Proceedings of the 1989 Exclusive Economic Zone Symposium on Mapping and Research: Federal-State Partners in EEZ Mapping

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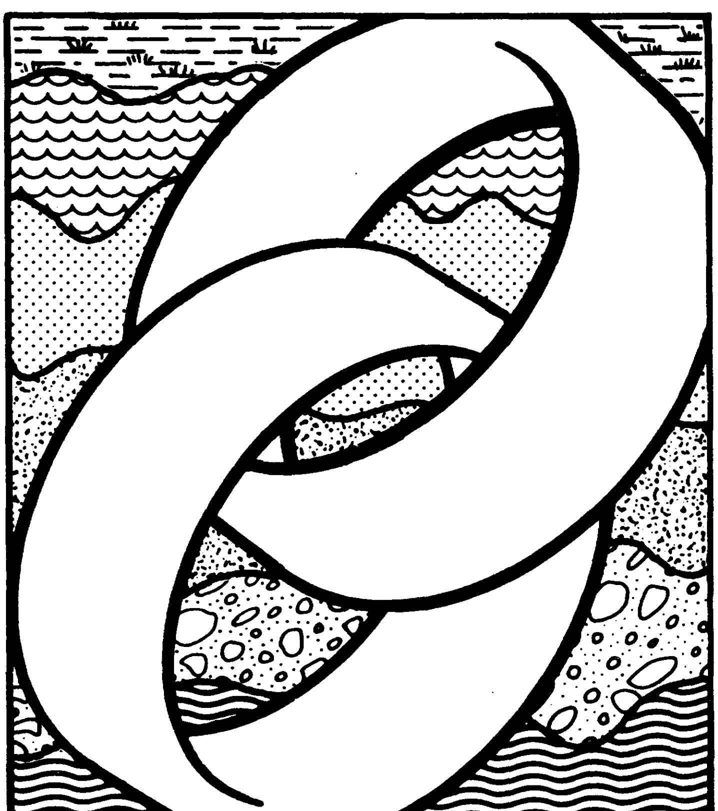

Proceedings of the 1989 Exclusive Economic Zone Symposium on Mapping and Research: Federal-State Partners in EEZ Mapping

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 14-16, 1989

Department of the Interior
U.S. Geological Survey

Department of Commerce
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Atmospheric Administration

U.S. GEOLOGICAL SURVEY CIRCULAR 1052

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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Proceedings of the 1989 Exclusive Economic Zone Symposium on Mapping and Research: Federal-State Partners in EEZ Mapping

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

Symposium Introduction and Overview

Millington Lockwood
Joint Office for Mapping and Research

The 1989 Exclusive Economic Zone (EEZ) Symposium was held from November 14 to 16, 1989, at the U.S. Geological Survey's (USGS) National Center in Reston, Va. A copy of the symposium program is contained in Appendix 1. This symposium was the fourth biennial national symposium held since the issuance of the EEZ Proclamation in 1983 by President Ronald Reagan. The meeting was sponsored by the USGS-National Oceanic and Atmospheric Administration (NOAA) Joint Office for Mapping and Research (JOMAR) and the Association of American State Geologists. Attending the meeting were approximately 220 individuals who represented Federal Government agencies, executive and legislative branches (63 percent); private industry, including consultants (10 percent); State governments (9 percent); academic institutions (8 percent); societies, nonprofit groups, and private citizens (7 percent); and foreign attendees (3 percent). A list of attendees and their affiliations is contained in Appendix 2. The meeting was separated into three sections. The first, or plenary, session dealt with broad programmatic objectives and policy issues, the second involved presentations of 16 case studies of regional mapping projects, and the final session consisted of 6 technical workshops.

The following highlights the major points and areas of discussion developed at the symposium. Details are contained in the papers submitted by the individual participants in the main section of the proceedings. In a few cases, written papers were not submitted by the participants; however, the presenters can be contacted directly for details.

FIRST DAY—PLENARY AND POLICY OVERVIEW

The keynote address was given by John A. Knauss, the Under Secretary of Commerce for Oceans and Atmosphere and the Administrator of NOAA. Dr. Knauss stressed the value of coordinated interagency cooperation to map the vast region of the EEZ efficiently. He also highlighted the recent accomplishments of the NOAA multibeam mapping program and expressed NOAA's satisfaction regarding the lifting of the national security restriction on the distribution of maps and data. Following the keynote address, a series of talks were presented on continuing activities; existing or planned Federal-State relations, needs, and opportunities were emphasized.

During the remainder of the first day of the symposium, presentations were given by representatives from the Association of American State Geologists, the Coastal States' Organization, NOAA, the National Science Foundation (NSF), the USGS, the Minerals Technology Center at the University of Mississippi, the Minerals Management Service, the National Research Council, and the Environmental Protection Agency (EPA).

SECOND DAY—CASE STUDIES

An introduction to the second day of the symposium was given by Dallas L. Peck, Director of the USGS. He

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stressed the significance of the continued cooperative efforts to accomplish the task of mapping the entire EEZ. Following Dr. Peck's introduction, Peter Lucas, Chairman of the Marine Board's Study on EEZ Information Needs, gave a brief overview of his committee's task, introduced the members, and gave an indication of the schedule of activities. The second day consisted of four panel discussions by expert practitioners in sea-floor mapping and information needs. Panel members were selected to represent a range of interests from the Federal, State, and local governments; academia; and the private sector. A case study approach was used to discuss individual activities. In keeping with the theme of the symposium, each talk focused upon Federal-State cooperative activities from the point of view of "users" of sea-floor data and information. A paper was requested of each panel member and is included in the symposium proceedings. Papers emphasize mapping accomplishments, needs for additional sea-floor data, and existing or planned coordination activities within a specific area.

Four case study panels were organized by geographical region of the EEZ—East Coast, the Gulf of Mexico, the West Coast and Alaska, and the Islands (Hawaiian, Puerto Rico, and Western Pacific). Topics included small-scale regional assessment projects, resource-evaluation mapping, high-resolution digital sidescan-sonar surveys, and geographical information systems (GIS).

THIRD DAY—TECHNICAL WORKSHOPS

On the final day of the symposium, six technical workshops were held, and each lasted about an hour. The workshops dealt with the following topics: NOAA Multibeam Data—Processing and Analysis; Applications of Computer Technology To Interpret Sonar Imagery and Multibeam Data; Leasing Considerations—Assessment and Evaluation Models; EEZ and Territorial Sea Mining Laws of the World; CD-ROM Tutorial and Demonstration; Management of Data; and Information—Computer Applications and GIS Development. Workshop descriptions are contained in Appendix 3. Following the workshops, there was a tour through the USGS's GIS Development Laboratory.

SYMPOSIUM RECOMMENDATIONS

Although the symposium covered a range of topics, the following principal findings and recommendations came from the symposium:

- Increased emphasis should be placed on surveying the nearshore; that is, within 12 nmi and shallower than 200 m water depth. Nearshore studies should include high-resolution bathymetric surveys, sediment sampling to determine basic sediment characteristics (grain size, engineering properties, geochemical characteristics, and so forth) for coastal zone planning, and resource (especially sand and gravel) assessment and characterization. Although it is unnecessary at the present time to conduct detailed surveys in the deeper waters and frontier regions of the EEZ, Federal and State nearshore waters do not have adequate maps for multiple user needs.
- Steps should be taken to establish standards for the collection and the distribution of digital sea-floor data, especially data collected from swath bathymetry and sidescan sonar instruments. That these steps should be taken was stated during many of the sessions, the question-and-answer period, and the exhibit and the poster discussions. Lifting of the restrictions on the distribution of NOAA's multibeam data has lead to a host of issues concerning the dissemination of digital bathymetric data. To make these various types of data useful to everyone, a common definition of data format should be established.
- Relations should be established with the Coastal States to coordinate mapping and surveying requirements and to facilitate exchange of data. It was suggested that the office within each State that houses the State Geologists could serve in this coordination capacity.
- There should be improved coordination between various Federal agencies (the USGS, NOAA, the EPA, the Department of Energy, the U.S. Army Corps of Engineers, and the NSF) regarding short (1-yr) and long-term coastal programs. It appeared that the various ongoing and planned activities in the coastal waters could benefit from closer cooperation.
- There should be additional sensors (gravity, magnetic, seismic reflection) carried aboard all ships operating in the EEZ. Survey and cruise plans should be widely circulated so that maximum use can be made of all ships surveying or transiting through the U.S. EEZ.
- A coordinated database management structure should be created to facilitate the inventory and the distribution of EEZ data for GIS applications. Because GIS is easily available, there is a growing need to make data readily available. One possible solution could be "focused" regional mapping centers, such as the one proposed at the University of Hawaii.

SUMMARY

The results of the 1989 symposium will serve as additional guidance for the direction of a national EEZ mapping and research program. Critical to the success of the program is knowledge of ongoing or planned activities between Federal and State governments in the coastal ocean of the United States. Information will be incorporated into the 10-yr plan being prepared by JOMAR. This plan will serve as a guidepost for subsequent activities, products, and research in the EEZ.

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Mapping Our Underwater Domain

John Knauss
National Oceanic and Atmospheric Administration

INTRODUCTION

Let me welcome you to the 1989 Exclusive Economic Zone (EEZ) Symposium on mapping the EEZ. I am looking forward to the results of this meeting to assist me in defining the direction of our mapping program for years to come. We have taken the mandate from the EEZ Proclamation seriously. We have heard from a number of national advisory boards and scientific committees in regard to the initial direction of our program. However, we continue to rely upon advice from meetings such as this to keep us on a steady course and to assure us that our surveys are responsive to national priorities and that our mapping products are delivered in a timely manner and in a useful form.

BACKGROUND AND HISTORY OF THE JOINT OFFICE FOR MAPPING AND RESEARCH

The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS) are joint sponsors of this effort of mapping the EEZ and have shared this responsibility since 1984. At that time, we negotiated a Memorandum of Understanding between the two agencies so as to exchange our mapping plans, data, and map products. Two years ago, our role was expanded on the advice of the National Advisory Committee on Oceans and Atmosphere to encompass the remainder of the user community—other Federal agencies, non-Federal (State governments, academic institutions) sector, and the commercial sector. At that time, the Department of Commerce and the Department of the Interior formalized our cooperation by signing a charter that established a joint office for mapping and research in the EEZ. The main objectives of this charter are

> ...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 the private sector involvement in the direction and use of EEZ-related data products.

I am pleased with our cooperative effort. It is going well, and I trust it will continue.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION-U.S. GEOLOGICAL SURVEY MAPPING ACTIVITIES

Although the USGS and NOAA have been heavily involved in surveying the EEZ since 1984, NOAA has had little to bring to the party until recently. We divided up the responsibility consistent with our mandates. NOAA was to do the detailed bathymetry by utilizing our survey ships that have multibeam mapping systems. The USGS, which has an interest in geological investigations, began by conducting sidescan-sonar surveys that utilized the GLORIA system. Concern over possible national security impacts was expressed by the U.S. Navy because of the quality of the high-resolution multibeam data and its potential use by an adversary. This resulted in a moratorium on the distribution of the maps and the data from NOAA's surveys. Meanwhile, the USGS continued to survey and release sidescan imagery data and maps showing spectacular ocean-floor morphology. Surveys off the West Coast of the United States identified over 100 previously unknown seamounts.

I am pleased to report that, after years of effort, the Navy (through the efforts of Admiral Richard Pittinger, who is the Oceanographer of the Navy) has lifted restrictions on the distribution of all but 3 percent of the sea floor in two small areas. NOAA approved the operational procedures on October 25, 1989. We are now prepared to expand our efforts accordingly.

NOAA's effort in multibeam mapping of the EEZ has been minimal. It has been difficult to generate resources or enthusiasm for a program whose future is under a classification cloud. However, we have surveyed about 3 percent of the sea floor and are gearing up to do a lot more.

THE MULTIBEAM MAPPING PROGRAM OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINSTRATION

The first map describes the sea floor near Monterey Canyon, Calif. This map, which was published at a scale of

1:100,000, shows extraordinary detail. I only wish that Fran Shepard (who taught me geology) could have lived long enough to see this chart and to follow the sinous path of Monterey Canyon and newly delineated tributaries. He, along with countless others, groped for years using poor echo sounders and limited navigation to understand these extraordinary features. It has only been in the last few years that we have had the technology to allow us to produce maps that virtually replicate the view one would visualize, if one were observing the ocean floor as if it were dry land.

As we anticipated, such charts have generated more questions than answers. We trust that they will prove to be useful tools for those interested in coastal geological processes and continental margin research. These maps provide baseline information for a continual research effort in the ocean.

NOAA has a long way to go. Surveying the 3.4 million nmi^2 of EEZ requires a continuous sustained effort. Now that we have a clear release from the Navy, we hope to increase our effort. Even with several survey ships, it will take many years to complete the work. Because the swath width of each survey line is proportional to the depth of the water, we need to investigate improvements in shallow-water swath systems to get increased mapping efficiency on the continental shelf.

My goal is to have a set of multibeam-generated charts of the EEZ that will compare with the wonderful Veatch and Smith charts of the old U.S. Coast and Geodetic Survey before World War II. This is a set of charts that has never been fully appreciated by this generation of geomorphologists. They were compiled by using accurate sonic depths and, more importantly, accurate navigation, radio buoys, wire line—all before radar and loran. This was a magnificent triumph of the state-of-the-art technology. What we are looking at today with NOAA's program is the next generation in the surveying of our coastal waters.

In the next 2 yr, we hope to publish about 40 multibeam charts that have detail similar to that of the Monterey Canyon chart, and we expect to develop a realistic schedule for charting and publication for the future.

COOPERATION WITH OTHERS

We are exploring ways to combine data from other ocean survey programs—the military surveys, the academic fleet, and the private sector. By using the Global Positioning System, the quality of navigation should no longer be a problem. We would like to generate multibeam-quality bathymetric charts by using many inputs of data. We need the help of many of you in this room to determine how to go about this.

I am also determined to find effective ways to make our data available to the academic and the industrial communities in digital form, perhaps on a CD-ROM, that will allow you to manipulate the data for your own uses. Beautiful charts like the one of Monterey Canyon continue to be useful for future study and aesthetically pleasing, but, as a researcher, I know that it is sometimes useful to get back into the basic sounding data. NOAA wants to make that data available to you in as timely a manner and as useful a form as possible. Again, we need your help and suggestions in this regard.

Our survey areas are not chosen at random. We initially concentrated on the Pacific Coast and the Gulf of Mexico for good economic reasons but, also, because of the spectacular geology. Our next series of charts, which are from the Gulf of Mexico, show depressions and swelling of the sea floor that will prove to be as interesting as those of the Monterey Canyon. However, since arriving here, I have examined a number of these multibeam-generated charts, and they all have exciting geology. I expect that that will be the case wherever we go. Because we cannot be everywhere at once, we are asking you to assist us in determining survey priorities.

SUMMARY AND CONCLUSIONS

Although this is an EEZ symposium dedicated primarily to the issues of charting and mapping the geology of the EEZ, I would like to say a few words about other aspects of EEZ studies and cooperation among Federal agencies.

There is very good cooperation between our agencies. One of the best examples is through the Committee on Earth Science (CES) under Alan Bromley, who is the President's science advisor. This committee is responsible for developing a long-term global change research program. It is an extraordinary effort to develop an integrated, comprehensive program across all agency lines; Dallas Peck chairs this committee. Many, including the Office of Management and Budget (OMB), did not believe that it was possible. There was, however, good support last year; hopefully, that support will continue.

The CES example is a possible blueprint for other programs. OMB is now looking at a "cross-cut" of all so-called coastal ocean programs, which may be expanded in the future.

There are some things that we cannot wait for the Federal bureaucracy to resolve—the Environmental Protection Agency (EPA) and NOAA coastal monitoring and pollution studies. I have met with William K. Reilly, who is the Administrator of the EPA, and have agreed to coordinate all our coastal programs with them. I am looking forward to similar agreements with the USGS, the National Aeronautics and Space Administration, the Department of Energy, and so forth.

There are more than enough problems to go around, and we must take advantage of the expertise each of us has. One goal of this symposium is to learn about, discuss, and understand the programs and the priorities of those active in the EEZ.

Many of us have different emphases and different priorities within the EEZ that range from "pure" science to regulatory matters. We must understand what and why we are doing activities for coordination and cooperation to be effective. I pledge to you that we in NOAA will do our part and are prepared to take the lead with the USGS in bringing together different groups that have different priorities.

Thank you.

Partnership-Stewardship—The Mission of the Department of the Interior

John Sayre
Department of the Interior

It is a pleasure to join Dr. Knauss and those attending from the National Oceanic and Atmospheric Administration (NOAA), as well as our distinguished guests from the Environmental Protection Agency, the Association of American State Geologists, Shell Development Company, and the National Research Council. And, of course, the people with whom I am most familiar from the Minerals Management Service (MMS), the Bureau of Mines, and the U.S. Geological Survey (USGS).

I am pleased to be able to represent the Secretary of the Interior, Manuel Lujan, at this important symposium. President Reagan's 1983 proclamation of the U.S. Exclusive Economic Zone (EEZ) was an exciting challenge to the Nation. This proclamation established the U.S. jurisdiction over minerals and other ocean resources in areas extending 200 nmi off our Nation's continental and island territory coasts—in effect, adding another frontier to the national domain, a frontier of over 3 million nmi^2. Not only is the EEZ an exciting frontier for scientific research, but it is an important economic frontier that scientific discovery can unlock. The EEZ holds important energy and mineral potential for the Nation. It is also essential for living resources of the marine realm, has aspects that affect our national security, and is important to recreational activities. Also, with heightened concern for the environment, the potential use of the EEZ as a possible means to help alleviate the waste-disposal problem must be viewed carefully to ensure that the quality of the ocean environment is not affected.

A particularly exciting aspect of the EEZ program, to myself and to Secretary Lujan, is that it touches on several of the Secretary's STEWARDSHIP (fig. 1) initiatives, endorsed by President Bush. The EEZ program encourages STEWARDSHIP by the promotion of partnerships with State and local governments and the territories; of interest in furthering the political, the economic, and the social development of our people; and of the wise management of our energy and mineral resources.

I am pleased to see that the Department of the Interior is such an active player in the EEZ; for example, the MMS is involved in Federal and State task forces that evaluate scientific information for the purposes of lease sales and development decisions; the Bureau of Mines has a Marine Mining Technology Center that contributes research in minerals information pertaining to the EEZ; and finally, the USGS has Federal-State cooperative studies in coastal regions and cooperative studies with State Geological Surveys. You will be hearing more about these bureau programs from subsequent speakers.

I am pleased with the progress made by the USGS-NOAA Joint Office for Mapping and Research since the charter was signed by the Departments of Commerce and Interior 2 yr ago. The USGS has completed sonar mapping of about 50 percent of the EEZ and has produced image maps of the sea floor that are comparable in clarity and detail to Landsat satellite photographs of land areas. NOAA has completed high-resolution bathymetric surveys of about 3 percent of the EEZ. This is an important partnership, and, during this symposium, you will have the opportunity to see exciting results and products prepared by the joint office.

The importance of a continued partnership cannot be overstated. Mapping and research activities in the EEZ are critical to our ability to identify resources, to evaluate and preserve the quality of the environment, and to determine multiple-use needs and priorities. This can be accomplished only through a combined program by Federal and State agencies, industry, and universities.

Again, I would like to emphasize the importance the Department places on symposia such as this. Thank you for the opportunity to be here. I am looking forward to an exciting symposium and wish you well in your endeavor.

STEWARDSHIP OF AMERICA'S PUBLIC LANDS AND NATURAL RESOURCES

President George Bush and Interior Secretary Manuel Lujan, Jr. agreed to the following 10–point agenda. The first letters of the agenda items form the acronym that is the overarching theme of this Administration's program— STEWARDSHIP.

STEWARDSHIP: We will be good stewards, conserving and wisely managing our national resources of limitless beauty and value.

TERRITORIES: We will work with the leadership of the Territories and Freely Associated States to further the political, economic, and social development of their peoples.

EDUCATION: We will place a high priority on the important role of education in ensuring the public's knowledge, appreciation, and support of our natural resource policies. We will use Departmental resources to help develop the Administration's long–range plan to reform, rejuvenate, and revitalize our education system for the benefit of all Americans.

WAR ON DRUGS: We will be aggressive soldiers in the Nation's war on drugs. We will take all appropriate measures to: (1) increase cooperative efforts with State and local law enforcement officials to eradicate illegal crops and to interdict the sale and transportation of drugs on public lands; (2) provide a drug–free workplace; and (3) encourage treatment for drug users.

AMERICA THE BEAUTIFUL: We will implement President Bush's "America the Beautiful" concept to strengthen and preserve our National Parks, National Wildlife Refuges, and Wilderness Areas.

RESPONSIBLE, EFFICIENT, AND ETHICAL MANAGEMENT: We will manage the Department in a fiscally responsible, efficient, and ethical manner, with a high priority placed on equal opportunity.

DOMESTIC RESOURCES: We will manage the multiple–use Federal lands and waters to provide the widest range of benefits from these domestic resources to the American people, including preservation, recreation, energy, minerals, water supply, food, and fiber.

SCIENCE AND TECHNOLOGY: We will aggressively apply the Department's unique scientific and technological resources to the solution of national and international problems such as water and air quality, global climate change, acid rain, and biodiversity.

HARMONY: We will strive to bring a spirit of harmony to our public policy discussions through consultation, cooperation, and coordination instead of confrontation among competing interests, consistent with President Bush's call for a "kinder, gentler Nation."

INDIAN TRIBES AND ALASKA NATIVE GROUPS: We are committed to making the ideals of Native American self–government and self–determination a reality. We will work with Native Americans to promote economic development, improved educational opportunities, and other measures to enhance their quality of life.

PARTNERSHIPS: We will promote partnerships with State and local governments, individuals, and public and private groups at all levels, as well as utilize President Bush's "thousand points of light" — the varied, voluntary, and unique organizations within our Nation of communities.

Figure 1. The 10-point agenda for STEWARDSHIP of America's public lands and natural resources.

The Role of the State Geological Surveys

Kenneth N. Weaver
Maryland Geological Survey

INTRODUCTION

I am pleased that the theme for the symposium is "Federal-State Partners in EEZ Mapping," and the Association of American State Geologists deems it a privilege to be one of the sponsors.

In this paper, I would like to address, in general terms, the State's role in Exclusive Economic Zone (EEZ) mapping, then to present some background on the State Geological Surveys' programs and mission and, finally, to discuss my perception of the State Surveys' role in the EEZ.

THE STATES' ROLE

The Coastal States have a large stake in the EEZ Program even though most of the people living in the Coastal States have never heard of the EEZ. Yet, the program for mapping and establishing a database for the EEZ will have a profound effect upon how we plan for and use the coastal and the offshore resources of this Nation over the next several generations. It is an oft-reported statistic that over 50 percent of the Nation's population lives within 50 mi of the ocean, and, by 2000, this figure could go as high as 75 percent. People living in this area have put a high priority on marine-related activities, such as fishing, swimming, and boating. Moreover, they are increasingly aware of the threats to these activities due to oil spills, sewage sludge, and garbage dumping on the Continental Shelf; hypodermic needles along the Nation's shorelines; declining fish populations; the disappearance of beaches that results from shore erosion; and the dying off of aquatic grasses due to over fertilization from land runoff and treated sewage. Thus, the public perceives that environmental conditions are not getting any better. There also appears to be a broad-ranging distrust that government, at any level, can do a great deal to correct the situation.

The resource-extraction industry, including hard minerals and oil and gas, also has an image problem in many areas of the United States because of perceived or real threats to the environment. This situation will undoubtedly be exacerbated by the increasing number of resource-extraction proposals for the offshore environment.

Why is this discussion important when we are basically talking about technical issues revolving around mapping the EEZ? I believe it is of the utmost importance to recognize the situation in which we will be operating. Scientific investigations of the EEZ should not be conducted in a vacuum. We should ask ourselves, "Will these studies give the public greater assurance that marine mining, oil and gas exploration and production, dredging operations, and waste disposal can be done with minimal effect on the environment?" This is an area in which I believe the States can play an important role in translating public concerns into appropriate scientific inquiries and also in relating the results of those scientific inquiries to the public as a feedback mechanism. Only by having a good communication network can we hope to accomplish the tasks set before us in the EEZ.

Building a database for the EEZ should take into consideration the data needs of the States. What kinds of problems do the States have that can be addressed by applied research on the part of the States, the Federal Government, and industry? Two problems that face Coastal States are diminishing supplies of sand and gravel from land sources and the need for beach replenishment to manage the continuing process of erosion. We can look to the EEZ for the potential solution to both of these problems. States are interested in mapping the nearshore ocean and estuaries as well as getting a handle on the resources in and below the seabed. It would be fair to say, however, that a State's interest in the EEZ is inversely proportional to its distance from shore.

BACKGROUND ON STATE GEOLOGICAL SURVEYS

Some of the State surveys came into existence less than 50 yr after the Nation was founded, and 30 surveys had been in existence by the time the U.S. Geological Survey (USGS) was established in 1879. The major missions of early survey work were mineral-resource investigations and geological mapping.

The State surveys, in general, have experienced a healthy growth over the past several decades, and, today, an agency dealing in State geological research is located in each of the 50 States. The aggregate of all 50 State Geological Survey budgets is $125 million, about 90 percent of which is applied to research, data compilation, and resource analysis.

A number of institutional arrangements exist. About one-third of the surveys are affiliated in some way with a State university, and the remaining two-thirds are affiliated with natural resources or environmental departments or another State entity.

