolution, whereas deep crustal studies require maximum penetration (EDGE, 1986). Two-ship techniques have been developed to improve deep seismic images. In two-ship, wide-aperture profiling, the second ship, towing its own streamer, follows behind the streamer of the source ship. This process increases the effective streamer length. In expanded spread profiling, the source ship and the receiving ship steam apart. This separation provides better information on velocity structure than single-channel, wide-angle reflection or refraction operations.

Electrical Techniques

Electrical techniques have been used successfully on land for mineral exploration. Adaptation to ocean use is still in experimental stages (Francis, 1987; OTA, 1987). The high conductivity of seawater limits ranges and inverts the normal contrast found on land. The techniques have shown good potential particularly in searching for placer and sulfide ore deposits.

Both frequency and time-domain electromagnetic techniques have been demonstrated. One coil is used to generate a field and a second to sense the field that results. An airborne system, also used for bathymetric measurements, is capable of mapping bottom conductivity variations in depths of up to 20 or 30 m (Won and Smits, 1985). A towed version, designed at Scripps, used a silver-silver chloride transmitting antenna and a series of horizontal electric field receivers placed on the seafloor at ranges of 1 to 70 km from the transmitter. The transmitter must be in contact with the seafloor and tow speeds are limited to 1 to 2 knots. Development is proceeding on a system in which the transmitter and receiver can be towed in tandem along the bottom. The MOSES experiment (Francis, 1987) used a vertical electric dipole extending from the surface to the seafloor and an ocean-bottom magnetometer as the receiver. By towing the transmitter, the researchers were able to map the sediment thickness and the underlying basalt resistivity, thickness, and porosity.

The first DC resistivity measurements on an ocean-floor sulfide deposit were reported by Francis in 1985. A Wenner array with 10-m spacing between electrodes was deployed from a submersible. Pillow basalts were found to be 40 times as resistive as seawater. Where sulfide was exposed, the resistivity was one to two orders of magnitude less. At one point the seabed was almost twice as conductive as the overlying seawater (Francis, 1987).

The self potential (or spontaneous polarization) technique has been considered for marine use but has demonstrated only limited success. The induced polarization (IP) technique has shown some promising preliminary results and is being developed by the USGS as a reconnaissance tool to aid in the search for offshore titanium placers. Two electrodes introduce current into the ground and cause ions to move from the surrounding electrolyte onto local mineral-grain interfaces and be absorbed there. When the field is turned off, two other electrodes sense the finite decay time as these ions bleed back into the electrolyte. The USGS system uses electrodes spaced 10 m apart, and is towed 1 to 2 m off the bottom. Anomalies were detected that are thought to be related to concentrations of ilmenite in the seabed (OTA, 1987).

Seafloor Sampling and Sample Analysis

Free-fall grab sampling is the simplest and least expensive sampling technique. It is only effective in obtaining surficial sediment samples but still provides much useful preliminary information, especially when equipped with a mounted still camera. Chain bag and box dredges permit a better assessment of surface mineral deposits. With improvements these may provide adequate sampling of hard deposits such as cobalt crusts (Schmidt and others, 1987). Although these techniques are not expensive in shallow water, they present considerable costs in deeper water where each sample or dredge haul may take 3 to 4 hours.

ROV's may prove economical in sampling, particularly where a dense grid (200-m spacing) is needed to define a deposit. RUM III is an example of a seafloor tractorlike vehicle designed for sampling. Any ROV will be limited in the volume of sample it can return to the surface. In-situ analysis techniques could alleviate this. The Continuous Seafloor Sediment Sampler, developed at the University of Georgia, provided some of this sort of capability (Duane, 1987). A sled, towed along the seafloor at 3 knots, agitated surficial sediments that were then pumped to the surface as a slurry. At the surface the sediments were collected on filters and an X-ray fluorescence unit was used to analyze the samples. Naturally emitted gamma radiation can also be detected to indicate the presence of minerals such as phosphorite, monazite, and zircon. Kunzendorf (1987) reviewed geochemical methods used in manganese nodule exploration and efforts at devising in-situ sensors to perform such analyses. Indirect methods involving contact or near-contact with the bottom material have also been proposed. For instance, short-range acoustic techniques may be able to measure the thickness of crust deposits (Hennigar, 1987).

A variety of probes have been developed to measure geotechnical properties of the seafloor. Conductivity measurements can be related to sediment porosity and bulk density (Hulbert and others, 1982). Temperature and conductivity can be used to calculate heat flow (Villinger and Davis, 1987). Piezometer probes can measure excess pore-water pressures in the sediment (Bennett and others, 1985). Compressional and shear-wave probes can be used to measure elastic moduli. Cone penetrometers can measure the shear strength of bottom sediments. These probes could be used by divers or operated from an ROV or manned submersible. Sonatech developed an expendable doppler penetrometer that enabled shear strength measurements to be done from a surface ship.

Drilling and Borehole Measurements

To obtain samples of hard bottom or more than a few centimeters below the surface, drilling and coring are required. Box cores have been very effective in manganese nodule exploration. However, gravity and free-fall corers are not efficient penetrators of granular sediments or hard rock (Duane, 1987).

Vibratory corers are the most effective coring devices for unconsolidated marine sediments such as in placer exploration. These have been very successful in obtaining undisturbed cores in excess of 10 m in up to 100 m of water. Sediment-lift and cuttings-lift systems, in which water, air, or a combination is used to raise material from the seafloor to the surface ship, can penetrate to 20 m or deeper and over a wider range of grain sizes than vibracores. Both percussion and vibratory drilling devices are used with these lift systems. Depths are limited to 30 to 40 m.

Several techniques have been developed for obtaining short cores in hard material in deep water (OTA, 1987). One is a tripod-mounted device that cuts disc-shaped cores 25 cm thick. Another is an explosive-driven device capable of collecting as many as 30 short cores during a deployment. For thicker deposits, drills are required. The Ocean Drilling Program has developed techniques for drilling into bare rock. This is a very expensive operation. An alternative, and relatively less expensive, approach is to use a remotely operated submersible drill. The Bedford Institute of Canada has developed and successfully obtained cores of a few meters in length (Ryall, 1987). Williamson and Associates has proposed a design to core to a depth of more than 50 m (Williamson and Petters, 1987).

Deeper cores require drilling techniques such as have been developed by the offshore oil and gas industry and the Ocean Drilling Program. A wide array of techniques and instruments is available to analyze the core material and to make measurements in the borehole.

Positioning

Sea Surface

Positioning is critical to the quality of any offshore data that may be gathered. LORAN coverage is provided for most of the U.S. EEZ. Nominal accuracy is from 0.25 to 1 nautical mi. Repeatability is often much better. Integrated navigation systems, combining LORAN data with transit fixes, gyroscope, and speed log data can provide positioning accurate to the order of 100 m. During periods when the Global Positioning System (GPS) is available, accuracy is of the order of 10 to 20 m. NOAA surveys and many industry surveys, which require continuous positioning with accuracy of better than 50 m, rely on dedicated or shared medium- and short-range positioning systems. These shore-based systems cannot provide coverage out to the edge of the EEZ. The most demanding of present requirements is for control of 3–D seismic surveys. The quality of these surveys is theoretically impacted by positioning errors exceeding 10 cm (National Research Council, 1983), although 10-m accuracy is more representative of what is being achieved now. A commercial positioning service, STARFIX, provides 10-m accuracy in most areas off the lower 48 States through the use of geostationary satellites (Dennis, 1987).

GPS is hoped to be the solution to most of these positioning problems. At the present time, when coverage is available, accuracy is of the order of 10 m. New satellites are scheduled for launch beginning in October of 1988. Twenty-four-hour, two-dimensional coverage should be available in October of 1989. The full Block II constellation should be in orbit in January of 1991. The Standard Positioning Service (SPS) is expected to be degraded, at that time, to 100-m accuracy. The Precise Positioning Service (PPS), with 10-m or better accuracy, will be denied to most users. Differential operation with the SPS should regain most of the lost accuracy. Receivers, shore stations, and telemetry links to support this type of operation are under development. Use of the carrier phase can permit accuracies of better than a meter to be obtained (Mader, 1986). NOAA has demonstrated this technique in application to aerial photogrammetry (Lucas, 1987). Difficulties in maintaining carrier lock may preclude this type of operation at sea, but, even there, carrier aiding can be employed to improve GPS accuracy (Lachapelle, 1987).

Positioning, in many instances, requires more than precisely locating an antenna. For seismic work, the streamer must be positioned by use of compasses distributed through the array and, possibly, a receiver in a tail buoy. For swath bathymetry, the vessel's heading and attitude must be known precisely. GPS, in a local-differential mode, may be able to improve on the electromechanical sensors now being used to determine attitude and heading. In addition, the sound velocity structure must be known well enough to calculate ray paths. When data are obtained from a deep-towed vehicle, the vehicle position must be determined through the use of long or short baseline acoustic positioning systems.

Seafloor

Techniques to determine positions on the seafloor are needed primarily to mark boundaries and to provide control for monitoring long-term processes such as plate motion and subsidence (National Research Council, 1983). Problems analogous to those on land will ultimately motivate extension of the terrestrial geodetic network into the sea (National Research Council, 1985). Seafloor, or near-seafloor, markers are also used to provide positioning for submersibles and towed bodies. Present operations normally involve the use of acoustic beacons or transponders anchored near the bottom. Their locations are determined from positions on the surface and calculations of acoustic propagation to the markers. Accuracies of the order of meters appear possible. Geodynamic applications will require higher accuracies. Passive, long-term benchmarks and implanting techniques, optical systems, and improved acoustic systems need to be investigated (Spiess, 1985).

Platforms

Surface Ships

Industry, government, and academic ships are being used to support research and mapping of the seabed in the EEZ. Continual modernization of components is needed to keep operating costs down. Some replacements will be required. Small water-plane area, twin hull (SWATH) designs appear attractive because of their stability in rough seas. Ship time is likely to be the major component of the cost of exploring the EEZ. Therefore, optimizing the use of ship time, both through technological and administrative means, is extremely important.

Few mapping and research ships are suitable for operation in ice-covered areas. Operations from aircraft or submersibles may be preferable in such areas.

Aircraft

Some aircraft operations could be effective in obtaining gravity and magnetic data as well as bathymetry in shallow water.

Satellites

The GPS will be a major aid in EEZ exploration by providing easily available, precise positioning. GEOSAT, TOPEX, and GRM data will be useful. Satellites also provide communication links. GOES and ARGOS are being used for low-data-rate applications and can provide a means for long-term, unattended installations to regularly report results and status to shore. INMARSAT provides the capability for voice and data links to ships at sea. Differential GPS telemetry links to cover the outer portions on the EEZ will use satellites. Data and control links to long-term ocean observatories may use satellite links.

Submersibles and ROV's

Manned submersibles have been working in the EEZ for many years. ROV's also have a history of service in the EEZ. Recently, the number of ROV's operating has increased markedly because of the improved manipulative capability that has been provided to these vehicles, although they have generally been limited to shallow and intermediate water depths. Full depth capability is awaiting the introduction of fiber optic cables for use on oceanographic winches.

The primary advantage of manned submersibles is the opportunity for direct, three-dimensional viewing (OTA, 1987). Another factor is the generally better manipulative capability that they provide. With technological improvements in ROV's, these advantages will diminish. At the present time, the ALVIN has the deepest diving capability (4,000 m) of submersibles in this country outside of the Navy. The Navy's SEA CLIFF, TURTLE, and NR-1 submersibles are made available for civilian work when not required by the Navy. Approximately 16 other manned submersibles are operated in the United States. Most of these have depth limits between 300 and 1,000 m.

ROV's have gained acceptance for many tasks previously consigned to submersibles. Risk to human life is reduced and endurance increased. More than 100 different models have been produced by different manufacturers. These range from low cost, limited capability devices to very sophisticated systems such as ARGO and JASON, Deep Tow, and CURV III. The ROV application has been a major driver in recent research activities in robotics. Improvements have been made in hydrodynamic modeling, nonlinear adaptive control techniques, and man to machine interfacing. Further work can be expected in these directions.

Drag on the umbilical cable presents a major limitation to ROV performance. Autonomous underwater vehicles (AUV's) offer a means to avoid this. Substantial research efforts are under way on vehicles such as EAVE (University of New Hampshire), SPURV (University of Washington), AUSS (U.S. Navy), and ARCS (International Submarine Engineering). Techniques of machine vision, artificial intelligence, and robotics promise to permit many tasks to be done without any operator interaction. Limited supervisory control and feedback will be possible through acoustic communications techniques. Improvements are being sought in power sources (fuel cells, Sterling cycle engines, buoyancy propulsion, artificial gills, lithium batteries, etc.) and materials (composites with strength-to-weight ratios better than 0.5, corrosion resistance, and so on).

Long-Term Ocean Bottom Observatory

Geological processes are not static but are slowly varying and episodic. Long-term monitoring technology is needed to characterize geodynamic and erosional processes on the seafloor. Proposals are being developed to monitor ridge crest processes over the time scales of days to years (Delaney and others, 1987). In addition to repeated surveys, sites would be instrumented with ocean bottom seismometers, tiltmeters, gravimeters, strain measuring devices, geochemical monitors, current meters, and more. Significant experiments in the past have been devoted to the study of turbidity currents and the action of high-energy benthic boundary layers. There are still no reliable techniques for predicting the initiation of debris flows or turbidity currents or for modeling their behavior. Long-term (20–50 year) creep deformation of slope sediments is not yet understood (Seymour and Webster, 1987). Instrumentation is needed for monitoring geotechnical parameters, disturbing forces, and movements.

Data Collection and Processing

The most difficult collection and processing requirements are posed by multichannel seismic operations. Data rates can be as high as two to four gigabytes per hour. Merely logging that amount of data is a formidable task. The multispectral scanner under development by the Navy for shallow-water bathymetry will also produce data at three to four gigabytes per hour. Video imagery from ANGUS and data from interferometric SeaMARC systems occupy the full bandwidth of present deep ocean cables (approximately 6 MHz). Magnetic tapes are the standard recording medium but require elaborate buffering at the highest data rates. Up to 25 high density (6,250 bpi) tapes per hour may be required. Optical discs (with storage capacities up to several gigabytes) are beginning to be used in conjunction with high-resolution side-scan and video systems. These applications tax the state of the art in computers and peripherals.

Most data acquired at sea do not approach these high rates. In fact, data collection at sea is, more often than not, agonizingly slow. Many data are still collected in analog form although the advantages of digital data are becoming increasingly clearer. The challenge of most data-collection systems is to integrate data and provide for quality control. Local area networks and multitasking operating systems provide the means to bring data together from the various sensors, synthesize a coherent picture, and make it available for analysis. Often that picture, itself, is the best quality-control aid. Monitoring of such parameters as signal-to-noise ratio, residuals of over-determined solutions, and agreements at junctions and crossings are other quality-control techniques that are automated in data-collection systems. Characteristic data anomalies must be sensed, and the operator alerted.

Multichannel seismic processing cannot be done in the field. Seismic processing is one of the applications driving the development of supercomputers. Each step of the present processing requires days of dedicated time on the biggest computers that are sent to sea and minutes to tens of minutes of time on supercomputers. Increasing data density escalates processing requirements.

Few, if any, other exploration techniques require such processing power. Gridding, contouring, and perspective viewing of bathymetric data, adjustment of gravity and magnetic data, image processing of side-scan data, and other common procedures presently employed are within the capability of DEC Microvax class computers (Tyce and others, 1987). At least an initial pass through these procedures is generally possible in the field within a day of collection of the data. This is important not only from the point of view of ensuring quality but because it offers the opportunity to adjust exploration strategy. Potential field inversion, pattern recognition, and mosaicing are examples of machine-intensive procedures being applied to exploration data in laboratories today. As these procedures and computer hardware continue to develop, some will be introduced into the field to improve and accelerate exploration. Interactive processing will become more feasible, and artificial-intelligence techniques will be applied.

Data Storage and Retrieval

Data relevant to exploration of the seafloor of the EEZ are gathered by several agencies of the Federal Government, by State governments, by universities, and by the exploration industry. Virtually all collection organizations maintain archives of their own data and exchange data on some basis. Much of the data gathered under the auspices of the Federal Government is submitted to the NOAA's National Geophysical Data Center (NGDC) for public dissemination. Although incentives for the collecting organizations to submit data are not strong, this collection is probably the largest data base of this type of information. About 5 gigabytes of digital data (worldwide—not limited to the EEZ) are in the archives at the present time, in addition to analog records. About half of this is bathymetric/hydrographic data and half is underway geophysics data (navigation, bathymetry, magnetics, and gravity). Geological data inventories and marine boundaries constitute the remainder of the digital data.

The CONMAP project, within the USGS, is aimed at compiling an inventory of all geophysical data in the EEZ. Data would be available both as printed maps and through remote access to a data base. The Strategic Assessment Atlas project, within NOAA, has similar aims but with emphasis on biological, physical oceanographic, sociological, and economic aspects of the EEZ. NGDC has also recently started to provide area summaries of its holdings. On-line access to indices of data is possible with present technology but is not yet available.

The amount of data available to the public through NGDC would increase substantially if significant amounts of multichannel seismic, high resolution side-scan, or multibeam bathymetric data were included in the collection. The USGS is planning to release GLORIA data from the Gulf of Mexico EEZ on a CD–ROM. Technology seems to be available to accommodate even orders of magnitude growth in the amount of data in archives. NASA has successfully handled substantially larger quantities of data from space programs. Ocean data, however, are most valuable if they do not have to be handled as sets of data. Geographic Information Systems (GIS's), currently being developed, may provide the optimum framework for handling these data. Procedures must be developed to maintain a data base in the context of a continuing flow of additional data of widely varying quality. A data base need not be physically consolidated but could be managed by an index and referral system, thus avoiding the necessity of duplicating files.

Multichannel seismic data would constitute the largest portion of data in archives, but very little has been submitted. Nearly all of these data are gathered by the geophysical industry. About 15 percent of these data are purchased by the Minerals Management Service. These data were to be held proprietary for 20 years then added to the public archives maintained by NGDC.

The largest portion of multibeam bathymetric data would come from NOAA surveys. Due to national security concerns raised by the Navy, these data are being held as classified information. The Navy has indicated that similar concerns may exist about other types of geophysical data.

PROGRAMS IN PROGRESS

There are no programs specifically aimed at the development of technology to characterize the EEZ. There are programs in several Federal Government agencies that are contributing to mapping and research in the EEZ and, indirectly, to the development of technology. The USGS and NOAA have coordinated efforts to focus on the EEZ. The USGS is in the midst of a program of complete surveys of the EEZ using the GLORIA side-looking sonar. A program of ground-truth work to aid in interpretation of the GLORIA imagery has been initiated. The USGS has also started the CONMAP program (described above) as a data base of available geological information. NOAA has embarked on a program of systematic surveys in which multibeam bathymetric sonars and 3.5-kHz subbottom profilers are used (NOAA, 1987). NOAA's National Geophysical Data Center, National Oceanographic Data Center, and Strategic Assessment Atlas project (also described above) are assembling available data from various aspects. NOAA's Sea Grant program and VENTS project have supported substantial research efforts in the EEZ. The Ocean Minerals and Energy Division has supported ocean mining studies outside the EEZ.

Other agencies also have substantial programs related to the EEZ. The Minerals Management Service (MMS) has supported extensive studies of the environmental impact of offshore oil and gas operations and the hazards they may face. It also purchases large quantities of seismic data (mentioned above) to evaluate the resource potential of offshore areas. A number of State-Federal task forces have been set up under the auspices of MMS to study the potential of mining hard minerals offshore. The Bureau of Mines has been developing estimates of offshore hard-mineral resources and examining mining and extraction techniques. The National Science Foundation (NSF) has no specific EEZ focus but continues a broad program of support for marine geology and geophysics including the Ocean Drilling Program and the UNOLS facilities. The Office of Naval Research (ONR) continues to support the study of seafloor geological properties that relate to bottom acoustics. A new Seafloor Terrains initiative has been started. Other Navy activities provide considerable support for the development of ocean technology but technology transfer to the civilian sector is limited. The Department of Energy (DOE) has supported the study of seafloor geological and physical processes for ocean disposal of nuclear wastes. Recent legislation renews that mission. The National Aeronautics and Space Administration (NASA) sponsors the Geodynamics Program, which is undertaking land- and sea-based observations of tectonic plate motion. The Environmental Protection Agency (EPA) has efforts to determine the environmental impact of ocean operations and disposal.

Few of these programs are currently able to support the development of new technology, although many have in the past. NOAA's Sea Grant program is an exception, still providing active support in ocean engineering (particularly autonomous vehicles) and some technology development in other research areas. NSF has conducted two workshops on engineering solutions for utilization of EEZ resources and has proposed initiatives to provide support to such efforts. The congressional Office of Technology Assessment (OTA) has recently completed a study of the marine mineral potential of the EEZ and the status of technology for its exploration (OTA, 1987). The Marine Board of the National Academy of Sciences has completed a working paper on technology requirements for the EEZ (Marine Board, 1987) and is nearing completion of a study on utilization of the seafloor of the EEZ. This study should aid in defining the requirements for the development of technology.

Workshop participants suggested that a specific portion (5 to 15 percent) of the exploration budget should be set aside for development. Such investments should be made at the front end of programs in order to reduce total program costs.

Innovative mechanisms for the development of technology are needed in order to reduce costs and improve incentives. The present marketplace does not provide sufficient incentive for the private sector to support the necessary effort. Government programs must forego the long-term benefits of supporting development in favor of immediate exploration and research work. Innovative arrangements to share the burden, risks, and benefits of development between the public and private sector are needed. The Small Business Innovative Research (SBIR) Program, which has participation from several Federal agencies, has had some success in this regard. In this program, some monies are set aside for the development of equipment relating to agency needs and also having a potential commercial market. Work done on successful proposals is permitted to remain proprietary. Other approaches are necessary to supplement and expand this start. Collaborative arrangements with industry, to the mutual benefit of both government and industry, are needed. Mechanisms developed by foreign countries (France, Germany, England, Japan, Canada, and so on) should be examined as possible models. Possibilities of increased international cooperation on technology development should also be examined.