The mission of the State Geological Surveys has been constant from their early beginnings. In most States, the mission includes geologic mapping, application of geology to environmental problems, mineral-resource studies, production of maps to meet special needs, cooperation with Federal geological and resource agencies, and generally acting as a geological and mineral-resources advisor to the executive departments of State governments. In addition, some State Geological Surveys are responsible for hydrogeological investigations, regulatory operations governing oil and gas exploration, water well drilling, and mineral exploration. Coastal State Geological Surveys (including the Great Lakes States) are becoming increasingly involved in the study of their coastal margins. These studies are focused on such geological processes as coastal flooding and shore erosion. Other studies are concerned with evaluating resources that may be available from shallow and deep formations, such as heavy minerals, sand and gravel, and oil and gas.

ROLE OF THE STATE GEOLOGICAL SURVEYS

The question before this symposium is, how may the State Geological Surveys help in the mapping and the resource appraisal of the EEZ? As an example, the Coastal State Surveys are already participating in the Continental Margins Program of the Minerals Management Service (MMS), which was developed in cooperation with the Continental Margins Committee of the Association of American State Geologists and is managed through the University of Texas. The studies constituting this program can be characterized as either shallow or deep framework investigation. The shallow framework studies address the possibility of heavy minerals and aggregates in the nearshore environment by investigating their occurrence, provenance, abundance, geologic setting, and framework. Most of the 21 State studies in some way address this topic. The deep framework studies examine the structure, the stratigraphy, the sedimentology, and the geophysics of the deep subsurface relative to the occurrence or potential occurrence of hydrocarbons. Only three State studies have concentrated on the deep framework studies.

All the Coastal State Geological Surveys have participated in the MMS Continental Margins Program. Perhaps one of the best features of this program is its ongoing nature. It is now in its sixth year, and the funding has been continuous for those States submitting proposals over that period of time.

Although the amount of funding per State is modest, the fact that funding could be depended upon means that the State Geological Surveys can maintain an active program in continental margin investigations. States have profited from the increased database generated by the studies but, perhaps more importantly, now have a better trained cadre to deal with offshore studies. The USGS, over the past several years, has been carrying out field investigations on the geologic processes associated with shore erosion on the barrier islands of Louisiana and high lake levels in Illinois and Indiana. A new study on erosion and pollution is just getting underway in Mississippi and Alabama. All these studies are being carried out in cooperation with the State Geological Surveys in the respective States.

Because of the success of these studies and the general awareness of the loss of coastal land resources, the USGS, at the direction of Congress, is preparing a plan to implement a national Coastal Geology Program. This plan will have input from State agencies, particularly the Coastal State Geological Surveys. The State Surveys welcome this new initiative and will work actively toward its implementation. We believe that the plan should provide the opportunity for close cooperative investigations by the USGS and the State Surveys.

Another type of cooperation between Federal and State agencies is already in place. At least five MMS-State Task Forces have been established to examine the potential for mineral leasing. These are Hawaii, cobalt-manganese crusts; Oregon and California, polymetallic sulfides; Georgia, heavy minerals; North Carolina, phosphates; and the Gulf Coast States, heavy minerals and aggregates.

Another model for cooperation between the States and the Federal Government has been the informal cooperation between two or more scientists from State and Federal agencies interested in the same subjects or problems. Such a model was used in working out the Quaternary geology of the Chesapeake Bay. The results were published in the Miscellaneous Field Studies series of the USGS under the joint authorship of geologists from the USGS, the Maryland Geological Survey, and the Virginia Institute of Marine Science.

Thus, the State Geological Surveys are already involved in the geological/geophysical/geochemical mapping of the resources and the nearshore environment of the coastal areas. What do the States perceive as future needs in furthering this effort?

- Studies on diagenetic processes operating within nearshore marine and estuarine sediments because these sediments provide important pathways for nutrient burial and regeneration. Another area of concern is toxics in the estuarine waters and sediments.

- Systematic studies of shore erosion and wetland loss on the barrier islands along the Atlantic and the Gulf Coasts. Many site-specific studies have been carried out, and a large database has been developed on historical erosion rates, but we need more process-oriented studies.
- Studies of offshore sources of sand and aggregate resources. In many coastal areas, available aggregate supplies have been depleted either by mining or by preemption by other land uses in the rapidly developing coastal areas. Coastal beaches in many locations are being stabilized by beach replenishment. New supplies of these resources will probably come from the EEZ.
- Sophisticated instrumentation and methods in geophysics and geochemistry. We need modern high-resolution bathymetric surveys of nearshore areas. In some areas of the Chesapeake Bay, for example, the survey data on which the charts are based are as much as 100 yr old.

SUMMARY

In summary, I believe the State Geological Surveys are well positioned to join in a Federal-State partnership for the mapping of the EEZ. The Coastal States understand the problems that they face concerning the EEZ. They are perhaps better prepared in terms of manpower and equipment than ever before, and, I believe, they eagerly look forward to the challenges arising from this monumental task.

The Coastal Ocean Program of the National Oceanic and Atmospheric Administration

Donald Scavia
National Oceanic and Atmospheric Adminstration

Our coastal oceans have been victim to a continual onslaught of problems—from wetland loss and coastal over-development to contaminated seafood and beach closures. In 1989 alone, we witnessed a number of devastating events, including the *Exxon Valdez* oil spill, Hurricane Hugo, record-low oyster harvests from the Chesapeake Bay, and destruction of a coral reef by a grounded ship. We can improve our abilities to predict and deal with these events.

The National Oceanic and Atmospheric Administration (NOAA), the "Earth systems" agency, has the scientific expertise, the mandate, and the resources to accomplish these goals. The Coastal Ocean Program combines all NOAA's components to develop and implement agency-wide programs to help the Nation solve immediate crises and to avoid or reduce future problems. Three critical improvements that form the core of the Coastal Ocean Program are as follows:

- Predictions of coastal ocean pollution and degradation,
- Conservation and management of living marine resources, and
- Protection of life and property in coastal areas.

The Program focuses NOAA's efforts in five critical areas—nutrient overenrichment, estuarine habitats, coastal fishery ecosystems, toxic chemical contamination, and physical impacts.

Nutrient overenrichment efforts will help us understand and predict the effects on coastal water quality and its living marine resources.

Nutrient overenrichment is caused by the accumulation of algae-producing materials, such as nitrogen and phosphorus, in our Nation's water bodies. This can result from natural processes or human-induced changes. The accumulation of excessive algae reduces the oxygen needed to sustain fish and other organisms in the marine food chain and can have negative effects on recreational and commercial fisheries. Excess plant materials can make our beaches and coastal waters unattractive and unfit for use and may play an important role in global climate change.

In fiscal year 1990, NOAA will examine the effects that human-induced nutrient enrichment has on the productivity and the water quality of the Mississippi River plume and the adjacent Louisiana continental shelf. NOAA will also study the impact nutrient overenrichment has on global climate change.

NOAA will focus fiscal year 1991 efforts in the following three specific areas:

- Continue nutrient research in the Mississippi River plume and the Louisiana continental shelf and expand efforts into the Southeast Atlantic Bight.
- Conduct a nationwide assessment of the severity of nutrient overenrichment problems in U.S. coastal and estuarine waters through its National Status and Trends Program. On the basis of this assessment, NOAA will initiate a program to monitor conditions associated with nutrient overenrichment in areas that have substantial problems.
- Study the atmospheric transport of nutrients into our coastal waters and develop strategies to confront this problem. Research suggests that significant amounts of nutrients are carried through the atmosphere and that prevailing wind patterns make the Atlantic Coast particularly vulnerable.

Estuarine habitat will be studied to ascertain the effects that environmental change has on the quality of estuarine habitats and on the living resources they support.

Estuaries are critical components of our marine environment. The 92 estuaries in the United States provide the foundation for productive coastal waters and are host to many recreational and commercial activities. In fact, two-thirds of commercially valuable fish depend on estuaries during some part of their life. Estuaries are extremely vulnerable to human activities. Nutrient overenrichment, pollution, overdevelopment, and erosion threaten the well-being of our estuaries.

To contribute to President Bush's goal of "no net wetlands loss," NOAA will initiate CoastWatch-land in fiscal year 1990 to inventory and analyze wetland habitats in the Chesapeake Bay. This will greatly improve our ability to monitor changes in coastal wetlands and to develop strategies to protect them.

NOAA will focus research efforts on seagrass and tidal wetland habitats because of their vulnerability to declining environmental quality and their wide distribution along the Nation's coast. NOAA will examine how these habitats function and support marine life; special attention will be focused on the effects that nutrient-enhanced productivity, diversion of fresh water flows, and wetland habitat loss have on the productivity and the health of estuarine species.

NOAA's efforts in fiscal year 1991 will focus in the following three areas:

- Expand CoastWatch-land by mapping wetlands in other regions and extending its seagrass mapping activities to North Carolina, Florida, and Texas. Mapping an area every 2 to 5 yr allows coastal resource managers to assess the conditions of the habitats to see if they are impacted by erosion, pollution, or development.
- Continue research on seagrass and tidal wetland habitats and begin research on mangrove swamps. Not enough is known about these habitats, which are rapidly disappearing due to human intervention.
- Develop models to predict the effect that large and small incremental changes have on coastal habitats and their living marine resources and evaluate current techniques for wetland restoration.

Coastal fishery ecosystem efforts will develop more accurate and effective models by taking into account natural changes in the ocean environment. This will help resource managers develop more effective fishery management plans.

In recent years, the demand for seafood has risen dramatically; however, no major new fisheries are available for development. Therefore, effective management plans, which are based on models that take into account natural variability are critical. Human activities and natural changes in the coastal ocean environment affect the dynamics and the populations of fisheries. These must be recognized as we develop more accurate and efficient fisheries management plans.

NOAA's fiscal year 1991 efforts will focus in the following two areas:

- Expand research into specific key fisheries ecosystems and focus on understanding the difference between the influences of nature and society on the success of important fish species and
- Develop CoastWatch-land for the West Coast to help detect, monitor, and evaluate the impact unusual environmental events (for example, El Niño and red tides) have on the Pacific Coast. CoastWatch-land uses remote sensing to provide decisionmakers with up-to-date environmental information on unusual environmental events.

Toxic chemical contamination efforts will help us understand the sources and the effects of toxic chemical contaminants entering coastal and estuarine waters as a result of human activities and will help resource managers, at all levels, develop strategies to respond to the problems these contaminants cause.

Society continues to add an alarming amount of toxic chemical contaminants to our coastal waters and estuaries. These damage living marine resources, threaten the economic viability of coastal waters, and endanger human health.

NOAA's National Status and Trends (NS&T) Program collects and maintains data to determine the status and to detect the changes in the level of toxic contaminants in coastal and estuarine waters. NOAA currently monitors concentrations of toxic chemicals in fish, shellfish, and sediments at 250 sites nationwide. In fiscal year 1990, NOAA will expand the NS&T Progam to study the effects contaminants have on living resources in our coastal waters and estuaries. NOAA also will study two highly contaminated areas, Tampa Bay and the Hudson-Raritan Estuary, to understand the effects contaminants have on estuary productivity and quality.

In fiscal year 1991, NOAA will continue efforts to define toxic chemical contaminant problems, to develop models to predict future events, and to provide options for resource managers to deal with problems. NOAA also will continue detailed assessments of highly contaminated areas and provide decisionmakers with information so they can implement effective plans to safeguard important living marine resources.

Physical impact efforts will improve our understanding of natural physical impacts, such as tsunami and hurricane flooding, and reduce hazards to coastal resources and populations.

These natural physical impacts cause hundreds of deaths and millions of dollars worth of property damage each year. NOAA's efforts will provide the data and research we need to understand and predict the impacts of severe events and to develop preventive measures.

In fiscal year 1991, NOAA will continue to develop more reliable predictions of the impacts of tsunami and storm surge inundation to lessen hazards to U.S. coastal resources and populations. Specifically, NOAA will upgrade the tsunami measurement system in Alaska and accelerate efforts to predict the hurricane flooding of vulnerable U.S. coastal locations.

COMMON PROGRAMS

Much of the research and the assessments needed to address these problems rely on similar sets of basic ocean observations. To meet this need, NOAA will enhance its coastal ocean observation network of buoys, ships, and other platforms. They also will develop an improved capability to acquire and disperse rapidly remotely sensed observations.

In fiscal years 1990 and 1991, NOAA also will expand CoastWatch-water to other regions in the United States, including the Great Lakes, the Gulf of Mexico, and the West Coast. CoastWatch-water programs now operate off the southeastern U.S. coast and in the Chesapeake Bay and provide analysis of satellite imagery to help anticipate and track unusual environmental events.

GETTING THE INFORMATION TO THE RIGHT PEOPLE

The data, the information, and the models that NOAA's Coastal Ocean Program is designed to produce are of little value unless we can get this information into the hands of scientists and the decisionmakers who must make critical judgments concerning our coastal oceans. Effective communication and data transfer systems help generate new information and understanding and are a critical component in solving coastal ocean problems. In fiscal years 1990 and 1991, NOAA will improve its existing communication and information transfer network.

NOAA's user-friendly computer system, the Coastal Ocean Management, Planning, and Assessment System (COMPAS), was designed for coastal resource managers to access data on rapidly changing coastal resources and to develop management strategies to safeguard important coastal resources. In fiscal year 1990, NOAA will work closely with State and local decisionmakers to demonstrate and evaluate COMPAS in Texas; additional States will be included in fiscal year 1991.

NOAA's Ocean Communication Network (NOCN, or "Notion") provides rapid communication and data transfer capabilities throughout selected NOAA facilities in the Untied States. NOCN will be expanded in fical year 1990 by upgrading telecommunications at the Beaufort, N.C., fisheries laboratory and by adding telecommunication capabilities at three new sites—the fisheries laboratory in Narragansett, R.I., and the Environmental Research Laboratories in Seattle, Wash., and Ann Arbor, Mich. NOAA will continue regional expansion and system upgrades in fiscal year 1991.

NOAA's Interactive Marine Analysis and Forecast System is a user-friendly, desktop computer that integrates analysis, display, data management, and communications capabilities for research and operations. NOAA will continue to enhance the program in fiscal years 1990 and 1991 and will make it available to more fisheries scientists, oceanographers, and meteorologists.

NOAA's Coastal Ocean Program sets the course for the Nation to solve the environmental problems confronting our coastal oceans and enables us to preserve and enhance our valuable coastal resources, to prepare for future challenges, and to ensure continued economic growth. Protecting the environment *is* good business!

The Marine Minerals Technology Center of the Department of the Interior

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SUMMARY

The Marine Minerals Technology Center (MMTC) was established by Congress in 1988 as a national research center within the Department of the Interior to be administered by the U.S. Bureau of Mines. The primary objective of the MMTC is to provide focus and guidance for the development of the marine mineral resources of the United States balanced with the protection and the conservation of the environment. As a national research center, the MMTC brings together leading scientists and engineers in marine minerals and ocean mining, thus linking universities, research institutions, and industry. The MMTC also functions as a training center and an information and reference center, particularly for the transfer of technological developments to industry. The two center divisions of the MMTC are the Continental Shelf Division (CSD) at the University of Mississippi and the Ocean Basins Division (OBD) at the University of Hawaii.

OPERATIONAL FACILITIES

The MMTC is administered from offices on the University of Mississippi campus; operations of the CSD centered in Biloxi, Miss. The CSD facilities include a machine shop, an office, and the Research Vessel *Kit Jones*, which is a 61-ft wood-hull vessel that is well-suited for the testing of sampling and surveying systems and for in-house and cooperative research and exploration programs. The OBD centers its operations around Look Laboratory at the University of Hawaii, where office space, machine shops, and small coastal craft are available. The Open Ocean Test Range and the Vertical Test Tank at Look Laboratory are under consideration for rehabilitation and improvement.

FUNDED RESEARCH PROJECTS

Qualified researchers submit proposals on an annual basis to be reviewed and selected by the MMTC and its Research Advisory Council. Current CSD research projects include the following:

- An Advanced Design for a Seafloor Gamma Measurement Data Collection System,
- Coastal and Marine Depositional Models for Aggregate and Heavy Mineral Exploration in the Northern Gulf of Mexico,
- Assessment of Sand Resources of Heald and Sabine Banks, Texas Exclusive Economic Zone,
- An Investigation of Potential Titanium and Zirconium-Bearing Placer Deposits Offshore Oregon, and
- Evaluation and Development of Geostatistical Methods for Marine Placer Exploration.

Current OBD research projects include the following:

- Development of a Free-Fall Seafloor Hard Substrate Corer,
- The Microtopography of Manganese Crust Deposits,
- Evaluation of the Cobalt Crust Continuum on Seamounts in the EEZ of Hawaii,
- Economics of Marine Polymetallic Sulfide Resources,
- Acquisition of a Graphite Furnace Atomic Absorption Spectrometer, and
- Computer Aided Design Methodology for Power, Communication, and Strength Umbilicals.

INDUSTRY AFFILIATIONS

The MMTC maintains active ties with industry and focuses many of its activities on current and projected industrial needs. In industry-cooperative research programs, the MMTC generally contributes personnel for the design, the construction, and the testing of new technology, and industry provides the majority of supplies, materials, and travel expenses. Because the resulting technology remains in the public domain, it is available to other researchers and to industries that have similar needs.

In a cooperative program with Western Gold Exploration and Mining Company (West Gold), the MMTC was asked to develop a mobile reconnaissance drill for use in the exploration of gold placer deposits offshore Nome, Alaska.

West Gold needed a drill that could be rapidly deployed from relatively small vessels and that would be capable of inexpensively sampling the variable sediments of the Alaskan Coast. To meet these needs, the MMTC constructed the Remote Placer Drill (RPD), which is a counter-flush drill system that combines a vibralift drill design with a pneumatic rock drill.

Because the initial results from the testing of the RPD were encouraging, West Gold sponsored the design, the construction, and the testing of a more advanced version that could be used for production drilling. The RPD II, which incorporates a hydraulic drill motor and drill feed, has a deeper drilling capacity and is of a sturdier design than the prototype pneumatically operated RPD. Testing of the new production version of the RPD II offshore Nome was completed in August and September 1989; the results were quite favorable. The hydraulic drill motor and constant drill feed system proved very effective, and the RPD II averaged an impressive rate of one 6-m hole per 30 min, transition positioning on close centers at a 1-m sampling interval. The MMTC will continue testing and modifying the RPD's in future in-house and cooperative projects.

Also at the request of industry, the MMTC has designed a series of prototype dredge systems capable of mining placer and (or) gravel deposits in light ice and rough sea conditions. One continuous bucket dragline design incorporates the flexibility of a dragline system with the efficiency of a continuous bucket line ladder dredge but without the limitations of the ladder. This system would be suitable for mounting on a low-profile surface platform for increased stability in rough seas or light ice. The continuous bucket dragline dredge also would be capable of working beyond the depth limits of a traditional bucket ladder system (approximately 15 m) and would have significant capital and operating cost advantages in conventional mining applications.

The MMTC plans to design and construct a prototype continuous bucket dragline dredge system in a cooperative venture with Miller Construction Company. Contingent upon the financial ability of the MMTC to assemble the prototype model, Miller Construction will provide a barge, a powerplant, and a drive system for the dredge and will test the prototype system in working deep gravels of the Mississippi River. Although the prototype dredge will be designed for working deep-river gravels, the concept also will be adaptable to rough offshore conditions. After some modification, the system could be mounted on an ice-belted barge that could be maneuvered in light sea ice, thus making the concept attractive for a variety of environments.

Negotiations with the Ocean Minerals Company (OMCO) have resulted in the acquisition by the MMTC of the entire set of reports and computer files produced by the OMCO Exploration Group. OMCO is one of the four U.S.-based consortia to have a claim, under U.S. law, to extensive deposits of deep-seabed manganese nodules in the Clarion-Clipperton Zone of the northeastern Pacific Ocean. The MMTC will archive these data and make them selectively available through publication, which will not compromise OMCO's proprietary interest.

COOPERATIVE RESEARCH PROGRAMS

MMTC cooperative research programs are the basis for networking efforts that encourage government agencies, academic institutions, and industry to work together toward common research purposes. Groups conducting similar or complimentary research are coordinated, and their interaction is frequently supported through MMTC contributions of technical expertise, shipboard time, and sampling and surveying systems. These cooperative programs promote technology transfer and help minimize the unnecessary and often costly duplication of research efforts.

One such cooperative research project with the Ocean Science Directorate of Naval Oceanographic and Atmospheric Research Laboratory involved a field test of the Remote Acoustic Sediment Classifier System in May 1989. This computerized, single-frequency system is capable of making remote and rapid determinations of a number of physical and acoustic properties of surface and nearsurface sediments. The system has a number of applications for rapid and remote seabed sampling and excellent potential for environmental assessment.

In a 1989 Minerals Management Service (MMS)-Georgia Task Force project in the nearshore waters of the Georgia coast, the MMTC worked in conjunction with Georgia State University and the Center for Applied Isotope Studies at the University of Georgia. This project, which was cosponsored by the Georgia Geological Survey and the MMS, had a twofold objective—to run a series of high-resolution seismic profiles between the Department of the Navy's Tactical Aircrew Combat Training System offshore platforms that would provide a regional stratigraphic framework for the phosphate-bearing Miocene deposits and to conduct a series of site-specific studies in targeted areas of the Georgia Continental Chelf that would determine the presence of heavy minerals, phosphorite, sand, and gravel.

In response to continued partial MMS funding, the MMTC will conduct a bulk sampling program in summer 1990 at promising sites identified in the 1989 survey. The RPD, which has been modified for use as a miniborehole miner, will be used in an attempt to recover 1 to 2 tons of phosphorite matrix material. If successful, then the recovered bulk material will be delivered to the Bureau of Mines' Salt Lake City facility for processing studies.

In an effort to delineate the placer potential near Cape Prince of Wales, Alaska, a 1990 cooperative project with the Bureau of Mines-Fairbanks will involve drilling a series of holes through the ice by using a percussion-waterlift drill system. MMTC will design and construct the drill system, which will be a slightly modified version of one previously constructed for the DuPont Corporation. Decisions concerning further project plans will be based upon the outcome of this preliminary drill sampling investigation, although a geophysical survey and a more extensive drilling program are expected to follow.

The MMTC also plans to join the Center for Cold Ocean Resources Engineering (C-CORE) in a cooperative project to develop an offshore Induced Polarization (IP)/Resistivity System. C-CORE has obtained funding to construct this system, which will be completed by October 1990. Field testing aboard the Research Vessel *Kit Jones* is slated for several Mississippi Sound sites for which ground truth data is presently available. The goal of this testing will be to integrate the IP/Resistivity System data with data taken during the comprehensive MMTC geophysical and drill sampling survey scheduled for summer 1990.

IN-HOUSE RESEARCH PROJECTS

Programs of in-house research include resource characterization studies and the technological development of new and modified systems in minerals exploration. The development of a number of sampling, surveying, and mining systems are initiated in-house, but applications are frequently extended to various cooperative and industry programs.

The MMTC seismic systems are developed in-house and are used to conduct in-house research and to provide cooperative support to industry, academia, and government agencies. Basic components include a highly portable Datasonics "bubble pulser," a factory reconditioned Teledyne spark gap, a Del Norte analog signal processor, a Teledyne minispark array, an EG&G uniboom transducer, and an EPC thermal recorder. Recent acquisitions include a 386/20 PC system that has a 60-megabyte internal tape backup unit, a 16-bit analog/digital converter capable of direct-memory access, a high-fidelity stereo videocassette recorder, a data-acquisition software package, and a data-processing software package. These items will be used in the in-house development of a PC-based system that will permit the conversion of analog seismic data resolution by expanding processing capabilities. Data will be archived in a convenient format available for accurate reproduction.

Other in-house projects involve deposit assessment and characterization studies. In addition to the projects in Alaska and Georgia, the CSD is conducting a sampling and geophysical survey in the Mississippi Sound, and the OBD and the CSD are conducting a major joint in-house program, "Sand for Hawaiian Beaches." This project will investigate the viability of using offshore sand deposits to replenish the beaches on the island of Oahu in Hawaii. This research will involve preliminary offshore deposit characterizations, first-order environmental impact assessments, and the design of preventative technology.

EDUCATION, TRAINING, AND TECHNOLOGY TRANSFER

The MMTC supports a number of graduate students each year on a full-time basis, thus introducing them to professional levels of research, possibly leading to meaningful thesis or dissertation topics, and often providing hands-on training during the data collection phases of specific projects. Both divisions of the MMTC maintain reference centers that are available to students and professionals in the fields of marine minerals and ocean mining. In addition to direct support for education and training, the CSD is active in the primary forums for marine minerals research activities. The MMTC provides support funding for the International Marine Minerals Society and the Underwater Mining Institute and presents technological developments at a number of conferences and meetings each year.

Our Seabed Frontier—Challenges and Choices

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PREFACE

The following is primarily derived from the executive summary of the report *Our Seabed Frontier—Challenges and Choices* by the Committee on Seabed Utilization in the Exclusive Economic Zone (EEZ) of the Marine Board, Commission on Engineering and Technical Systems, National Research Council. The report was published in November 1989 (Library of Congress Catalog Card Number 89–63099) and is available from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418; telephone (202) 334–3313.

INTRODUCTION

The establishment of the U.S. EEZ by Presidential proclamation in 1983 "for the purpose of exploring, exploiting, conserving and managing natural resources" presents the Nation with an opportunity and a challenge to wisely use its divers resources. In addition to living resources, such as fisheries, this vast region (over 3.4 million nmi^2) contains extensive and potentially valuable mineral and energy resources and is used for many other purposes, such as waste disposal, pipelines, cables, and military uses.

The opportunities for resource recovery and other uses carry with them the challenge of determining the most appropriate development and management policies for such an extensive and complex area. A prerequisite to formulating adequate policies for managing this region in the Nation's best interest over the long-term is a comprehensive understanding of the region's sediments and seabed processes. Understanding these processes will depend on a variety of data-gathering systems and techniques. Finally, all potential uses of the region need to be determined, along with the environmental effects of these uses on the ocean's environmental systems.

The ocean's resources are relatively untapped. The role of the oceans in transportation, communications, and disposal of waste; as a source of food, energy, and mineral resources; and as an aesthetic and recreational asset is likely to increase worldwide under the pressures of demographic and economic growth. This study focused on the present and the future uses for the seabed of the U.S. EEZ; its objective is to stimulate the efficient and environmentally sound utilization of the resources.

The utilization of the EEZ presents a variety of technological challenges. Much of the future development will be dependent on having the necessary tools to survey, map, probe, sample, and monitor the seabed. Improved technology also will be needed for most of the actual uses—whether to mine and process minerals, to bury cables and pipelines, or to dispose of waste. A carefully conceived and coordinated plan for EEZ development will assure that the United States will retain its leadership role in offshore technology for scientific research, resource recovery, and other long-term activities while minimizing degradation of the environment.

The EEZ is a national resource of unprecedented dimensions. What we do in the U.S. EEZ over the next 10 to 30 yr will have long-range economic and environmental implications not only for our Nation, but for significant areas of the globe. It is clear that all future uses of the EEZ must take into account possible negative ecological impacts and, therefore, manage this area in the best interests of present and future generations.

SEABED CHARACTERISTICS AND GENERAL NEEDS

This study assessed the state of knowledge of the seabed as related to future activities within the U.S. EEZ and concluded that all projected industrial, commercial, public, and military development prospects will require expansion of basic and applied data about the characteristics and processes in the ocean environment and on the seabed.

In terms of geologic settings and oceanographic conditions and processes, the frontier deepwater and Arctic areas of the EEZ are especially complex compared to areas where previous development activities have been conducted. Expanded utilization of these regions must be based on a thorough understanding of seabed characteristics and processes at prospective sites and the likely consequences to the environment of each use.

The seabed regimes within the U.S. EEZ are composed of virtually all types of ocean seabed features and processes. The diversity of conditions, together with the remoteness of the seabed, creates a very complex and challenging environment. A multidisciplinary approach is necessary to understand natural seabed processes in frontier areas, to increase our knowledge about the genesis of ore bodies, and to monitor the impacts of human activities.

In this study, the major present and potential uses of the EEZ seabed, the technical and the nontechnical constraints to their development, and their likely impact on the seabed environment were identified. Information and technology needs for each use are assessed in terms of achieving the most efficient use of existing research and technology development. Information needs for monitoring the effects of present and planned activities on the marine environment and ecosystem also are determined. Also considered were the problems associated with managing the large amounts of data gathered on the EEZ seabed and preliminary recommendations for ensuring the broadest accessibility and dissemination of data by all users.

Management structures are proposed for planning and coordinating research and development activities in the EEZ and for resolving potential conflicts among future seabed uses. An evaluation was made of existing Federal policy and regulatory frameworks with respect to their role in limiting or encouraging expanded use of the EEZ seabed.

USES AND RELATED ISSUES

Oil and Gas Resources

In terms of strategic importance and economic value, the exploration for and production of offshore oil and gas resources will remain the most important economic activities in the U.S. EEZ into the next century. Currently, about 12 percent of total crude oil production and 25 percent of total gas production is produced offshore; it is estimated that U.S. dependence on these resources will continue to increase each year as land reserves decline. Although current technology is adequate to develop nearshore oil and gas resources, many technical constraints face the offshore oil and gas industry as it moves farther onto the continental slope and into unexplored Arctic regions. The environmental hazards of operating in deep and ice-infested waters are considerably greater, and overcoming them will be far more costly than previous offshore oil and gas development operations.

Development of these areas will be affected not only by technical progress, but also by nontechnical factors, such as fluctuating world oil prices, the impact of unstable political regimes in oil-producing countries, and a domestic regulatory climate subject to public pressure to protect offshore lease areas. Equally significant will be the extent to which government and industry cooperate to achieve a proper balance between meeting the Nation's energy needs and environmental concerns and maintaining a competitive and technically innovative domestic oil and gas industry.

Mineral Resources

Except for construction materials, such as sand and gravel, and some placers, it is unlikely that substantial amounts of hard mineral resources will be commercially recovered from U.S. EEZ deposits within the next decade. Depressed market prices, together with high costs of mining in marine environments, create an unfavorable economic condition for development of most seabed mineral resources.

Future national needs for certain strategic materials could spur development of offshore mining industries for selected critical materials, such as cobalt, chromium, manganese, and the platinum group metals, that are now imported by the United States. Because lead times of up to 15 yr are required for developing commercial seabed mining systems, it seems prudent to establish the scientific and technical base necessary to assess and recover strategic or critical materials should national interests require them in the future. An integrated long-term (5–10 yr) program of technology development is needed to perfect the tasks for comprehensive assessment of hard mineral resources in the EEZ seabed. Basic research also is needed in mineral sampling and recovery technology requirements for exploitation of deepwater deposits.

Waste Disposal

For many years, the ocean waters surrounding the United States have been used for disposing of municipal and industrial wastes, particularly sewage sludge and dredged materials. Recent legislation places restrictions on such practices and, in some cases, requires phasing them out during the next few years. However, comparisons between land and ocean disposal options frequently indicate that marine disposal is less expensive and less environmentally damaging than land alternatives. This leads many experts to believe that marine waste disposal is likely to increase in the next 10 to 20 yr, despite present public disapproval. Future pressures on land-based repositories may increase incentives to explore the use of subseabed geologic formations for permanent repositories for containerized low-volume, highly toxic, and radioactive wastes.

Devising environmentally acceptable ocean waste-disposal strategies depends on understanding the physical and the chemical oceanic processes and how they affect sedimentation and mobility of contaminants. Distinguishing and isolating contaminated from uncontaminated material and specifying appropriate disposal methods for each type is another major requirement for developing sound seabed waste-disposal practices.

Innovative engineering approaches to isolating and disposing of wastes in the ocean need to be tested and evaluated through pilot or demonstration projects so that their effectiveness can be determined; for instance, placement of contaminated sediment in excavated pits or trenches that are then capped by clean sediment could be one of the most effective means of isolating certain toxic materials from the food chain.

Future use of the EEZ seabed for waste disposal will depend on socioeconomic pressures, innovative technologies that will not compromise the use of other marine resources, and better understanding of the processes of dispersal and deposition of waste particulates. Additionally, a comprehensive national policy for selecting long-term waste-disposal strategies, which includes evaluation and comparison of land- and ocean-based options and their impacts on the marine, terrestrial, and atmospheric components of the ecosystem, would provide a framework for making wise choices about waste disposal.

Communication Cables and Military Uses

Increasing use of the EEZ seabed for the installation of commercial submarine cable systems and a number of military applications is driven primarily by advances in fiber optics and digital transmission, as well as improvements in the technology capability for secure emplacement of various devices in or on the seabed. Commercial communications cables constitute the majority of ocean cable installations. The military uses the EEZ as an operational arena; as a laboratory for researching, developing, testing and evaluating operational systems and techniques; and to train personnel. Military activities in the ocean are expected to continue indefinitely; cables, sensors, and transducer systems are likely to increase as their technological applications are improved.

Geological processes and the composition of the substrate are the most crucial physical conditions affecting emplacement, maintenance, and survivability of ocean cables and seabed military systems in the EEZ seabed. Improved geophysical survey equipment, sediment sampling, and in situ testing, along with more effective procedures for interpretation of geotechnical data, would yield benefits to military and commercial operations in the seabed.

A major issue related to the expansion of military uses of the seabed is the conflict between military applications and commercial, recreational, and (or) environmental interests. An additional problem associated with military uses of the EEZ seabed has been the imposition of military classification restrictions on some categories of data. Recent changes in Navy policy have reduced some of the requirements for classification. Because of the likely expansion of the military presence in the EEZ seabed, it is important that potential conflicts with other uses be anticipated and that policies be developed for resolving them.

Biological Resources

Living resources associated with the EEZ seabed fall into one of two categories—commercially important fishery resources and organisms of special scientific interest or of potential importance as biotechnological or genetic resources. The United States is one of the world's largest consumers and importers of seafood products. There is potential for expansion of the domestic fisheries industry into deeper waters to capture a larger share of this market. Although most experts believe that traditional fisheries are being harvested at or near maturity, some additional resources of the continental slope can be harvested by extending existing technology into deeper waters.

Many bacterial species found in chemically unusual marine environments are logical candidates to study for their ability to degrade toxic chemicals. Some marine benthic invertebrates are potential sources of pharmaceutical agents in the treatment of cancer, AIDS, and other diseases.

Research should be focused on the basis, the variation and the effects of human activity on biological productivity in deep water. Newer techniques that are based on remotely operated vehicles, better sensors, acoustics, and improved data interpretation may alleviate present assessment problems. Such fundamental knowledge of biological and living resource processes will contribute to the expansion of American fisheries, the development of new biotechnology products, and the protection of the quality of marine environments.

Ocean Energy Systems

Ocean energy systems and related technologies are in the very early stages of development, and the commercial feasibility awaits more favorable economic conditions. In the near future, the most likely candidate for development that will affect the EEZ seabed is ocean thermal energy conversion (OTEC); this is a process that harnesses the temperature differences between surface and deeper waters as energy. The first commercial OTEC installations probably will be shore-mounted facilities on islands and will have the intake pipe extend to nearby deepwater sources, possibly into the EEZ. Moored OTEC facilities will require information on the physical properties of steeply sloping sea floors that border U.S. subtropical and tropical islands and have access to deep, cold water relatively close to their shorelines. In some configurations, the electrical energy would have to be transmitted to shore by sea-floor cable, thus creating a need for detailed sea-floor information along the cable route.

Commercial feasibility of any ocean energy systems depends on more favorable economic conditions than presently exist, mainly higher oil prices. These systems are, therefore, not likely to be developed in the near term.

Cultural and Recreational Resources

Cultural and recreational resources of the EEZ include marine archaeology, treasure seeking and commercial salvage, recreation, and marine sanctuaries. It seems likely that new and improved sea-floor exploration technology and availability of affordable submersibles will stimulate interest in marine archaeology and submarine tourism.

The identification and the protection of unique U.S. underwater areas and habitats have been a limited effort. To designate and manage a marine sanctuary, a substantial amount of information on the resources and the physical environment of the area is needed. Federally sponsored mapping and exploration programs in the EEZ could include the identification of potential marine sanctuaries. Early identification of such areas would forestall potential conflict among competing uses by including sensitivity to environmental considerations in advance planning for the development of other resources.

TECHNOLOGY AND INFORMATION ISSUES

Assessment of the constraints to engineering development and the impacts of EEZ use at specific sites will require a systematic, integrated approach that involves investigation of oceanographic, geologic, geotechnical, and biological data to develop a site performance model for predictive capability related to a specific use or a combination of uses. Such an approach involves mapping, sampling, and measurement of sea-floor conditions and processes through a variety of in situ sampling, monitoring, and laboratory techniques tailored to seabed use. Acquiring information essential for achieving efficient and nondestructive use of the EEZ seabed will require expanded or, in some cases, new tools and technologies for exploring and gathering seabed data.

Surveying and Mapping

A variety of individual acoustic and optical technologies are available for the collection of bathymetry, bottom imagery, and subbottom sediment data. However, each survey system has its own operational characteristics, particularly in terms of resolution and coverage rates. Improvements are needed to make surveying methods and use of the results more efficient, particularly balancing survey data quality with survey costs in dollars and in time. Additionally, the use of digital acquisition techniques and the ongoing development of realtime data image enhancement will result in improved survey and mapping effectiveness. The mapping priorities and geographic areas of interest to all potential EEZ user groups will require further definition as a first step toward cost-effective and efficient sharing of mapping activities, survey and ship time, and equipment.

Geotechnical Investigation Systems

Detailed knowledge of the seabed sediments will require measurements by sampling and in situ and experimental testing. Various systems for data acquisition are highly developed for water depths of less than 300 m, but little development has occurred for systems that can be used in the Arctic or in offshore regions where water depths exceed 300 m. Technology needs for geotechnical and geological data acquisition include improved sampling and in situ testing equipment for use in frontier areas, field monitoring of installations, and laboratory experimental modeling.

Monitoring of the Seabed

The environmental consequences of expansion of activities in the seabed of the EEZ are difficult to predict in advance. A monitoring program would establish environmental baseline information that could be used for such predictions. Monitoring of environmental impacts is particularly important in relation to the use of the seabed for waste disposal, oil and gas exploration and production, and mining.

The required monitoring will fall into three categories—reference monitoring to determine the natural range and variability of environmental parameters of the EEZ seabed, process-related monitoring to understand major EEZ seabed processes, and use-related monitoring to evaluate the suitability of EEZ sites for specific uses and to determine their environmental consequences. Monitoring priorities and strategies should be established within the framework of a national EEZ program.

Technology Development

Mapping and surveying, geotechnical research, and monitoring programs will benefit from expansion of existing technology or development of new equipment and techniques for gathering data on the seabed. Efficiency of present activities related to mapping and surveying the EEZ can be improved through application of existing and emerging technologies and optimization of their use. New tools also can be developed to indicate directly the presence of valuable resources and to monitor processes. Monitoring capabilities would be improved by the ability to record data from buoys by using satellites.

Technology development for acquiring information must be closely related to plans for utilizing the EEZ seabed. Requirements for data and specifications for equipment to acquire, manage, and analyze such data need to be defined in terms of specific user needs. The complexity, the cost, and the timeframes required to improve existing technology and to develop new data acquisition systems for the frontier areas of the EEZ will require a cooperative effort among academia, industry, and the Federal Government.

GOVERNANCE AND POLICY ISSUES

The variety of uses envisioned for the EEZ seabed and the amount of data and information needed to plan and manage the rational conservation and development of the EEZ seabed require joint planning and coordination by government, industry, and academia. Effective and efficient programs for the systematic mapping and surveying, the development of technology to gather data, the identification and the resolution of potential conflicts, and the development of approaches for multiple uses of certain areas depend on a successful cooperative relation among a broad range of public and private entities that have varied views.

A broad foundation will be necessary upon which to build an institutional framework capable of developing and managing the EEZ seabed resources. Such a framework needs to be based on a commitment to a national EEZ seabed plan that delineates programs for basic and applied research, technology development, and industrial and environmental policy developed in cooperation and consultation with representatives of State and Federal agencies, marine industries, research institutions, and public interest groups.

CONCLUSIONS AND RECOMMENDATIONS

The investigations resulted in two major conclusions about the future uses of the seabed in the EEZ. First, it is highly probable that the present uses of this region are likely to increase in the next 20 yr. These include exploration for and development of oil and gas resources, waste disposal, emplacement of cables for civilian and military purposes, harvesting of fisheries resources, recovery of certain hard minerals, identification of cultural resources, such as marine sanctuaries. Potential uses of the EEZ seabed related to a broader spectrum of mineral exploration and development, other biological resources, development of ocean energy systems and technologies, and recreational uses are less likely in the near term but will probably become more important in the time frame beyond 20 yr.

The second major conclusion of this study is that for all foreseeable uses of the EEZ seabed, improved coordination and increased joint planning are needed to implement effective and efficient programs for systematically mapping and surveying the EEZ, developing new or improved technology to support EEZ mapping, and surveying and research programs, improving access to and sharing of EEZ data, developing approaches for multiple uses, and identifying and resolving potential conflicts between the various users. Such a strategy would provide the Nation with the foundation for a coherent plan for developing its ocean territory.

To accomplish these objectives, the Committee on Seabed Utilization in the EEZ recommended that the following actions be initiated:

- Congress should enact legislation to create a formal joint planning and coordination process that includes a lead agency mandated to develop a national EEZ plan; an external commission composed of representatives of industry, academia, and public interest groups; and an internal interagency committee. On the basis of recommendations and the advice of the commission and the interagency committee and in cooperation with the Coastal States, the Federal Government should formulate a national management policy for EEZ uses that identifies the needs of specific user groups and determines ways of enhancing cooperation and efficiency of operations among the various agencies and industries and identifying and resolving potential conflicts among users.
- As part of the planning and coordination process, Federal agencies that have EEZ programs should pursue cooperative and joint agreements with Coastal State governments in planning and implementing EEZ activities.
- The U.S. Congress should ensure that a coherent policy is developed that addresses specific concerns of industry and Coastal States, especially economic and environmental issues affecting the development of EEZ mineral resources. Appropriate agencies should provide the leadership to ensure development of the necessary science and technology for assessment, evaluation, and verification of critical hard-mineral resources.
- A comprehensive long-term national waste-management policy based on an evaluation of waste disposal in all media, including land and ocean disposal options, should be formulated by Congress to provide a predictable framework for planning and developing acceptable ocean waste-disposal strategies.
- Research activities in the EEZ should be coordinated through a designated agency to enhance cooperation and efficiency of operations among various agencies, industries, and academia and to promote basic research efforts that will increase our understanding of seabed processes in the EEZ.

- As a part of the national EEZ plan, a formal government/industry/academia EEZ program should be established to set priorities for seabed surveying and mapping activities and to promote the development of technologies for obtaining EEZ seabed data. The technological developments should include expanded use of multisensor systems for task-specific and reconnaissance surveys in frontier areas, use of autonomous and towed vehicles, and improved techniques for processing and interpreting remotely acquired seabed data.
- The agency designated to coordinate EEZ research activities should ensure that programs are set in place to develop the necessary technology for geotechnical and geological data acquisition in concert with the projected uses and needs. These systems and techniques will include improved sampling and in situ testing equipment for use from surface and submerged vessels in frontier areas, field monitoring of installations, and laboratory experimental modeling for seabed-structure interaction studies.
- Government should provide leadership in fostering communication and exchange of data among all agencies and other organizations conducting research in the EEZ through development of a comprehensive EEZ data management system.
- In conjunction with the joint planning and coordination process and the research efforts recommended above, a national EEZ monitoring program should be established that has input from industry; Federal, State, and local governments; academia; and public interest groups to determine EEZ monitoring priorities and strategies and the commitments by government and users required to implement them. Such a program should be based on the framework of projected uses of the seabed and should include long-term reference monitoring, seabed process-related monitoring, and use-related monitoring at specific sites. It also should incorporate the capability to respond to detrimental impacts.
- Federally sponsored EEZ activities should include a marine sanctuary reconnaissance component for discovery and identification of such unique areas of the sea floor. Such designations should occur well in advance of resource development in EEZ areas to forestall potential conflict among competing uses.

Offshore Activities of the Minerals Management Service

William D. Bettenberg
Minerals Management Service

It is a pleasure to be here to participate in this fourth biennial symposium on the Exclusive Economic Zone (EEZ). From every indication, this well-organized event will be the success we have come to expect. I am looking forward in particular to tomorrow's panel discussions in the hope that they will result in a clearer picture of future mapping needs in the EEZ. I appreciate this opportunity to say a few words about the offshore activities of the Minerals Management Service (MMS) because our mission and the industries with which we work are important to the Nation's energy security and overall economic well-being.

I think that we should begin with a few statistics. The Outer Continental Shelf (OCS) contributes about one-fourth of the natural gas and one-ninth of the oil currently produced in the United States. To produce the vast resource potential of the OCS, more than 3,700 production facilities are in place—one is as far as 129 mi from shore, and one began production this past year in a record water depth of 1,760 ft. Over 28,500 wells have been drilled, the deepest of which is in 7,520 ft of water.

As onshore fields become depleted, these offshore resources are becoming increasingly important to our ability to help meet U.S. energy needs. With the *Exxon Valdez* oil spill, it is also increasingly important that offshore development have the confidence of the public and take place in a responsible manner that protects the marine and coastal environments. Toward that end, the MMS manages an Environmental Studies Program that has invested nearly $0.5 billion since its implementation in 1973. The purpose of this program is to obtain information to understand better and to mitigate potential environmental impacts associated with drilling and production in specific areas. We also have been operating (jointly with Canada) the Federal Government's only oil spill containment and cleanup research program; earlier this year, the program saw increased Federal funds and industry participation through the American Petroleum Institute. We also have reviewed all our oil spill contingency plans and stepped up our pace of oil spill equipment inspections and response drills.

Exploration and development of the OCS is implemented under the OCS Lands Act. The 1978 Amendments to the OCS Lands Act added a provision that requires the Department of the Interior (DOI) to prepare and maintain OCS oil and gas leasing programs in 5-yr increments. The current program, which was approved in July 1987, scheduled lease sales through June 1992. A new planning cycle has just begun that will provide an opportunity for a transition from the existing program to one that will carry us through 1996. It is hoped that this program will balance national and local interests in a way that will allow offshore development to proceed without the threat and the disruption of the moratoria that we have experienced during these past several years. The next step in the process of developing the new plan will be the release of a "draft proposed program," which is tentatively set for March 1990. It will reflect comments received from the States and the public since the start of the new cycle last July. The draft proposal also will reflect the findings and the recommendations of the President's OCS Leasing and Development Task Force, which is charged with examining environmental concerns in lease sales that had been scheduled for 1990 off southern Florida in the eastern Gulf of Mexico and off northern and southern California.

Concerns expressed to the task force range from the visual aesthetics of oil rigs and platforms to fear of impact on mangrove forests, coral reefs, and seagrass communities. Clearly not all concerns are equal in weight, especially in view of national needs for petroleum. However, all concerns are sincerely motivated and will be taken into account in the task force recommendations to the President.

Following comments on the draft proposed program, two additional versions will be developed and released for public review. This process, which will have heavy State and public input, will take more than 2 yr. We should have the new program in place by late 1991 or early 1992.

The 5-Year OCS Leasing Plan is just our initial step. For each sale in the 5-yr program, there is a separate 2-yr or longer process that has additional opportunities for public input before final sale design.

Estimates of the remaining, as yet undiscovered, oil and gas resources are lower than those made earlier in the decade because of lower energy prices coupled with disappointing results from exploration efforts by industry from

1980 to 1986. Nevertheless, exciting offshore discoveries are not a thing of the past as witnessed by recent events.

Last year's lease sale in the Chukchi Sea drew 653 bids, which was a record number for a sale outside of the Gulf of Mexico. High bids totaled $478 million. Since then, Shell Western Exploration and Production, Inc., has drilled and successfully completed one well and has begun two others. Several lessees are conducting preliminary activities on leases in the Beaufort and the Chukchi Seas in preparation for upcoming exploration activities.

On another front, delineation drilling by Freeport-McMoran suggests that a Gulf of Mexico sulphur discovery will develop into one of the largest Frasch sulphur reserves in North America. Earlier this year, the company drilled 17 wells to delineate a salt dome structure that contains a sulphur-bearing rock sequence that ranges in thickness from 42 to 204 ft. Analysis of the wells indicates that the deposit could support a production rate of 2 million to 3 million long ton/yr. The gross value of this discovery is estimated to be roughly equivalent to a 0.5-billion-bbl oil field. This sulphur discovery presents a unique challenge for multimineral production because it is colocated with a significant oil discovery by Chevron under a Federal oil and gas lease. Our Gulf of Mexico Regional Office is working with the two companies to optimize the simultaneous development of both resources.

In the Atlantic, Mobil Oil Corporation has submitted a draft Plan of Exploration for unitized exploration of the Manteo Prospect, which is located approximately 47 mi off North Carolina. Industry estimates the hydrocarbon potential of the play to be approximately 5 trillion ft^3 of natural gas.

A Memorandum of Understanding (MOU) between the State of North Carolina, Mobil Oil, and the MMS was signed on July 12, 1989, to satisfy the State's needs for information and the analysis concerning the environmental impacts of Mobil's proposed exploration activities. The information and the analysis will be contained in an Environmental Report that the MMS is preparing under the MOU. The Environmental Report is "custom made" to address a broader range of State concerns than is customarily considered in Environmental Impact Statements (EIS's). Public hearings on the draft Environmental Report are set for December 1989, and the final Environmental Report will be available before the submission of Mobil's final Exploration Plan.

Unlike the oil and gas program, hard-minerals activities are not keyed to 5-yr programs. Rather, the MMS is seeking to encourage activity on a case-by-case basis where the potential for economically recoverable resources is greatest and State and industrial interests coincide. The MMS has moved under the OCS Lands Act to provide "a climate of certainty" conducive to industry initiative by promulgating regulations that cover a full spectrum of activities, which range from prospecting to mining; those rules were completed in January of this year. I think of our role at this early state of a pioneering industry is that of a catalyst. We are working closely with the States and bringing together the various interests to identify where commercial potential is greatest and to resolve environmental and other concerns early in the process. We are not into heavy subsidization because we do not want to elicit uneconomic activity. We are prepared to commit modest funding where others are also willing to contribute and where we can see near-term industry interest.

Typically, we have proceeded through a Federal-State cooperative agreement involving a task force; this follows a request from a State to the Secretary of the Interior or the Director of the Minerals Management Service. Following the development of a cooperative agreement, which is tailor made to each specific case, a team of Federal and State experts is assembled; industry and other interests act as advisors. I will comment briefly on each of the six task forces that involve nine Coastal States. You will undoubtedly hear more during the panel presentations tomorrow.