SPECIFIC RECOMMENDATIONS AND STRATEGIES FOR FILLING THE GAPS

Collection, Integration, and Standardization of Existing Information

In planning for the next 10 years we must consider the plans already in progress as well as the work already done and incorporate them into our thinking, as well as their results into our archive for EEZ data. To make use of available, as well as future, data will first require an assessment of available data, followed by collection, standardization, and integration into a well-defined EEZ data base. A coordinated effort amongst the various agencies will be required to determine just how data can be organized and archived. First of all NOAA and USGS should undertake the job of compiling lists of existing data of various forms from reconnaissance and site surveys. All new data acquired in the EEZ should be organized and collected in standard digital form for broad distribution, with NOAA taking the lead role in data base definition. Standard formats have already been established for many types of data. They need to be developed and adopted for other types of data, such as digital 3.5-kHz seismic, conventional side-scan sonar or multibeam seafloor backscatter data. NOAA's National Geophysical Data Center should take the lead in working with equipment manufacturers, operators, and data users to define and encourage use of these standards.

Application of Existing Capabilities

Government

Plans are already in progress to make significant use of existing capabilities for EEZ exploration. NOAA and USGS will have the lead roles in government-sponsored work. With more than 1 million nautical mi^2 of GLORIA surveys completed and 350,000 nautical mi^2 per year planned, most of the EEZ will have been mapped by GLORIA in the next 5 years. Availability of this monumental digital data base will require techniques for access, processing, display, distribution, and registration of these data with other data sets to be developed or adapted. Since the low-resolution side-looking sonar data provided by GLORIA are considered truly reconnaissance in nature by most geologists, site selection and planning for limited site surveys and potential bottom observatories become the next task for USGS, including determining requirements for higher resolution survey systems as well as sampling systems.

For NOAA, three Sea Beam ships are already in operation, and installation of two new shallow-water (less than 1,500 m) swath bathymetry systems is expected by 1990. Beginning in 1989, 1,050 ship days per year are requested for EEZ bathymetric and 3.5 kHz seismic mapping. The present capability can produce about 2,500 nautical mi^2 per month, with production directly proportional to depth for each type of system. Approximately 50,000 nautical mi^2 have been covered as of January 1988. At this rate of production, 70–100 years of survey would be required, so survey work must be prioritized. Wider swath systems obviously need to be developed to improve production. To make efficient use of this enormous investment in ship time, the survey ships need to be equipped with all appropriate capabilities, such as magnetometers, gravimeters, digital seismic profiler, swath backscatter data logging, and so forth. Because of the length of time required to survey the EEZ with present technology, new developments in other sensors as well as in swath mapping can significantly impact and augment this program in the next 10 years.

Upgrades in NOAA shipboard and shore-based computing are in progress for the EEZ program and should extend to definition, establishment, and distribution (once classification restrictions have been relaxed) of standard digital data bases for bathymetric data. Addition of nonconflicting data collection in digital form must be considered for magnetics, gravity, 3.5-kHz seismic profiling, and swath roughness/backscatter measurements, along with data bases or storage formats for such data. USGS, NSF-sponsored academic researchers, and industry representatives should cooperate in the geological interpretation of these data as they become available.

Academic

Academic institutions are expected to participate in EEZ research and mapping through research programs of particular scientific or engineering focus, as well as through use of UNOLS survey capabilities to augment NOAA and USGS resources. Reconnaissance survey work is possible aboard the three Sea Beam-equipped UNOLS ships once they have appropriate navigation control and data collection and processing systems equivalent to those used by NOAA. Site survey work can be expected to involve various vessels and instruments of the academic research community, and care must be taken to combine application of instruments in order to optimize coverage and resources. Academic institutions and industry are expected to take the lead in development of improved site survey capabilities, including remotely controlled and autonomous vehicles, as well as bottom observatories. Workshops of agencies and researchers will be required to define standards in navigation, data collection, formats, and so forth.

Industry

Mapping of the EEZ has a long history in the oil industry, with a wealth of proprietary data in existence already, though for relatively shallow water. Three-dimensional seismic profiling is an advanced technology relatively common to oil industry surveys, that effectively provides subsoil swath mapping of geological strata. Employment of such capabilities in site surveys will almost certainly involve contracting with industry survey crews or proprietary site surveys. Ocean dumping and ocean mining interests have had more recent requirements for EEZ mapping. As prospective sites for development are identified from EEZ mapping efforts, industry can be expected to conduct detailed site surveys, in addition to making use of EEZ data bases. A policy for encouraging industry contribution to the EEZ data base should be devised. Incorporation of available, as well as future, industry data into an EEZ data archive should be a part of the EEZ mapping program. To this end, existing data must be cataloged, archive formats and standards established, distribution established, and computer programs and access developed. Optical disk formats will soon be well established and available for distribution of large data sets. Advances in computers over the next few years will make processing of large data sets straightforward and network access to large data bases common.

Development and Application of New Capabilities

What Are Our Priorities?

New developments are appropriate to all phases of EEZ mapping, including reconnaissance surveys, site surveys, and long-term or bottom observatory measurements. Of particular relevance is the report of the recent NSF-sponsored conference "Engineering Solutions for the Utilization of the Exclusive Economic Zone Resources" (Yuen, 1987). While dealing with questions of broader scope than this symposium on mapping and research in the EEZ, this conference identified systems for "characterization of the ocean bottom resource . . ." as a primary development need. The relevant parameters of seafloor characterization referenced include bottom topography, bottom roughness, and physical and chemical properties of seafloor rocks and sediments. Only in the case of seafloor topography do we presently have available systems capable of meeting reasonable requirements for detailed surveys. In all other areas we are limited either by absence of adequate systems or technological barriers.

Reconnaissance Surveys

Present plans for EEZ reconnaissance mapping involve long-range side-looking sonar surveys that use GLORIA and swath bathymetry mapping that uses multibeam sonars. Both systems can be expected to produce gridded digital data with 200- to 250-m lateral resolution, one representing an image of sound scattering from seafloor roughness and the other representing depth. This resolution is relatively coarse for side-looking sonars and relatively fine for echo sounders. GLORIA has a swath of about 10 times water depth, while Sea Beam has a swath about 0.8 times water depth. These systems are not optimum, but they represent the state of the art. What few people realize is that the Sea Beam sonar was not designed as a swath-mapping sonar. It was designed as a high-resolution echo sounder with one beam stabilized in roll and pitch, for a system called the Narrow Beam Echo Sounder (NBES). The transmitted signal is a narrow side-looking sonar beam stabilized for pitch but with swath beam width reduced for echo sounding. As the ship rolls, the echo from beneath the ship is interpolated from the two beams nearest to downward out of the 16 beams formed. The swath width results from the requirement to accommodate a ship rolling 20 degrees to either side, and not from swath survey considerations. Sea Beam represents the addition of a computer echo processor to the old NBES sonar to process all of the 16 beams available.

Thus, it is not surprising that a German company, setting out to design a new swath-mapping sonar (Hydrosweep), was able to achieve a swath 2 times water depth with equal accuracy. Intermediate-depth swath sounders achieve 2.5 times water depths, while side-looking sonars adapted for phase comparison between two receivers achieve 3.4 times water depth, though with reduced accuracy. Side-looking sonars typically achieve images of 10 times water depth when not operating at frequencies too high for the depths involved. Thus it would seem that greater swath widths are possible, since swath sonars use exactly the same acoustics that side-looking sonars employ. They should also be capable of producing the bottom acoustic backscatter images associated with side-looking sonars in addition to depth measurements. In fact, UNOLS operators have experimented with Sea Beam digital images with success, using added computer data acquisition systems.

Considering the investment in ship time planned for EEZ mapping, it is surprising to discover that there is presently no commercial or unclassified government-sponsored research in multibeam sonars underway at present in the U.S. There is considerable foreign development currently, but no work on a multibeam system with combined side-looking sonar digital imagery and bathymetry. Some support is being provided for the development of interferometric systems, which provide combined output. The imagery is essentially a measure of bottom roughness, though the relationship is not completely understood (work on this subject is presently being supported by ONR). Development is clearly needed in this area, with NSF and ONR taking the lead role to develop new combined systems for deep and shallow water. Increases in productivity of more than tenfold are possible with present technology, particularly if current sonar technology is combined with remote controlled launch technology in the hydrographic tradition.

The introduction of digital acoustics in imaging and mapping has come of age in the past decade. Thus it would seem appropriate that NOAA should collect digital rather than analog 3.5-kHz seismic profiling data. Such systems have been developed by university labs and commercial firms and should be accommodated by NOAA's improved shipboard computing capability. Paper analog records are difficult to interpret quantitatively and are generally subject to uncalibrated gain adjustments. Advances in digital data storage have made the problems of storing and distributing such digital data manageable.

Shipboard magnetics and gravity measurement systems have been commonplace aboard research ships for some time, without interference with underway survey. New high-resolution magnetic systems can operate continuously and high-resolution gravity systems are commonly available, though costly. Such systems should be aboard NOAA and UNOLS ships used for reconnaissance surveys of the EEZ, considering the minimum impact and considerable investment in ship time. NOAA, NSF, and USGS should take responsibility for ensuring data processing and integration into the EEZ data base. Airborne magnetic and gravity survey capabilities, comparable to those available shipboard, should be considered a viable alternative once these capabilities mature.

Accurate survey ship navigation is critical to survey work at all scales. Accuracies of 50 m or better are required throughout the EEZ. At present, this accuracy is only possible near shore with shore-based systems such as ARGO and Miniranger or offshore during GPS satellite availability. By 1990, 24-hour GPS coverage is expected, but reduction in CA code accuracy to 100 m by the Defense Department is likely. Techniques for improving this accuracy to 10 m have been demonstrated, and development of such capabilities for EEZ surveys must be fostered.

Site Surveys

Detailed site surveys will involve application of various towed sensors, such as multichannel and 3–D seismic profiling systems, side-looking sonars, thermal, magnetic, electromagnetic, and gravity sensors, and camera sleds that presently exist or are being developed. Detailed acoustic imagery and bathymetry for selected sites is within the realm of present technology but because of reduced ship speeds tends to be site specific. One of our greatest deficiencies, however, is in our ability to make in-situ measurements and take accurate samples of seafloor materials. We still use sediment and rock samplers lowered blindly to the seafloor to collect random samples. Development of remote monitoring and control of sampling systems is important to site survey work, particularly in complex areas, such as those associated with hydrothermal deposits. Remotely controlled vehicle development is already rather advanced, and the introduction of fiber optic cables to the oceanographic environment will allow vehicles already developed to be used in deepwater applications. Autonomous vehicles can be expected to play a role in site survey work as well, though this technology is not as well advanced. NSF should take the lead role in developing new vehicles for EEZ exploration, along with new bottom samplers. Better underway sampling devices, designed to optimize survey ship time, should also be developed. Underwater navigation systems are critical to detailed site survey work. Acoustic transponder systems need to be improved to provide rapid net calibration and centimeter accuracy for geodetic measurements. Such developments are already in progress in academia and industry and need to be encouraged.

Standard shipboard and shore techniques for seabed sample analyses need to be established so that government, academic, and industry efforts can produce common results. Techniques for efficient seafloor sampling of sediments need to be improved, and techniques for rock sampling in complex environments need to be developed.

Long-Term Monitoring—Seafloor Observatories

Our capability for long-term monitoring of seafloor sites is extremely poor. While we may leave simple instruments on the bottom for several years, we have little capability for installing them in complex environments other than by using very expensive submersibles with limited payloads. We have not developed either power or data communication systems for long-term, complex installations and have limited satellite communication capacity for remote monitoring or control. This is an area of development detailed in the NSF "Engineering Solutions . . ." conference as well (Yuen, 1987). With present-day technology it is not unreasonable to imagine an observatory with robot vehicles controlled remotely via satellite doing systematic sampling and monitoring of seafloor hydrothermal sites, but much of the seafloor analog of available laboratory technology does not yet exist. Considerable long-term development is required in these areas that should be of benefit to everyone working in the ocean. This development should be led by either NSF or ONR.

Combined Application Strategies

Combinations of survey and sampling programs at all scales will be essential to efficient utilization of resources, particularly ship time. Reconnaissance surveys should incorporate all noncompeting sensors. Site surveys should utilize towed sensor packages with multiple standard sensors when possible and include multiple measurement programs on the same survey cruise. Seafloor observatories must involve careful interdisciplinary planning to make efficient use of these expensive installations.

SUMMARY

- The development of technology has played, and will continue to play, a crucial role in the exploration of the U.S. Exclusive Economic Zone.
- Marked improvements can be made in the efficiency of present activities through application of existing technology and optimization of its use. An order-of-magnitude improvement in the efficiency of mapping systems is possible within 10 years with a directed development effort. New tools can be developed to directly indicate the presence of valuable seafloor resources and to monitor seafloor processes.
- Technology development must be closely related to user needs. Requirements for data and specifications for equipment to acquire, manage, and analyze such data need to be better defined. This symposium, and the 10-year plan which is to follow, as well as the efforts of advisory groups such as the Marine Board, should provide such a foundation. Particularly during this 10-year exploration period, the direction of technology development should remain sufficiently flexible to respond to evolving perceptions of data needs.
- Innovative mechanisms are needed to support technological development. Arrangements that encourage cooperation between the private and public sectors are necessary. The burden, risks, and benefits of development must be shared. Possibilities for international cooperation should be examined. A specific portion (5 to 15 percent) of the exploration budget should be set aside for development. Such investments should be made at the front end of programs in order to reduce total program costs.
- Current restrictions on the availability of data must be removed as far as possible without causing damage to national security or economic incentives. Exploration of the EEZ cannot proceed efficiently under the present restrictions. The decision to classify bathymetric data should be reviewed. The period of proprietary holds on data obtained by the government must be minimized.
- Accessibility of data needs to be improved. Substantial quantities of data that have already been collected must be included in inventories and made available. New data must be acquired in digital and standardized form. Standard formats should be established where they do not exist. Provisions must be made for management of several orders of magnitude more data than is presently archived. New, denser storage technologies, such as optical disks must be integrated into the data management scheme. Techniques to accommodate and maintain varying levels of quality must be devised. Interconnection of data bases maintained by various organizations should be examined as an alternative to centralized management. Provisions for remote access, with inventory, browse and order software, need to be developed.
- Substantial improvements in current operations are possible. The use of expensive acquisition platforms can be optimized. Bathymetric survey ships need to be equipped with magnetometers, gravimeters, digital seismic profilers, and other instrumentation that can be operated without conflicting with their basic mission. Wider swath bathymetric systems can improve survey efficiency and should be configured to log backscatter imagery in addition to bathymetry.
- The most productive directions for near-term improvements are in the areas of navigation and direct sampling. The GPS should be operational by 1990. The development of techniques and user equipment to exploit it offshore must continue. Construction of better remotely operated rock drills, crust corers, and large sample dredges can greatly improve the success of direct sampling.
- The most productive areas to direct a longer term (5- to 10-year) program of technology development include:

- o Quantitative, remote techniques—Have shown promise to determine surface and subsurface composition, electrical techniques, such as induced polarization, and acoustic techniques, using, for example, multiple frequencies, texture analysis, or tomography. Development will require analysis and testing, including ground truthing with direct sampling techniques. Techniques should be devised to determine both resource estimates and geotechnical properties of the seafloor.
- o Long-term monitoring techniques—Seafloor geodetic techniques at least an order of magnitude more sensitive than those available today need to be developed. Sensors need to be devised that are capable of detecting changes in the shape and composition of the seafloor. Sensors to monitor possible disturbing forces need to be incorporated. Telemetry techniques need to be developed and energy sources improved. Strategies need to be developed that integrate these time-series data with data on spatial extent.
- o Remote and autonomous vehicles—The objective is to develop highly flexible, cost-effective robots capable of operating in the most difficult ocean environments. Advances in artificial intelligence, machine vision, energy sources, control systems, telemetry techniques, and materials will all contribute to this effort. In-situ analysis techniques must be developed to make optimum use of these vehicles.

The program should also include continued development of wide-swath bathymetry and imaging systems and direct sampling devices. It should attempt to make maximum use of technology developed for other applications, such as fiber optics.

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Workshop 7: Information Needs and Availability for Oil and Gas Leasing, Exploration, and Development of the EEZ

Panel Co-chairpersons:
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INTRODUCTION

This session was concerned with the currently available geological and geophysical (G&G) data that characterize the seabed/subsoil of the Exclusive Economic Zone (EEZ) of the United States and defined what types of efforts may be necessary over the next 10 years to fill in any gaps in these data to support the Minerals Management Service (MMS) oil and gas leasing, exploration, and development program. An important factor to keep in mind in reviewing the data needs of the Department's oil and gas leasing program is that it is market driven. Where leasing occurs and where industry collects information are a direct consequence of industry interest and economic expectations. The industry has already collected extensive amounts of subsurface data, drilled in water almost 1½ mi deep, and explored in areas of the Outer Continental Shelf (OCS) more than 150 mi from shore.

In the early stages of leasing offshore lands to the oil and gas industry, the MMS focus is on determining the regional subsurface geological framework of a planning area. Within the planning area a geological model(s) of potential hydrocarbon generation, accumulation, and distribution is (are) developed. Potential source, reservoir, and impermeable cap rocks are identified and potential hydrocarbon-bearing horizons mapped. This information provides the basis for a geology report and associated subsurface maps that describe the geology, resource potential, and potential geological hazards of the planning area.

As the leasing process progresses, the focus shifts from planning areas to the specific tracts being offered for lease and the identification of individual prospects in the area. More detailed mapping and analyses are conducted to estimate the resource potential of individual prospects within the area and to determine parameters for postsale bid analyses for purposes of assuring receipt of fair market value. Specific geological structures and (or) stratigraphic traps, such as salt or shale diapirs, anticlines, fault traps, unconformities, and pinchouts, are identified. Tract- and prospect-specific subsurface maps and analyses are produced for resource economic evaluations. During this process, an Environmental Impact Statement (EIS) is prepared that addresses the proposed lease sale. Estimates of the potential quantities of undiscovered resources are critical in analyzing the proposal and the various alternatives.

The G&G data are also used in the regulation of operations on leased lands such as in preparing unitization agreements, determining the potential for drainage between State and Federal leases, and mapping potential geohazards.

The portion of the EEZ of interest from an oil and gas perspective is currently limited to the area surrounding the contiguous States and Alaska. Much of these areas is already included in the Department's recently issued 5-Year OCS Oil and Gas Leasing Program, covering the period from July 1987 to June 1992. The areas included are depicted in figure 1.

Those planning areas not included, that is, Kodiak, Aleutian Arc, Bowers basin, Aleutian basin, and St. Matthew-Hall, are of little or no current interest, but attractive prospects may be found with more data coverage, the evolution of new geologic theories, or better economic conditions for oil and gas development. If industry interest evolves, they would be considered for the program covering the period from 1992 through 1997. Also, as technology evolves more hostile and remote frontier areas of the OCS will be explored by industry and thus more data and information will be available. Because of MMS's right to select from industry's vast data base, the MMS does not generally need to supplement its data acquisition efforts with other Government-sponsored research efforts to carry out its mission.

MMS vs. USGS ROLES

The MMS exercises all appraisal and management functions in direct support of the OCS/EEZ leasing program. The MMS functions include the following:

1. Acquisition, interpretation, and dissemination of data and information collected under permits and leases issued by MMS.

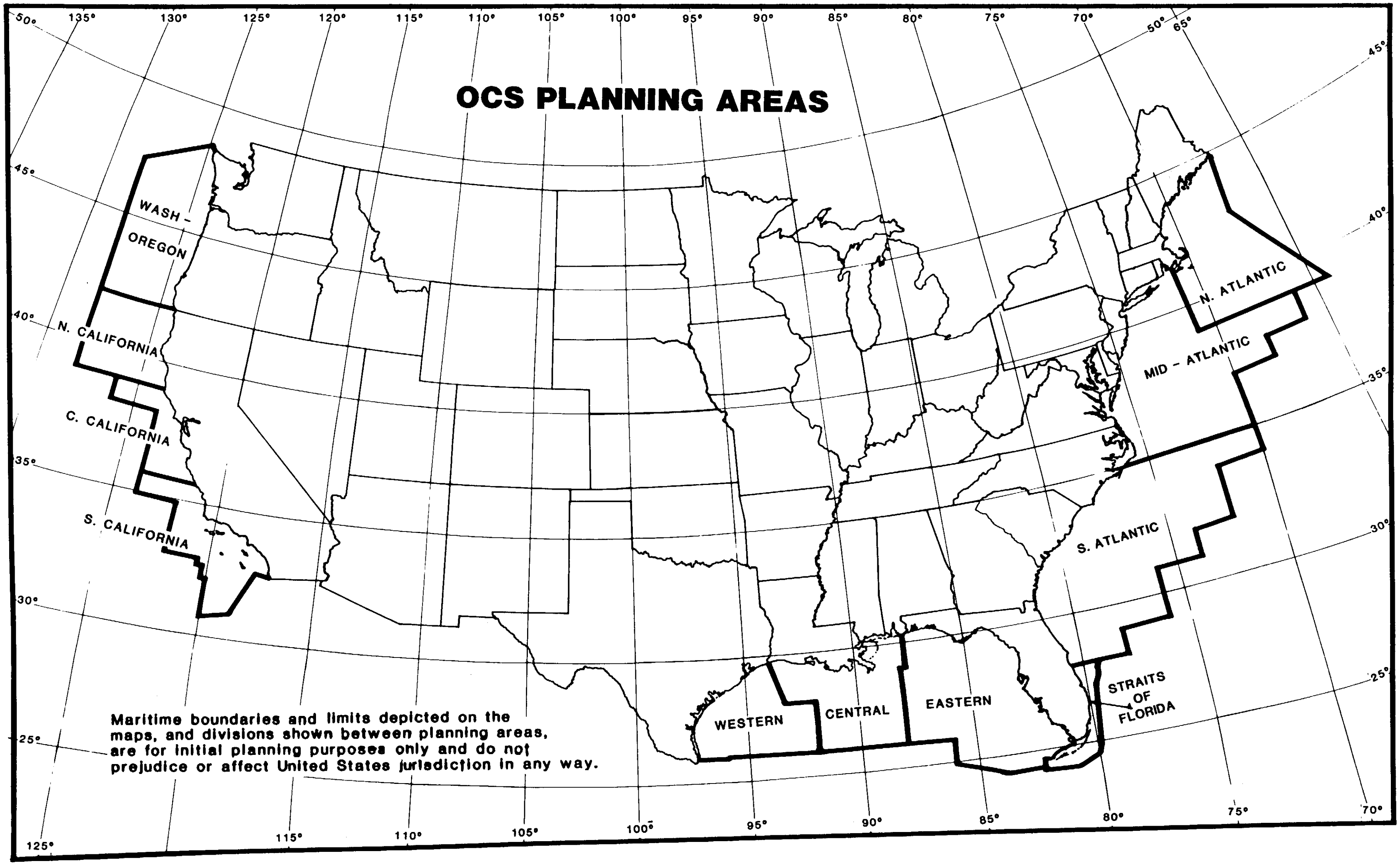

Figure 1*A*. Outer Continental Shelf planning areas—lower 48 States.