Onshore phosphorite production in the Southeastern United States comes from Miocene formations deposited on the ancient sea floor in basins adjacent to topographical highs. One such deposit is being mined at Aurora, N.C. Seismic surveys off North Carolina and Georgia indicate that the Miocene thickens downdip—offshore. One drill hole plus several shallow vibracores reveal phosphorite in the upper sediments. In 1986, task forces were formed with North Carolina and Georgia to consider the potential for either dredging sea-floor phosphorite outcrops or slurry mining the deep phosphorite through drill holes, if it continues to exist at depth. The Georgia task force also is considering the significance of assemblages of heavy minerals observed in grab samples. You will hear more about this from Roger Amato during the East Coast panel discussion tomorrow.

A task force formed in 1987 involving Texas, Louisiana, Mississippi, and Alabama has decided to focus not on marine mining per se, but on the practicality of transferring offshore sand to beaches and barrier islands where shoreline retreat has become a critical concern. The Mississippi River has shifted its channel several times in the geologic past, which has resulted in the reworking of abandoned deltas and the creation of blanket-type deposits and linear shoals. The State of Louisiana and the MMS have recently initiated an 18-mo project to examine the feasibility of developing Ship Shoal as a source of sand for the Isles Dernieres off Louisiana. The hope is that this will be economically feasible and that the project can serve as a model for other wetlands protection and beach development ventures in the Gulf.

An Oregon task force created in 1988 is looking into the potential of recovering strategic minerals, such as chromite, ilmenite, and gold, from ancient beaches' black sands now on the Continental Shelf. During World War II, over 50,000 tons of chromite concentrate was mined, along with some gold and platinum, from the present beach and now-elevated relict terraces. Numerous concentrations of black sands and traces of gold have been found in the surficial sediments offshore. Magnetic anomalies suggest a third dimension—bathymetry reveals several submerged beaches. The transgressing sea would have reworked the now-submerged beach deposits and might have concentrated the heavy minerals. At least we hope so.

Commercial gold mining in State waters off Nome, Alaska, led to the establishment in 1988 of a Federal-State coordination team to address issues surrounding a possible OCS lease sale. Questions raised during the preparation of an EIS regarding the potential effects of mercury now appear to be answered. A revised draft EIS is planned to reflect the results of new water column and sea-floor samples, the first phase of a public health study, and a workshop to evaluate all results that take place later this month (November 1989). The delay in incorporating this important new information and in completing the EIS process probably will move the lease sale to about February 1991. You will hear more about this activity from Mark Bronston and Irv Palmer during the West Coast/Alaska panel presentations tomorrow.

The Hawaii task force is addressing the opportunities and problems associated with the potential exploitation of ferromanganese crusts, which are draped over seamounts and have been found to contain fairly high amounts of cobalt and, in places, over 1 percent platinum, as well as nickel, copper, and manganese. Although the task force was originally created in 1984, a new cooperative agreement was signed late last year that increases the role of the State regarding marine mining off Hawaii. Objectives of the agreement are to resolve issues of mutual interest, to develop coordinated program and policy positions, to coordinate legislative and regulatory initiatives, and to oversee leasing and development activities. The agreement calls for a "Joint Planning Arrangement" that has two committees—the four-member Cooperative Steering Committee prepares joint plans, to resolve issues, and to work directly with DOI and State decisionmakers on program and policy issues, and the Coordination Committee coordinates project activities and to provide technical support to the Steering Committee. Both committees met for the first time in Honolulu last April. New initiatives resulting from the meetings include publication of a Request for Interest and a "workshop" in spring 1990 to solicit industry comments on potential leasing and development of cobalt-rich manganese crusts and a coordinated public information effort that succinctly describes the results of the final EIS and the future direction of the project. A draft final Request for Interest (including Johnston Island) is nearing completion and the information program which will be coordinated with the release of the EIS, probably in January, is being jointly scoped. I am sure John Wiltshire will discuss this initiative in more detail at tomorrow's panel devoted to Island activities.

As you can tell, the MMS has a considerable interest in the OCS/EEZ. We are heavily involved with States to ensure that concerns they might have are fully considered and addressed, as we make decisions and pursue the important mineral resources that lay offshore.

From Data to Decisions—New Opportunities for Cooperation Between the National Oceanic and Atmospheric Administration and State Agencies

Charles N. Ehler
National Oceanic and Atmospheric Administration

During the 1987 Exclusive Economic Zone (EEZ) Symposium, Armand Silva and I chaired the workshop on "Information Needs for Sea-Floor–Seabed Utilization." Our workshop identified at least 11 thematic areas that focused on multiple uses of the EEZ. In summarizing the conclusions of the workshop, I pointed out an obvious "fact of life"—that uses of the seabed and the sea floor will be affected by what is going on in the water mass above the sea floor and at its edges; that is, the coastal zone. This region represents a national resource base that extends far beyond bathymetry and bottom sediments.

I want to emphasize two ideas today—information synthesis and information transfer, particularly to State agencies. The first idea is important because we are already drowning in data, and, in our rush to handle all the new data, we often lose sight of what we already know. My point is that we should put a high value on efforts to organize existing data and to synthesize information for decisionmaking. The second idea is important because we do not do a very good job in delivering our best information to decisionmakers in a timely and understandable form. Within the National Oceanic and Atmospheric Administration (NOAA), we are trying to do something about both.

We all work in an environment that is data rich and information poor. Today, we have at our disposal more scientific data than ever before, more scientists and engineers working on problems and spending more money than ever before, and more published scientific literature than ever before. However, most indicators tell us that problems, especially environmental quality problems in coastal and oceanic areas, are getting worse.

A disconnect often exists between the needs of decisionmakers for information about multiple-use problems, including alternatives to solving them, and our collective ability as scientific problem solvers to deliver the goods. If we are going to plan and manage the multiple resources of the EEZ, then we need some new ways of doing business that emphasize and support information synthesis and transfer as an integral part of the process.

INFORMATION SYNTHESIS—A CRITICAL LINK BETWEEN DATA AND DECISIONS

For the past 10 yr, NOAA's Office of Oceanography and Marine Assessment has been devoting a substantial effort toward synthesizing information about the coastal areas and the adjacent EEZ. We have been organizing information that summarizes what we know about selected characteristics of the "American ocean." Our best-known products have been a series of comprehensive thematic atlases that cover land and water areas from the head-of-tide to the seaward extent of the EEZ. In 1980, we published an atlas of the East Coast; in 1985, one of the Gulf of Mexico; and, in 1989, an atlas of the Bering, the Chukchi, and the Beaufort Seas; we will complete the series by 1991, when the atlas of the West Coast of North America from the Bering Sea to Baja California will be published. In 1988, we distributed review versions of sections of the West Coast atlas on marine mammals. This year, we will print a volume about fishes. The section on West Coast economic activities and environmental quality conditions will be distributed toward the end of 1990. Each of these 1:4,000,000-scale thematic atlases contains comprehensive information on the physical and the biological characteristics of each particular region of the EEZ, information on the life histories of important living resources and their habitats, economic activities and environmental quality, and jurisdictions of Federal and State management agencies.

More recent publications of our *National Estuarine Inventory* atlas series synthesize information by themes, such as physical characteristics and hydrology, habitats, and pollutant discharges, within the drainage areas of about 125 estuaries of the United States. The maps within the atlases are important as easy-to-understand information summaries of large data sets. However, the basic databases that have been compiled in the process of organizing information for presentation are perhaps more important. Over the past 10 yr, we also have organized large georeferenced digital data sets on pollutant discharges, including nutrients and pesticides entering coastal and oceanic areas from most sources; freshwater inflows and salinity regimes of coastal waters; coastal wetlands; classified shellfish-growing waters; and the distribution in time and space of over 300 individual species of living resources.

We are not only deriving information from large data sets, but are experimenting in its use; for example, we have helped analysts and decisionmakers in NOAA and other Federal and State agencies to use the results of our programs in the assessment of estuarine problems. We have provided information to the Environmental Protection Agency's (EPA) National Estuary Program for near coastal waters assessment to evaluate alternative living resource-management decisions, including shrimp management in the Gulf of Mexico, and to evaluate oil and gas development alternatives on the Outer Continental Shelf. But we can do more.

INFORMATION TRANSFER—AN EXPANDED USER FOCUS

I said earlier that an important problem—and perhaps the most important problem—is our collective inability to bring the best information about the nature of and solutions to coastal ocean problems to decisionmakers. This happened in the response to the *Exxon Valdez* oil spill. NOAA provided decisionmakers with a powerful tool to access information for allocating and tracking scarce resources used in clean-up activities.

As scientists and managers, we have to make fundamental changes in the way we do business, and much of this change will be in how we organize and use information. There is a revolution going on in information technology, and we must be part of it. Scientists and other experts are no longer the sole—or even the primary—user of large data sets or their information content.

We want to adapt and use technology to support people, particularly those who influence and make decisions about the use of coastal and oceanic resources. We want to provide sophisticated information directly to the decisionmaker—get the best information to the "point of attack." State decisionmakers are important clients for our information and capabilities.

DEVELOPING DESKTOP INFORMATION SYSTEMS

Recent developments in microcomputer technology now make it possible to bring to the desktop of the resource manager or researcher a wide range of capabilities and data that previously could be accessed only on large mainframe database systems. These "desktop information systems" serve a different purpose and, if properly constructed and used, can considerably augment the applications and the interpretation of data from large mainframe systems.

Effective and efficient desktop information systems have several characteristics. First, they are developed to be either problem- or theme-specific (for example, managing the shrimp harvest in the Gulf of Mexico) so that the logic of how the data can be used is clear, almost transparent, to a user. Second, they are designed to answer a limited number of questions well and do not attempt to provide a generic capability to answer any question that could be asked of a database. Consequently, they typically contain a subset of the data in the larger database. Third, they typically are more user-friendly than most mainframe systems. Little or no training is usually required to perform often complex operations by using the desktop system. A user does not need to understand programming or specialized syntax. This broadens the number of potential users and applications of a database; this often leads to new and innovative uses of existing data and provides insights into improving the larger overall database.

However, before describing some of our new information system capabilities, a note of caution should be sounded. The more simplified and aggregated the data contained in a desktop system, the higher the level of expertise required to interpret results intelligently. Although the data are more accessible to computer-illiterate professionals, a high level of experience and understanding of the data is still required to interpret results. Streamlining and making computer operations user friendly are not substitutes for an in-depth working knowledge of the subject.

Cmas—A COMPUTER MAPPING AND ANALYSIS SYSTEM FOR LIVING MARINE RESOURCES

Cmas is a compact desktop information system designed for use with large databases that contain information characterizing biological aspects and spatial and temporal distributions of marine and coastal species of invertebrates, fishes, birds, and mammals (fig. 1). Information stored in Cmas applications comes from a wide range of sources, including published scientific literature, technical reports, and field data. Cmas applications are fast, interactive, and user friendly. For Cmas applications, species data are digitized and entered into the system, along with locational, seasonal, and behavioral information. By designating and coding these elements, the user can define analysis areas (for example, the northwestern Gulf of Mexico) for designated species; develop maps and simple summations by species, month, year, and area; select

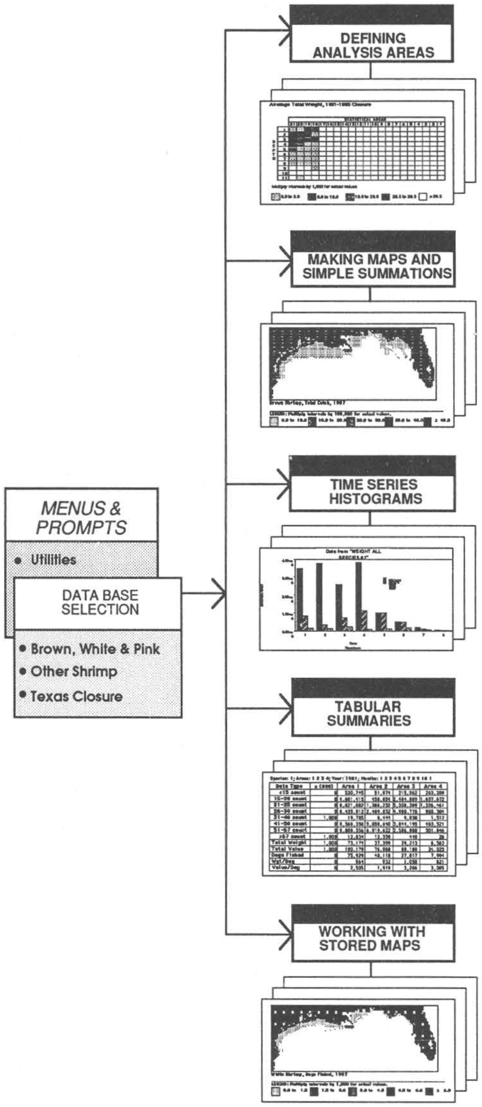

Figure 1. Cmas flow chart for a shrimp harvest.

combinations of species and attributes for time-series histograms or tabular summaries; and compute ratios and other comparisons for specified subareas of previously stored maps. Cmas applications are currently available for over 200 marine and coastal species found in the Gulf of Mexico; the Bering, the Chukchi, and the Beaufort Seas of Alaska; and portions of the Pacific Ocean off the West Coast of North America.

Development of Cmas is an evolving process. Plans are to increase distribution to users over the next year. The system will continue to be refined as more experience is gained with its applications, especially by these users. A major goal is to increase communication between scientists and resource managers of the coastal ocean through the use of Cmas.

COMPAS—A COASTAL OCEAN MANAGEMENT, PLANNING, AND ASSESSMENT SYSTEM

COMPAS is a powerful desktop information system designed to access and manage coastal resource information at a rapid rate and to provide a variety of automated capabilities, including simple data sorts and summary analyses in either mapped or graphic formats (fig. 2). It will soon include simple water-quality modeling capabilities that will simulate pollutant transport in estuarine and coastal waters. Although COMPAS may eventually be used by a variety of public and private organizations, it is designed initially for State-level coastal planners and resource managers. Its objectives are as follows:

- Bring existing, but disparate, coastal resource information into a single user-friendly microcomputer environment;
- Simplify the transfer of information to and from State-level resource managers and planners and the Federal Government; and
- Improve Federal and State capabilities to integrate large data sets and apply them toward problem-solving and conflict resolution in the Nation's coastal areas.

A COMPAS prototype has been developed for eight Texas estuaries by using data primarily from NOAA's National Estuarine Inventory. The prototype includes information on physical and hydrologic characteristics of each estuary, land use, habitats, shellfish-growing waters, distribution and abundance of fishes and invertebrates, point and nonpoint sources of pollution, site-specific monitoring data from NOAA's National Status and Trends Program, and regulatory data from such programs as the EPA's National Pollutant Discharge Elimination System and the U.S. Army Corps of Engineers' 404 permits for wetlands modifications. A cooperative agreement has been signed with the Texas Water Commission to coordinate with other Texas State users the evaluation and evolution of COMPAS through its application to real problems.

GeoCOAST—A COASTAL OCEAN GEOGRAPHICAL INFORMATION SYSTEM

GeoCOAST is a state-of-the-art hardware and software information facility developed by NOAA's Office of Oceanography and Marine Assessment. The facility is being developed to help address environmental quality issues concerning the management and the protection of coastal areas, including the EEZ. Its function is to provide the resources for developing and supporting information systems used to store and analyze the spatial and the temporal relations of data on these areas. The NOAA GeoCOAST facility provides a series of analytical tools and supports desktop systems for studying the effects of human activities on the Nation's coastal and marine areas.

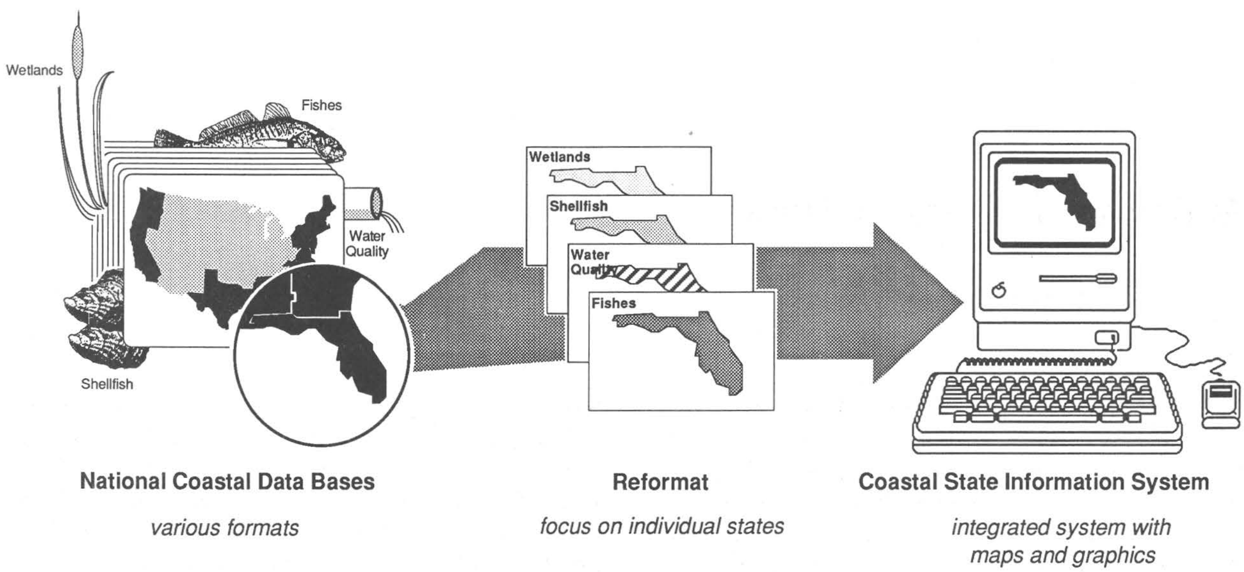

Figure 2. The COMPAS concept.

GeoCOAST uses commercially and NOAA-developed software packages. The major commercial packages are geographic information systems consisting of the Environmental Systems Research Institute's ARC/INFO, TYDAC's Spatial Analysis System (SPANS), and the Earth Resources Data Analysis System (ERDAS). ARC/INFO is used to load, edit, manipulate, and analyze map-based vector data and to generate high-quality vector map products. SPANS is used for more complex spatial problems, such as modeling and statistical analysis, by using an innovative "quad-tree" approach. ERDAS is used to analyze raster-based satellite images and other types of remotely sensed data.

All computer processing in the GeoCOAST facility is performed by microcomputers. Currently, there are five independent Geographic Information Systems workstations, one ERDAS workstation for processing remotely sensed data, two CD-ROM stations that read optical disks, and several distributed PC database management systems. All workstations use Compaq 386 microcomputers and a variety of input and output devices, including tape drives, digitizing tablets, scroll plotters, and color printers.

WHAT MORE CAN WE DO IN THE FUTURE?

Development of a body of information on the EEZ and adjacent coastal areas and operational capabilities to use it intelligently has been under way in NOAA for over 11 yr. One of the lessons that we learned was that there are simply no shortcuts to developing these capabilities systematically and carefully. The operational task of integrating disparate databases and analytical capabilities is a difficult one requiring creativity, consistency, and continuity.

Until the introduction of the compass by Portuguese mariners in the 13th century, navigation was based primarily on courage and luck and a little bit of knowledge of landmarks, winds, and currents thrown in. For a long time after its initial introduction, however, the compass was a rather inefficient instrument. Often the ship's master took a reading that with a rough approximation, either confirmed or denied what he had already guessed through other means.

In many ways, today's decisionmakers are in the same boat. Many important decisions that affect the EEZ are made only on the basis of courage or luck, and a little bit of experience thrown in. We move from decision to decision with little or no information about where we are, where we have been, or where we are going. Like the ancient mariner, we need to make and learn how to use new tools to provide better information for decisionmaking. We have to be prepared to use that information to act to solve problems.

When over 10 million gal of crude oil from the *Exxon Valdez* spilled into Alaskan coastal waters, it caused some obvious and many still-unmeasured environmental and economic damages. Perhaps even more importantly, the most significant long-term damage is the accelerated erosion of public confidence in our institutions and public and private decisionmakers to deal with resource-management problems in coastal and oceanic areas. If public confidence is to be restored, then we have to make fundamental differences in the way we think about and decide strategies for dealing with these complex problems

Mapping the Ocean Floor

Christian Andreasen
National Oceanic and Atmospheric Administration

First, I would like to publicly thank Rear Admiral Pittenger, Oceanographer of the Navy, and his staff for bringing the data classification issue to a successful conclusion. The Department of Defense (DOD) has withdrawn its objection to public release of the National Oceanic and Atmospheric Administration's (NOAA) multibeam survey data for 97 percent of the U.S. Exclusive Economic Zone (EEZ). Only the submarine ingress/egress areas remain subject to controls in the interest of national defense (fig. 1). I would also like to thank the National Academy of Sciences (NAS), the American Geophysical Union, and those of you, including Dr. Gary Hill and the U.S. Geological Survey (USGS), who persevered in supporting us through this initial 5-yr period.

OPPORTUNITIES AND CHALLENGES

Classification of NOAA's mapping effort precluded most of the interactions needed to operate a fully functional scientific endeavor. Cooperative projects with scientists were all but impossible because NOAA was unable to give any assurance that data could be made available. To date, only government scientists have sailed on NOAA multibeam cruises, but, now, there is the opportunity for others to participate. Dr. Gary Greene (USGS) sailed with the NOAA Ship *Surveyor* during surveys off the Monterey, Calif., area. He has produced an open-file report, which includes a geologic interpretation of the bathymetry. Also, a lengthy article about Monterey Bay will appear in the February 1990 issue of *National Geographic*, including a three-dimensional depiction of the bay produced by NOAA that shows Dr. Greene's geologic interpretations. I hope that those of you who have expertise in the various regions of our EEZ will rise to the challenge and follow Dr. Greene's lead in interpreting data sets.

The evolution of the USGS-NOAA Joint Office for Mapping and Research (JOMAR) can now proceed as Dr. Gary Hill and I originally envisioned. The GLORIA imaging effort has given us a quick look at major areas of the U.S. EEZ, which has provided newly discovered sea-floor features, and the excitement of new scientific curiosities. Future GLORIA coverage of the Pacific island areas of the U.S. EEZ, which constitutes almost one-half of the U.S. EEZ (fig. 2) and is largely unknown territory, will provide important guidance as to what areas should be given priority for investigation in the future. The islands typically have poor economies, and just locating seamounts and potential fisheries can be of significant value. Under the umbrella of JOMAR, NOAA and the USGS also are cooperating on possible nearshore surveys and have recently completed a plan for mapping the U.S. Great Lakes shoreline.

The USGS has done a wonderful job of getting GLORIA data into atlas and CD-ROM form. The JOMAR CD-ROM provided a sampling of USGS GLORIA data and NOAA multibeam data of the Monterey Canyon area, plus a number of other data sets pertaining to the region. This certainly illustrates the building of the foundation for a marine geographic information system.

During this year's symposium, we hope to take up the challenge of developing a National Plan for Mapping and Research in the EEZ. In 1984, we developed our initial plan and held a workshop for representatives from government, private industry, and academia. The conclusions of that group were very supportive. However, due to classification, the followup 5-yr plan had to be focused on the USGS and NOAA. We now have an opportunity to develop a 10-yr plan to incorporate the requirements of others and to develop a system for monitoring the requirements. A Technical Working Group, which was formed at the same time as JOMAR, meets monthly. This past year, a Federal Coordination Committee was formed to provide a mechanism for input from such agencies as the Environmental Protection Agency, the U.S. Army Corps of Engineers, the U.S. Coast Guard, DOD, and so forth. Most recently, the NAS-National Academy of Engineering, Marine Board, is providing an avenue for input of non-Federal requirements.

MAPPING EFFORT OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

At the present time, five NOAA ships are outfitted with multibeam systems, four of which are active. To date,

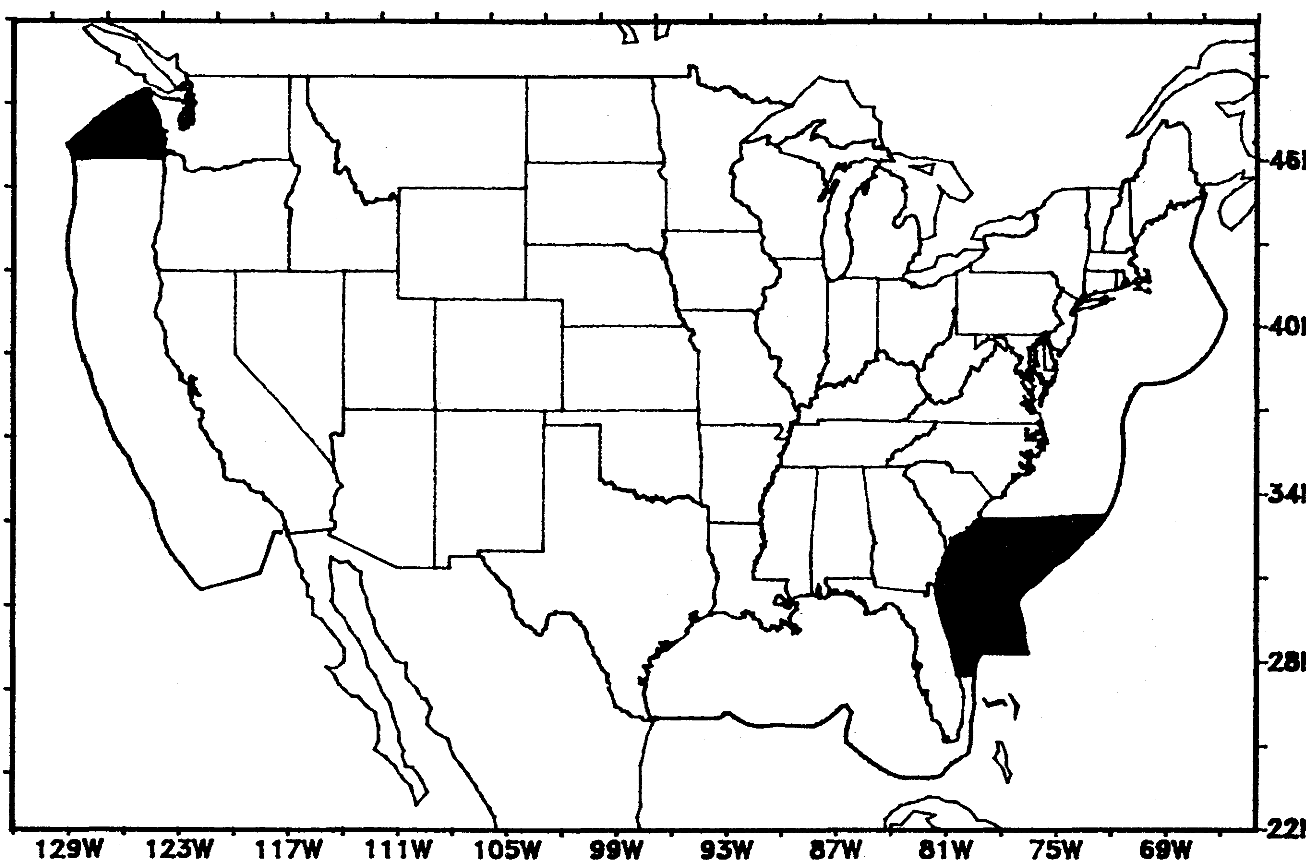

Figure 1. The Exclusive Economic Zone (EEZ) off the 48 contiguous United States. Blackened areas (approximately 3 percent of the total EEZ) are where multibeam data restrictions apply.

nearly 0.25 million km^2 have been mapped. It should be noted that this has been primarily in the shallower complex regions where progress is slow. As global positioning system (GPS) satellite navigation becomes available 24-hr/d and deeper water surveys are conducted, progress will increase. Also, advancing technology will improve capability.