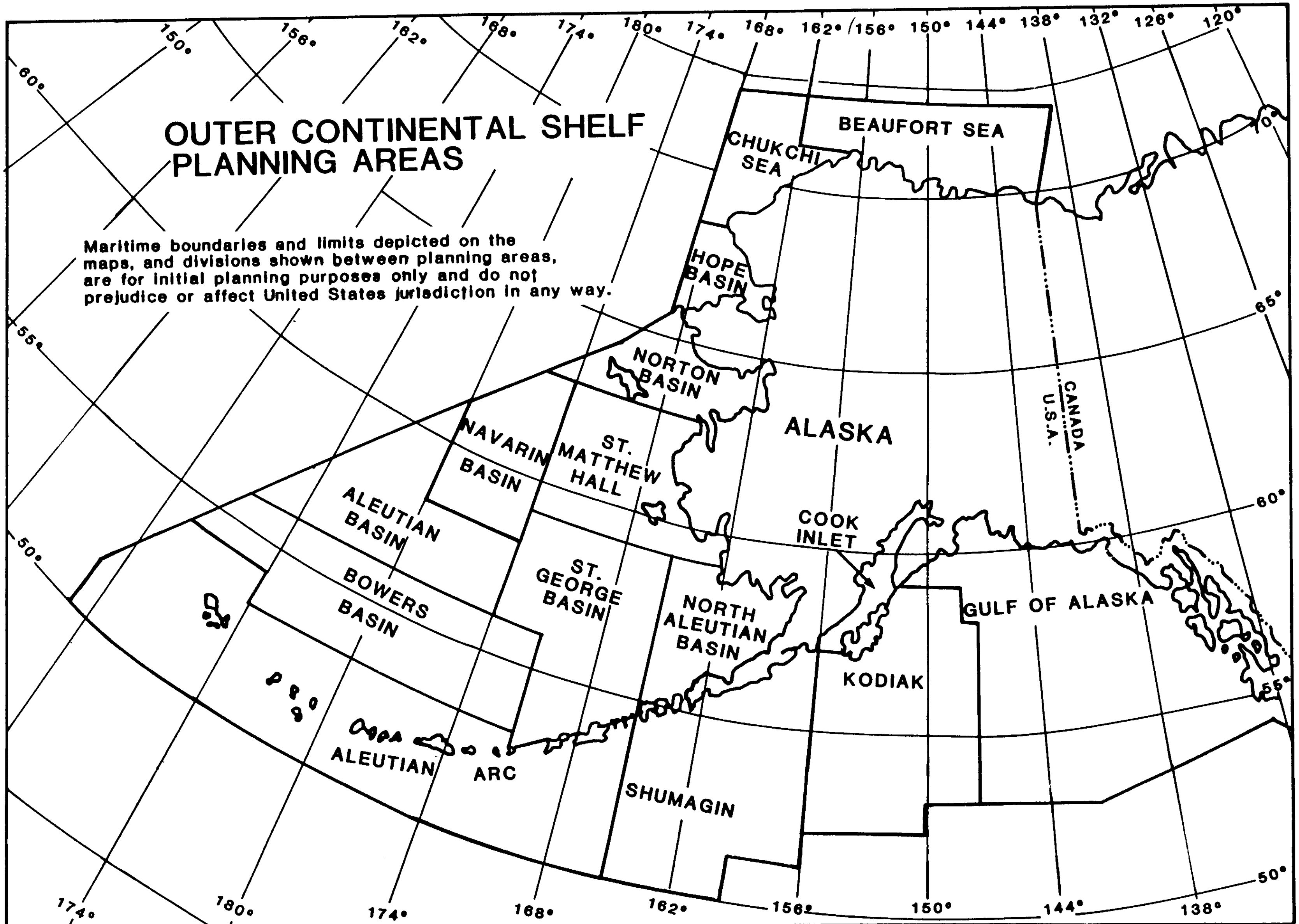

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Figure 1*B*. Outer Continental Shelf planning areas—Alaska.

2. Preparation of all OCS/EEZ appraisals and resource estimates including the biennial reports required under section 606 of the OCS Lands Act, resource estimates for proposed legislation pertaining to OCS/EEZ energy and nonenergy programs, resource estimates of OCS planning areas and for the sale alternatives within these planning areas, and resource estimates for preparation of the 5-year OCS lease sale schedule. This includes estimates for energy minerals and, as required, nonenergy minerals.
3. Determination of the areas of hydrocarbon/mineral potential in each OCS planning area and recommendations of those areas to be included in the Call for Information and Nominations.
4. Preparation of regional hazards data and analyses necessary to support the NEPA and Secretarial decision process for OCS/EEZ mineral leasing activities.
5. Preparation of geologic or resource reports required by the OCS/EEZ lease sale process.
6. Fair market value determinations for OCS/EEZ energy and nonenergy mineral leases.

The USGS exercises functions derived from its Organic Act. These activities include research and dissemination of results for nationwide assessments of the geology and mineral resources of the national domain including coastal waters, the continental margins, and the EEZ but not in direct support of the OCS/EEZ leasing program. The USGS functions include the following:

1. Collection of new data as fundamental to its research mission.
2. Preparation, synthesis, and dissemination of resource data and information generated as a result of research.
3. Preparation and dissemination of geologic framework studies, topical and process studies, and the synthesis of nonproprietary data related to geologic potential generated as a part of research activity.
4. Synthesis, analysis, and dissemination of available regional hazards data generated by USGS in its research mission, including descriptions of major regional phenomena, such as faults, earthquakes, seafloor instability due to erosion and slumping, volcanic activity, and seismicity.
5. Petroleum geology and nonenergy minerals geology and environmental geology studies generated as a result of its research effort, and syntheses and dissemination of these and related data.

DATA AVAILABILITY

Industry collects and owns the vast majority of the data and information that are used by the Federal Government for decisions related to offshore oil and gas leasing, exploration, and development. The seismic method accounts for 97 percent of all expenditures in petroleum geophysical activity. From 1976 through 1986, industry acquired approximately 3,693,600 line mi of seismic data on the U.S. OCS. From FY 1976 through FY 1986, MMS acquired approximately 906,400 line mi of seismic data, mostly from industry as a condition of the permits issued by the MMS for data collection on the OCS.

Most seismic data collected by the oil and gas industry are collected by geophysical companies who contract for exclusive surveys with major or independent oil and gas companies or who collect data on a speculative or group shoot basis in areas of potential interest to the industry. Generally in frontier areas regional surveys are initially conducted, followed by prospect-specific surveys where further interest is generated by analysis of the regional surveys. Three-dimensional (3–D) surveys are conducted prelease by oil and gas companies or by geophysical contractors where great detail is desired in prospect-specific areas and postlease to locate optimum sites for exploratory drilling operations.

Other types of geophysical data acquired by industry and the MMS are marine gravity and airborne gravity and magnetics. Approximately 97 percent of the permits issued by the MMS were for geophysical exploration. Geological exploration permits accounted for only 3 percent. Permits for Continental Offshore Stratigraphic Test (COST) wells account for about 9 percent of the geological permits. These statistics illustrate the dominant role that geophysics plays in prelease hydrocarbon exploration.

The MMS also has acquired geological, geophysical, and engineering data, as a condition of granting leases, from exploration and development wells drilled on the U.S. OCS. More than 25,000 wells have been drilled on the OCS. While seismic data and information reveal subsurface detail over broad areas of the OCS, data and information from these wells yield the most accurate and definitive information concerning the subsurface.

The oil and gas industry is exploring frontier areas of the OCS. Drilling has occurred 160 mi from shore in Garden Banks Block 543, Central Gulf of Mexico (GOM). The farthest offshore discovery well is located 145 mi from shore, also in Garden Banks. The lease farthest from shore is in the Navarin basin approximately 450 mi from mainland Alaska. Technology has made possible drilling in greater water depths. Recently, Shell exceeded its record drilling water depth set in the mid-Atlantic by spudding a well in 7,520 ft of water in Mississippi Canyon Block 657, again in the Central GOM. The greatest water depth for a recovery well is 5,759 ft, in the Mississippi Canyon. The lease issued in the deepest water is on Block 955, in Alaminos Canyon, GOM (9,800 ft).

Nonproprietary scientific data collected by the Federal Government are limited to mostly bathymetric, side-scan sonar, and widely spaced geophysical seismic survey lines, which are not the primary types of data used by MMS for resource evaluation and engineering studies of the OCS. Surveys such as GLORIA, while very valuable as a basic earth-science research tool, are not generally needed by the MMS to fulfill its mission responsibilities. The MMS acquires from the oil and gas industry all G&G and engineering data necessary for presale geologic mapping and postsale review and approval of operations and reserve mapping.

In summary, the MMS, under provisions of the OCS Lands Act, has the responsibility to oversee the acquisition of G&G data and information collected by industry on the OCS. In addition it also retains a right to these data and information and under certain conditions to data collected on the OCS for scientific research. Authorizing regulations govern permitting, data collection and release, leasing, and postlease operations on the OCS. These regulations prescribe when a permit or the filing of a notice is required to conduct G&G exploration on the OCS and operating procedures for conducting exploration, as well as requirements for disclosing data and information, conditions for reimbursing permittees for certain costs, and other conditions under which exploration shall be conducted.

Types of Data Available to the MMS from Industry

The MMS obtains geophysical, geological, geochemical, and engineering data from industry as well as information related to archaeological/cultural resources surveys. The most important types of geophysical data needed for MMS purposes are deep and shallow penetration CDP seismic reflection data, shallow penetration analog seismic reflection data, gravity data, and magnetics data. Other geophysical data available to the MMS are 3–D seismic reflection data, seismic refraction data, shear (S) wave seismic refraction and reflection data, vertical seismic profiles, cross-hole primary (P) and shear (S) wave velocity data, and side-scan sonar data.

Geological data include well logs (electrical, radioactivity, sonic, electromagnetic), well cuttings, shallow cores, and bottom samples. Related data include bathymetry, geochemical, heat flow, and paleontological information.

Engineering data from lessees include formation pressures, casing record, producing interval, production rates, geotechnical boring, and the amount and direction of deviation of any well from the vertical.

Uses of Data Acquired by MMS

Data are used to map the subsurface geology and determine structure, stratigraphy, porosity, permeability, water saturation, paleontological content, and other indicators of hydrocarbons.

Sale Activities

The MMS uses the result of in-house data interpretations and analyses to identify areas and blocks having potential for the occurrence of oil, gas, and shallow hazards. These data are also used to develop geological profiles, resource estimates, and regional and prospect-specific subsurface geologic maps.

Regional mapping and analyses identify prospective areas that are used in reviewing and developing lease schedules for oil and gas. These analyses are the basis for a geology report and area of hydrocarbon potential determination used in the early stages of the leasing process and are used later for resource economic and engineering evaluations and analyses activities. On the basis of these data and subsequent mapping, resource estimates are prepared for lease sale proposals and alternatives for use in EIS and economic analyses that provide, in part, the basis for decisions concerning individual sales. Resource estimates are made for broad, general areas as well as small, specific areas during the lease sale planning stage.

After area identification, the emphasis shifts to more detailed mapping and analyses needed to estimate the resource potential of individual prospects within the area offered for lease. These prospect-specific data, maps, and analyses are also used to determine parameters for postsale bid analyses for purposes of assuring receipt of fair market value.

Upon completing the evaluations and analyses for a specific lease sale, the prospect-specific analyses are incorporated into the regional maps and analyses, and the process is repeated for the next sale.

Other Resource Evaluation Products

The G&G data are combined with economic and engineering analyses to develop products that are essential to completing major steps in the leasing process. These products include input to the annual review and development of the 5-Year OCS Oil and Gas Leasing Program and comprehensive information on the availability of undiscovered offshore oil and gas resources essential to the national security of the United States. The data are critical to the joint MMS/USGS National Assessment of undiscovered conventional oil and gas resources of the United States (the MMS is conducting the offshore assessment, State waters). The results of this assessment have been used to update the 1981 USGS Circular 860 and the 1985 MMS OCS Report MMS–85–0012. Results of this study are expected in early 1988, although the publication will not be available until early fall.

The format of the assessment will provide for the reporting "undiscovered resource base" as well as the "economically recoverable" resources for the onshore and offshore areas. Inasmuch as the 1985 MMS report provided significantly lower estimates of undiscovered, economically recoverable oil and gas resources for the offshore areas than the 1981 USGS assessment, it is anticipated that the overall estimates currently being prepared for the offshore areas will not be significantly different than the 1985 MMS results (although some reduction to reflect the revised lower economic scenarios associated with the future oil and gas supply outlook is likely). However, the resource estimates for the Bering Sea planning areas will probably indicate a more significant reduction to reflect the extremely disappointing results of exploratory drilling in those areas since previous MMS estimates were prepared. The development of the "undiscovered resource base" category for estimating offshore resources will allow MMS to recognize the potential existence of oil and gas accumulations in circumstances presently excluded from MMS estimates because of economic and technological caveats associated with the contribution of such potential resources to the future oil and gas supply of the United States.

Procedures Under Section 8(g) of the OCS Lands Act

Section 8(g) of the OCS Lands Act, as amended in 1985, requires that governors of States adjacent to proposed leasing areas be provided with information describing the area at the time of the Call for Information and Nominations. The MMS provides information on the G&G characteristics of the area or region, including a geology report, reserve estimates, and a tract list, to the Governor of the affected State. Certain proprietary G&G data or information will be provided upon request to States that have entered into an official data sharing agreement between the Department of the Interior and the State.

Under section 8(g) of the OCSLA, as amended, the adjacent coastal States are provided with certain proprietary information on leased and unleased lands within 3 nautical mi of the State's seaward boundary, provided that the State has entered into a data-sharing agreement as outlined under section 26 of the OCSLA.

This agreement is in three parts. Part I provides the terms and conditions. Part II establishes the authorization of the State to receive proprietary G&G data or information from leased or unleased lands within 3 nautical mi of the State's seaward boundary. Part III establishes the State's authority to inspect proprietary G&G data or information on leased lands.

To satisfy the requirements of section 8(g) of the OCSLA and respond to litigation concerning disputes between the Federal Government and States, it is frequently necessary for MMS to purchase CDP seismic reflection data in State waters that are acquired under State permits. The acquisition costs of these data are usually much more expensive than permit data from Federal waters, as MMS is required to pay the full commercial price as opposed to either a share of the processing costs or solely the reproduction costs.

Postlease Permitting to Drill

To satisfy requirement for drilling permits, including placement of structures, lessees submit to the MMS high-resolution data and information (high-resolution seismic, side-scan sonar, and magnetometer data and interpretations) and (or) reports. Parallel survey lines are spaced 300 m apart to detect potential bottom or near-bottom hazards to exploratory drilling operations, including placement of drilling rigs, well bores, and pipelines. This survey may also fulfill the requirements for a prehistoric resources survey. Survey lines are spaced 150 m apart when it is determined that there is a possibility of the existence of historic shipwrecks on the lease.

Limitations to Acquiring Data

The MMS has rights to all G&G data and information collected on the OCS under prelease G&G permits and operations conducted pursuant to a lease, but funding limitations and data redundancy limit the amount of data that are actually acquired. Under current regulations the MMS must reimburse permittees and lessees for reproducing all scientific and engineering data and information requested by the MMS. In addition, the MMS must reimburse permittees for a portion of geophysical digital data processing costs for prelease permits issued before FY 1986. Data can only be acquired from permittees by MMS within certain time limits after data are collected by industry. Data on non-Federal lands are usually very expensive to acquire and are acquired only when necessary to tie data on the OCS to data in State waters or on land.

Managing Data Sets

The MMS has a large inventory of data to preserve and archive. Data are kept in original condition, protected from unauthorized disclosure, and inventoried for authorized access and eventual public release.

Most well logs are released directly on expiration of the appropriate proprietary term. Most of the remainder of the data are released through the National Geophysical Data Center of the National Oceanic and Atmospheric Administration when the proprietary term expires.

Current regulations issued by the MMS provide a 10-year period of time during which G&G data and information acquired by the MMS under a permit are not available to the public without the consent of the permittee. Proposed rules to change the proprietary term were issued by the MMS in the *Federal Register* in 1983 and again in 1986. In response to comments concerning the proposed changes, the MMS issued a temporary rule that suspended the release of prelease proprietary geophysical data and information for a period of 1 year, effective upon publication in the *Federal Register* on June 22, 1987.

Subsequently, on September 29, 1987, in the *Federal Register* the MMS proposed a rule that would extend the time frame for protection of proprietary G&G data and information collected on the OCS under prelease permits. This revision would provide additional assurance that the party that incurred the cost to produce the data and information would have a reasonable opportunity for exclusive use during a subsequent lease sale in the general area.

In developing this proposed rule change, MMS is considering both the needs of the public and the States for these data and information and the need to provide certain minimum protection for the party incurring the cost of obtaining the data.

COOPERATIVE STUDIES

In an effort to broaden the base of data and information on the offshore, the MMS entered into a cooperative agreement with the Bureau of Economic Geology (BEG), University of Texas at Austin, in September 1983. The Texas BEG acts as a central contact between the MMS and the Geological Surveys of coastal States and monitors multidisciplinary, scientific activities conducted by the State surveys for the MMS. The two general areas that the cooperative effort addresses are (1) strategic/critical minerals and (2) geologic studies relating to hydrocarbon resources.

Projects from participating coastal States include identification of existing and potential production trends for the Texas OCS, geologic framework studies of offshore California, Washington, Alabama, Delaware, and Virginia and a Hope basin stratigraphic report. Recently, the MMS renewed the cooperative agreement with the Texas BEG for $540,000 to continue a special studies program with 22 coastal States, Hawaii, and Puerto Rico. These studies have helped the MMS in analyzing the geologic framework of the offshore areas of the OCS and in identifying hydrocarbon and mineral resource potential of specific areas of State and adjacent Federal waters.

FUTURE DATA REQUIREMENTS FOR THE NEXT 10 YEARS

Expectations concerning the price of oil generally drive seismic and other prelease offshore activities. Since offshore seismic surveys are expensive to conduct, industry tends to look for new oil prospects when oil prices rise and tends to concentrate on the other phases of oil exploration and development when prices fall. Figure 2 indicates a positive correlation between the price of oil and worldwide marine seismic activity between 1970 and 1986.

The number of permits issued by the MMS and the areas for which the permits are issued are leading indicators of oil and gas activities and their locations on the OCS. Figure 3 shows the number of permits issued each calendar year since 1969 for prelease geophysical and (or) geological exploration and the total number of permits issued since 1960.

The MMS anticipates an increase in industry exploration activity over the next 10 years. Data collected will shift to a more dense coverage of certain areas currently surveyed and to those frontier areas where there is little or no coverage. More accurate navigation for locating seismic, bathymetric, sampling, and site surveys will be available from the Global Positioning System, a constellation of satellites with 24-hour coverage on the OCS.

Seismic data and the drilling of wells are the main sources to the MMS of geological, geophysical, and engineering data and information. The amount and extent of data and information that will be available to the MMS from permittees and lessees should meet most of the data requirements of the MMS during the next decade.

Further details concerning G&G data acquisition and permitting activities, including the permitting process, kinds and amounts of G&G data and information that the MMS has acquired, MMS data coverage of the OCS, and uses by the MMS of the data and information may be found in MMS OCS Report 87–003, entitled "Geological and Geophysical Data Acquisition—Outer Continental Shelf Through Fiscal Year 1985."

The MMS also has responsibilities related to nonenergy marine minerals. In 1983 MMS established the Office of Strategic and International Minerals to develop policy guidelines and implement a leasing program for exploration, development, and production of minerals other than oil, gas, and sulfur from the OCS. Panel 8 of this symposium addressed information availability for hard mineral leasing and development of the EEZ.

The G&G data and information and related analyses and reports play a large part in analyzing marine mineral prospects on the OCS. Prelease grab samples and coring, high-resolution seismic data, and well cuttings can be used with other information to locate site-specific prospects.

Deep-penetration seismic data and related geologic framework studies can be used to locate geological structures and stratigraphic features favorable for marine mineral occurrence. For example, thick sequences of sediments and various combinations of glacial, subaerial, and marine processes can be identified to locate potential sand and gravel resources. Regional geological studies furnish data regarding potential sources, stream transport paths, mineralized zones, geochemical anomalies, and deposits of placers that are a source of heavy minerals such as gold, tin, platinum, titanium, and chrome.

Regulations specifically governing prospecting for minerals other than oil, gas, and sulfur are being formu-

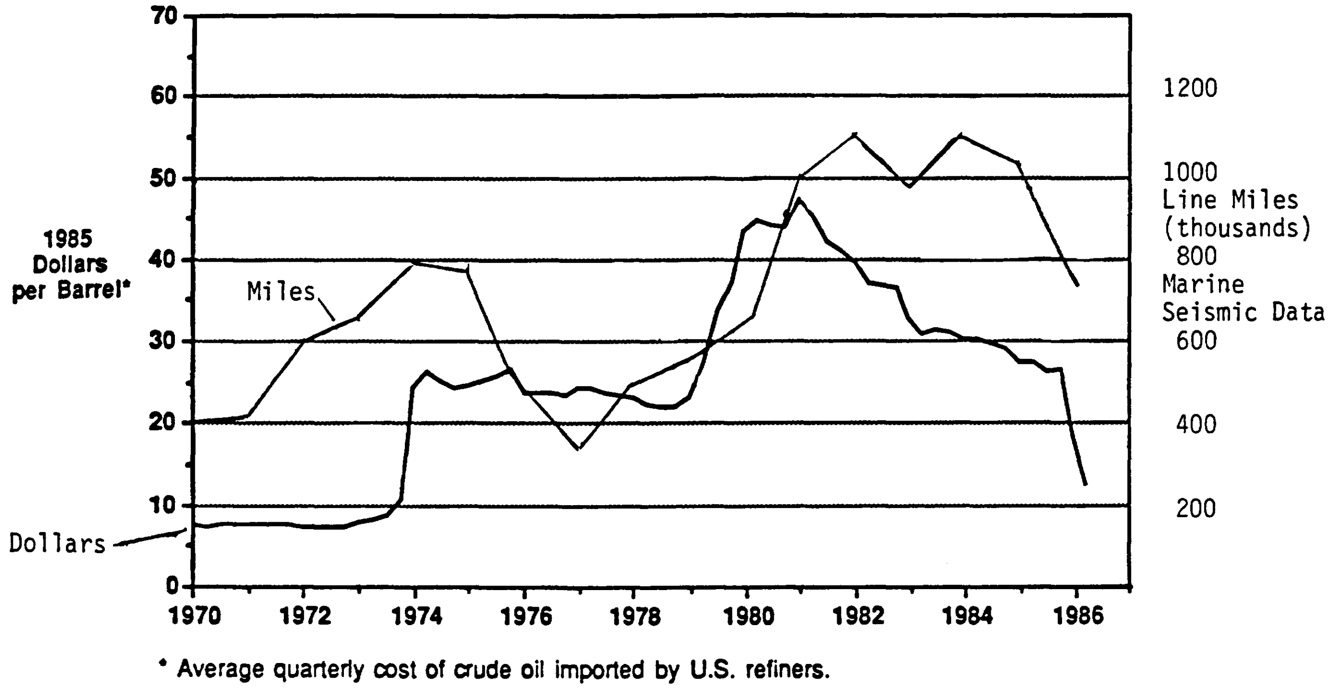

Figure 2. Price of oil vs. worldwide marine seismic activity. (Sources: U.S. Energy Information Administration (dollars per barrel); Society of Exploration Geophysicists (marine seismic line miles).)

lated; in the meantime, G&G permits have been issued for mineral exploration, for example, offshore Florida, Georgia, and Alaska.

Much of the environmental study performed for oil and gas exploration, development, and leasing can be applied to marine mineral exploration on the OCS. Since the program began in FY 1973, close to a half billion dollars have been spent for environmental studies through FY 1987.

In summary, the current system allows the oil and gas industry to collect data in areas where it sees hydrocarbon potential, and the MMS in turn sets its leasing schedule in response to industry interest consistent with other statutory requirements.

DISCUSSIONS

Discussions at the Workshop 7 session were concentrated on USGS GLORIA surveys and MMS postlease shallow hazards requirements, and the data gap between tract-specific hazards data and the broad, regional GLORIA data. Results of GLORIA surveys to date were depicted as most beneficial in areas where there is little known about the seabottom and the broad, regional view of vast areas of the EEZ. In the long term, analyses of the GLORIA surveys along with other information may lead to an understanding of how geological structures evolve. In the short term, GLORIA-type surveys yield a seabottom "photograph" that can reveal surface manifestations of structures and tectonics in the subbottom. However, according to one oil company representative, false indications of potential geologic hazards, especially upslope of potential lease blocks, could lead to inappropriate decisions whether to offer some areas for lease or to issue leases to successful bidders.

The other area of discussion concerned the large gap of knowledge in frontier areas between the results of large-scale reconnaissance surveys, such as GLORIA, and small-scale, tract-specific surveys, such as the high-resolution type surveys that lessees are required to supply to the MMS as part of the process for obtaining a drilling permit. Lessees are required to furnish appropriate G&G data and information on their leases and, if there is evidence of a potential hazard on an adjacent lease, that portion of the adjacent lease which may affect the lessee's block. Lessees do create geological models of areas beyond their leased blocks, but information is scarce in frontier areas. The discussion resulted in an open-ended question as to who, if anyone, was responsible for filling in the knowledge gap of potential geohazards on unsurveyed, unleased blocks that could affect leased blocks in the same area. The MMS formerly contracted for shallow hazards surveys on unleased blocks that were considered for leasing but changed this policy in 1982, when the responsibility for site-specific hazards data collection was shifted to the lessee.

To perform its mission the MMS obtains most of the geological, geophysical, and engineering data and informa-

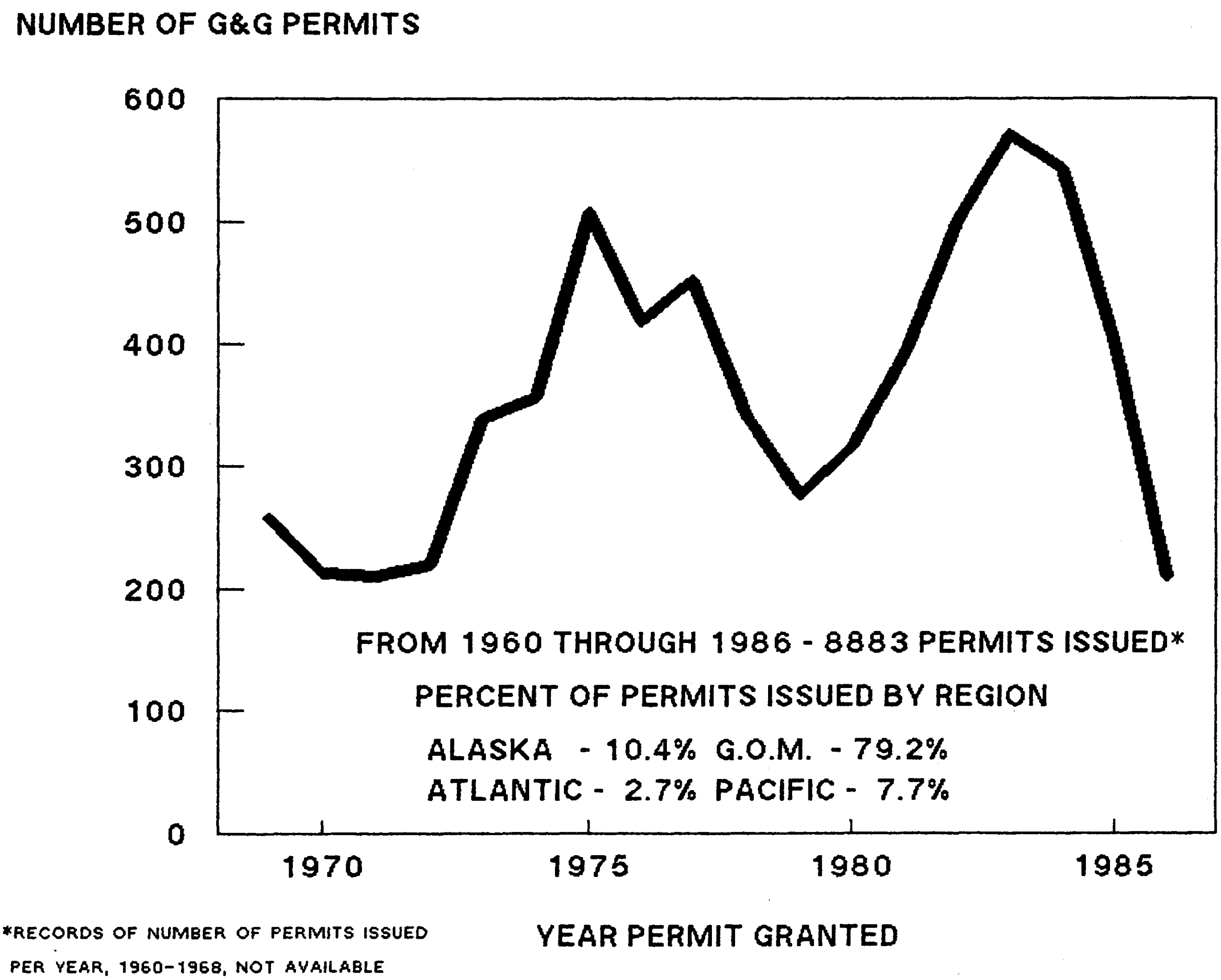

Figure 3. Number of permits issued for geological and geophysical (G&G) exploration of the OCS. GOM, Gulf of Mexico.

tion it needs from the private sector, which is reimbursed in part for the data and information submitted. Where additional data and information are needed to supplement the MMS data base, the MMS has the option of awarding specialized contracts, if needed. Because of the extensive MMS data base and industry's ability to collect data in new areas as interest evolves, MMS has available to it the data and information to carry out its leasing and regulatory program over the next 10 years.

At the same time, it is recognized that the Government-acquired bathymetry and GLORIA survey data can enhance MMS's understanding of the OCS, particularly in frontier areas and (or) on the continental slope. Furthermore, the Global Positioning System, when fully capable of providing 24-hour coverage on the OCS, will increase the positioning accuracy of seismic survey lines and other surveys and thus better locate potential areas of hydrocarbon and marine mineral prospects.

WORKSHOP PARTICIPANTS

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Workshop 8: Information Availability and Utilization for Hard Minerals Leasing, Exploration, and Development of the EEZ

Panel Co-chairpersons:
Reid T. Stone and John B. Smith, Minerals Management Service
D.S. Cottell, ARC Marine Limited

INTRODUCTION

The primary objective of the Workshop on Information Availability and Utilization for Hard Minerals Leasing, Exploration, and Development of the EEZ was to provide a forum for user groups to discuss information needs for mineral leasing, exploration, and development decisions and to relate these needs to the development of a 10-year program for the EEZ. The agenda for the workshop included presentations by a panel of 10 speakers representing various Federal, State, industry, academic, and private groups followed by a roundtable discussion that provided opportunities for members of the audience to question members of the panel and offer comments and advice. The workshop was chaired by Reid T. Stone of the Minerals Management Service and D.S. Cottell, Managing Director of ARC Marine Limited. Other speakers were Harry J. Olson from the University of Hawaii, Alan C. Bauder of the New York State Office of General Services, Randal M. Waterman of McCormack Sand Company, Inc., George L. Marshall of Marshall Engineering Geologists, Joseph R. Wilson from the U.S. Army Corps of Engineers, Donald G. Rogich of the U.S. Bureau of Mines, Robert F. Dill of Dill Geomarine Consultants, and William P. Pendley from the law firm of Comiskey and Hunt. This paper reviews the presentations made by each of the panel members and summarizes the recommendations of the panel for development of a 10-year program for the EEZ.

WORKSHOP PRESENTATIONS

Reid T. Stone, Minerals Management Service

The workshop began with remarks by Mr. Stone, who introduced panel members, described the purpose of the workshop, and reviewed the status of the leasing and regulatory program for marine minerals being developed by the Minerals Management Service (MMS). Mr. Stone emphasized that the primary objective of the workshop was to survey the needs of user groups concerned with various aspects of marine minerals leasing, exploration, and development activities. For the purposes of the workshop, user groups were defined as private sector firms directly involved in exploration and development of marine minerals, State and Federal agencies having administrative and regulatory authority over marine mining, and academic institutions and other private sector groups having a direct involvement or interest in the development of a domestic marine mining industry. Mr. Stone stated the workshop would focus on information needs for sand and gravel and other nearshore, shallow-water minerals because these resources had the greatest potential for development in the near term.

Mr. Stone also briefly described the leasing and regulatory program being developed by the MMS under the authority provided by the Outer Continental Shelf Lands Act. He stated that the program is being developed on a case-by-case basis and that the MMS was working closely with the coastal States in developing the program. This is being accomplished through joint Federal/State task forces that have been established to investigate leasing opportunities and conduct reconnaissance mineral resource investigations to study the commercial viability of marine mining. A total of five task forces involving the participation of nine of the coastal States had been formed during the 3-year period from 1984 to 1987. The task forces were established with Hawaii to examine possible leasing of cobalt-rich manganese crust resources, Oregon and California to examine the leasing potential of polymetallic sulfides, North Carolina to study offshore phosphorites, Georgia to examine heavy minerals, and the gulf coast States of Alabama, Louisiana, Mississippi, and Texas to study the commercial potential of shell, heavy mineral, and sand and gravel resources. Mr. Stone also reported that the MMS was proceeding with the development of a regulatory framework for marine mining.

In his final comments Mr. Stone stated that commercial interest in marine mining was increasing, particularly for nearshore sand and gravel and gold placer resources. He noted that marine mining of these resources was ongoing within the territorial sea offshore New York and Alaska and that task forces may be established in the near future to study the leasing potential of submerged Federal lands offshore those States.

D.S. Cottell, ARC Marine Limited

Mr. Cottell discussed the United Kingdom's (U.K.'s) marine mining experience and the information requirements associated with mining offshore sand and gravel deposits. In his presentation Mr. Cottell discussed the importance of the U.K.'s offshore sand and gravel mining industry, technological innovations in marine mining, and the legal and administrative framework governing marine mining of sand and gravel in the U.K. He indicated that ARC Marine Limited was currently operating 13 ships and producing 8 million tonnes of sand and gravel annually from the North Sea.

Mr. Cottell stated that the mining of marine sand and gravel is a major industry in the U.K. that currently supplies 15 percent of the U.K's sand and gravel requirements. The marine mining fleet consists of 54 vessels ranging in size from 500 to 8,000 tonnes, some of the more modern of which can achieve production rates of 2,000 tonnes per hour. One of the key technological advances has been the development of submerged pumps that have extended dredging operations to 50-m water depths.

All marine minerals, with the exception of oil and gas, are owned by the Crown and administered by the Crown Estate Commissioners (CEC). The CEC administers offshore mining of sand and gravel in the U.K. by licensing exploration and development of the resources.

The licensing system is a two-step process. One applies to the CEC for an exploration license over a defined area of the seabed. At this stage, no formal consultations are initiated with any other interested government department, although the Department of Environment, through its minerals division, is informed in confidence of the intention to issue the prospecting license.

The exploration licenses are usually granted for a minimum period of 1 or 2 years and can be renewed. The conditions attaching to such licenses are not onerous, but bulk sampling is sometimes limited to 1,000 to 2,000 tonnes from the entire area.

The company acquiring an exploration license typically conducts an in-house study of the area before initiating field surveys of the area that include bathymetric mapping, seismic profiling, and bottom sampling by means of gravity coring, vibracoring, and high-pressure jetting. A typical survey covering a 100-km^2 area of the seabed and involving around 400 boreholes at 0.5-km intervals was estimated to cost about $270,000.

If commercially viable resources are discovered as a result of these surveys, the company can file an application with the CEC for a production license. At this state the CEC begins consultations with a host of government departments, local authorities, and environmental groups to review the application. If this review process is favorable, a production license can be granted.

Mr. Cottell stated the most common concerns associated with dredging sand and gravel were with coastal erosion and fisheries impacts. To address these concerns, a Voluntary Code of Practice establishing clear guidelines has been developed to ensure that dredging operations were conducted in a manner that resulted in minimum interference and damage to other resources. In addition, the CEC commissions the Hydraulic Research Station to conduct in-depth coastal erosion studies prior to the issuance of production licenses.

Mr. Cottell summarized his presentation by describing the key data sets necessary for marine mining. He grouped these data sets into two general categories: (1) mapping and mineral resource assessment studies and (2) environmental baseline data. These categories were further subdivided into bathymetric and geological mapping and surveys of the chemical, biological, environmental, and oceanographic conditions. Mr. Cottell emphasized that these studies should be conducted in a way to define the economic potential of the mineral resources. He recommended that areas having commercial potential be determined and that mapping and environmental baseline studies be concentrated in these areas as a matter of first priority. The limited availability of oceanographic vessels and the high costs of operating the vessels were factors cited by Mr. Cottell that necessitated the establishment of priorities. To facilitate data collection and improve its utility, he recommended that maps be produced on standard scales and that standard formats for reporting data be developed.

In his concluding remarks, Mr. Cottell expressed concern that ongoing EEZ mapping programs were neglecting the nearshore environment where the commercial potential of the mineral resources is the greatest. He emphasized that the consequences of not mapping and collecting data on nearshore mineral resources would be a further delay in development of the EEZ's mineral resource potential.

Harry J. Olson, University of Hawaii

Mr. Olson discussed the specific geologic and environmental data needed for leasing, exploration, and development, and the respective roles of government, industry, and academia in collecting the required data. He stated that his comments were based on his many years of experience with the mining industry in hard rock and geothermal exploration.

Mr. Olson began his presentation by emphasizing the need for maps at various scales showing information on bathymetry, features, rock types, and the minerals of potential economic value associated with these rocks. He also stressed the need for geophysical surveys as well as the need to periodically publish and update geologic, geochemical, and geophysical data in a standard map series. He stated that 1:100,000- and 1:250,000-scale maps were the most useful for leasing and industry exploration.

Mr. Olson also recommended that libraries be established to maintain samples collected by researchers and other groups. Other information needed for leasing and exploration includes parameters of the ocean environment such as temperature, currents, upwelling zones, and circulation patterns.

With regard to the development of mining technology, Mr. Olson emphasized the need for pilot demonstration projects to test mining techniques for certain types of mineral occurrences. The pilot projects would serve to identify cost parameters, potential problems that would be encountered in actual mining of the deposits, and possible technological solutions to these problems. Other topics requiring study are processing technology, the handling of waste materials, and transportation logistics. Mr. Olson stated that industry alone cannot support these studies and that the role of government and academia should be to provide assistance in conducting basic research in these areas.

Mr. Olson stressed that the regulatory framework for marine mining should provide assurances that firms conducting exploration activities will have the right to develop a deposit if a discovery is made. In addition, he emphasized the need to adopt measures to minimize up-front costs. He further stated that the regulations should be general and flexible because geologic factors, mining techniques, and environmental conditions will vary widely from one geographic location and mine site to another. He also called for the adoption of measures that provide for reasonable environmental protection requirements, limit the potential for litigation, and are responsive to economic cycles and rapidly changing market conditions for minerals. Mr. Olson stated that the Federal Government can assist industry by conducting environmental baseline studies that provide background information on the types of environmental problems likely to be faced by industry. Mr. Olson concluded his presentation by emphasizing that marine mining is possible and that industry has the capability to develop technology not yet available. He stated the burden is now on MMS to demonstrate that it can implement a regulatory framework that addresses industry needs and encourages exploration and development of marine minerals.

Alan C. Bauder, New York State Office of General Services

The major topics discussed by Mr. Bauder were the need for sand and gravel in the New York metropolitan area, the history of sand mining in New York Harbor, and the types of information and studies required to evaluate the potential environmental impacts resulting from offshore sand mining operations.

Mr. Bauder began his presentation by informing workshop participants that the New York State Office of General Services was preparing a draft environmental impact statement for sand mining in New York Harbor. He also stated that the Office of General Servces had assumed the responsibility for obtaining all necessary State and Federal permits and preparing an Environmental Impact Statement in order to prevent duplication of efforts by industry.

Mr. Bauder reported that sand and gravel for building and highway construction projects is in short supply because 7 out of 10 mines in the New York metropolitan area have closed in response to environmental and social concerns. He indicated that New York was being pressured to find a solution to the problem and that the mining of offshore sand deposits was an option receiving serious consideration.

According to Mr. Bauder, approximately 89 billion cubic yards of material were removed from New York Harbor during the 1960's and 1970's for several large construction projects in New Jersey, one of which was the New Jersey Turnpike. Mining ceased in the 1970's, however, in response to changing economic conditions and environmental concerns. The major environmental concerns were related to potential coastal erosion problems and fisheries impacts. These problems led to the prohibition of dredging operations on the west bank of the harbor.

Mr. Bauder states that large-scale mining of sand from New York Harbor will not take place until environmental concerns are satisfactorily addressed. Some of the key areas of concern are impacts on fisheries and benthic organisms, shipping channel impacts, coastal erosion, mining techniques, turbidity standards, aesthetic impacts, multiple use considerations, and monitoring procedures.

Randal M. Waterman, McCormack Sand Company, Inc.

Mr. Waterman briefly described the dredging operations of McCormack Aggregates in New York Harbor, which are annually producing approximately 1.5 million cubic yards of concrete sand. He also reviewed the basis for his company's decision to initiate mining operations in New York Harbor and the need for an efficient and reasonable government regulatory process.