The watchword of NOAA's survey effort is quality. Most of NOAA's survey work has been within 161 km of the coast because NOAA strives to maintain a positional accuracy of 50 m or less to comply with International Hydrographic Organization product standards. Medium-range positioning systems calibrated by using GPS have controlled most surveys. Satellite positioning by means of the Starfix system (5–7 m accuracy) has been used in the Gulf of Mexico. Sound velocity, which not only affects the depth measurement, but also the horizontal position, is measured in each survey area. Water column variability is monitored through the use of expendable bathythermograph data taken periodically in conjunction with our normal shipboard weather observations. Heave and the biases associated with alinement of the multibeam array are monitored, and correctors are applied. Roll bias, pitch bias, and G-bias are taken into account.

Because bias computations are quite labor intensive and time consuming, two NOAA agencies—the Office of Charting and Geodetic Services and the Office of NOAA Corps Operations—are in the process of automating the procedure. Once GPS becomes available on a round-the-clock basis, we anticipate being able to measure ship altitude in near realtime to within 0.1° of arc, thus further improving data quality. Careful quality control is an important factor in obtaining data from these high-resolution narrow-beam systems. Accurate position is essential to the realization of the value of high-resolution data. The result of our effort is the type of quality map product upon which NOAA's National Ocean Service and its predecessor organizations, such as the Coast and Geodetic Survey, have built their reputations. A quality base map and digital data set will become an important part of modeling and of the future development of the marine GIS.

PROGRESS AND PLANS

Public dissemination of multibeam data is now the focus. Numerous individuals have requested maps and data sets since the Navy first announced that NOAA would be

EXCLUSIVE ECONOMIC ZONE

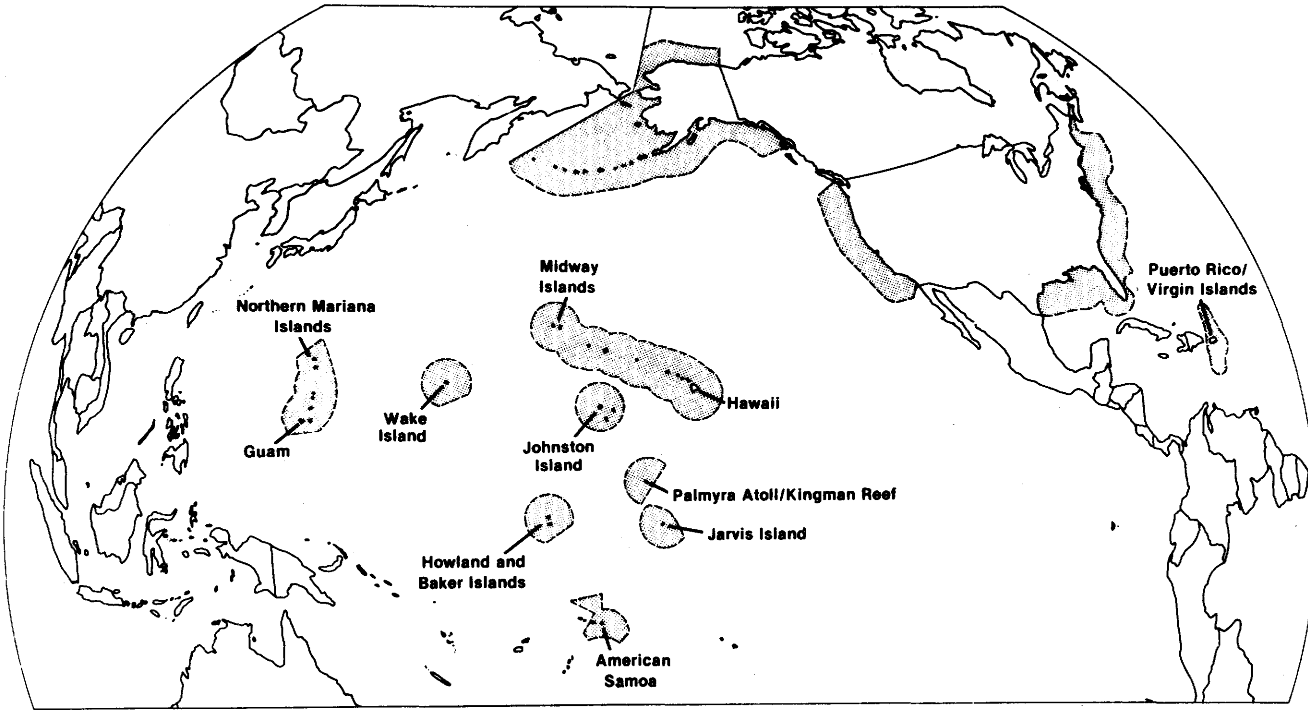

Photo credit: U.S. GEOLOGICAL SURVEY

Figure 2. The Exclusive Economic Zone of the United States and its Trust Territories.

allowed to release the data to the public. Because we had no warning of this, we have not been able to respond as quickly as we would have liked. The Ocean Mapping Section, Mapping and Charting Branch, is a small group. Rather than respond to individuals, our primary effort has been to develop the desired mechanism for the flow of data through our distribution system. To those of you who have been waiting to acquire maps or data sets, I apologize and ask your indulgence.

Before the Navy announcement, our effort was focused on the application of multibeam data to available nautical charts. This involved the development of digital representation of generalized contours and the computer selection of background soundings, which are representative depths from their actual position rather than a selection of grid points that are interpolated values. The first nautical chart, No. 18520, based on multibeam data from along the Oregon coast was issued on April 8, 1989.

The first step since then has been to revise the NOAA *Bathymetric Map Catalog 5* and to make ozalid copies of existing multibeam maps immediately available for $10. Copies can be obtained through the NOAA Distribution Branch, 301–436-6990.

Our second step was to begin the process of publishing the printed bathymetric maps. The first EEZ bathymetric map, Monterey Canyon, was published in October 1989 and is on display at this symposium. These maps are being distributed at a cost of $10. By early next year, maps of Pioneer Canyon (off California, northwest of the Monterey map), two maps from the Gulf of Mexico in the area of the Sigsbee Escarpment, a Gulf of Mexico map in deep water off the entrance to the Mississippi River in an area characterized by salt domes, and a map of Shepard's Meander (immediately south of the Monterey, Calif., map) will be published. These will be followed by six maps covering the area southwest of the island of Hawaii. Over the next year, we will continue to work on our backlog of about 40 maps. The published hard copy maps are being made available through NOAA's standard map and chart distribution system, which includes about 4,000 chart agents.

The next step is distribution of the digital data. The contract for NOAA chart distribution, which is with a private firm, will eventually be renegotiated to include distribution of digital data.

One of the demonstrations at this symposium is a PC that computes and displays three-dimensional depictions of portions of a digital 250-m grid. This consists of an entire map area loaded from a single high-density floppy disk containing about 100,000 grid points. The disk is in Universal Transverse Mercator coordinates rather than Geographic Position, but parameters are given on the disk so the data set can be transformed for other depictions. Our intent is to make the digital grid available for distribution as each printed map becomes available.

As each bathymetric map is compiled, the data sets are provided as source data for NOAA's nautical charting process. Where digital inshore NOAA surveys exist, the EEZ multibeam data are supplemented by these data to produce complete alongshore maps; this was done for the Monterey Canyon map. A data source diagram shown on each map and chart provides a depiction that identifies each data source.

The digital data will be an input to NOAA's Automated Nautical Charting System II, which is under development by Intergraph Corporation at this time. The system is to be brought on line beginning in 1992. By then, round-the-clock satellite navigation that uses GPS will become available to the mariner. Mariners will no longer be satisfied to know vessel position at timed intervals because accurate vessel position can then be displayed continuously on an electronic chart.

The gridded data from a multibeam data set represents about 1 percent of the observed data. NOAA will make observed data available through the National Geophysical Data Center. However, doing this for the first 160 NOAA field surveys will not be easy. Five years ago (when NOAA had classification imposed), I had interim levels of processing tapes destroyed to reduce the volume of data that we had to maintain under control. In retrospect, this was a bad decision. For these surveys, we face a significant reprocessing effort (nearly 1 hr of processing per 1 hr of data acquisition). We will establish a system to do this, but it will take some time. During the 1989 field season, all processed data have been retained. Thus, the most recent data for the Gulf of Mexico will become available before data for California, Hawaii, and Alaska. These data will initially be available in a binary format comparable to that of the U.S. academic ship operations; that is, ship position and crosstrack distances to individual depths. We are interested in learning if this is adequate for distribution or if there is a need for the position of each depth to be included. To do so would markedly increase the size of the data set.

Availability of USGS and NOAA data to the public makes it possible for us to take advantage of a multitude of opportunities and challenges. A cooperative effort in support of the JOMAR coordinating mechanism will reap the benefits of data and information exchange in our free society. It will help us build a strong marine program for the United States.

Thank you.

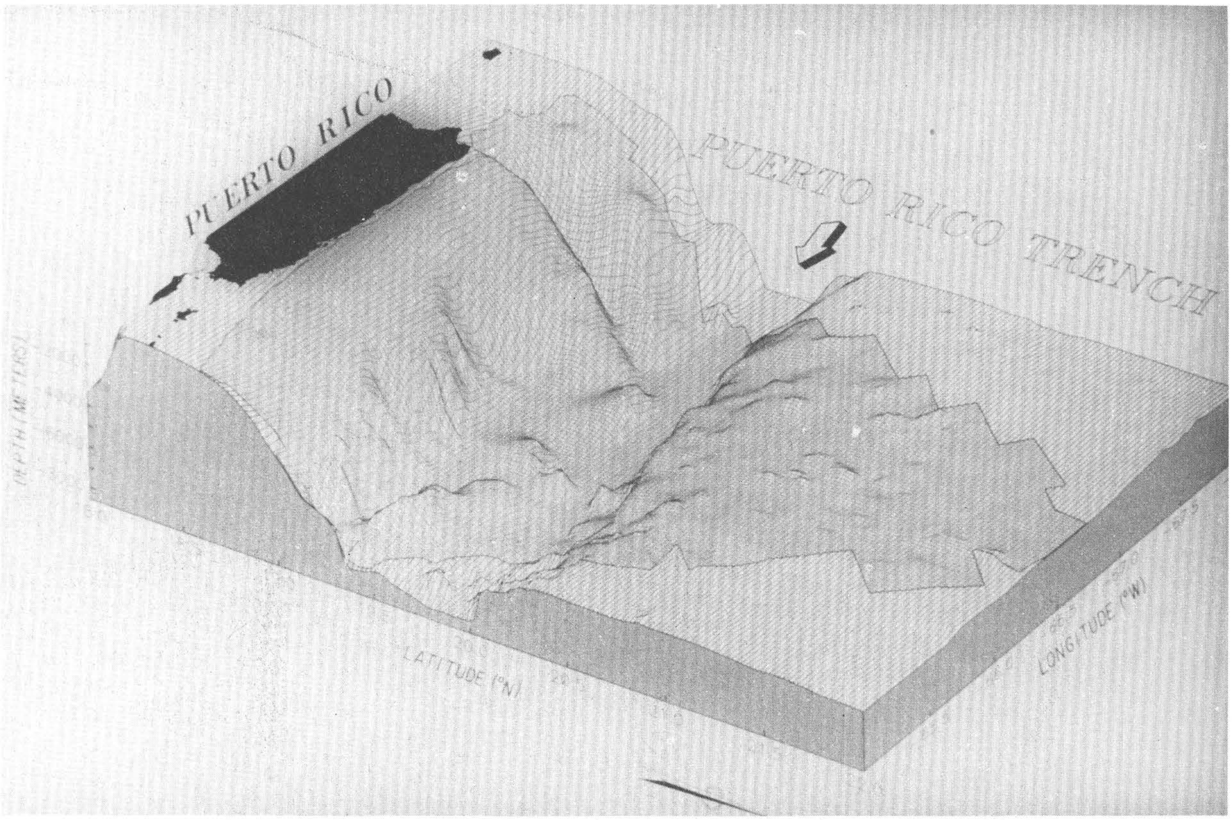

Figure 1. Puerto Rico Trench bathymetry.

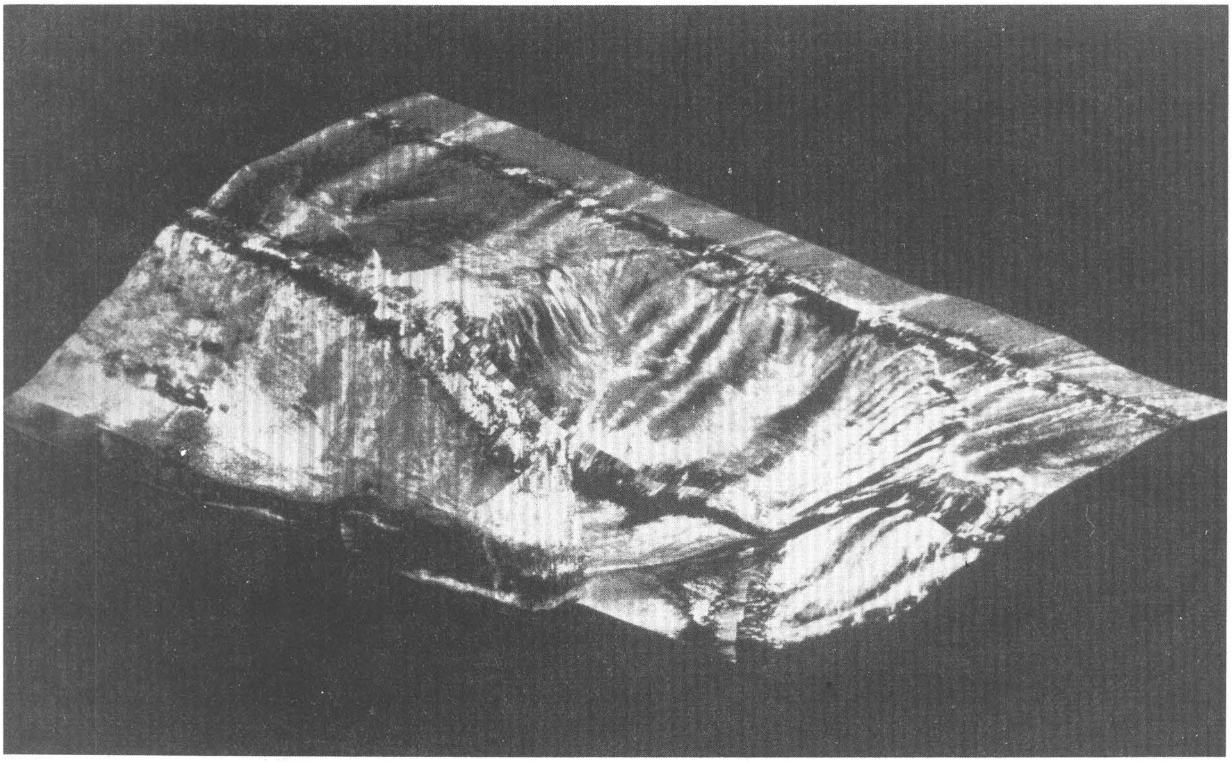

Figure 2. Amphitheaterlike landslide scar on the wall of the Puerto Rico Trench.

Federal-State Partnerships in Exclusive Economic Zone Mapping and Research

Dallas L. Peck
U.S. Geological Survey

I would like to welcome everyone to the U.S. Geological Survey (USGS) and to the second day of the Fourth Biennial Exclusive Economic Zone (EEZ) Symposium. The theme of this symposium is "Federal-State Partnerships."

Our host for this symposium, the USGS-National Oceanic and Atmospheric Administration (NOAA) Joint Office for Mapping and Research (JOMAR) is an example of an effective partnership. To make it easier, we just call this joint venture JOMAR. I take great pride along with John Knauss, Administrator of NOAA, that we have this Joint Office. This is a true partnership—the office is staffed by USGS and NOAA personnel. The EEZ mapping programs of the USGS and NOAA complement one another nicely and are providing remarkable views of the sea floor.

Digital data collected as part of the USGS and NOAA mapping programs allow us to manipulate the information and enhance our understanding. One can almost sense flying through the Puerto Rico Trench, the deepest place in the Atlantic Ocean and also within our EEZ (fig. 1). The microtopography on the floor of the trench hints at geologic processes occurring on the walls high above.

A huge landslide scar is present where over 90 km^3 of the wall of the trench has collapsed (fig. 2). This is only one example of spectacular features formed by the geologic processes operating on the sea floor, which were unknown before the systematic EEZ mapping program.

As John Knauss mentioned yesterday, integrated data and information systems are important in making available the results from both of our mapping programs. JOMAR has two data sets ready for release at this symposium, both of which use optical CD-ROM technology.

The GLORIA sonar data for the Atlantic Coast EEZ—all 200,000 nmi^2 of it—is now available. The view (fig. 3) of the 4,000-m-high carbonate escarpment of the Blake Plateau seaward off Florida, Georgia, and South Carolina is part of the data included on the CD-ROM disk.

Release of NOAA's SeaBeam data includes the bathymetry data set off Monterey, Calif. (fig. 4), where numerous canyons cut the continental margin. The disk of Monterey data includes onshore and offshore topography and image data. These CD-ROM disks make a personal computer almost as exciting as a video game. The disks of the Atlantic Coast EEZ and the Monterey Canyon area are available through JOMAR.

The workshops of the symposium also highlight these types of data and the technology available to implement their use. As John Knauss mentioned, being able to integrate the digital data sets from the many disciplines involved in marine research is the key to understanding the vast area of the EEZ. Peter Lucas, representing the National Academy of Engineering, Marine Board, will be sharing with us the information needs of users of the EEZ. We look forward to working with Peter and his committee as they obtain this profile of user information needs.

Our EEZ mapping activities are on schedule. When we meet again at the fifth EEZ Symposium in 1991, we will have completed the blue water reconnaissance phase of mapping the EEZ around the 50 States—a total of 2 million nmi^2—and will have begun to map the additional 1 million nmi^2 of sea floor around the American Flag Islands of the Pacific Ocean.

As we have been exploring the blue water frontier areas of the EEZ, we have not forgotten about the green water—the coastal ocean. Of the U.S. population, over 50 percent lives within an hour's drive of a coast, and that percentage is increasing annually; consequently, the pressure on the coastal ocean portion of the EEZ is great. The recent skirmish between people and ocean in Charleston, S.C., Puerto Rico, and the Virgin Islands during Hurricane Hugo is all too vivid in our minds. The President's initiative on the coastal ocean is also focusing attention on the need to develop a better understanding and information base on this area. His pledge of "no net loss of wetlands" is something that will surely echo through our efforts in the coming years. As with the deepwater frontier region, the coastal ocean portion of the EEZ contains resources that have the potential to be economically important, provides an option for waste disposal, and is used for manmade objects placed

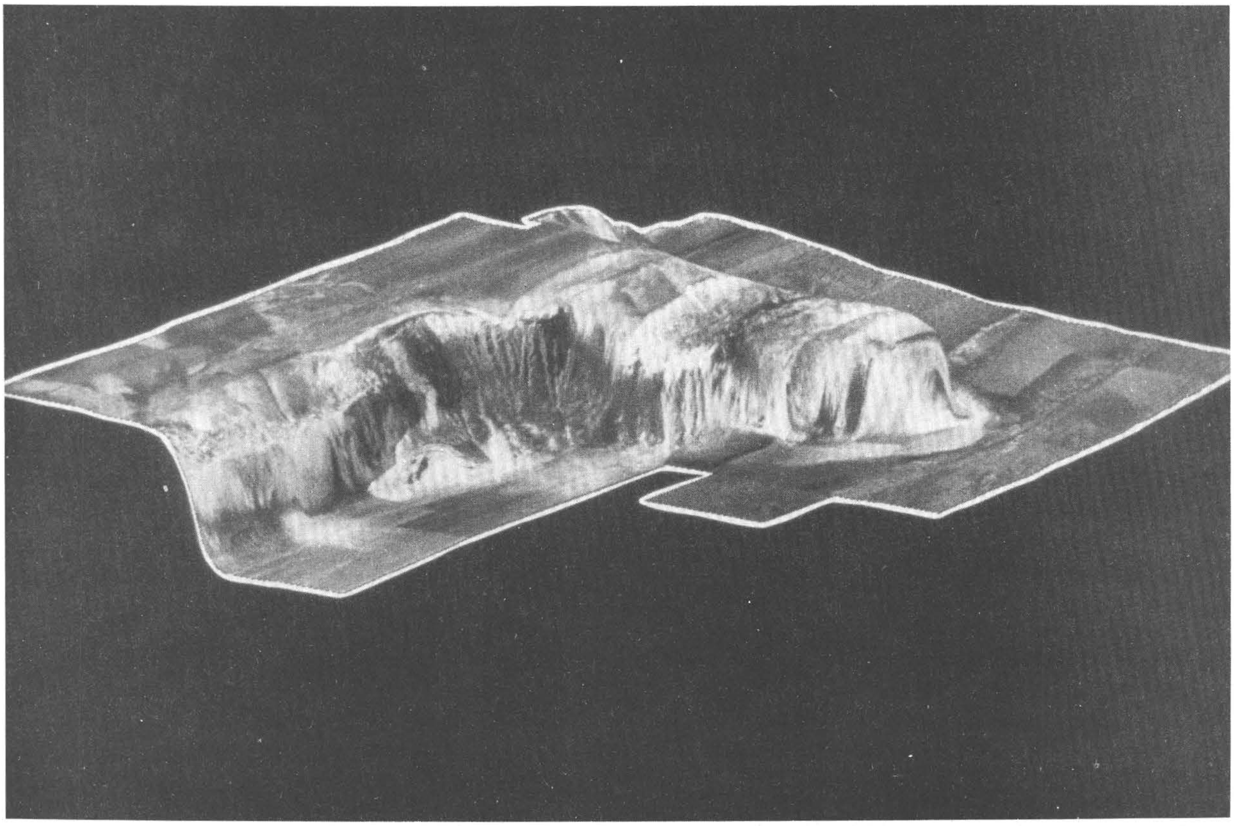

Figure 3. GLORIA image of the Blake Plateau Escarpment.

on or within the sea floor, such as submarine communications cables.

As Dr. Sallenger described yesterday [paper not in volume], the USGS has been requested by Congress to develop a National Coastal Program. This program will be developed on a regional basis. Input from the Coastal States will be used to develop this program.

As an example of the USGS's concern for coastal issues, we opened a new Center for Coastal Geology in St. Petersburg, Fla., on the campus of the University of South Florida in June of this year. Scientists from the University and the Center are working cooperatively on coastal problems. Here again, partnership is our key to progress. Our coastal program is very much a cooperative effort with the States.

Mapping in the coastal ocean by using high-resolution sonar techniques is underway. This mapping is targeted at population centers to develop a coastal information base. This database will tie to the GLORIA image maps and multibeam bathymetry data offshore. In the panel discussions, two of our studies will be described, one in Massachusetts Bay and the other off San Francisco Bay. These studies are providing an information base on sediment transport, erosion, and depositional processes, which is necessary for addressing such issues as offshore disposal and pollution. The four panel sessions highlight a variety of activities and studies in the coastal ocean and focus on the East Coast, the Gulf of Mexico, the West Coast and Alaska, and the islands, including Hawaii. These studies include mapping programs, identification of mineral resources on the continental shelf [such as aggregate, phosphate, and placers (for example, gold)], energy resources, and tracking fine-grained sediment transport on the shelf with relevance to pollution issues.

The importance of this symposium is not only in sharing information with one another but also in learning from one another about opportunities for partnership. We appreciate the time and the information that you share at these EEZ symposia and value your input. We are here not only to join in the excitement of new discoveries, but to listen. This is an opportunity to renew and expand our partnerships with the States. The vastness of the EEZ—about 60 percent of the national domain underwater—highlights the importance of the information we are sharing in this symposium and in our work together in our partnerships among Federal and State government agencies, the private sector, and academic institutions.

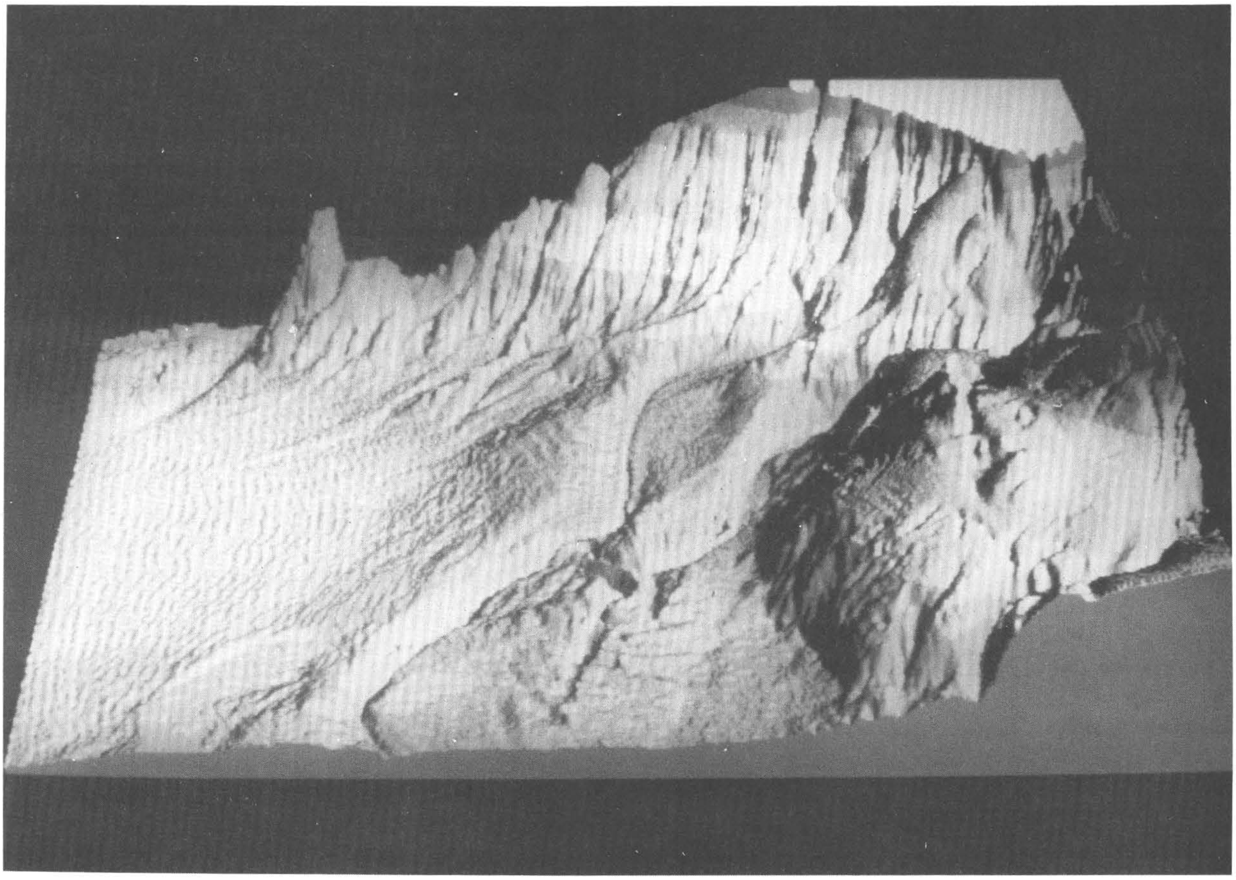

Figure 4. Monterey Canyon bathymetry.

The National Research Council's Marine Board Committee on Exclusive Economic Zone Information Needs

Peter J. Lucas
Shell Development Company

My purpose is to describe the activities of the National Research Council's Marine Board regarding the Exclusive Economic Zone (EEZ). First, I will discuss the overall objectives of the Board and then the newly formed Committee on EEZ Information Needs.

The Marine Board sees its task as assessment and prediction of future uses of oceans and coasts, as well as how they may be affected by present uses. Contrasting with the Ocean Studies Board, whose focus is toward fundamental research questions, specific interests of the Marine Board include the following:

- Improving the technical basis for evaluating ocean and coastal uses,
- Evaluating safety and environmental protection in the marine environment, and
- Advancing marine engineering and technology as a basis for policy formulation and program management.

We have heard in various presentations that optimum utilization of the EEZ will require a number of tasks to be accomplished. These include the following:

- Assessment of the major areas of future ocean development,
- Identification of technical requirements and program development needs,
- Development of government's regulatory and technology promotion roles, and
- Development of methods for avoiding and resolving conflicts among potential uses.

Yesterday, Armand Silva outlined the challenges and choices developed by his Marine Board's Committee on Uses of the Sea Floor. As a followup to this effort, the U.S. Geological Survey and the National Oceanic and Atmospheric Administration are sponsoring a new Marine Board Committee that will address EEZ information needs. The task of the committee is to provide an external view of the Federal plan for activities in the EEZ. To accomplish this, we intend to do the following:

- Assess user information requirements by reviewing all the diverse uses;
- Recommend priorities, data type, and location;
- Evaluate mapping and resource characterization technologies; and
- Recommend needs for development of acquisition and data handling technologies.

The committee will focus on what to do, where, and with what priority and will advise on what should be done in the next phase following GLORIA and SeaBeam mapping.

Over the last few years, many workshops and symposia attendees have expressed a need for data in several areas as an objective basis for decisionmaking. These include data for developing resources, for evaluating the risk to the environment, for understanding sea-floor processes, for resolving conflicts among uses, and for government sponsorship of research and technology development.

These data needs combined with the vast area of the EEZ define a mammoth task. Clearly with limitations on resources, priorities must be set. Through its activities the committee hopes to contribute to orderly progress in providing government and public users with the information they require.

Members of the Committee are as follows:

Robert Chase	The Analytic Sciences Corporation (TASC)/University of Colorado
Donald A. Hull	State of Oregon
Peter T. Lucas	Shell Development Company
C. Barry Raleigh	University of Hawaii
Robert C. Tyce	University of Rhode Island
J. Robert Woolsey	Mississippi Mineral Resources Institute
Alan G. Young	Fugro-McClellan Engineers

Five committee members will be participating in the symposium, and we expect to benefit greatly from the discussions. We hope that those who can contribute to our understanding of your specific needs and priorities will contact members of the committee.

East Coast Sea-Floor Mapping and Information Needs for Offshore Dredging for Sand and Gravel

George L. Marshall
Engineering Geologists

INTRODUCTION

Dredge mining the sea floor for concrete sand and gravel materials that will be used in infrastructure and other types of construction is "relatively" new to the East Coast of the United States. This type of mining, however, was begun in the 12th century by the Dutch in their coastal waters for land reclamation purposes. Offshore sand and gravel mining is common in many other parts of the world, including the United Kingdom, northern Europe, Scandinavia, and Japan, to meet market demands that cannot be met by dwindling onshore sources. McCormack Aggregates is a U.S. company that originated on Long Island. The amount of their sand and gravel reserves was limited by local law and the "not in my back yard" syndrome. As those available reserves approached depletion, McCormack turned to the sea and is now one of the principal North American producers of concrete sand from seabed raw material. McCormack dredges raw material for concrete sand from the sea floor and processes that material at their South Amboy, N.J., plant. Their excavation, which is within the Ambrose Channel of the Lower Bay of the New York Harbor area, is under contract with the U.S. Army Corps of Engineers, and a royalty is paid to the State of New Jersey. This scenario is expected to be played out in the future with other producers along the East Coast, as onshore reserves become depleted. Accordingly, the necessity of the sand and gravel resources as a part of the Exclusive Economic Zone (EEZ) Program is self evident.

Worldwide production of sand and gravel from marine sources is thought to range between approximately 125 million and 150 million t/yr. Japan, which is the world leader, has an annual production of approximately 80 million t. Approximately 300 individual dredging companies supply about 40 percent of its concrete sand needs. Japan is followed by the United Kingdom and the Scandinavian countries, which supply from 15 to as much as 50 percent locally from the sea floor. In the future, the U.S. East Coast area may be in third place.

Presented on behalf of McCormack (Amboy) Aggregates of South Amboy, N.J.

GEOLOGICAL BACKGROUND

The East Coast Continental Shelf is about 3,218 km long, averages approximately 120 km wide, and covers an area of approximately 150,000 mi^2. The potential sources of sand and gravel lying on the shelf are considered to be large and primarily occur adjacent to the New England, the New York, and the New Jersey coasts; scattered smaller sand and gravel deposits are found to the south.

The majority of the sand and gravel deposits initially began as deltas of various sizes and complexity. They formed at the mouths of rivers, flowing from melting ice into the ocean during the final days of the last ice age. At that time, much of the Earth's water was locked up in continental ice sheets and alpine glaciers; consequently, sea level was much lower than it is today, and the Continental Shelf was a large plain.

MARKET CONSIDERATIONS

Many major East Coast cities lie near the drowned valleys of ice age rivers that built deltas of sand and gravel on the Continental Shelf. These cities and environs are the principal potential future markets for the materials of the marine sand and gravel deposits that may lie within economical shipping distances.

Sand and gravel are high-volume, low-value commodities. It is of prime importance, therefore, to develop future sources of supply as close to the market as possible to minimize shipping distances and transportation costs; that is, the economy of the operation will govern the capital investment for marine sand and gravel mining and raw material processing, which is in the millions of dollars. Consequently, economic as well as market considerations will determine if a given marine sand and gravel deposit will be worked, all else being equal. These considerations also govern the mapping and the information needs of the industry.

MAPPING AND SUBSEA-FLOOR INFORMATION NEEDS

Usable maps are the first step in locating new reserves of construction-grade sand and gravel. They form the base on which all other deposit information is built and developed. The most detailed and important sea-floor mapping and subsea-floor geological information is needed adjacent to the major market areas of the East Coast. At this time, less attention is requried for the seabed areas between those markets. The inbetween areas should not be bypassed, however, or large sand and gravel deposits may be missed that will eventually become essential.

Sea-Floor Topographic Maps

Nautical charts, such as the harbor and coast charts, which are distributed by the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA), could be used as base maps expanded seaward, where necessary to cover the areas of concern. The 1:40,000-scale New York Harbor Chart, for example, which has 1-fathom bottom contours and soundings in feet below mean low water, has been a good base map for McCormack's operations. I suggest that this scale be used for the desired maps because it is adaptable to exploration work and allows sufficient room to add the results of that exploration. I also suggest that 1-fathom bottom contours be used because this interval readily permits dredging operation planning; their outline may help to locate sand and gravel deposits. In addition, all depths should be shown in feet below mean low water, which is the standard of the U.S. maritime industry.

Bathymetric Map Coverage

The oceanward extent of detailed sea-floor mapping can be placed at the depth limit of anticipated future dredging. The Japanese claim that their new excavation equipment is capable of dredging at a maximum depth of 100 m. Thus, the proposed bathymetric maps should cover the 110-m line in a band along the East Coast, perhaps averaging 110 km or more wide.

Geologic Maps

The desired sea-floor bathymetric maps would make good base maps for plotting the "ground truth" geological information required for a successful dredging operation. The geologic maps might be developed as suggested in the following steps:

1. Seismic Profiles

The initial geologic maps should be based on high-resolution seismic profiles so that the stratigraphic and the subbottom geologic characteristics of the seabed materials can be delineated; pinger and boomer types of seismic equipment have been used with good results. The seismic profiles could be run in two sequences—widely spaced lines on a reconnaissance basis and a more-detailed sequence run in those areas showing promise. Several pairs of profiles at right angles to each other should be generated to "checkerboard" each area of interest.

2. Test Holes

After the acoustic-based geologic (stratigraphic) maps have been constructed from the seismic profiles, a series of bottom sediment cores should be obtained from the more-promising areas. Continuous vibracored test holes to at least 30 ft are recommended. Ideally, the cores would reach 50 ft, be on a 3,000-ft center, and be logged in sufficient detail to substantiate the seismic information.

3. Samples and Gradation Analysis

Each successive full 2 ft of each core should be sampled, and a gradation analysis run on a representative sample split-out (by using a sample splitter) of the 2-ft sample; that is, a 50-ft continuous core would yield 25 full samples, 25 representative sample splits, and 25 analyses. The testing should follow the American Society for Testing and Materials (ASTM) Standard Specification for Concrete Aggregates No. C33. That specification and its test methods are considered to be the standard of the industry. Other, more technical, gradation analyses are not ordinarily used in evaluating a given deposit area for potential concrete sand supplies.

Figure 1 is a common type of laboratory report sheet that is used by the industry for recording and comparing sieve test results and is based on ASTM No. C33. Table 1 shows the ASTM No. C33 grading specification for concrete sand.

Gravels are commonly considered by the industry to be material coarser than 6.35 mm. They should be sieve tested separately and noted if found in the core sample. The first part of figure 1 lists the regular gravel sizes of the industry. Because gravels are desired, it is important that they be included in the analysis.

Gradation testing in successive 2-ft intervals is necessary because the commonly used method of excavation removes only a few inches of the exposed top of the deposit with each straightline pass of the dredger; each pass may cover 1.6 km or more. The gradation variations within each horizontal layer from test hole to test hole, consequently, govern where to dredge, how to blend to make specification sand, and so forth.

GRADATION ANALYSES

Company: ____________________

Project: ____________________

Sample Descriptions: ____________________

Analyses by: __________ Sampled by: __________ Date Sampled: __________

	GRAVEL							
SIEVE	% Ret'd	% Pass	% Ret'd	% Pass	% Ret'd	% Pass	% Ret'd	% Pass
4"								
3½								
3								
2½								
2								
1½								
1								
3/4								
5/8								
1/2								
3/8								
1/4								
Pan								
% Gravel								
	SAND							
3/8"								
#4								
8								
16								
30								
50								
100								
200								
Pan								
Wash								
F.M.								

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Table 1. Concrete sand gradation specification information

[The standard fine aggregate gradation specification customarily followed by the industry. The size fractions of a processed sand must fall within the Percentage Passing limits to be considered as an approved concrete sand. Concrete sand gradation specification information is given in the American Society for Testing and Materials Standard Specification for Concrete Aggregates C33, 1988 Annual Book of ASTM Standards, Volume 04.02, Concrete and Mineral Aggregates. The sand grains should be sound and free of injurious amounts of deleterious substance]

Test sieve size	Percentage passing
3/8" (9.5 mm)	100
No. 4 (4.75 mm)	95–100
No. 8 (2.36 mm)	80–100
No. 16 (1.18 mm)	50–85
No. 30 (600 μm)	25–60
No. 50 (300 μm)	10–30
No. 100 (150 μm)	2–10
No. 200 (75 μm)	0–3

Table 2. A list of sand gradation descriptions that are commonly used in the industry

[The descriptions are to indicate which parts of a marine deposit should be capable of making a concrete sand with minimal processing at the onshore plant, those parts that may require extensive processing and (or) mixing, and those parts that should be used for other purposes. Suggested word texture descriptions for general areas of a sand deposit are based on one or two significant grains size fractions of a gradation analysis. Combine words when a significant grain-size fraction falls in between, for example, Medium-Coarse Sand]

Very Fine	More than 60 percent passing the No. 50 sieve.
Fine	More than 70 percent passing the No. 30 sieve and 40 to 60 percent passing the No. 50 sieve.
Medium	60 to 70 percent passing the No. 30 sieve and 30 to 40 percent passing the No. 50 sieve.
Coarse	Less than 85 percent passing the No. 16 sieve or less than 60 percent passing the No. 30 sieve and less than 30 percent passing the No. 50 sieve.

4. Isopleth Maps

After the 2-ft core samples have been analyzed, it would be very helpful to have the results shown on stacked isopleth maps. An isopleth map shows the areal distribution and (or) magnitude of a general grain size for a given layer of the deposit by depth below the sea floor. These maps should be constructed for each area of interest and have the general areas of finer and coarser sand (and gravel, if present) outlined on each. Together, they would form a "layer cake" of sand and gravel gradations.

Table 2 lists suggested "word" texture descriptions for the overall grading of a 2-ft sample that is based on one or two significant individual sand-size fractions from its analysis. The texture words could be used to outline general grain-size areas; for example, coarse sand on each isopleth map and the gradation parameters included in the map's legend.

5. Exception

An exception to the 2-ft sample-based isopleth map may be those areas of the seabed where a very thick layer of sand that is too fine grained to be capable of yielding concrete sand completely overlies coarser materials indicated in the seismic survey but not reached in test drilling. In this case, core sampling and isopleth maps might be increased to 5 ft or more thick to reduce laboratory and map work.

◀ **Figure 1.** This blank form is an example of a typical coarse and fine aggregate gradation analysis laboratory report sheet. The test sieves sizes follow ASTM No. C33, except that a 1/4-in. sieve is substituted for the No. 4 in the gravel section as a 1/4-in. screen is commonly used in production screening plants. Coarse aggregates are processed gravels (or crushed stone) conforming to a specified gradation and quality. Fine aggregates are processed sand materials (concrete sand) conforming to a specified gradation and quality. A discussion of aggregate quality is beyond the scope of this paper. However, quality tests are only run on raw materials potentially capable of meeting minimum gradation requirements. That is why sieve tests are very important.

Geologic Cross Sections

Geologic cross sections drawn through the areas of coarser materials capable of producing specification sand would be of great help for long-term planning purposes (25–50 yr). The sections should reach to the horizontal and depth limits of the coarser materials when known.

Even thin layers of coarser materials should be shown; for example, a 10-ft-thick sand and gravel deposit covering 1 nmi^2 should yield approximately 10 million yd^3 of raw material for processing and would supply a small metropolitan market for several years.

OTHER CONSIDERATIONS

Water current velocities and directions at various depths and on the sea floor, baseline turbidity, and the location of ebb and flow channels and (or) patterns for each prospective dredging region would be very helpful for planning day-to-day dredging operations.

SUMMARY

The need to replace dwindling supplies of onshore construction-grade sand and gravel materials for metropolitan markets that have nearby offshore supplies is evident. The EEZ Program will help to resolve these imminent shortages.

The East Coast Continental Shelf is very large and likely contains significant volumes of construction-grade sand and gravel supplies. Deposits of those materials formed near the end of the last ice age from meltwater-fed rivers flowing on the shelf during that period of lowered sea level.

Many East Coast metropolitan market areas appear to lie near potential offshore sand and gravel deposit regions. Detailed sea-floor topographic, geologic, and isopleth maps and geologic cross sections are needed to locate and delineate usable materials for those markets. The seaward limit of that mapping may arbitrarily be placed at the maximum depth of dredging of modern equipment.

The sea-floor topographic maps could be logical extensions of existing NOAA nautical charts used for maritime navigation. The sea-floor maps would be used as the foundation on which all other deposit information is built.

Descriptive isopleth maps covering areal sand gradation distribution in 2-ft deposit intervals are needed for dredge operation planning purposes and to enable the industry to make the major capital investments necessary for deepwater dredging.

Deposit descriptions should follow the standard language of the industry so that the information be used most effectively and economically.

Coastal Mapping—Preliminary Results From a Pilot Study of Contaminant Transport in Boston Harbor and Massachusetts Bay

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U.S. Geological Survey

INTRODUCTION

The geologic and the oceanographic processes that control the transport and the distribution of sediments in coastal regions are poorly documented and understood. Especially in coastal areas near major population centers, where wastes are often discharged directly into the ocean, several basic questions need to be answered. What are the sources of contaminants to the coastal ocean? How are they transported? Where do they accumulate and how fast? Are contaminants diluted by natural sedimentation? What are the long-term effects on marine resources? Because many of the contaminants are particles or are transported on fine-grained sediments, the answers require an understanding of the geology of nearshore regions and of the processes that transport and distribute sediments throughout the coastal ocean.

The Boston Harbor-Massachusetts Bay region was selected by the U.S. Geological Survey (USGS) for a pilot study of sediment and contaminant movement because discharge of wastes to Boston Harbor has created serious environmental contamination; a major plan to reduce the contamination required additional information on the sediment transport regime, which is complex and poorly understood; studies conducted by the State of Massachusetts, the Environmental Protection Agency (EPA), and the Massachusetts Water Resources Authority (MWRA) presented an opportunity to develop a large multidisciplinary program to study the complex transport processes; and the coastal geometry, the topography, and the sediment distribution in the region provided a range of sedimentary and geologic environments for study. Thus, results and techniques developed in this study would have broad applicability to other regions around the United States.

BACKGROUND

Municipal waste from the Boston metropolitan area has been discharged into Boston Harbor for decades. Effluent from the primary treatment plants located on Deer and Nut Islands is continuously discharged into the harbor, and sludge from both plants is discharged on the out-going tide in President Roads. As a result, the harbor sediments are contaminated, shellfish beds are closed to fishing, swimming is often curtailed, and there is a high incidence of tumors in fish. The MWRA, which is a new independent State agency that provides for water and sewer service to the metropolitan area, has developed a comprehensive plan to eliminate the discharge of wastes to the harbor. By 1992, ocean discharge of sludge will end; the sludge will be composted on land and recycled. By 2000, a new secondary treatment plant will be constructed on Deer Island, the effluent from which will be discharged 13 km seaward of the harbor mouth into Massachusetts Bay through an 8-m-diameter tunnel drilled in the bedrock about 300 ft (100 m) beneath the sea floor. The average volume of effluent discharged into Massachusetts Bay will be about 500 million gal/d (20 m^3/s), which is about twice the discharge of the rivers entering Boston Harbor. The cost of this construction program is estimated to be $6 billion.

Massachusetts and Cape Cod Bays form a semienclosed embayment to the east of Boston Harbor (fig. 1). Stellwagen Bank rises to within about 30 m of the sea surface and partially separates Massachusetts Bay from the Gulf of Maine. Stellwagen Basin, located to the west of Stellwagen Bank is about 90 m deep. The sea floor in western Massachusetts Bay contains numerous hummocks and hills, which reflect the glacial influence on the region; topographic changes of 5 to 10 m over spatial scales of 1 to 5 km are common. In contrast, the topography in Cape Cod Bay is relatively smooth. The sediment texture in the western part of Massachusetts Bay is a varied mixture of gravel, sand, and fine-grained sediments (Schlee and others, 1973). Sediments in the deeper basins are primarily fine-grained silt and clays. The Merrimack River, which discharges into the Gulf of Maine to the north of Cape Ann

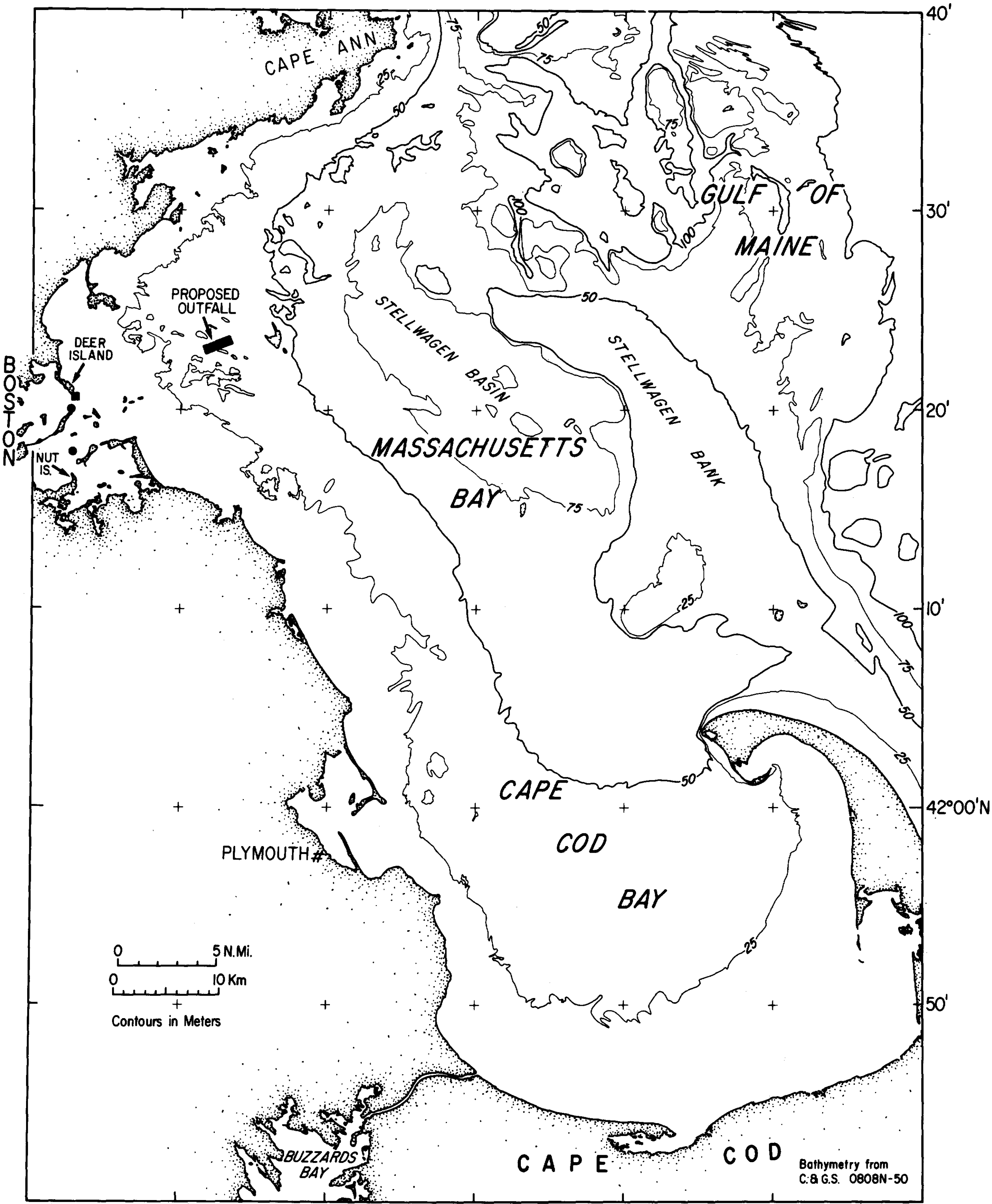

Figure 1. Massachusetts and Cape Cod Bays. Topography is simplified from a Coast and Geodetic Survey (1970) chart. Square indicates present location of effluent and sludge discharge from Deer Island; circles indicate outfalls from Nut Island; rectangle is location of proposed new ocean outfall for effluent from new Deer Island secondary treatment plant.

at a rate of about 215 m^3/s is a source of fresh water and sediments to the Massachusetts Bay system.