Mr. Waterman stated that his company has been in the business of mining sand and gravel since the early 1930's and that it operates several mining operations in the New York metropolitan area, including one dredging operation located about 20 miles inland. About 4 years ago the company sensed that the development of new mines within reasonable transportation distances to the New York market was being seriously hampered by economic and social factors such as rising land values and strong opposition to mining near residential areas. In response, they began to investigate offshore resources by examining data that had been collected by the U.S. Army Corps of Engineers and other sources. The results of their investigation revealed tremendous inconsistencies in the data base, so they then raised serious questions about locating material suitable for mining in New York Harbor. To confirm the location of mineable deposits, McCormack Aggregates conducted an extensive sampling program to verify the results obtained by other investigators. Mr. Waterman reported that the samples collected proved to be far superior to those obtained from onshore deposits. On the basis of these results, McCormack Aggregates sought and received the necessary permits to mine sand from the Ambrose Channel of New York Harbor.

Mr. Waterman stated that McCormack Aggregates' dredging operations are located in the shipping channel of New York Harbor on lands owned by New York and New Jersey and that dredging permits were obtained from both of these States as well as the U.S. Army Corps of Engineers. He also indicated that the permitting process was complex and time consuming and appealed for the development of a one-stop process where one lead agency has responsibility for coordinating the permitting process. Mr. McCormack commended the New York State Office of General Services for taking the initiative to develop a marine mining program and was hopeful that the MMS could play a similar role on the Outer Continental Shelf.

In his concluding remarks, Mr. Waterman stated that McCormack Aggregates was extremely fortunate in having an offshore source of high quality sand within a few miles of one of the densest metropolitan areas of the world. He also indicated the company had the unique advantage of being able to assist the U.S. Army Corps of Engineers in channel maintenance while providing much-needed concrete sand to the New York metropolitan market. Mr. Waterman was hopeful that McCormack Aggregates' pioneering efforts in New York Harbor would improve the public perception of offshore mining and pave the way for other offshore mining operations.

George L. Marshall, Marshall Engineering Geologists

Mr. Marshall discussed the information needed for industry capital investment decisions and the general character of the sand and gravel mining industry. One of the key points made by Mr. Marshall was that sand and gravel deposits suitable for meeting construction industry specifications were limited in supply, particularly in the New York metropolitan area. He also stated that sand and gravel were high-volume, low-value commodities and emphasized the importance of developing sources of supply in proximity to the market to reduce haulage distances and transportation costs.

With respect to capital investment decisions, Mr. Marshall stressed that a favorable market outlook must exist before industry can justify investing scarce capital resources in exploration programs and the development of new mining and processing facilities. He stated that the role of government is to conduct basic research and provide an investment climate that encourages industry exploration and development. Mr. McCormack concluded his talk by stressing the need for additional mapping, geophysical surveys, and sampling programs of marine aggregates to further define their commercial potential.

Joseph R. Wilson, U.S. Army Corps of Engineers

Mr. Wilson presented an overview of the laws and regulations that apply to U.S. Army Corps of Engineers dredging and disposal operations and described how those laws and regulations may apply to EEZ activities. He stated that there were nine major environmental laws that may apply to certain EEZ activities. These laws included the National Environmental Policy Act of 1969, the River and Harbor Act of 1899, the Coastal Zone Management Act of 1972, the Fish and Wildlife Coordination Act of 1958, the Clean Water Act of 1977, the Endangered Species Act of 1973, the Antiquities Act of 1906, Marine Protection, Research, and Sanctuaries Act of 1972, and the Coastal Barriers Resources Act of 1982.

Mr. Wilson concluded his presentation by stressing the importance of providing documentation to demonstrate compliance with environmental laws and providing opportunities for public input into the decision-making process. He stated that the MMS must demonstrate that marine mining in the EEZ can be conducted in an environmentally acceptable manner.

Donald G. Rogich, U.S. Bureau of Mines

Mr. Rogich discussed the results of economic reconnaissance studies conducted by the Bureau of Mines and the need to acquire additional resource data in marine minerals. He stated that the Bureau had performed an economic/engineering study of sand and gravel and heavy minerals in the EEZ that resulted in the publication of two technical reports. The sand and gravel report concluded that three of the seven offshore sites it investigated near metropolitan areas had potential for development and that two sites (Boston and New York City) were strong candidates for near-term development. The heavy minerals report established resource criteria (tonnage, grade) that would be required to support commercial development of placer gold deposits located offshore Nome, Alaska, and heavy mineral deposits offshore Oregon and Virginia.

Mr. Rogich stated that fragmentary resource data and lack of operating experience were major problems the Bureau encountered in conducting its economic reconnaissance studies. He indicated that the Federal Government could play an important role in filling these data gaps by conducting regional mapping and mineral resource assessment programs and funding basic research to support the development of marine mining and processing technology. He believed this type of support would be required to stimulate industry interest in further exploration. In his closing remarks, Mr. Rogich cautioned that there could be a conflict between the need for additional government-sponsored studies and the desire to avoid providing subsidies to industry.

Robert F. Dill, Dill Geomarine Consultants

Mr. Dill appealed to Federal Government officials attending the EEZ symposium to support the basic research required to foster and encourage the development of a marine mining industry. He emphasized that development of EEZ mineral resources would languish if the Federal Government failed to promote basic research and develop a regulatory framework for marine mining that encourages private sector investment in this high-risk industry.

Mr. Dill was also in agreement with other members of the panel who expressed concerns that EEZ mapping programs were neglecting the nearshore environment, where the commercial potential for marine mining was the greatest. He also questioned the priority given the GLORIA EEZ mapping program by the U.S. Geological Survey (USGS) and the utility of the maps being produced. It was his opinion that the priority placed on the GLORIA mapping program was diverting scarce financial resources that could be more productively used to support critically needed field studies, including site-specific mineral resource investigations and geologic framework studies of high-potential areas. Mr. Dill recommended that the USGS reevaluate its mapping priorities and develop an effective process for soliciting private-sector advice regarding the establishment of mapping and basic research priorities.

In his concluding remarks, Mr. Dill encouraged the private sector to support the National Oceanic and Atmospheric Administration's Sea Grant Program and the joint Federal/State task force concept the Department of the Interior has established for the purposes of working closely with the coastal States to study the development potential for marine minerals. He emphasized that it was extremely important that programs such as these receive the support required to encourage young scientists to enter the marine science field.

William P. Pendley, Comiskey and Hunt

In his presentation, Mr. Pendley discussed the prospects for congressional enactment of new marine mining legislation and the need for the Department of the Interior to demonstrate that it is committed to moving forward with the development of a regulatory framework for marine mining under the Outer Continental Shelf Lands Act.

Mr. Pendley stated that the prospects for new legislation were not bright because the issues involved (that is, revenue sharing, State rights) were extremely controversial and not likely to be resolved in the near future. To support his position, he noted that the Deep Seabed Hard Minerals Resources Act had taken 8 years to be enacted, the Surface Mining Control and Reclamation Act 7 years, and that amendments to the Geothermal Steam Act of 1970, first proposed in 1977, had not yet been enacted.

In addition, he emphasized that the outcome of the legislative process can never be assured. He stated that this was the primary reason for the U.S. mining industry's reluctance to advocate fine-tuning of the location and patenting provisions of the 1872 Mining Law.

In his closing remarks, Mr. Pendley strongly encouraged the Department of the Interior to move forward with its initiative to develop a regulatory framework for marine mining. He indicated that the continued delay in issuing the regulations was being interpreted by the private sector as a lack of commitment by the Federal Government to encourage marine mining.

SUMMARY

The primary objective of Workshop 8, Information Availability and Utilization for Hard Minerals Leasing, Exploration, and Development of the EEZ was to provide a forum for user groups to discuss information needs for mineral leasing, exploration, and development decisions and to relate these needs to the development of a 10-year program for the EEZ. It was the general opinion of workshop participants that the Federal Government could best address the needs of user groups by supporting mapping and mineral resource assessment studies, the collection of environmental baseline data, the development of mining and processing technology, and developing a regulatory framework for marine mining that would encourage the private sector to invest in EEZ exploration and development activities. The key findings and recommendations of workshop participants are summarized below.

Mapping and Mineral Resource Assessment

1. The Federal Government should support geological mapping and mineral resource assessment studies as well as bathymetric surveys.

2. EEZ mapping and mineral resource assessment programs should be focused on areas where development is likely to occur to reduce costs and address user needs. Less emphasis should be placed on large, broad scale mapping and mineral resource assessment programs.
3. EEZ mapping programs are presently neglecting the nearshore environment where user needs and the commercial potential for resource development are the greatest.
4. The private sector has had little or no role in the establishment of EEZ mapping and basic research priorities. A formal process should be established to provide user groups with an effective role in the establishment of program priorities.
5. Maps are needed at various scales showing information on bathymetry, geologic features, rock types, and minerals of potential economic value. Map scales of 1:100,000 and 1:250,000 are the most useful for leasing and industry exploration decisions.
6. Geologic, geochemical, and geophysical data should be periodically published and updated and sample libraries established.
7. Sampling programs and mineral resource assessment studies are needed to verify geological interpretations and investigate the engineering and economic parameters associated with developing marine mineral deposits.
8. The private sector should support the National Oceanic and Atmospheric Administration's Sea Grant Program and the joint Federal/State task forces the Department of the Interior has established to study marine minerals.

Environmental Baseline Studies

1. The Federal Government should support the collection of environmental baseline data that provide background information on the types of environmental problems likely to be faced by industry.
2. Environmental baseline studies should be prioritized to focus on areas of high commercial potential to reduce costs and address the needs of user groups.
3. Environmental studies must be conducted to ensure compliance with environmental laws and to demonstrate that marine mining can be conducted in an environmentally acceptable manner.
4. Key areas of environmental concern are impacts on fisheries and benthic organisms, coastal erosion, turbidity standards, aesthetic impacts, multiple-use considerations, and monitoring procedures.

Technology Requirements

1. The Federal Government should support the development of exploration, mining, and processing technology.
2. Pilot demonstration projects are needed to test mining techniques for certain types of mineral occurrences and waste-handling techniques.
3. Mining technology has been developed and is being widely used in the United Kingdom and Japan, that is capable of dredging sand and gravel and other unconsolidated deposits from 16 m water depths. Technology also exists for mining manganese nodules from the deep sea bed.
4. Little exists for mining consolidated mineral deposits in water depths greater than 75 to 100 m.

Regulatory Framework

1. The Federal Government must develop a regulatory framework for marine mining that encourages private sector investment in the development of this high-risk industry.
2. The regulatory framework should be flexible because geologic factors, mining techniques, and environmental conditions will vary widely from one deposit to another.
3. The regulatory framework must minimize up-front costs to encourage private sector investment in this high-risk industry. It must also provide the firm making a discovery with a priority right to develop the deposit.
4. The regulatory framework should provide for reasonable environmental protection requirements, limit the potential for litigation, and be responsive to economic cycles and rapidly changing market conditions.
5. The prospects for new marine mining legislation being enacted in the near future appear remote because the issues involved are very controversial and not likely to be easily resolved. Moreover, the outcome of the legislative process cannot be assured.
6. The MMS's delay in issuing marine mining regulations has increased doubts by industry that the Federal Government is committed to moving forward with the development of a regulatory framework.

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Workshop 9: Information Needs for Seafloor-Seabed Utilization

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INTRODUCTION

This document summarizes the principal information needs for future use of the seafloor within the Exclusive Economic Zone (EEZ) of the United States. Eleven topical areas are examined, each from the point of view of (1) existing uses of the seabed and future technology needs; (2) information needs for future use; (3) constraints that might limit the acquisition of information; (4) consequences of not obtaining information; and (5) a strategy for acquiring and managing information. A selected bibliography is listed at the end of this document.

Acquisition and use of data are critical to any decisions related to use of the EEZ. Although this workshop identifies a number of potential utilization activities that may occur in the EEZ, they are not likely to occur without timely development and availability of required information. When a 10-year plan is written, information development becomes a key part of it. It does little good to map the total EEZ if key decisionmaking information is missing. Both industry and policymakers need it to carry out their tasks or responsibilities related to EEZ management.

Much of the information compiled and summarized in this document is derived from papers presented and notes taken at a workshop sponsored by the National Research Council, Marine Board Committee on "Seabed Utilization in the EEZ," convened in Keystone, Colorado, August 1987. This document does not represent the Marine Board's position on this topic.

Eight other workshops at this symposium reported on information and research needs and provided substantial overlap and some differences of opinion. There are five workshops concerned with regional needs, one on oil and gas, and one on hard minerals. To provide comprehensive coverage, this document summarizes some information needs on oil and gas and hard mineral exploration/exploitation activities. However, these two topics are covered in detail elsewhere in these EEZ proceedings.

The eleven topical areas reviewed and summarized from the perspective of information needs are:

1. Oil and Gas Exploration and Exploitation
2. Hard Mineral Exploration and Exploitation
3. Waste Disposal (Industrial, Sewage, Nuclear, and Dredged Materials)
4. Offshore Facilities (Pipelines and Cables)
5. Living Marine Resources Exploitation
6. Living Marine Resources and Habitat Protection
7. Military and Security Uses
8. Ocean Energy Conversion
9. Marine Recreation
10. Underwater Archaeology and Cultural Resources
11. Scientific Research

A large body of information is needed to promote efficient use and management of the seabed of the EEZ. In order to set priorities and acquire new data sets, information, and knowledge, we must know better how current information and data are being used, their adequacy (content, format, quality), and deficiencies. Although many of the present data and information are stored and analyzed by advanced computer techniques, we need better identification of, access to, and dissemination of information. Toward this end, USGS, NOAA, and other organizations are developing geographic information systems that are capable of organizing large digital data sets and producing thematic maps and other data displays on characteristics of the EEZ and the seafloor.

Many of the data and information needs identified during the workshop cut across individual uses of the seafloor and seabed. For example,

1. Improved oceanographic and meteorological data for real-time forecasts to improve operations and public safety.
2. Improved data on sediment characteristics, including shear strength and stress-strain parameters, compressibility, and effects of slope deformation and failure.
3. Improved information and knowledge of seafloor geologic processes, including landsliding, turbidity currents, faulting, erosion and scour, vulcanism, and sediment transport and deposition rates.
4. Improved physical, chemical, geological, biological, and economic data and information to improve models for risk analyses.

5. Improved information and knowledge of the long-term and cumulative effects on environmental quality and habitat loss of individual and multiple uses of the seafloor, including the need for improved environmental quality monitoring of seafloor uses and their effects.
6. Improved information on the conflicts among uses of the seafloor.

Many of the data described in this report would be incorporated in documents such as design guidelines for safety and protection of property, environmental impact statements, operational plans, and especially for the present objective of this EEZ symposium—to develop a 10-year plan. In many areas there is a need for advances in technology for more effective and accurate information gathering, resource assessment, exploitation, and conservation to reduce delays in economic growth and to improve international competitiveness. To improve productivity, there is a need for closer cooperation between government, industry, and academia in high-potential, high-risk research and exploratory development activities. Public-private partnerships are one way to promote research and development in these areas.

This document identifies many uses of the seafloor and some of their benefits. However, related to these many uses is the obvious concern of dealing with some of the multiple-use conflicts that are inevitable. Each of the uses has varying degrees of effects on the others, which are briefly identified in each section of this report. Figure 1 (developed during the workshop) illustrates the scale of multiple-use conflicts and rates subjectively the degree of conflict in three categories: (1) no conflict, (2) minor conflict, and (3) major conflict.

The scale of multiple-use conflicts and the related issues of inefficiency, delays in productive use, or the losses due to nonuse, are major concerns affecting fulfillment of future needs, economic growth, and international competitiveness. Multiple-use conflicts within the EEZ and coastal ocean are inevitable, and in some cases desirable, to obtain the most economic and social benefit without harming the environment or impairing national security. To help resolve these conflicts, a comprehensive, geographically organized information base on geological, physical, biological, chemical, and other characteristics of the EEZ, as well as information on the location and extent of human activities in the EEZ, is desirable. With this general base of information and understanding of specific conflicts, it is possible to conduct initial, "strategic" assessments to determine the need for more site-specific data.

Finally, two points about use of the seafloor and seabed should be emphasized. First, the ocean is a multidimensional, dynamic system. Priorities for the conduct of mapping and research on the seafloor and seabed should not be considered exclusive of the multiple uses that take place on and over the seabed, including environmental protection and habitat conservation.

Second, marine regions, including the seafloor and seabed, are used to produce multiple goods and services. Few, if any, regions of the seafloor will be used exclusively for any single use. As human activities make increasing use of these regions, inevitably conflicting uses will compete for limited access to resources of the seafloor and seabed. Without improved information and knowledge, these competing uses and conflicts among them could damage the marine environment and lead to underuse or overuse of the resources of these regions. The challenge is to develop the data, information, and knowledge that will permit society—both the private and public sector—to decide what is the best mix of goods and services that should be produced from the multiple uses of any given region at any point in time—and over time.

Many of the conflicts identified in the cross-impact matrix are not apparent or important today. However, as uses of the EEZ and seafloor increase over the next 10 to 20 years, the first steps toward production of the data, information, and knowledge required to remove or reduce these real or perceived multiple-use conflicts will be the real contribution of this workshop.

OIL AND GAS EXPLORATION AND EXPLOITATION

Introduction

Because the U.S. oil and gas industry provides the Nation with important supplies of energy, there is a need to develop the required technology necessary to meet future national energy demands and to reduce reliance on other nations for oil and gas. Recent studies confirm that the production of oil and gas reserves offshore will continue to increase each year as onshore reserves continue to decline. The exploration and exploitation of deepwater oil and gas reserves have increased dramatically since 1975, and new technologies, specific to deepwater production and other frontier areas, are being developed.

Current activities and future trends indicate that installation of production facilities in the deep waters of the continental slope and the Arctic will increase during the next decade. As offshore drilling moves farther out to sea, economic constraints will eliminate the installation of standard, fixed offshore structures, and other solutions, such as tension leg platforms and guyed towers, will be implemented. New subsea technologies (for example, autonomous vehicles and robotics) will be required for seafloor uses on the continental slope in water depths greater than 1,000 m and in Arctic regions. To accomplish this objective, industry, academia, and government will first need to

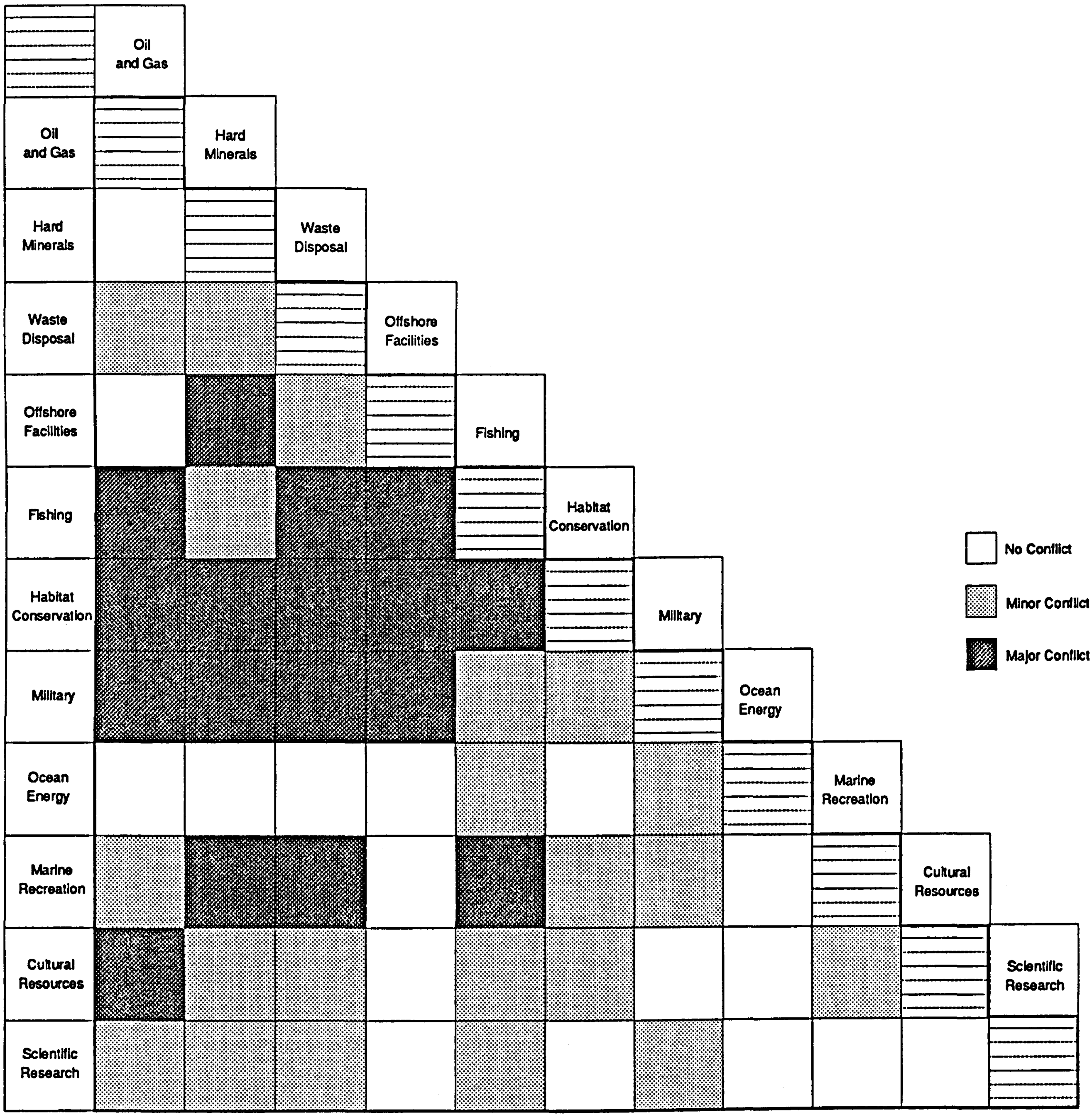

Figure 1. Multiple-use conflict matrix of seabed uses.

collect, analyze, and assess information and data sets that characterize the EEZ and to conduct research and technology development to facilitate future operations.