STUDY COMPONENTS

The pilot study in Boston Harbor and Massachusetts Bay, which began in 1987, consisted of three major components—geologic mapping of the sediment surface and subbottom, measurements of water circulation and sediment transport, and estimates of sediment accumulation and mixing rates. A major long-term objective of a continuing study is to provide a regional, basinwide perspective of sediment and contaminant transport. The pilot study has increased our understanding of the oceanography of this coastal region and has been used to help design and locate the new ocean outfall.

PRELIMINARY RESULTS

Mapping

Geophysical surveys were conducted in Boston Harbor and selected regions of Massachusetts Bay. These surveys collected sidescan-sonar, high-resolution seismic reflection, and bathymetric data. Maps have been generated that show the morphology and the texture of the sea floor in Boston Harbor as well as the thickness of sediments above the acoustic basement (Rendigs and Oldale, in press).

One map derived from the analyses of the sidescan-sonar records outlines the areal distribution of modern sedimentary environments in Boston Harbor (fig. 2). Areas of sediment erosion in the harbor are characterized by outcrops of bedrock and till and also by lag deposits; they are covered by coarse gravelly sands that have been scoured and winnowed by tidal currents and waves. Areas of sediment deposition are found over shallow subtidal flats and in broad bathymetric lows where tidal currents are weak. The sediments here are watery, organic-rich, sandy, and clayey silts. Areas of sediment reworking reflect a mixture of erosional and depositional processes. Reworked sediments have divers textures that are transitional between those of the other two sedimentary environments. This map of the areas of erosion and deposition provides an important picture of the locations where contaminants presently accumulate in the harbor and can be used to devise plans to sample and monitor these contaminants in the future.

A sidescan-sonar survey also was conducted in western Massachusetts Bay in the region selected for the new ocean outfall (fig. 3). The sidescan observations were made by means of a Klein 100-kHz system, and the data were collected digitally by using a Q-MIPS data acquisition system manufactured by Triton Technology. The survey line spacing was 150 m, thus providing a 50-percent overlap in coverage, and navigation was by means of a shore-based miniranger system that provided ship position with a precision of about 3 m.

The sidescan-sonar observations show a complex alternating pattern of sediment texture and bottom morphology; texture and reflectivity change dramatically over scales of a few tens of meters in many regions of Massachusetts Bay (fig. 4). Areas of small sand waves, or megaripples, are found adjacent to coarse gravel and areas of fine sediments. In many cases, the coarser sediments are highly reflective of the sidescan-sonar signal and are associated with topographic highs. The finer sediments show lower reflectivity and generally occur in topographic lows. Bottom photographs and grab samples have confirmed these interpretations on the basis of the remote mapping techniques. The extremely varied topography and the sediment texture provide a wide range of environments for biologic communities and suggest different rates of sediment and contaminant accumulation in areas that are close to each other.

A detailed digital sidescan-sonar mosaic that covers an 81-km^2 area in western Massachusetts Bay is being made. The digital processing allows the image of the sea floor to be easily analyzed and displayed. A subsection of the digital mosaic, which includes the region where the diffuser for the new outfall will be located, has been completed (fig. 5*A*) and merged with the bathymetric observations (fig. 5*B*). This image clearly shows the correlation between the topographic highs and coarser sediments that have high sonar reflectivity.

Circulation and Sediment Transport

Currents and near-bottom suspended sediment concentrations were measured in three locations in western Massachusetts Bay (depth range 24–72 m) during winter and spring 1987. The measurements were designed to describe the currents and the associated sediment movement in western Massachusetts Bay when strong storms would be most likely to resuspend and transport sediments. The near-bottom observations were made by means of an instrumented tripod (Butman and Folger, 1979). Current, temperature, and light transmission also were measured at mid-depth and near the sea surface by using moorings next to the tripod. Sediment traps were used to collect material suspended in the water column.

In general, the mean flow (the net vector-averaged current calculated over the length of observation) was less than a few centimeters per second, and the spatial pattern was poorly resolved by the measurements. The mean current flow at station A, which is near a location considered for the outfall early in the selection process, was toward shore at all levels of the water column (fig. 6); this onshore flow suggests an eddy in the region south of Nahant

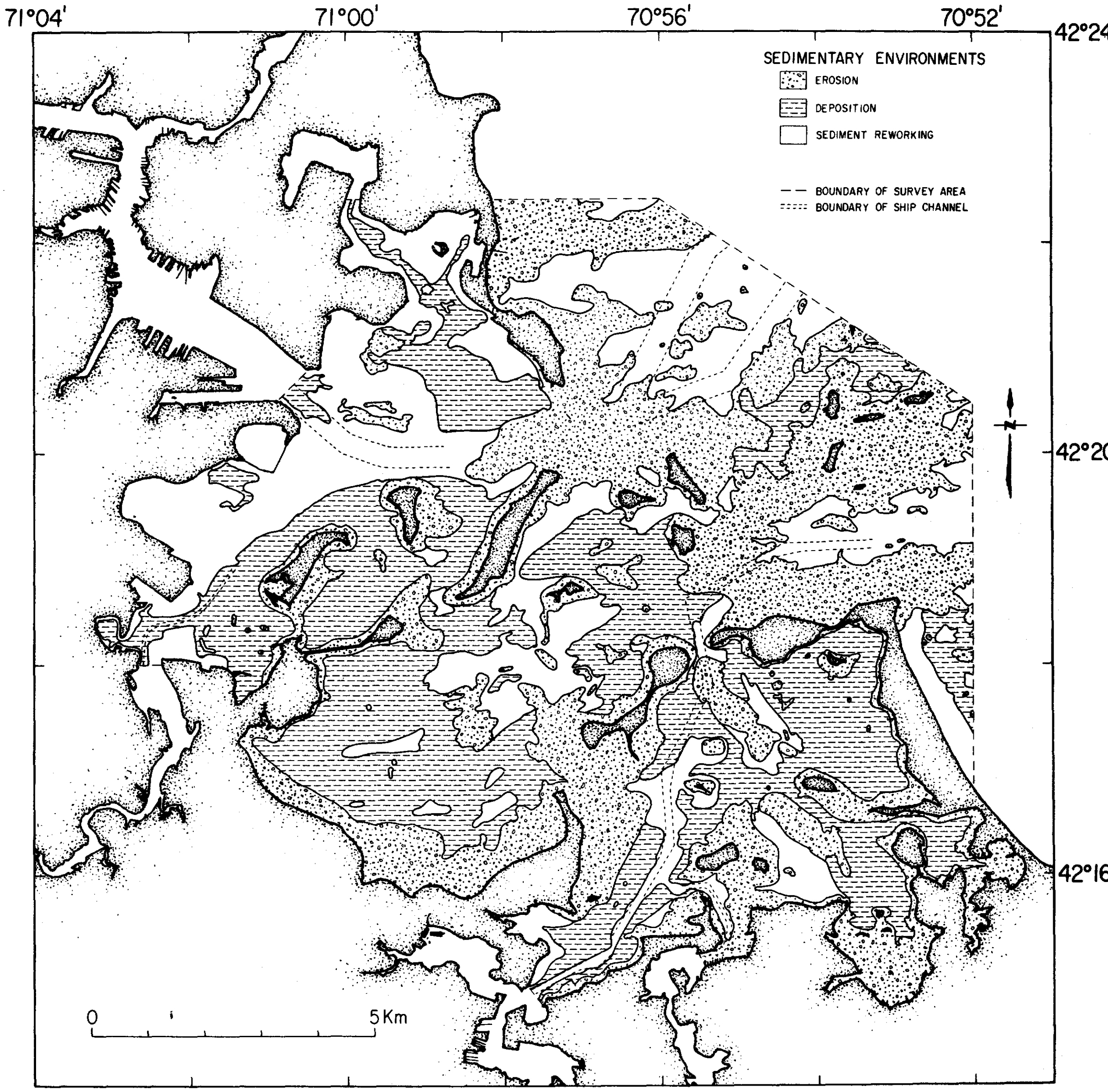

Figure 2. Areas of sediment accumulation and deposition in Boston Harbor based on sidescan-sonar, high-resolution seismic reflection, and sediment texture. The tidal currents are sufficiently strong in the major channels to prevent fine-sediment deposition.

and argues that discharge of treated effluent in this location would be unwise. In coastal areas that have complex topography, however, the excursion of water and particles, which are the result of tides and 2- to 10-d wind events, may be larger than the residual flow features. In these regions, the residual circulation may not indicate the long-term trajectories of water or particles. Indeed, the observations suggest that the currents caused by storms may be more important than the mean flow in determining the transport of water and the long-term fate of sediment particles. Moored instrumentation sufficient to map the current flow in this complex region will be impossible, and, thus, numerical models designed to resolve the complex spatial pattern of the flow field are essential to interpret and map the residual and storm-driven current field.

The near-bottom observations showed resuspension of the surficial sediments during winter storms (fig. 7). The most severe storms resuspended sediments at each of the mooring locations, but storms of less intensity resuspended material only at the two shallower sites. These data suggest that accumulation of fine-grained sediments may occur during the summer months when storms are infrequent, but

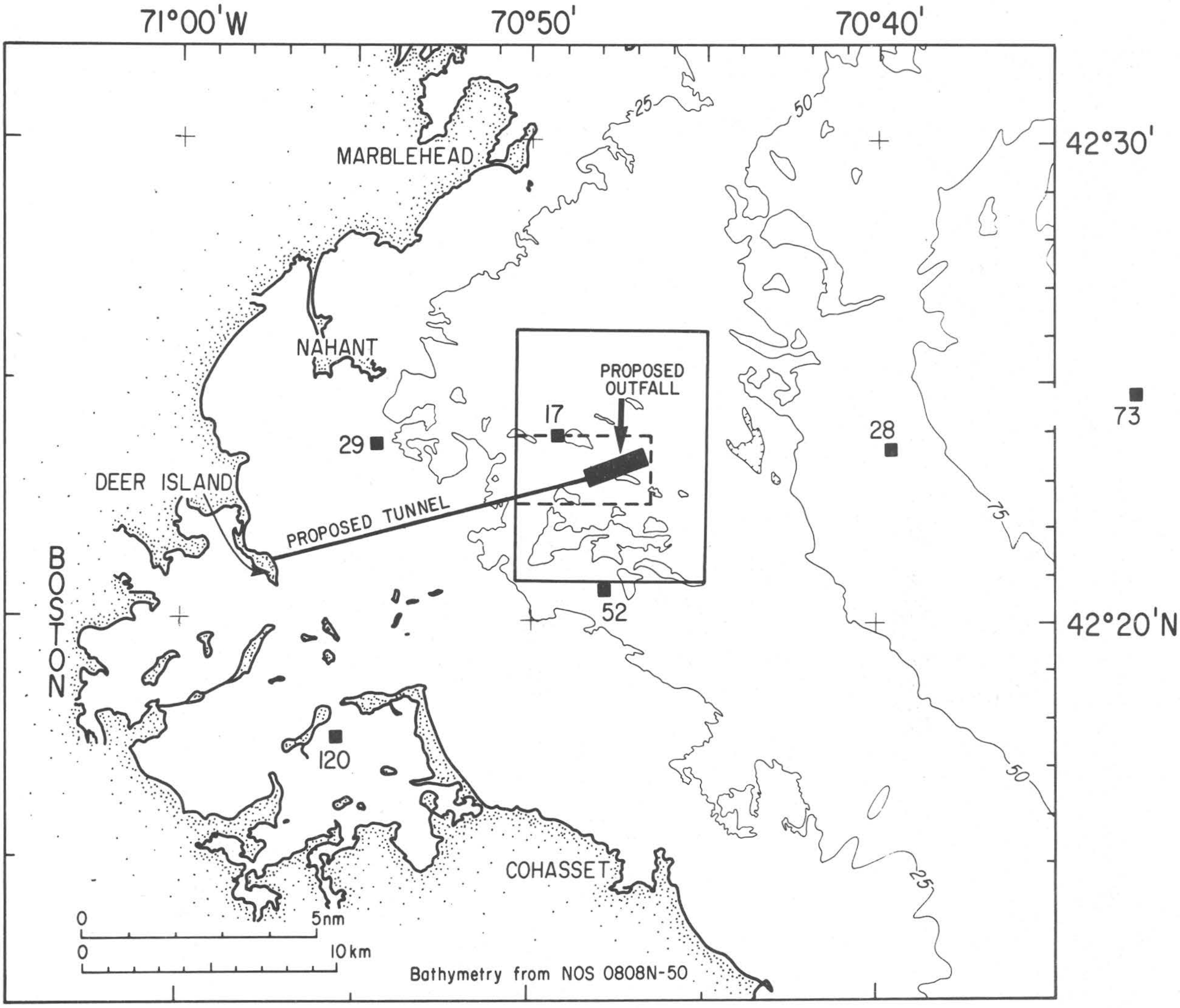

Figure 3. Western Massachusetts Bay showing the area of the sidescan-sonar survey (boxed region), the approximate path of the proposed tunnel, the site of diffuser, the area of the perspective mosaic shown in figure 5 (dashed box), and the inventory of ^{210}Pb at selected stations (numbered boxes). ^{210}Pb inventories in excess of 32 disintegrations per minute per square centimeter in Boston Harbor and Stellwagen Basin indicate long-term accumulation sites for contaminants and sediments (fig. 9). Variability in inventories near the site of the proposed outfall reflects the extreme variability in sediment texture and the geologic environment as indicated in the sidescan survey.

they may then be resuspended and transported toward deeper water or protected inshore areas during winter storms. All the resuspension events observed were caused by oscillatory currents associated with surface waves; some of these waves were generated by local winds, but some were generated by storms in the Gulf of Maine.

The 1987 current measurements coincided with the largest April discharge on record from the Merrimack River, which is located just north of the study area. Sea-surface temperature maps, which were obtained from satellite observations, were examined to aid in the interpretation of the current measurements; the images showed a large surface plume extending southward from the Merrimack River and into Massachusetts Bay (fig. 8). Daily average northwestward flow in excess of 30 cm/s was observed in association with the western edge of the plume at a depth of 8 m (fig. 8). These observations show the important influence of nonlocal forcing on circulation and sediment transport in Massachusetts Bay and underscore the need for a regional perspective in these studies. Long-term synoptic observations are also essential to document and evaluate the importance of infrequent or catastrophic events, such as floods or strong storms, on sediment transport and coastal circulation.

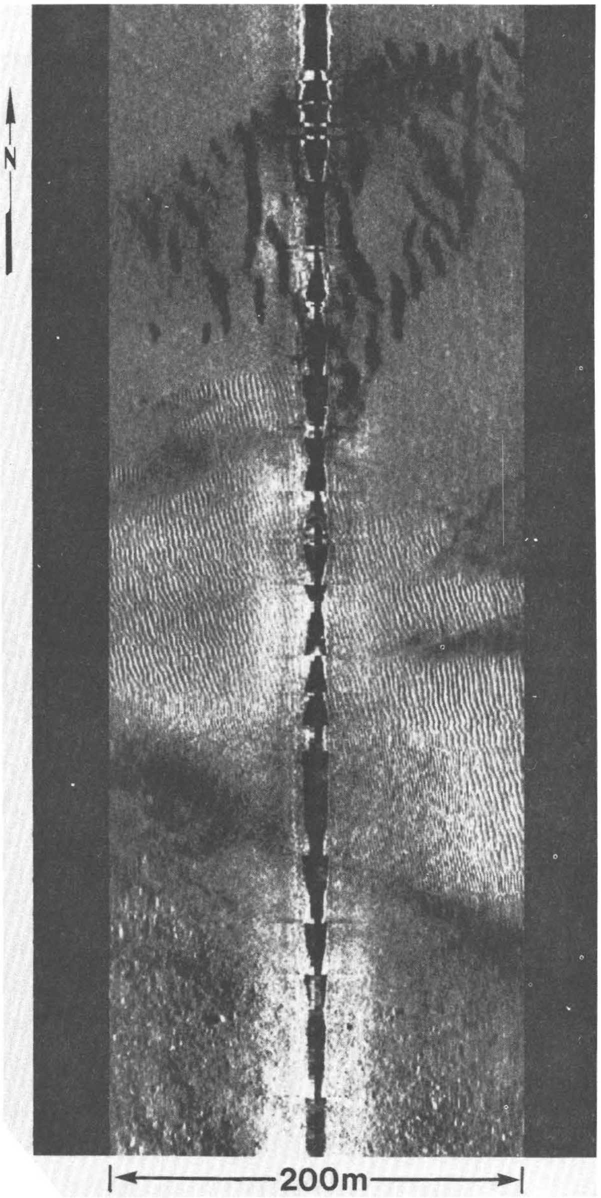

Figure 4. Typical sidescan-sonar image in Massachusetts Bay showing the rapid transition of bottom reflectivity, which indicates changes in sediment texture and roughness. The line down the center of the image marks the ship track, the image extends 100 m to each side. Dark areas are finer-grained sediments; light areas indicate coarser sediments. The megaripples have wavelengths of between 2 and 3 m and are probably between 25 and 50 cm high. Note the changes in reflectivity and sediment texture that often occur over distances of only a few meters.

Geochemistry and Sediment Accumulation

Geochemical and geotechnical studies typically examine sediment characteristics that have developed over a time span of years to centuries. Heavy metals, such as Cr, Cu, Pb, Zn, and so forth, are significantly enriched in surface sediments of the harbor compared to subsurface sediments deposited before the Industrial Revolution. A critical question is whether these sediments will be a long-term source of contaminants to the water column and benthic organisms after the present waste discharge is reduced or eliminated.

A number of radioactive isotopes have been analyzed to determine the rates of sediment accumulation, the rates of sediment mixing (bioturbation), and the potential for contaminant accumulation. ^{210}Pb, which is a sediment-reactive isotope that behaves like many contaminants in the marine environment, can be used as a contaminant tracer (fig. 9). ^{210}Pb concentrations have been measured in a number of undisturbed cores obtained from Boston Harbor and Massachusetts Bay. Inventories of excess ^{210}Pb are between 0.6 and 2.3 times that predicted from atmospheric and seawater sources (fig. 3). In areas where the inventories are highest, preferential accumulation of ^{210}Pb has occurred and accumulation by means of focused deposition or more intense scavenging of contaminants by the fine-grained sediments of other contaminants would be expected. Other isotopes, such as ^{14}C, ^{234}Th, and Pu, contribute to our understanding of where sediments are actively accumulating. Areas of accumulation identified to date include Stellwagen Basin offshore and protected areas of the harbor inshore. These areas should probably be closely monitored to evaluate the long-term environmental effects of the elimination of waste discharge to the harbor and the operation of the new ocean outfall.

FEDERAL-STATE COORDINATION

The USGS study in coastal Massachusetts is closely coordinated with other agencies and research organizations through the Massachusetts Bays Management Committee, which is composed of representatives from Federal and State agencies that have an interest in the coastal environment of Massachusetts. The committee, which is spending $1.6 million for a carefully coordinated research program through 1991, has applied to the EPA to include Massachusetts and Cape Cod Bays in the National Bays Program.

FUTURE WORK

The USGS has established, in cooperation with the MWRA, a long-term environmental monitoring station in western Massachusetts Bay near the proposed site of the new ocean outfall (fig. 1). This station will provide the first long-term observations of current, temperature, salinity, and suspended-sediment in Massachusetts Bay. The measurements will be used to determine the importance of seasonal variability and infrequent catastrophic events in sediment movement. Instrumentation has been installed to collect samples of suspended material during major storms. This new equipment will improve our estimates of the concentration and the composition of suspended matter during storms, when resuspension and transport of bottom sediments (and any associated contaminants) may be most significant and when sampling from a surface ship is impossible. In addition to the long-term measurements, the USGS is conducting numerical studies of the tidal circulation in Boston Harbor to improve understanding of the flow patterns and the exchange of water and particles between the harbor and western Massachusetts Bay.

The Massachusetts Bays Program is funding additional field studies, including a major physical oceanographic field program to understand the circulation in the bays and the exchange of water with the Gulf of Maine. This work is closely coordinated with the ongoing USGS program.

SUMMARY

Major results from the pilot study conducted in Boston Harbor and Massachusetts Bay in 1987–88 are as follows:

- Mapping of the sea floor by using sidescan sonar has shown a complex pattern of sediment texture and bottom morphology; the maps indicate areas of sediment and potential contaminant accumulation. Within the harbor, finer sediments are found on the shallow mud flats and coarser sediment in the deep tidal channels. In western Massachusetts Bay, coarser sediments are associated with topographic highs, and finer sediment, with local topographic lows. The complex sedimentary environments provide a wide range of biological habitats and geologic conditions that vary over short spatial scales.
- Remote mapping techniques are essential to determine adequately the complex spatial variability of the bottom sediment texture and morphology; accurate maps could not be prepared from analyses of grab samples alone. Digital processing of the sonar observations allows sonar data to be easily manipulated, displayed, and merged with other data sets.
- The surficial sediments in western Massachusetts Bay are frequently resuspended and transported by winter storms. Understanding the transport during these episodic events is essential to determine the movement and the fate of particles and contaminants in coastal regions.
- Radioactive isotopes can be used to identify potential areas of long-term accumulation of contaminants. Increased inventories of ^{210}Pb in Boston Harbor and Stellwagen Basin suggest that these areas will preferentially accumulate sediments and contaminants over the long term.
- The current flow pattern is weak and is not well resolved by the available measurements; these observations may be typical of coastal areas that have complex topography and where the currents are forced locally by wind and river runoff as well as by the flow in adjacent regions. Numerical models will be essential to interpret the complex spatial flow patterns in these regions and to understand the physics of water and particle exchange.
- The geologic mapping of the sea floor, direct in situ observations of near-bottom flow and sediment movement, and geochemical measurements carried out as part of the pilot study were complementary, and all contributed to an increased understanding of long-term fate of particles and the processes that transport them in the coastal ocean. Similar studies in other coastal areas would provide basic information on areas of contaminant accumulation.

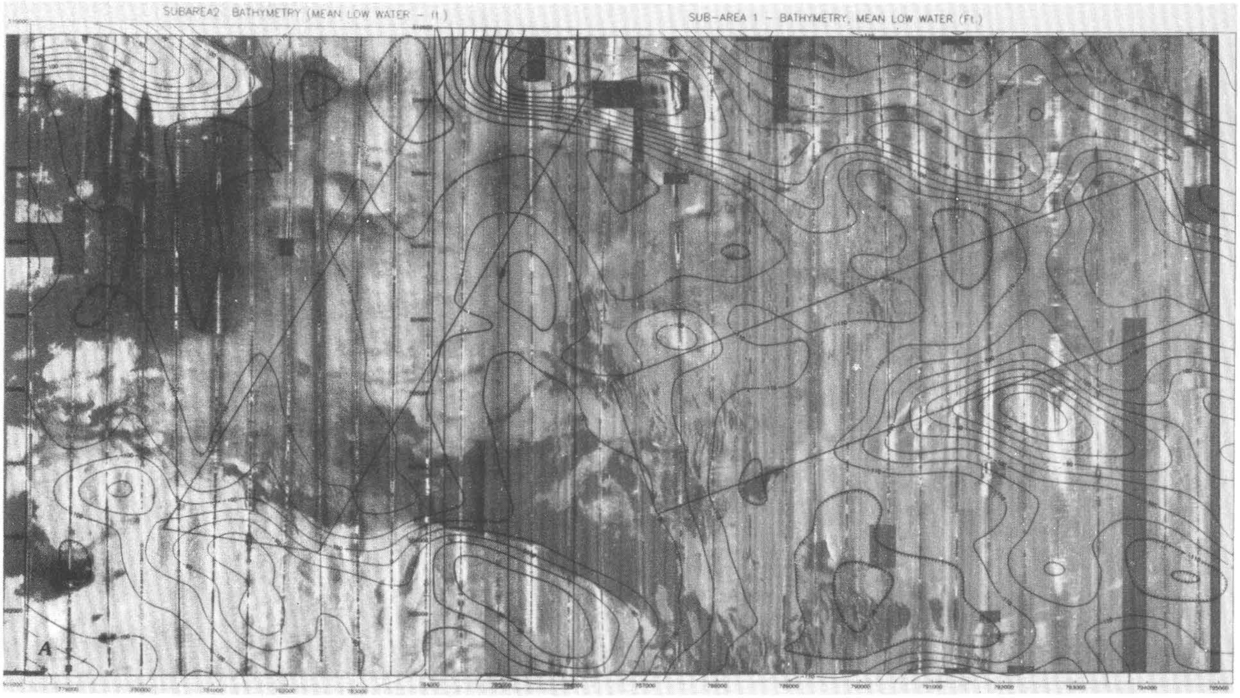

Figure 5. Study areas. *A*, Mosaic of the sidescan observations for the region within the dashed box shown in figure 3; bathymetry is superimposed. The north-south-trending stripes indicate the ship track and are an artifact of the data collection. The two open rectangles are proposed outfall orientations; the dark rectangles indicate data gaps. *B*, Perspective three-dimensional map of the region near the proposed diffuser site looking eastward from an elevation of about 30°; the image is created from the digital sidescan and bathymetric observations. The light areas of high reflectivity typically correspond to the topographic highs that have exposed gravel and boulders. The black-bordered box indicates the corridor selected for the location of the diffuser of the new ocean outfall (fig. 3). The north-south-trending stripes indicate the ship track and are an artifact of the data collection. The dark rectangles indicate data gaps.