Information Needs

- Sediment Characteristics: The properties of sediments, which are fundamentally important to the evaluation of geologic processes and to engineering design, are frequently unique on the continental slope (for example, gas hydrates) and therefore will need to be characterized. In this regard, the following information will be required: strength and stress-strain-time parameters, compressibility and stress history, permeability, effects of drilling by-products on sediment characteristics, and effects of slope deformation and failure.

- Facilities and Systems: Information is needed on the interaction between the structure and seabed of new production facilities (for example, guyed towers, tension leg platforms, or subsea well heads) being considered for the frontier areas, as in deepwater and steep-sloped environments and Arctic regions. Important issues include the long-term effectiveness of various types of production systems, their cost-effectiveness, their long-term behavior in dynamic deepwater environments, and the long-term interactions with the seabed.
- Risk Analysis: Appropriate geological and geotechnical models need to be developed for the unique, complex interactions in the deep waters of the continental slope and in the Arctic. Similarly, input parameters for deepwater phenomena, such as earthquakes, and their effects on sediments, need field validation. Quantitative data, with which to build models and calibrate them to specify design conditions, are needed.
- Seafloor Geologic Processes: Information is needed on downslope deformations, landsliding, turbidity currents, debris flows, faulting, erosion and scour, volcanism, and diapiric uplift, all of which are prevalent to various degrees on the continental slope. The distribution and intensities of these processes are currently unknown and cannot be predicted from the available regional geologic information.
- Surveying and Mapping: A process is needed to identify and define information requirements. The rate of data collection needs to be improved (estimates are that, with the current technology and four-ship operation, it will take over 100 years to complete the bathymetric surveying of the EEZ). There is a need to improve the resolution and accuracy of data derived via seabed imaging techniques and subbottom profiling. Subsurface information, such as stratigraphy and geologic structures, based largely on seismic profiles, needs to be extended to areas beyond the upper continental slope and the ice-covered oceans of the Arctic. Surveys via satellite remote sensing are needed for near real-time synoptic ocean measurements.
- Environmental Quality Effects: In deep water, environmental concerns include effects of drilling, muds, and oil spills, and increased difficulty of dealing with blowouts and spills in sensitive areas, including long-term, cumulative effects. The fragile and hostile environment in high latitudes presents some special problems and research requirements. Removal of obsolete structures and facilities may have an impact on the disturbed ecosystem.
- Conflicts with Other Uses: Major conflicts can occur with commercial fishing, habitat conservation, cultural resources, and military uses, especially the latter. Minor conflicts with waste disposal, marine recreation, and scientific research were also identified.

Constraints

- Financial: Many of the research and operational needs are expensive, and costs are frequently directly related to distance from shore and depth of water. Research and development of technology are largely dependent upon future oil and gas prices, as well as costs of production and the size and quality of resources discovered in deepwater environments.
- Seafloor Gradients: The bathymetry of the continental slope is far more complex than that found on the shelf. Some areas with steep slopes and rough seafloor may be too difficult and uneconomical to develop.
- Legal and Political: Environmental organizations and some coastal State governments may oppose offshore oil and gas development for its potential adverse impact on the environment and living marine resources. Disputes concerning EEZ boundaries present legal constraints to oil and gas development.
- Classification of Data: Prohibiting release of NOAA Sea Beam bathymetric data slows EEZ development; data obtained by the private sector are usually considered proprietary and not available to the general public.

Consequences of Not Obtaining Information

Lack of information could result in denial or delay of development of offshore oil and gas resources, continued reliance on foreign sources, and reduced competitiveness.

Strategy for Acquiring and Managing Information

Cooperative partnerships between government and industry to acquire and manage information are needed, with government conducting broad-scale surveys and environmental studies and industry collecting and disseminating site-specific information.

HARD MINERAL EXPLORATION AND EXPLOITATION

Introduction

Vast amounts of hard minerals lie beneath the oceans. However, uncertainties still remain about the distribution and abundance of minerals that are of economic interest. As hard mineral deposits on land become depleted and as world economies become increasingly unreliable, some underwater deposits will become economically attractive. Most land mineral deposits appear to be in abundant supply, but a concern lies in the potential for disruption in the supply of imported minerals, particularly strategic minerals (cobalt, chromium, manganese, and platinum group metals).

Given the relative abundance of hard minerals on land, demand for seafloor hard minerals is currently relatively low. However, there is a growing effort to develop the technology needed to exploit strategic minerals critical to American industry and security. The long-term national needs make it imperative to assess the U.S. EEZ hard mineral reserves and to develop the technological capability to recover them within an appropriate time frame. The amount of time needed for development is dependent upon a variety of factors: availability of domestic and foreign sources of supply, discovery of new onshore deposits or expanded reserves, amount of research needed to augment supplies by recycling, substitution of materials, technical problems, and difficulties in satisfying environmental and regulatory requirements.

Future technology needs will be for development of (1) remotely operated vehicles (ROV's), both tethered and untethered, to acquire high-resolution data, (2) improved navigation technology to generate accurate seafloor topographic maps, (3) directional wave and current spectra to design environmentally acceptable tailings disposal schemes, (4) tools to sample massive deposits (tools that record properties of mineral deposits or processes are not necessarily universally applicable, and different meteorological conditions, such as those found in the Arctic, require different sets of tools for sampling and surveying), (5) dredges with the appropriate technology (current law forbids foreign dredges to mine in U.S. waters), and (6) less costly recovery technology. To accomplish these objectives, industry, academia, and government will need to collect and analyze data aimed at assessing hard mineral resources in the EEZ, and conduct research and technology development to facilitate future operations.

Information Needs

- Sediment Characteristics: The properties of sediments, which are fundamentally important to the evaluation of geologic processes and to engineering design, are frequently unique on the continental slope (for example, gas hydrates) and therefore will need to be characterized. In this regard, the following information will be required: transport and settling characteristics of disturbed sediment, shear strength and trafficability of sediment as related to bottom-roving equipment, slope stability, and postmining effects and recovery rate of bottom to original conditions.
- Geomechanical Characteristics of Deposits: Consolidated or massive deposits that may need drilling, fracturing, or chemical dissolution require much information about their physical properties. Mining plans are dependent on data about the sediment and rock. Demonstration projects will have to be conducted over broad areas, as most hard mineral deposits are not homogeneous in composition or in physical properties. Better and more efficient sampling tools are needed to recover samples at depth for assessment of the resources.
- Facilities and Systems: Advances in technology are needed for efficient and effective resource assessment, economic extraction, and processing. This is a ripe area for government-industry cooperation.
- Resource Assessment: Resource assessment is a high priority. Improved knowledge will be needed for the five classes of hard mineral deposits (construction minerals, placers, phosphorites, manganese nodules and crusts, and polymetallic sulfides). A data base will need to be developed to permit mapping of known deposits and to make reasonable estimates of their economic significance. The type, quality, and accuracy of data vary with deposit type, constituent minerals, water depth, distance from shore, exploration techniques, and marketability.
- Risk Analysis: Appropriate geological and geotechnical models need to be developed for the unique, complex interactions in the deep waters of the continental slope and in the Arctic. Similarly, input parameters for deepwater phenomena, such as earthquakes, and their effects on sediments, need field validation. Quantitative data, with which to build models and calibrate them to specify design conditions, are needed.
- Seafloor Geologic Processes: Information is needed on downslope deformations, landsliding, turbidity currents, debris flows, faulting, erosion and scour, volcanism, and diapiric uplift, all of which are prevalent to various degrees on the continental slope. The distribution and intensities of these processes are currently unknown and cannot be predicted from the available regional geologic information. Data are also needed on the potential of seabed mining operations triggering seafloor instabilities.
- Surveying and Mapping: Suitable technology for high-resolution bathymetric mapping will be necessary. The accuracy of bathymetric information seaward gradually diminishes as positional accuracy degrades. There is a need for better and more efficient subbottom profiling systems with the capability of remotely assessing the seabed stratigraphy in terms of resources. Deep-towed surveys will be needed to reduce surveying-sampling costs and to increase resolution. Resource surveys should be accompanied by surveys of local biota and environment wherever possible and cost effective.
- Environmental Quality Effects: The effects of disrupting the seabed and marine organisms and their habitats are concerns, as are the fate of resuspended sediments and transportation of the resources to the shore. Effects of mining by-products, such as plumes, must be considered. Information is also needed on effects of onshore processing and disposal of mining materials.

- Conflicts with Other Uses: Major conflicts could occur with offshore facilities (disruption of cables), habitat conservation (disruption or loss of habitat), military uses, and marine recreation, especially from sand and gravel mining in coastal waters. Minor conflicts could arise with waste disposal, commercial fishing, cultural resources, and scientific research.

Constraints

- Financial: At any water depth, seafloor mining is expensive compared to land mining, with the expense being proportional to depth of water. Most of the technology for continental margin deposits in water less than 50 m deep is basically available. In deep water, lift systems are well developed for depths to 5,000 m, but excavation and collection systems in hard rock environments require a considerable investment for research and development. In addition, some minerals, such as sulfides and oxides, are found only in deepwater areas. The cost of recovering a mineral and the price it commands are dependent on such physical factors as geographic location, grade, size, and mineralogical complexity of the deposit, besides such economic factors as demand and interest rates. Transcending these issues are the long-term national concerns in terms of industrial competitiveness and the security needs of the military for strategic materials.
- Seafloor Gradients: The bathymetry of the continental slope is far more complex than that found on the shelf. Some areas with steep slopes and rough seafloor may be too difficult and uneconomical to develop. The effect of mining operations on seabed stability must be carefully considered.
- Legal and Political: Environmental organizations and some coastal State governments may oppose hard mineral mining for its potential adverse effects on the environment. A management regime for offshore sand and gravel mining in State and Federal waters does not exist. Clear, unambiguous legal titles to access the seabed for mineral extraction are needed.
- Technological: Technology is needed for sampling and resource assessment and economical extraction.
- Classification of Data: Prohibiting release of NOAA Sea Beam bathymetric data slows EEZ development.

Consequences of Not Obtaining Information

Lack of information will delay developing a U.S. capability to economically mine strategic and other hard minerals.

Strategy for Acquiring and Managing Information

Government is acquiring and providing large-scale reconnaissance information on the entire EEZ; industry is providing site-specific data.

WASTE DISPOSAL (INDUSTRIAL, SEWAGE, NUCLEAR, AND DREDGED MATERIAL)

Introduction

As the costs of land-based disposal options increase, interest has grown within the last 10 years toward use of the seafloor of the EEZ for waste disposal. Growing international restrictions on deep-sea disposal and State government opposition to near-coastal dumping leave the EEZ as the only ocean regime for the disposal of many types of materials, including hazardous wastes and dredged materials. The seabed of the EEZ should be considered along with land-based alternatives with a view toward selecting the most environmentally sound solution. Surveys of the EEZ, including information on habitat, will be needed to locate suitable potential sites for specific classes of wastes. It will be necessary to conduct comprehensive studies with due regard for interactions between the overlying water and the sediments.

Information Needs

- Sediment Characteristics: The properties of sediments, which are fundamentally important to the evaluation of geologic processes and engineering design, are frequently unique on the continental slope and therefore will need to be characterized. The following information will be required: shear strength for subbottom excavation and emplacement, thermal effects, radiological effects, permeability, pore fluid migration, plasticity of sediment, geological stability, physiochemical property changes of sediments, scour characteristics of the bottom, bottom stability, and long-term behavior.
- Risk Analysis: Appropriate geological and geotechnical models need to be developed for the unique, complex interactions in the deep waters of the continental slope. Similarly, input parameters for deepwater phenomena, such as earthquakes, and their effects on sediments, need field validation. Quantitative data, with which to build models and calibrate them to specify design conditions, are needed.
- Seafloor Geologic Processes: Information is needed on downslope deformations, landsliding, turbidity currents, debris flows, faulting, erosion and scour, volcanism, and diapiric uplift, all of which are prevalent to

various degrees on the continental slope. The distribution and intensities of these processes is currently unknown and they cannot be predicted from the available regional geologic information. Basic sediment properties, sediment thickness and transport, spatial variability, and sediment interaction models are needed, and the rates of sediment deposition are needed for geochronological indicators.

- Surveying and Mapping: There is a need for better and more efficient means of remotely determining subseabed characteristics, both vertically and areally, especially for deep seabed disposal.
- Environmental Quality Effects: Biota and sediment analyses for organics and metals, with good controls and selective leaching studies on the sediments, will be needed to determine the long-term effects that contaminants in dredged materials have on the biota. Criteria for degradation identification will need to be established by conducting detailed monitoring of sediments, water, and organisms around waste sites. Microcosmic experiments will be needed to provide simulations of the consequences of dumping. Estimated release rates of metals and toxic organics in waste materials and the ability to identify forms of released metals will be needed. Detailed studies will be needed to assess the effectiveness of the sediment as a barrier to waste migration from subseabed waste sites to the biosphere. This should be primarily a government-supported function.
- Environmental Quality Monitoring: Long-term, in-situ monitoring is needed to obtain information on the status and trends of environmental quality. This should be primarily a government-supported function.
- Conflicts with Other Uses: Major conflicts exist with commercial fishing (although some forms of wastes could benefit living marine resources), habitat conservation, military uses of the seafloor, and marine recreation. Minor conflicts exist with offshore facilities, cultural resources, and scientific research.

Constraints

- Financial: The long-term costs and benefits of ocean disposal of specific wastes will need to be assessed and compared with other alternatives.
- Seafloor Gradients: The bathymetry of the continental slope is far more complex than that found on the shelf. Some areas with steep bottom slopes and rough seafloor may be too difficult and uneconomical to use for disposal activities.
- Legal and Political: Growing international bans on deep-sea disposal and State government opposition to near-coastal dumping and land-based alternatives leave the EEZ as one of the few alternatives for the disposal of hazardous wastes. Also, there is a continuing unresolved question of how to handle radioactive wastes. At one time, there were three low-level dumpsites in the U.S. EEZ. There are problems in handling incinerated waste, for example, the transport of gases and ash over coastal and EEZ areas as well as the potential occurrence of highly toxic compounds produced from organic wastes during combustion. There is also local resistance to the transporting and storing of hazardous materials in port facilities. Port operators are concerned about liabilities and increased insurance needs.

Consequences of Not Obtaining Information

Without improved information, public perception will slow or prohibit disposal activities in the EEZ.

Strategy for Acquiring and Managing Information

The Federal Government is responsible for acquiring, assessing, and disseminating information on the use and management of public-trust ocean areas for waste disposal.

OFFSHORE FACILITIES (Pipelines and Cables)

Introduction

Many areas of the EEZ are crossed by thousands of miles of cable for commercial and military communications, tactical systems, and research. In other areas, hydrocarbons are brought from offshore production facilities to land through pipelines on or in the seabed. As these operations move into deeper water and into more hostile environments (the Arctic), the design and construction of offshore facilities will require further development to cope with the range of constraints presented by these unique environments.

Information Needs

- Sediment Characteristics: The properties of sediments, which are fundamentally important to the evaluation of geologic processes and engineering design, are frequently unique on the continental slope and therefore will need to be characterized. Knowledge of the following will be required: potential for slope deformation and mass wasting, sediment-structure interaction, potential for sediment transport, potential for liquefaction from interaction of waves on the bottom, bioturbation and scour, hostile environments for design and temporal variability, strength and stress-strain parameters, compressibility and stress history, permeability and trafficability of bottom-crawling vehicles for cable and pipe laying.

- Facilities and Systems: Information on the installation and maintenance of pipelines and undersea cables on and under the seabed will be needed, especially in deep water, on steep slopes, and in the Arctic. This is primarily the responsibility of the private sector.
- Risk Analysis: Appropriate geological and geotechnical models need to be developed for the unique, complex interactions in the deep waters of the continental slope and in the Arctic. Similarly, input parameters for deepwater phenomena, such as earthquakes, and their effects on sediments, need field validation. Quantitative data, with which to build models and calibrate them to specify design conditions, are needed.
- Seafloor Geologic Processes: Information is needed on downslope deformations, landsliding, turbidity currents, debris flows, faulting, erosion and scour, and diapiric uplift, all of which are prevalent to various degrees on the continental slope. The distribution and intensities of these processes are currently unknown and cannot be predicted from the available regional geologic information. Of critical importance is better knowledge of the effects of installation operations on the stability of sediment masses.
- Surveying and Mapping: Subsurface information (such as stratigraphy and geologic structures), based largely on seismic profiles, needs to be extended to areas beyond the upper continental slope and the ice-covered oceans of the Arctic. Charting of cables and pipelines in multiple-use areas is needed for planning purposes. There is also a need to improve the resolution of bathymetric data.
- Environmental Quality Effects: Environmental concerns include effects of oil and gas spills from damaged pipelines, effects that disrupting the seabed would have on marine organisms, and eventual need to remove facilities after their service life.
- Conflicts with Other Uses: Because of the areal extent and distance covered by these facilities, there are potential conflicts with most of the other seabed uses. Major conflicts exist with hard mineral exploration and exploitation, commercial fishing (especially trawling), habitat conservation, and military uses. Minor conflicts exist with waste disposal activities.

Constraints

- Financial: The costs associated with pipelines will be factored into the overall systems costs. These will be especially expensive in frontier areas. The use of fiber-optic cables dictates burial in most of the EEZ.
- Seafloor Gradients: The bathymetry of the continental slope is far more complex than that found on the shelf. Some areas with steep bottom slopes and a rough seafloor may be too difficult and uneconomical to develop, as will be the Arctic with its special processes (like ice scour processes and permafrost).
- Legal and Political: Environmental organizations and some coastal State governments oppose the construction of offshore facilities and the laying of buried apparatus for their potential adverse impacts on the coastal and nearshore environment.

Consequences of Not Obtaining Information

Seabed information is essential prior to any industry activities in pipeline and cable-laying on or under the seabed. Improper installation could result in failures and possible large-scale slope instability.

Strategy for Acquiring and Managing Information

Government should continue to provide most of the general reconnaissance survey data and related information, and industry should obtain the site-specific data needed for pipeline and cable-laying.

LIVING MARINE RESOURCES EXPLOITATION

Introduction

Most of the world catch of marine species occurs in coastal waters, where many of the species are closely associated with the seafloor, such as bottom-feeding fish and invertebrate species. Assessment of population sizes becomes increasingly important as more and more nations harvest mass quantities of marine life. Assessments, however, can be difficult in topographically complex regions of the seafloor, such as banks, escarpments, and seamounts; conventional sampling techniques (nets and dredges) are frequently inappropriate. New techniques, relying on ROV technology, are being used increasingly.

Expansion of mariculture and aquaculture, traditionally concentrated in the nearshore zone, to areas farther offshore is a possibility. Information on the physical and chemical properties of sediments and their erosion potential will be needed. Potential multiple-use conflicts between living marine resources and human activities, such as offshore oil and gas and waste disposal, must be resolved.

Information Needs

- Resource Assessment: The primary concern is with overfishing of particular species and possible extermination of certain fisheries. There must be a proper balance between exploitation and conservation with due regard for the entire ecosystem. Spatial and temporal characteristics of oceanic features that affect the distribution of living marine resources and the activities and pollutants affecting them within the U.S. EEZ will need to be determined. Detailed information on the life histories of selected marine resources for various regions of the EEZ will have to be developed. Computer mapping of the spatial and temporal distribution of species life histories within various regions of the U.S. EEZ (as could be provided by geographic information systems) will be useful.
- Sediment Characteristics: Seabed studies will be needed on the cohesiveness of the uppermost seabed, seabed chemistry, and the potential for erosion, deposition, and transport.
- Environmental Quality Effects: The primary concern is with overfishing of particular species and possible extermination of certain fisheries. There must be a proper balance between exploitation and preservation with due regard for the entire ecosystem. Habitat degradation studies will need to be conducted on the effects of ocean pollution, dredging and mining activities, military operations, bottom trawling, and more. Monitoring of environmental quality will be needed to determine the existing status and the long-term trends of conditions in coastal and marine waters. This will include benthic surveillance to monitor toxic chemicals in both surface sediments and in marine life that inhabits these areas.
- Conflicts with Other Uses: There are major conflicts with many other uses of the seabed including oil and gas, waste disposal, offshore facilities, cable routing, habitat conservation (as in alteration and destruction of habitat by trawling), and marine recreation. Minor conflicts exist with hard minerals, military security, ocean energy, cultural resources, and scientific research. Additional multiple-use conflict studies will be needed to determine the impact of human activities on living marine resources.

Constraints

- Financial: The design and construction of offshore mariculture and aquaculture facilities, especially for offshore operations, will be expensive. The American fishing fleet is currently overcapitalized.
- Legal and Political: There is potential for multiple-use conflicts, as well as long-term implications relative to overall food resources.

Consequences of Not Obtaining Information

Overfishing, stock depletion, and fishing limitations set because of prohibited areas are all concerns. Undetected pollution effects can provide short- and long-term impacts on stocks and increase the risk of fishing operations.

Strategy for Acquiring and Managing Information

There is a need for the Federal Government to improve the collection and use of existing information and the assessment of multiple-use conflicts.

LIVING MARINE RESOURCES AND HABITAT PROTECTION

Introduction

The topography of the seafloor, together with currents and other environmental factors, creates a wide variety of ecosystems in offshore waters. While open ocean waters are generally less productive than the nutrient-rich coastal waters, they do support a great mass of microscopic organisms that eventually become food for benthic animals, including commercially important fish and shellfish. Where physical and topographic conditions are right, nutrient-rich upwelling occurs. This phenomenon produces large growths of phytoplankton, a source of food for zooplankton, which in turn becomes food for fish, seabirds, and marine mammals, including some threatened and endangered species. Areas of frequent upwelling are, therefore, some of the most productive marine ecosystems.

Submarine canyons, hydrothermal vents, seamounts, and hard bottoms are other important habitats. Submarine canyons, for example, are especially rich ecosystems, since they focus on food spilling from the surrounding continental shelf. Seamounts that reach into the euphotic zone are especially rich ecosystems that are well known to commercial fishermen, seabirds, and marine mammals. Several of these areas, for example, submarine canyons and hydrothermal vents, have only recently become the focus of scientific research. Little is known of the geologic processes that form these areas, their productivity, their interactions among their inhabitants, and their importance relative to other deepwater habitats.

In addition to specific areas of the seafloor that deserve special attention as important habitats of living marine resources, 13 species of marine mammals are classified as "threatened" or "endangered" throughout their range under the Endangered Species Act of 1973. Many of these animals range over large areas of the EEZ, and their habitat requirements must be considered in the planning of uses of the seafloor.

Information Needs

- Resource Assessment: Spatial and temporal characteristics of oceanic features that affect the distribution of living marine resources and the activities and pollutants affecting them within the U.S. EEZ will need to be determined. Detailed information on the life histories of selected marine resources for various regions of the EEZ will have to be developed. Computer mapping of the spatial and temporal distribution of species life histories within various regions of the U.S. EEZ should be encouraged.
- Sediment Characteristics: Special studies will be needed to determine the importance of various areas of the seabed as habitat. Seabed studies will be needed on the cohesiveness of the uppermost seabed, seabed chemistry, and the potential for erosion, deposition, and transport.
- Environmental Quality Effects: Special studies, including measurements and surveys, are needed to assess the effects of pollutants on habitats. Improved technology is needed for more accurate and rapid measurements over a wider area.
- Conflicts with Other Uses: Major conflicts exist with oil and gas, hard minerals, waste disposal, offshore facilities, and commercial fishing. Minor conflicts exist with military uses, marine recreation, and cultural resources. Multiple-use conflict studies will be needed to determine the effects of human activities on habitats of living marine resources.

Constraints

- Financial: Obtaining new information and knowledge of habitats will be expensive; management, including monitoring of environmental quality of these areas, will be expensive.
- Legal and Political: Many living marine resources and their habitats are protected under national and international laws and regulations.

Consequences of Not Obtaining Information

Not having this information increases the risk of habitat loss and, over time, will reduce populations of living marine resources.

Strategy for Acquiring and Managing Information

The acquisition and use of this information is the responsibility of the Federal Government.

MILITARY AND SECURITY USES

Introduction

Military interests in the EEZ range from operational uses including cable and sensor installations to research and development, and test and evaluation activities. Many of the activities are classified, but in a broad sense, the military requires most of the information that all other users of the EEZ need. In addition, the military is concerned with the protection of offshore economic interests and, hence, national security.

Current technology requirements include (1) ocean cables for voice and (or) data transmissions among shore-based facilities as well as for data transmissions from sensor systems located at sea to shore-based processing facilities; (2) sensor and transducer systems to increase knowledge and understanding of basic scientific processes that can be applied to military operations; (3) mooring systems; (4) remotely-operated vehicles (ROV's) and autonomous underwater vehicles (AUV's) for research activities and tactical systems; and (5) disposal of a variety of surplus, outdated, or dangerous defense assets. Future systems may involve increased use of active acoustic systems.

Information Needs

- Sediment Characteristics: The properties of sediments, which are fundamentally important to the evaluation of geologic processes and engineering design, are frequently unique on the continental slope and in the Arctic and therefore will need to be characterized, especially with regard to mooring and cable technology. Knowledge of the acoustic properties of sediments, in-situ properties of the seafloor for installation of equipment, potential for sediment transport, overall knowledge of distribution of sediment types and properties, and temporal variability of the seafloor will be needed. Areas that have sediments exhibiting beneficial acoustic properties for sensor systems will need to be determined.
- Facilities and Systems: Information on the soil characteristics and the engineering properties for design of various production facilities (for example, guyed towers, tension leg platforms, or subsea well heads) will be needed to assist the military in its defense of such valuable, but vulnerable, facilities.
- Risk Analysis: Appropriate geological and geotechnical models need to be developed for the unique, complex interactions in the deep waters of the continental slope and in the Arctic. Similarly, input parameters for deepwater phenomena (such as earthquakes) and their effects on sediments, need field validation. Quantitative data, with which to build models and calibrate them to specify design conditions, are needed.

- Seafloor Geologic Processes: Information is needed on landsliding, turbidity currents, debris flows, faulting, and erosion and scour, all of which are prevalent to various degrees on the continental slope. Special processes in the Arctic (like permafrost and ice gouging) need to be better understood. The distribution and intensities of these processes are currently unknown and they cannot be predicted from the available regional geologic information.
- Surveying and Mapping: Subsurface information (stratigraphy and geologic structures), based largely on seismic profiles, needs to be extended to areas beyond the upper continental slope and the ice-covered oceans of the Arctic. A data base will need to be developed for storing detailed information on bathymetry and bottom-surface topography vital to national security.
- Environmental Quality Effects: Environmental quality concerns include the effect of active sonar on marine life and possible ecological damage from installation operations of subsea systems. Microcosmic experiments will be needed to provide simulations of the consequences of military waste disposal. Estimated release rates of metals and toxic organics in waste materials and identification of forms of released metals on seawater and organisms will be needed.
- Conflicts with Other Uses: Major conflicts exist with oil and gas, hard minerals, waste disposal, and offshore facilities. Minor conflicts exist with commercial fishing, habitat conservation, ocean energy, marine recreation, and scientific research. Specific examples include the bottom-trawling fishing industry and the oil industry's exploration activities that interfere with the effective performance of sensor and transducer systems. Seismic profiling for oil and gas exploration seriously interferes with acoustic surveillance systems.

Constraints

- Seafloor Gradients: The bathymetry of the continental slope is far more complex than that found on the shelf. Some areas with steep bottom slopes and rough seafloor may be too difficult and uneconomical to develop. A variety of natural characteristics of the seabed, such as bottom topography, bottom sediment types, jetting/trenching/plowing bottom characteristics, trafficability of the bottom, and bottom scour and stabilization, constrain military development.
- Legal and Political: Military uses of the seafloor have few, if any, political or legal constraints.

Consequences of Not Obtaining Information

Conflicts between military and nonmilitary uses will continue unless adequate information is available for assessment and resolution of multiple-use conflicts.

Strategy for Acquiring and Managing Information

Acquisition and management of information and data for military use are the responsibility of the military establishment.

OCEAN ENERGY CONVERSION

Introduction

Because of the increased availability and moderate prices of oil and gas, the emphasis on energy activities that relate to the ocean has been reduced in recent years. The principal area of interest in ocean energy in the EEZ pertains to ocean thermal energy conversion (OTEC). A temperature difference on the order of 20 °C is required to operate a rankine-cycle heat engine. OTEC plants are presently being considered primarily for the island communities of the U.S. EEZ (such as Hawaii) where the plant is shore based and the cold water pipe extends down steep slopes to a depth of about 1,000 m to access the cold water. Offshore OTEC plants are also being considered. Both types of plants need information pertaining to the use of the seafloor. Tidal power and salinity-gradient-based energy-conversion systems are directed toward installation near the mouths of large rivers or estuaries. Wave, current, and wind energy facilities are more likely to be located in relatively shallow coastal waters.

OTEC development for commercial use is in its formative stages but is being considered by at least five nations. Engineering information needs similar to those required for shallow-water, offshore structures, offshore sewer pipelines, and moored oil rigs will be required for OTEC systems.

Information Needs

- Sediment Characteristics: The properties of sediments, which are fundamentally important to the evaluation of geologic processes and to engineering design, are frequently unique on the continental slope and therefore will need to be characterized. In this regard, the following information will be required: strength and stress-strain time parameters, compressibility and stress history, permeability, and effects of slope deformation and failure.
- Facilities and Systems: Information on seafloor characteristics and engineering properties will be needed for the design and construction of onshore or nearshore bottom-fixed, at-sea floating facilities ("grazers"), as well as on the engineering problems associated with the

technical needs of the facilities, such as cold water pipes, electrical power riser cables, and deepwater moorings.

- Resource Assessment: Temperature profiles need to be examined to determine the differences between surface ocean water and deeper waters as an energy source for OTEC.
- Seafloor Geologic Processes: Information is needed on landsliding, turbidity currents, debris flows, faulting, and erosion and scour, all of which are prevalent to various degrees on the continental slope. The distribution and intensities of these processes are currently unknown, and they cannot be predicted from the available regional geologic information. Information is needed on nearshore seafloor properties on a site-specific basis to successfully "fasten" cold water pipes to a sharply sloping seafloor. Also, information on the load-bearing properties of the seafloor and on slope stability is important.
- Surveying and Mapping: Subsurface information (concerning, stratigraphy and geologic structures, for example), based largely on seismic profiles, needs to be extended to areas beyond the upper continental slope.
- Environmental Quality Effects: The environmental effects of OTEC systems pumping cold water nutrients to the surface and mixing cold water with warm surface and subsurface waters need to be resolved relative to their effects on living marine resources. The effects of discharging antifoulants used in cleaning heat exchangers are also a concern.
- Conflicts with Other Uses: Shore-based OTEC facilities pose few serious conflicts with other uses. Offshore, moored OTEC facilities could have some minor conflicts with commercial fishing and military uses.

Constraints

- Financial: The extent to which energy conversion devices can be economical depends on the relative initial capital cost per installed kilowatt, the relative cost per kilowatt hour at which energy can be delivered to a grid, and the location of markets relative to the location of the generating facility. The single most important barrier to OTEC development is the uncertainty of financial backing associated with unproven cost estimates and comparatively moderate oil prices.

Consequences of Not Obtaining Information

Delays in proving technical and economic feasibility of ocean energy systems can affect future economic growth of island economies and reduce their competitiveness.

Strategy for Acquiring and Managing Information

In its formative stages, the Federal Government should take the primary lead in ocean energy research and development.

MARINE RECREATION

Introduction

Over 50 percent of the U.S. population lives within 50 mi of the ocean, and by the year 2000, this could be as high as 75 percent. This large, coastal population has placed increasing demands on marine recreation, a steadily growing multibillion dollar per year industry. Much of this industry concerns boating, swimming, sport fishing, and other related activities.

Seabed utilization in these areas pertains primarily to construction of shore-based and nearshore facilities for ports, marinas, and moored facilities but also includes the quality of the underwater and seabed environment for divers. Dredging activities associated with such facilities are a major, continuing activity. Most of these facilities are within the coastal waters, not in the EEZ, but development activities in the EEZ could affect the quality of coastal environments.

There is new (relatively small) interest in undersea recreational habitats, underwater recreational vehicles, and underwater hotels. Implementation of these interests will require detailed siting information on the characteristics of the ocean environment, and especially the seabed.

Information Needs

- Sediment Characteristics: Information will be needed on load-bearing characteristics, bottom topography, thickness of unconsolidated sediments, bottom stability, and the potential for sediment erosion, transport, and deposition.
- Facilities and Systems: Information on the seabed-structure interaction could be needed to determine the most suitable designs for underwater habitats and hotels of the future.
- Risk Analysis: Appropriate seabed models will need to be developed for the various interactions that are likely to take place in the coastal waters where recreational habitats and hotels are to be constructed.
- Seafloor Geologic Processes: Information is needed on landsliding, turbidity currents, erosion and scour, and faulting, all of which are prevalent to various degrees on the continental slope. The distribution and intensities of these processes are currently unknown, and they cannot

be predicted from the available regional geologic information. Information on seafloor characteristics and engineering properties will be required on the advantages and disadvantages of fixed or mobile habitats; permanent, semipermanent, and temporary habitats; and hyperbaric or atmospheric habitats.

- Surveying and Mapping: Site-specific, high-resolution bathymetric information will be needed for coastal waters.
- Environmental Quality Effects: Information is needed on the overall quality of the ocean environment where nearshore facilities are planned. Also needed is information on temperature profiles and circulation and stratification of coastal waters in site-specific areas.
- Conflicts with Other Uses: Major conflicts exist with hard minerals (for example, sand and gravel), waste disposal, and commercial fishing. Minor conflicts exist with oil and gas, habitat conservation, military uses, and cultural resources.

Constraints

- Financial: Investments in recreational underwater habitats are in an exploratory phase to sample the market demand. Early investments are risky. Most of the detailed site-specific information needs for such facilities will probably be factored into the cost of the facility development.

Consequences of Not Obtaining Information

Marine recreation activities in the EEZ will be slowed without this information.

Strategy for Acquiring and Managing Information

Since most marine recreation areas are made available for the public good, general information will probably be acquired and managed by Federal and State Governments. Site-specific information will be acquired, when needed, by the private sector.

UNDERWATER ARCHAEOLOGY AND CULTURAL RESOURCES

Introduction

Recovery of artifacts from several well-known shipwrecks has spurred interest in underwater archaeology and shipwreck salvage activities. A report by the Office of Technology Assessment (OTA) indicates that most underwater historical resources are suffering rapid attrition because the United States lacks a coherent national policy to guide identification and preservation of underwater and maritime cultural resources. The OTA report indicates that underwater maritime cultural resources are so vulnerable to a variety of natural and human threats that Federal support is needed.

Presently, seven national marine sanctuaries, covering about 2,500 nautical mi^2, have been designated by the Federal Government. Similar in concept to land-based national parks and wildlife refuges, marine sanctuaries are an essential part of our national heritage. However, the terrestrial analogy may not be entirely appropriate, since boundaries of marine ecosystems are less discernible and less geographically stable. For example, isotherms, water masses, and salinity are true barriers but are difficult for our land-oriented legal and management systems to deal with effectively. Criteria for the establishment and management of these sanctuaries are developed by NOAA. Other kinds of marine reserves and stable, pristine reference areas should be acquired in the course of development of the EEZ. These areas are growing in importance and value to society.

Information Needs

- Sediment Characteristics: For underwater archaeology and shipwreck salvor activities, information on the site-specific nature of the seafloor and sediments is required. Information is also needed on load-bearing characteristics; bottom topography; thickness of unconsolidated sediments; bottom stability; and the potential for sediment erosion, transport, and deposition. Similar information is required for pristine reference areas designated in the EEZ.
- Surveying and Mapping: High-resolution bathymetric mapping is needed, especially for location and identification of historical shipwreck sites. Accurate surveying and mapping of marine sanctuaries and pristine reference areas are also required.
- Environmental Quality Effects: Information on environmental health of marine sanctuaries and reference areas is needed through a long-term, environmental monitoring program that obtains a comprehensive reference base and periodically measures quality and reports on status and trends.
- Conflicts with Other Uses: A major conflict exists with the offshore oil and gas industry. Minor conflicts exist with hard minerals, waste disposal, commercial fishing, and military uses.

Constraints

- Financial: Budgets for archaeological activities, preservation of historic shipwrecks, and establishment and monitoring of marine sanctuaries and pristine areas are minimal and require additional funding support.

- Legal and Political: The legal aspects of artifact recovery and ownership are a major concern.

Consequences of Not Obtaining Information

The location, designation, and protection of cultural resources will be delayed or inadvertently lost.

Strategy for Acquiring and Managing Information

Since this seabed usage pertains to the public good, related information should be acquired and managed by Federal and State Governments.

SCIENTIFIC RESEARCH

Each of the previous uses of the seafloor requires and involves scientific research that includes a better understanding of sediment characteristics, erosion, transport, and deposition; bottom stability; seafloor geologic processes; environmental quality; and resource assessment. The conduct of this research is in itself an important and competing use of the seabed. It must contend with the constraints and impacts of multiple-uses of seabed regions.

Scientific research is one of the means for providing the required data, information, and knowledge for seabed utilization.

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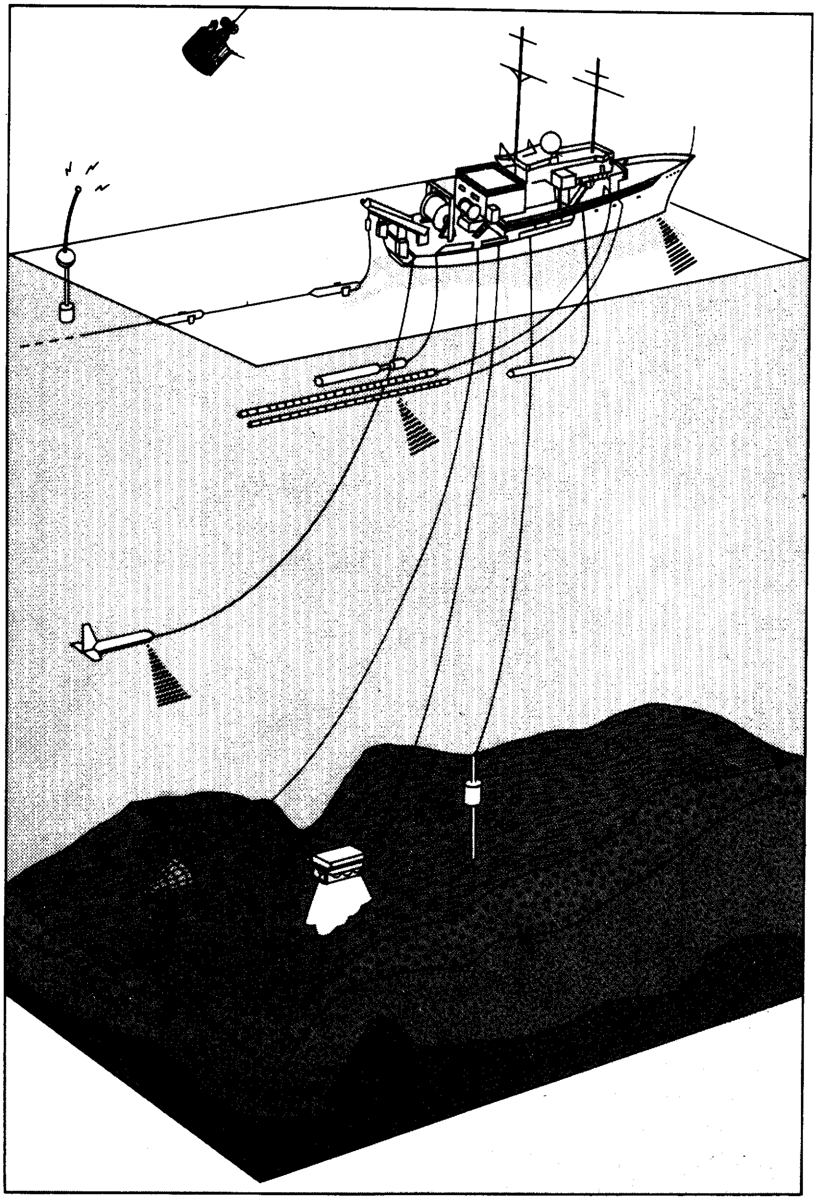
APPENDIXES 1–3

APPENDIX 1:

1987 EXCLUSIVE ECONOMIC ZONE SYMPOSIUM



MAPPING AND RESEARCH: Planning for the Next 10 Years

USGS-NOAA Office for
Coordination of Mapping
and Research in the EEZ

November 17-19, 1987

SYMPOSIUM OVERVIEW

This will be the third in a series of biennial symposia dedicated to the development and implementation of a National Program for Mapping and Research for the non-living resources of the sea floor of the United States Exclusive Economic Zone (EEZ). Through overview presentations and nine (9) individual workshop panels, a scientific framework for EEZ mapping and research will be developed. Five of the panels will discuss issues relative to each of the EEZ regions — East Coast, Gulf, West Coast, Alaska, and the Hawaiian Islands and U.S. Territories. The other four panels will cover technology needs and information needs for oil and gas, hard minerals, and seafloor-seabed utilization.

SYMPOSIUM OBJECTIVES

- Review and update of significant ongoing Federal, State, Academic, and Industrial activities.
- Examine the essential elements for a National Plan to characterize the seafloor and subsoil of the EEZ within 10 years.
- Determine attributes of EEZ data and information: time, space, resolution, scale, geographical areas, measurements required to characterize the seafloor and subsoil.
- Assess the requirements of users of EEZ data and information. Who needs what data, when, where, why, how much, how often?
- Determine the data management and data archival requirements for the building and maintenance of a National EEZ data base.

SYMPOSIUM STEERING COMMITTEE

Chairmen:
Gary W. Hill, U.S. Department of the Interior, U.S. Geological Survey
Millington Lockwood, National Oceanic and Atmospheric Administration, National Ocean Service

Bonnie McGregor, U.S. Geological Survey
Robert Rioux, U.S. Geological Survey
Richard Perry, National Oceanic and Atmospheric Administration
Joe Vadus, National Oceanic and Atmospheric Administration
John Goll, Minerals Management Service
Pat Pecora, Minerals Management Service
John Rowland, Bureau of Mines

Symposium support is provided by Buhler and Abraham, Inc., 8700 First Avenue, Silver Spring, MD 20910, 301-588-4177.

SYMPOSIUM SPONSORS

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PROGRAM AGENDA

Tuesday, November 17, 1987

10:00 a.m. **Registration** (North Wing) Adjacent to Auditorium
(Lunch available in cafeteria)

1:00 p.m. **Introduction** (Auditorium)
The Need for Mapping and Research of the Seabed-Subsoil of the EEZ
James W. Ziglar, Assistant Secretary, Water and Science, Department of the Interior

Keynote Speaker
The Importance of the EEZ and the Need for a National Program
D. James Baker, Joint Oceanographic Institutions

The Needs of Users of EEZ Mapping and Research
J. Steven Griles, Assistant Secretary, Land and Minerals Management, Department of the Interior

Science and the EEZ as Part of a Global Program
M. Grant Gross, National Science Foundation

Technology Assessment for the EEZ — A National Perspective
James W. Curlin, Office of Technology Assessment, Congress of the United States

Mapping of the Seafloor — Progress and the Plan
Paul M. Wolff, National Oceanic and Atmospheric Administration

Information Needs to Develop Technology to Recover the Mineral Resources of the EEZ
David S. Brown, Bureau of Mines

3:00 p.m. **Coffee Break** (North Wing)

3:20 p.m. (Auditorium)
The OCS Program — Information Needs and Sources
William D. Bettenberg, Minerals Management Service, Department of the Interior

Information Needs for Multiple-Use Decisions — An Environmental Perspective
Clifton E. Curtis, Oceanic Society

U.S. Oil Supply and Demand Outlook — An Industry Perspective
Theodore R. Eck, Amoco Corporation

The EEZ, An Offshore Extension of the Continent — The States' Perspective
Charles G. Groat, Association of State Geologists

The Face of the Deep — Road Maps of Discovery
Dallas L. Peck, U.S. Geological Survey

5:00 p.m. - 7:00 p.m. **Exhibits Show and Reception** (North and South Wings)
Adjacent to Auditorium, National Center, U.S. Geological Survey

PROGRAM AGENDA

Wednesday, November 18, 1987

8:00 a.m. **Coffee and Doughnuts** (North Wing)

9:00 a.m. (Auditorium)

Organization and Role of the U.S. Geological Survey/National Oceanic and Atmospheric Administration Joint Office
Gary W. Hill, U.S. Geological Survey

Presentation of the Draft 10-Year National Plan and Purpose and Makeup of the Workshops
Millington Lockwood, National Oceanic and Atmospheric Administration

9:30 a.m. **Workshop Sessions** (Concurrent) (Designated Workshop Rooms)

12:00 noon **Lunch** (On Your Own) (USGS Cafeteria)

1:00 p.m. **Workshop Sessions** (Continued)

3:00 p.m. **Coffee Break** (North Wing)

3:30 p.m. - 5:00 p.m. **Workshop Sessions** (Continued)

Thursday, November 19, 1987

8:00 a.m. **Coffee and Doughnuts** (North Wing)

9:00 a.m. (Auditorium)

Workshop Panel Presentations
Moderator: Millington Lockwood, National Oceanic and Atmospheric Administration

Workshop Reports and Discussion
Workshop Chairpersons

Summary —Joint Office's Role in Development of 10-Year Plan
Gary W. Hill, U.S. Geological Survey

12:30 p.m. **Symposium Adjourns**

Exhibits, results of EEZ mapping and research projects, and EEZ-related products and services will be on display in the North and South Wings. Poster boards will be available to workshop chairmen and others wishing to show results of EEZ-related projects.

WORKSHOPS

Workshop Session Introductions

REGIONAL PANELS

Workshop 1 Rm. 7A 212
Scientific Mapping and Research to Characterize the EEZ — Alaska
Co-Chairperson:
Douglas A. Wolfe, National Oceanic and Atmospheric Administration
Michael S. Marlow, U.S. Geological Survey

Workshop 2 Rm. 3B 327
Scientific Mapping and Research to Characterize the EEZ — West Coast
Co-Chairperson:
William R. Normark, U.S. Geological Survey
Donald A. Hull, State Geologist, Oregon

Workshop 3 Rm. 3A 409
Scientific Mapping and Research to Characterize the EEZ — East Coast
Co-Chairperson:
John S. Schlee, U.S. Geological Survey
David B. Duane, National Oceanic and Atmospheric Administration

Workshop 4 Rm. 5A 217
Scientific Mapping and Research to Characterize the EEZ — Gulf Coast
Co-Chairperson:
James M. Coleman, Louisiana State University
Chacko J. John, Louisiana Geological Survey

Workshop 5 Rm. 2A 405
Scientific Mapping and Research to Characterize the EEZ — Islands
Co-Chairperson:
Bruce M. Richmond, U.S. Geological Survey
Charles L. Morgan, Research Corporation of the University of Hawaii

MAPPING AND RESEARCH TECHNOLOGY PANEL

Workshop 6 Rm. 1D 111
Technology Needs to Characterize the EEZ
Co-Chairperson:
Robert C. Tyce, University of Rhode Island
Donald Pryor, National Oceanic and Atmospheric Administration

SEAFLOOR-SEABED USE PANELS

Workshop 7 Rm. BA 102A
Information Needs and Availability for Oil and Gas Leasing, Exploration, and Development of the EEZ
Co-Chairperson:
Carolita L. Kallaur, Minerals Management Service, Department of the Interior
Carl H. Savit, Oil and Gas Consultant

Workshop 8 Auditorium
Information Availability and Utilization for Hard Mineral Leasing, Exploration, and Development of the EEZ
Co-Chairperson:
Reid T. Stone, Minerals Management Service, Department of the Interior
D.S. Cottell, ARC Marine Limited

Workshop 9 Rm. BA 102C
Information Needs for Seafloor-Seabed Utilization
Co-Chairperson:
Charles N. Ehler, National Oceanic and Atmospheric Administration
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Charter for Coordination of Federal Exclusive Economic Zone Mapping and Research Programs

Purpose

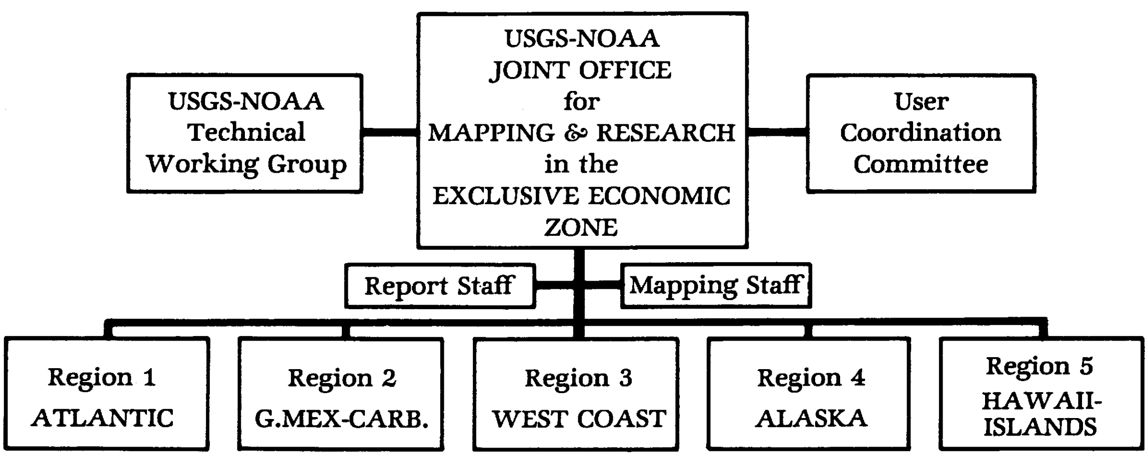
The Exclusive Economic Zone (EEZ) of the United States has a vast potential for resource development. In order to develop these resources in an efficient manner, it is necessary for a coordinated mapping and research endeavor to be formed, involving the Federal Government, State governments, private industry, and academic interests.

The purpose of this charter is to provide a formal mechanism for the coordination of the Federal mapping and research activities in the EEZ of the United States. Coordination will avoid duplication of activities, assure adequate response to needs of users and provide for timely delivery of products and services and exchange of data. Coordination will also facilitate private sector involvement in the direction and use of EEZ-related data products.

To Meet This Purpose, We Hereby Establish the U.S. Geological Survey (USGS)-National Oceanic and Atmospheric Administration (NOAA) Joint Office for Mapping and Research in the EEZ

Mapping and research activities involved in the EEZ range from long-term ocean surveying programs, preparation of atlases and maps from new and existing data, and site specific research to determine the nature of the seafloor geology.

Much of this research and mapping activity is conducted by the USGS in the Department of the Interior and by NOAA in the Department of Commerce. The joint USGS-NOAA office will provide natural leadership for the design, implementation, and coordination of a national EEZ program of mapping and research and investigation of the nonliving resources of the EEZ seafloor. The Joint Office will also ensure participation by all interested groups in the formulation of goals, objectives, and priorities for a national EEZ mapping and research program.



Joint Office for Mapping and Research in the EEZ Organizational Chart

EXHIBITS — DISPLAYS — RESEARCH RESULTS

North Wing

- **GLORIA Mosaics** — Results from U.S. Geological Survey cruises aboard the R/V FARNELLA are shown. Geographical areas include East Coast, Gulf of Mexico, Puerto Rico, West Coast, Bering Sea, and a portion of Hawaiian waters. Copies of West Coast and Gulf of Mexico atlases are also on display.
- **Gorda Ridge** — Minerals Management Service — Office of Strategic and International Materials has produced a video tape of live filming on the seafloor during the 1986 DSRV dives. Related publications are also available.
- **Hawaiian Seamounts and Cobalt Crusts** — Joint Minerals Management Service and the State of Hawaii display showing results of activities carried out by the State Task Force.
- **Cenozoic Sediments** — Minerals Management Service display showing correlation of Cenozoic Sediments consisting of geological and geophysical cross-sections of a study area in the central Gulf of Mexico.
- **Hawaii Survey Results** — Seafloor Surveys International, Inc., has surveyed portions of the seafloor off Hawaii showing the value of having co-registered side-scan sonar images and swath bathymetry.
- **Continental Margin Maps** — U.S. Geological Survey, Office of Energy and Marine Geology will have maps and computer display of its digital mapping capability.

South Wing

- **Strategic Assessments of the EEZ** — NOAA's National Ocean Service's Office of Oceanography and Marine Assessments has a national program to evaluate the environmental and economic effects of policies affecting the use of the ocean. Display includes interactive computer demonstrations of strategic assessment capability.
- **Mining Technology Developments** — Bureau of Mines conducts numerous research activities in the Exclusive Economic Zone in order to determine approaches to seafloor mining and recovery of resources therein.
- **Oil and Gas Resources** — Overview of Minerals Management Service's programs in the EEZ, Royalty Management and the National Studies Program.
- **Sea Grant and Undersea Research** — Summary of EEZ activities sponsored by NOAA's National Sea Grant and Undersea Research Program.
- **Geophysical Products and Services** — National Oceanic and Atmospheric Administration has many programs that produce data and information useful to characterize the seabed subsoil of the EEZ. This display describes some of these data.
- **Bathymetric Mapping** — Overview of NOAA's Exclusive Economic Zone Bathymetric Mapping. Description of mapping systems, geographical areas to be surveyed and products available. Handouts describe NOAA's 5-year EEZ mapping projections.
- **EEZ Development in the Nation's Interest** — University of Washington - Institute for Marine Studies has prepared a display in conjunction with the Seattle Waterfront Awareness Exhibit highlighting the significant activities ongoing in the EEZ.

THE WHITE HOUSE
Office of the Press Secretary

Embargoed for release at 4:00 pm EST — March 10, 1983

EXCLUSIVE ECONOMIC ZONE OF THE UNITED STATES OF AMERICA

A PROCLAMATION BY THE PRESIDENT OF THE UNITED STATES OF AMERICA

WHEREAS the Government of the United States of America desires to facilitate the wise development and use of the oceans consistent with international law;

WHEREAS international law recognizes that, in a zone beyond its territory and adjacent to its territorial sea, known as the Exclusive Economic Zone, a coastal State may assert certain sovereign rights over natural resources and related jurisdiction; and

WHEREAS the establishment of an Exclusive Economic Zone by the United States will advance the development of ocean resources and promote the protection of the marine environment, while not affecting other lawful uses of the zone, including the freedoms of navigation and overflight, by other States;

NOW, THEREFORE, I, RONALD REAGAN, by the authority vested in me as President of the Constitution and laws of the United States of America, do hereby proclaim the sovereign rights and jurisdiction of the United States of America and confirm also the rights and freedoms of all States within an Exclusive Economic Zone, as described herein.

The Exclusive Economic Zone of the United States is a zone contiguous to the territorial sea, including zones contiguous to the territorial sea of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands (to the extent consistent with the Covenant and the United Nations Trusteeship Agreement), and United States overseas territories and possessions. The Exclusive Economic Zone extends to a distance 200 nautical miles from the baseline from which the breadth of the territorial sea is measured. In cases where the maritime boundary with a neighboring State remains to be determined, the boundary of the Exclusive Economic Zone shall be determined by the United States and other State concerned in accordance with equitable principles.

Within the Exclusive Economic Zone, the United States has, to the extent permitted by international law, (a) sovereign rights for the purpose of exploring, exploiting, conserving and managing natural resources, both living and non-living, of the seabed and subsoil and the superjacent waters and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds; and (b) jurisdiction with regard to the establishment and use of artificial islands, and installations and structures having economic purposes, and the protection and preservation of the marine environment.

The Proclamation does not change existing United States policies concerning the continental shelf, marine mammals and fisheries, including highly migratory species of tuna which are not subject to United States jurisdiction and require international agreements for effective management.

The United States will exercise these sovereign rights and jurisdiction in accordance with the rules of international law.

Without prejudice to the sovereign rights and jurisdiction of the United States, the Exclusive Economic Zone remains an area beyond the territory and territorial sea of the United States in which all States enjoy the high seas freedoms of navigation, overflight, and laying of submarine cables and pipelines, and other internationally lawful uses of the sea.

IN WITNESS WHEREOF, I have hereunto set my hand this tenth day of March, in the year of our Lord nineteen hundred and eighty-three, and of the Independence of the United States of America the two hundred and seventh

RONALD REAGAN

Accompanying the release of this proclamation were a statement by the President (Appendix A) and an oceans policy fact sheet (Appendix B).

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Appendix 3: Guidance for 1987 Exclusive Economic Zone (EEZ) Symposium Workshops

A Strategy for Developing a 10-year National Plan for Characterizing the Seabed and Subsoil of the United States through the Implementation of a National Mapping and Research Program

Introduction and Background

Mapping and research on the seafloor of the Exclusive Economic Zone (EEZ) has been a national effort, involving primarily the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, certain academic institutions, and elements of the private sector. The long-term objective is to characterize the seabed and subsoil of the EEZ of the United States. This will be accomplished by studying the geologic framework and seafloor processes to better determine the nonliving resource potential. The program was accelerated in 1983, following the issuance of the EEZ Proclamation by President Reagan with the intent of expanding the exploration already begun on the Outer Continental Shelf (OCS) to the frontier regions of the EEZ. The need for expanded exploration is based on the premise that the earlier the EEZ is fully explored, the sooner the Nation will realize the benefits this territory has to offer.

Previous efforts to explore the seafloor of the continental margins have focused on that portion which was clearly under the legal authority of the United States, that is, the OCS, for the purposes of leasing and development of oil and gas, sulfur, and other mineral resources. This has largely been an effort by private industry, which has been concerned with those areas having a high potential for recovery of energy or selected minerals. Now that authority has been extended, by the EEZ Proclamation, it is appropriate to continue exploring the ocean frontier to supplement information from the continental shelf areas and to begin a process of developing an information base in a comprehensive, systematic manner.

The ocean has played a key role in the history of this country. Fisheries, transportation, and defense are examples of national issues where the ocean has been a major factor. The ocean holds much potential for our future. This includes marine energy and mineral resources, the disposal of waste, multiple-use opportunities, boundary determinations, technology developments, and national defense applications. These issues will continue to play an increasingly important role in our efforts to secure and maintain the quality of the American lifestyle and our international leadership. A well-developed, comprehensive mapping and research program will provide much of the knowledge essential to meet this challenge.

Advancements in technology, such as high-speed computers, satellites, and new measurement systems, coupled with an awareness of the "earth system," allow us to build on past efforts in the EEZ. From this information base we can design and conduct a program consisting of studies involving the geologic framework, seafloor processes, and nonliving resources of an area as large and as complex as the EEZ in a relatively short time frame.

This effort must be aggressively pursued and combine the expertise and technology found in government, academia, and the private sector. It should have clearly defined (measurable) goals and be coordinated with other ongoing activities in the ocean. It cannot be accomplished in a haphazard, isolated manner. In short, to be successful it must be based upon a carefully thought out long-range plan. The purpose of the 1987 EEZ symposium is to develop the essential elements of that plan.

Goals and Objectives

The goal of the National EEZ Mapping and Research Program is to describe the framework and understand the processes—geological, geochemical, and geophysical—that interact at and within the seabed and subsoil of the EEZ and that contribute to the development of the continental margins and the formation of various nonliving marine resources on and within the seafloor.

Specific objectives are to characterize and evaluate the seabed and subsoil of the EEZ in a timely manner by understanding the geological framework and processes related to this frontier; identifying marine energy and mineral and other nonliving resources; understanding geohazards, basin evolution, and geomorphic and sedimentologic processes; and developing baseline information, which would allow activities involving use of the EEZ to be carried out in an efficient manner.

Development of a 10-Year Plan

The strategy for developing the plan is based on the principal of identifying relevant scientific objectives, within the context of national issues in order to focus the direction of the program toward a 10-year goal. On the basis of previous symposia, workshops, and studies by national advisory boards, we have chosen to develop the program based on five geographical regions (Alaska, West Coast, Gulf of Mexico, East Coast, and Islands) and three ocean resource categories (oil and gas, hard minerals, and other seafloor uses). Additionally, one element of the program will concentrate on technology needs for seafloor mapping.

National Need and Benefits

It has been recommended further that a national effort involving cooperation, coordination, and communications between Government, academia, and the private sector would have the best chance of accomplishing the goals of the program. A successful program will address the following:

1. Identification of resources from the EEZ could be significant to the economy and national security, especially strategic and critical materials.
2. The ocean crosses State, Federal, and international boundaries; thus, EEZ data can be used by many elements of society.
3. A cooperative program will stimulate and encourage private sector involvement in EEZ mapping and research efforts.
4. The national program would significantly advance our scientific understanding of the formation of our continental margins and the processes therein, thus increasing opportunities for practical application.
5. The program would develop an information base that will address the multiple-user aspect of the ocean.

Program Constraints and Limitations

In order to be successful in meeting the program's goals we must, of necessity, limit the activity to those which can be clearly identified as relevant to the program's objectives and can be linked to the identified components. To accomplish this, certain limits or constraints have been placed on the program. These limiting factors include:

1. Geographical area, baseline to 200 mi with primary emphasis on the outer shelf, slope, and rise (that is, those areas not extensively studied in the past).
2. Program goals and objectives set in a 10-year time frame.
3. Program emphasis is to answer questions regarding the seafloor (seabed and subsoil) relative to geologic framework, processes, and resources, eliminating much of the water column and biological aspects considerations except as they relate specifically to the seabed.
4. Mapping and research should stress exploration and scientific interpretations and investigation of the unknown frontier regions of the EEZ. Emphasize a "telescope" approach, from reconnaissance-scale (regional) to studies of individual features (local).
5. Emphasis on wide involvement of user groups in program design, rapid turnaround of results, cooperative projects, and preparation of products and data bases for multiple uses, such as maps, atlases, and interpretative reports.
6. Program management philosophy is one of coordination, cooperation, and communications, rather than centralized control.

Program Development

The development of the National EEZ Mapping and Research Program on the seabed and subsoil will be accomplished in three phases:

1. Establish the scientific objectives in terms of national issues.
2. Create a strategy for program development.
3. Develop a range of options for program implementation.

EEZ Symposium and Workshops

The primary purpose of the EEZ symposium and workshop is to provide scientific and technical expertise for program development by identification and analysis of the currently available data and information relevant to the program's goal and, through an appraisal of this data base, identify gaps between current knowledge and the program's goals. The topics that each workshop should address are (1) framework, (2) processes, and (3) resources, hazards, and utilization.

This program development will be accomplished by the following steps:

1. Analyze current programs and data relating to the state of knowledge in each topic area.
2. Identify "gaps" between current state of knowledge and program goals through use of the following procedures:
   a. Develop specific objectives for each program component in each region or ocean use-category.
   b. Enumerate "gaps" between current state of knowledge and 10-year objectives for each component.
   c. Answer the following questions as they relate to the framework, processes, and resources:
      (1) What specific data and information sets do we need and for what purposes?
      (2) What are the attributes of these data and information sets?

(3) What are the constraints to acquiring these data and information sets?
(4) What is a viable strategy to acquiring and managing these data and information sets?
(5) What are the consequences of not gathering these data and information sets?

Note: In regard to the panel dealing with technology the phrase "mapping and research technology" should be substituted for "data and information sets."

Each workshop chairman has been asked to prepare a preliminary or "working" draft of the workshop report prior to the meeting. To maintain a consistent format and to ensure that each workshop covers the same subject matter, the symposium steering committee has prepared the report outline and table of contents for participants. Workshop participants should be prepared to discuss or otherwise contribute to each of the report sections as their expertise and interest dictates.

3. Propose or recommend specific data-collection elements and implementation strategies to fill the gaps. Suggest institutional arrangements, technologies, cooperative agreements, or organizations. The preference is to accomplish the work within an existing structure or organization, that is, whether work could be performed by Government, academia, or the private sector. Recommend phasing-in of each element based upon the analysis of gaps and any knowledge of resources available.

Preparing a 10-Year National Plan

The results of the symposium workshops will serve as the main elements of the 10-year national plan. Following the symposium the Joint U.S. Geological Survey-National Oceanic and Atmospheric Administration Office will compile the results and workshop papers into a symposium volume. This report will serve to document the present status of activities and serve as the source material for a 10-year mapping and research plan.

This plan, which will be prepared by the staff of the Joint Office in cooperation with affected agencies and organizations, will be used as guidance for activities in the EEZ. Over the next 10 years, the Joint Office will host periodic meetings in each region or participate with other existing activities, (for example, State geologists, regional management councils) in order to encourage cooperation, coordination, and communication. A review of the plan, from a national perspective, will be a main purpose of the EEZ symposium held every other year.

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