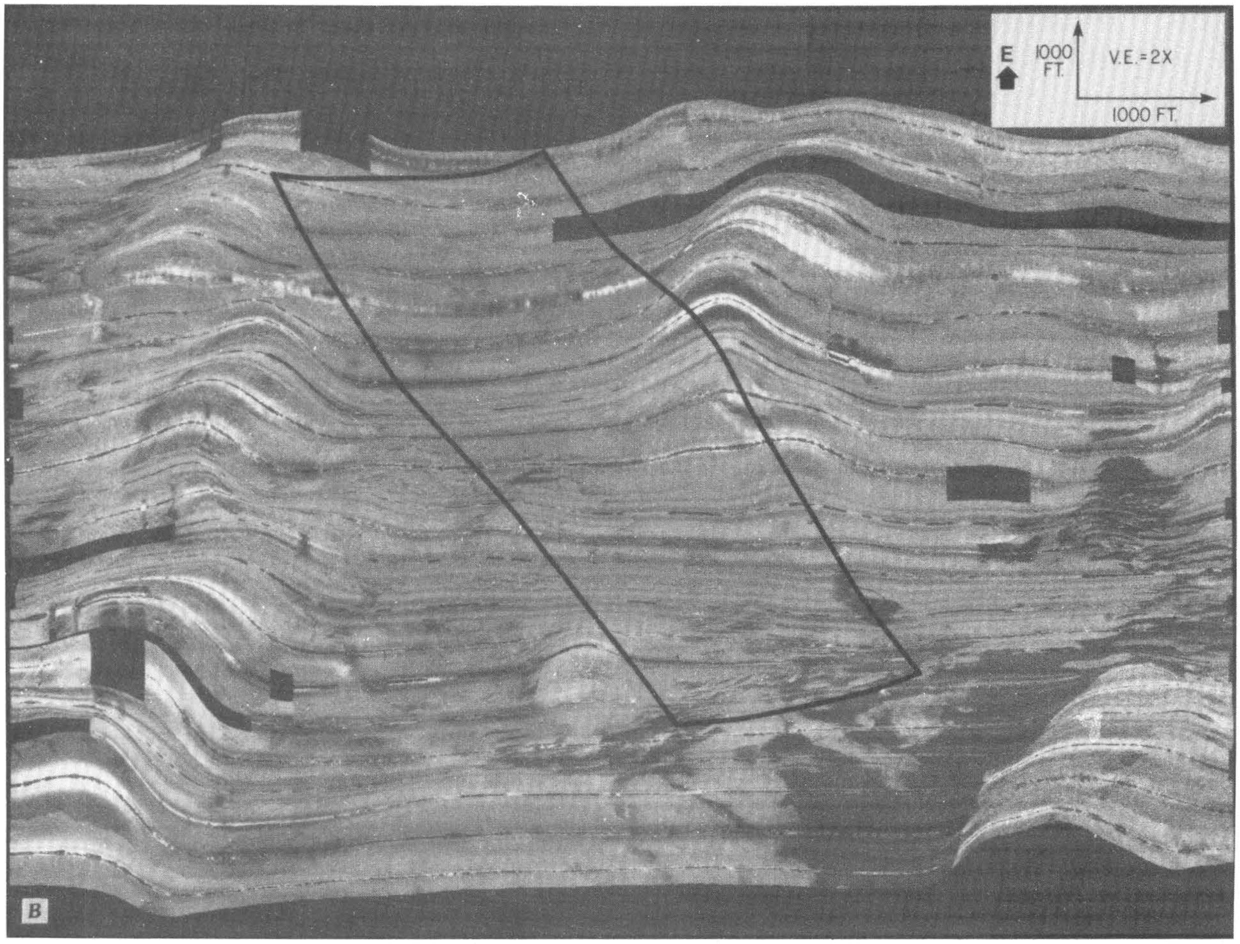

Figure 5.—Continued.

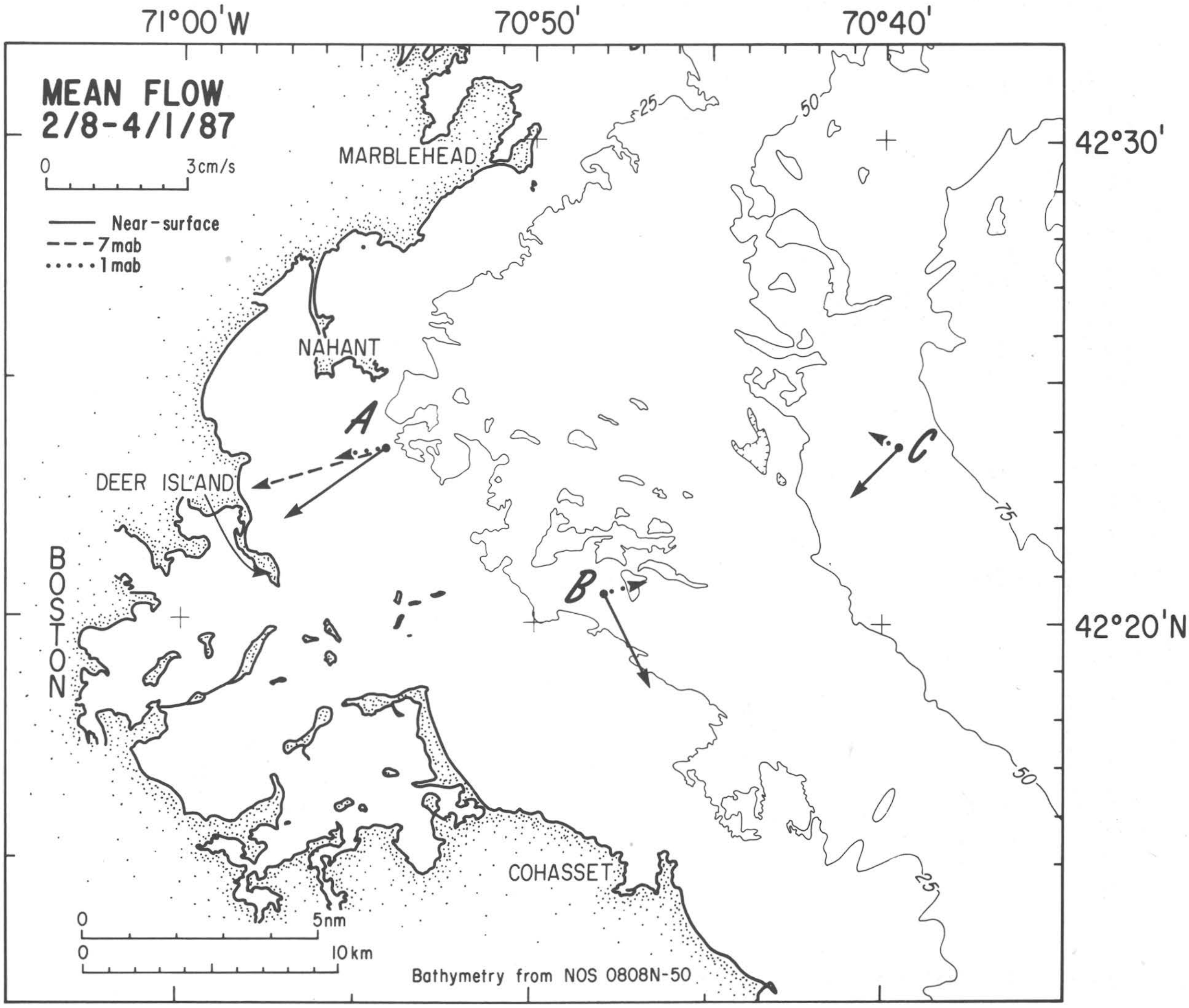

Figure 6. Western Massachusetts Bay showing the mean flow (the vector-average current over the entire observation period) at three locations-A–C-measured during winter and spring 1987. Although weak, the observations are consistent with a mean shore-parallel flow near the surface. The mean flow at 1 m above bottom (mab) was weak and not statistically significant. Note the onshore flow observed at station A south of Nahant at all instrument depths.

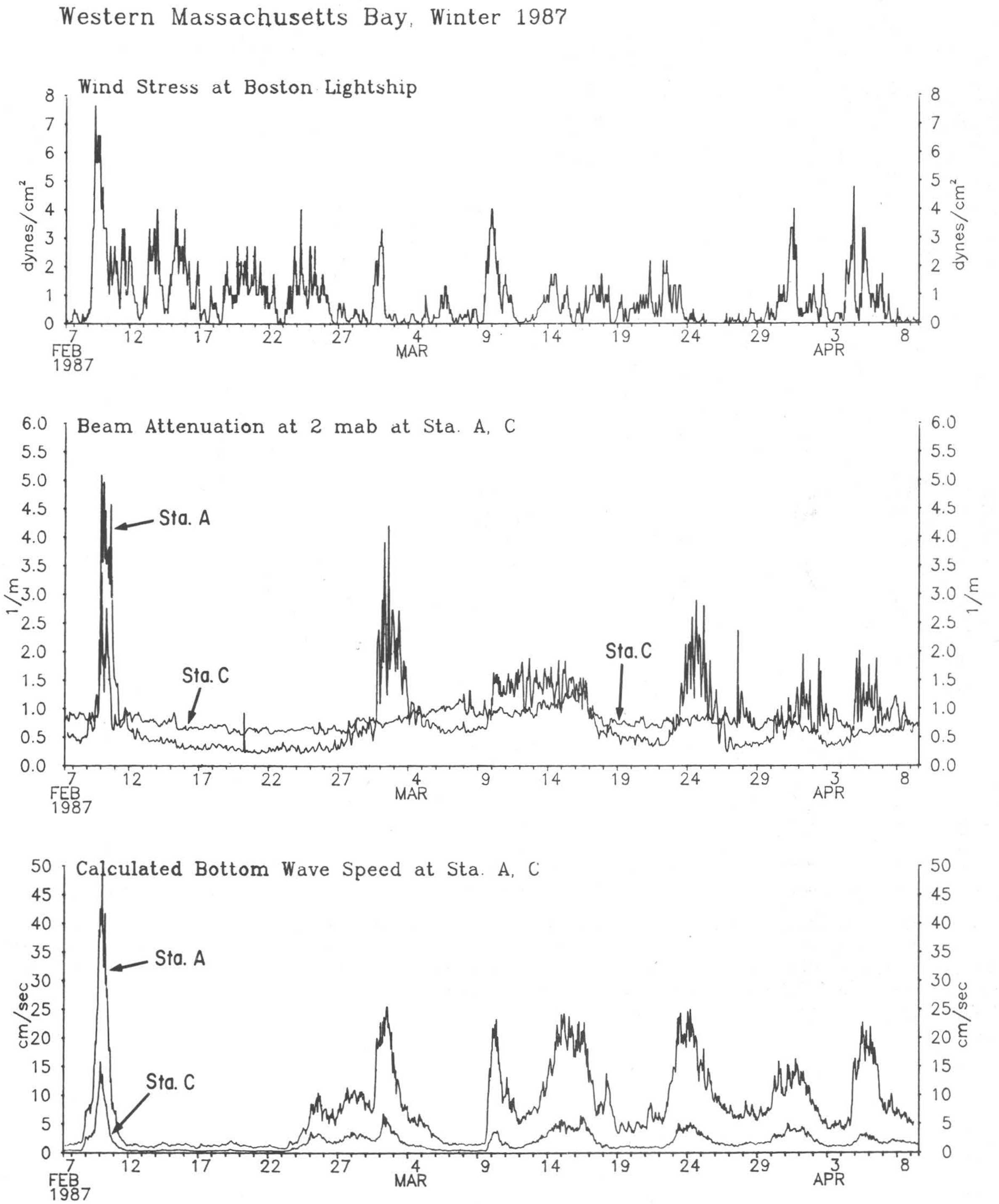

Figure 7. Time series of wind stress during winter 1987 at the Boston Lightship, beam attenuation at 2 m above bottom (mab) (large beam attenuation indicates high suspended-sediment concentration) at stations A and C, and bottom wave currents measured at stations A and C (fig. 6) by means of bottom instrument systems. Periods of large bottom wave currents indicate storms; note the strong correlation between wave currents and beam attenuation, especially at station A (27-m water depth), which indicates episodic resuspension of the bottom sediment. Only the largest storm (February 9) was strong enough to resuspend the sediments at station C in 72-m water depth. The near-bottom wave currents do not always correlate with the wind measured at Boston; swell generated by storms in the Gulf of Maine enters Massachusetts Bay from the east and is often strong enough to resuspend the bottom sediments. During nonstorm periods, beam attenuation is generally larger at station C than at station A, which indicates increased near-bottom suspended sediment concentrations in the deep basin. Beam attenuation measurements at station B at 37-m water depth (not shown) closely matched those at station A.

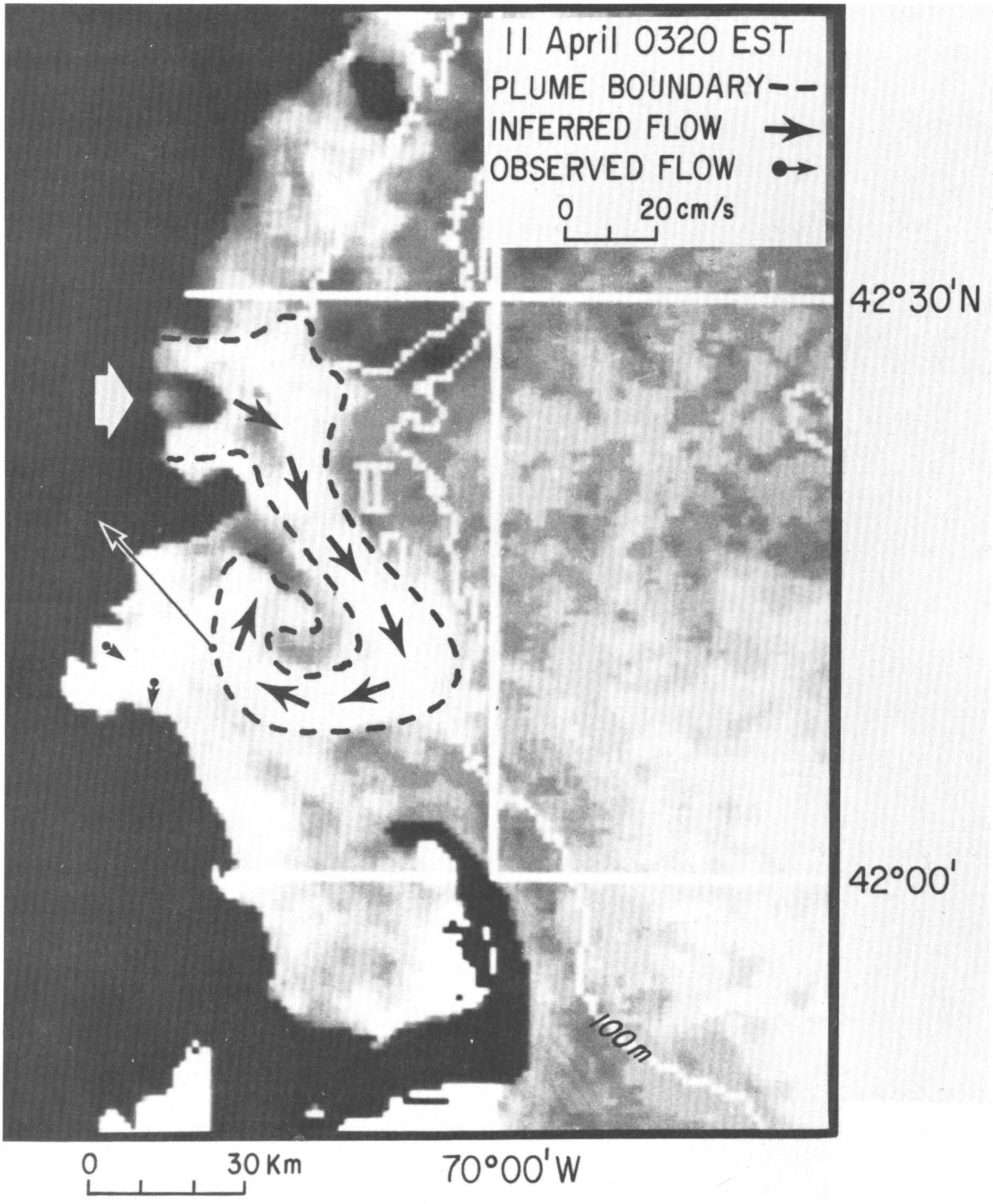

Figure 8. Sea-surface temperature derived from satellite observations showing a plume of warmer water extending southward into Massachusetts Bay from the Merrimack River (white arrow). See figure 1 for geographic reference. Large arrows show inferred flow; smaller arrows show near-surface (8-m) daily averaged flow measured by current meters at stations A–C. The observations show the importance of distant sources of contaminants and sediments to the Massachusetts Bay system. (Image courtesy of George Milkowski and Peter Cornillion, University of Rhode Island).

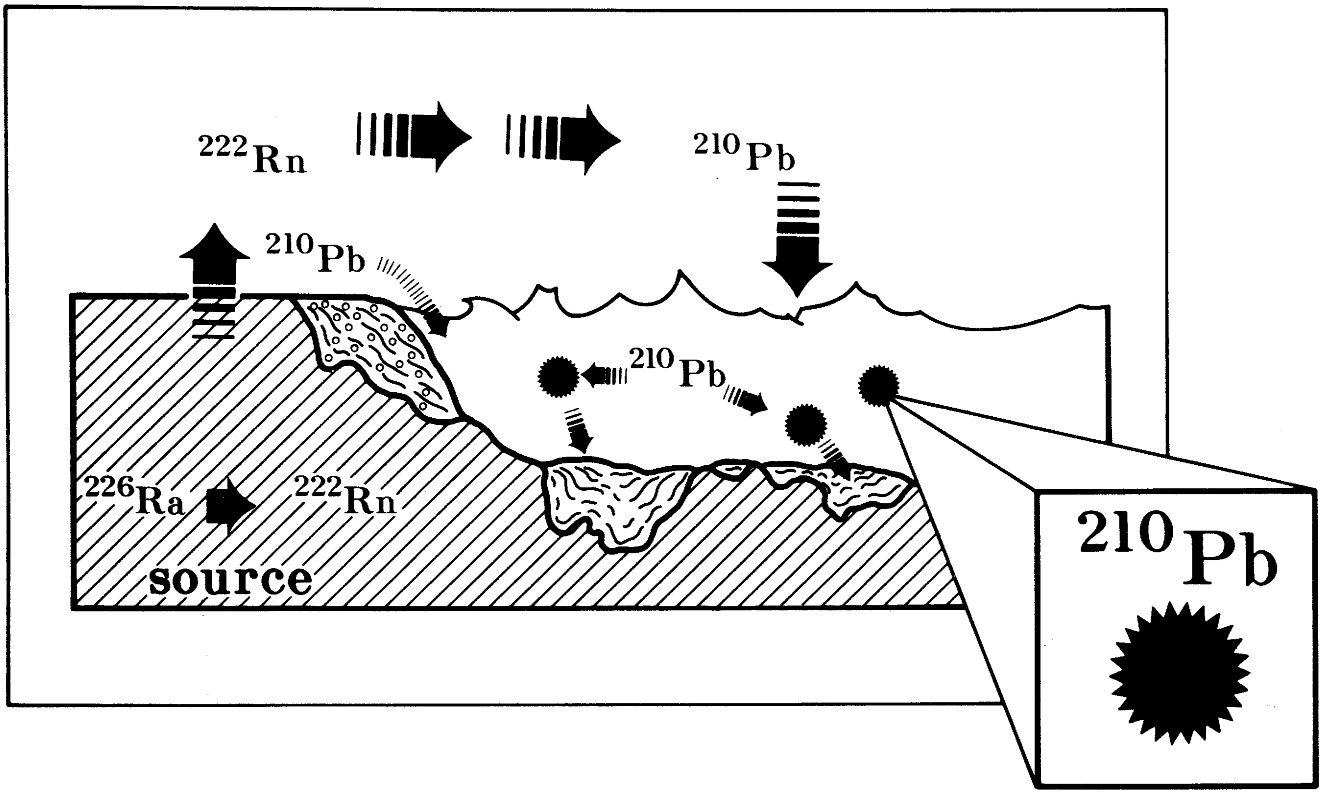

Figure 9. Schematic diagram showing the ^{210}Pb cycle. ^{210}Pb is a naturally occurring radio isotope that forms from the decay of ^{226}Ra in the Earth's crust; ^{222}Rn is the source for ^{210}Pb in the atmosphere. The flux of ^{210}Pb to the sea surface is relatively well known and is about 1 disintegration per minute per square centimeter (dpm/cm^2). If this input were evenly distributed over the sea floor, then it would result in an equilibrium inventory of about 32 dpm/cm^2 on the sea floor. ^{210}Pb is scavenged from the water column by sediments and thus acts as a proxy for other contaminants that behave in similar manner. Areas that have high inventories of ^{210}Pb suggest potential contaminant accumulation. See figure 3 for inventories measured as part of this study.

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East Coast Physiography and Surficial Sediments Along the Inner Continental Shelf of Maine

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The Maine Geological Survey, with support from the Minerals Management Service and in collaboration with the University of Maine, has begun a mapping program from Maine's shoreline to the 100-m isobath. On the basis of several thousand kilometers of seismic reflection and side-scan-sonar profiles, thousands of bottom samples, and about 50 submersible dives, the shelf has been divided into five depositional environments—nearshore basins, nearshore ramps, shelf valleys, rocky zones, and outer basins. The nearshore basins are muddy and connect to intertidal mud flats and eroding bluffs of glaciomarine mud. Natural gas occurrences associated with occasional slump scars and pockmarked fields are common here. Vast areas of rippled sand cover the nearshore ramps, which abut sandy beaches in southern Maine. Shelf valleys extend from the nearshore region to the 60-m isobath, where the Holocene lowstand shoreline is found. The bathymetry of the valleys appears to be conducive to transport material from shallow to deep water. Modern carbonate sediment is collecting around the rocky zones, which are irregular in bathymetry and occur at all depths. The outer basins are muddy regions that have relatively thick accumulations of sediment. These extend seaward of the 100-m depth into the deeper Gulf of Maine.

For more information regarding Joseph T. Kelley's presentation at the Exclusive Economic Zone Symposium, read *Sedimentary Framework of the Southern Maine Inner Continental Shelf-Influence of Glaciation and Sea-Level Change* by Joseph T. Kelley and others (1989, Marine Geology, v. 90, p. 139–147).

The Georgia-Federal Nonenergy Minerals Task Force

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Abstract

The Georgia-Federal Nonenergy Minerals Task Force was formed to evaluate the potential for mining offshore Georgia and to recommend future action to State and Federal officials. The discovery of phosphate near the Savannah Light Tower and the exploration for heavy minerals offshore Georgia by industry led to the formation of the Task Force in 1986. An economic feasibility study was completed by the Task Force in 1988. Hypothetical mine sites for phosphate and heavy minerals were selected and evaluated. In an effort to better define these potential resources, the Task Force has acquired additional geological and geophysical data. These include analyses of phosphate in cores from the U.S. Navy Tactical Air Command Test Site platform sites, heavy-mineral analyses of 50 grab samples, new vibracores obtained at prospective locations, new seismic and neutron activation data, and information from several new core holes on Tybee Island for correlation with the offshore data. These data are being analyzed, and a series of resource maps will be prepared. The data and map products will enable the State and Federal Governments to better evaluate the mineral-resource potential offshore Georgia and may encourage industry to explore and evaluate this area.

INTRODUCTION

When the Georgia-Federal Nonenergy Minerals Task Force was organized in 1986, industry was actively exploring the Georgia Outer Continental Shelf for heavy-mineral deposits. Phosphate deposits have long been known to occur in the Georgia Coastal Plain and offshore Savannah. Although offshore heavy-mineral deposits have not been discovered to date, several deposits are known along the Georgia coast. Abundant supplies of sand and gravel, which have potential use for beach nourishment and construction materials, are available offshore Georgia. The Task Force was charged with examining the resource potential of phosphate and heavy minerals offshore Georgia, the technologic and economic feasibility of mining these minerals, and the environmental constraints to offshore mining; establishing a database of all existing information on resource and environmental studies in the area; and obtaining new data to fill in gaps in the database. The Task Force consists of a Federal cochairman from the Minerals Management Service, a State cochairman from the Georgia Department of Natural Resources, 6 members from the Department of the Interior and State agencies, and 10 to 12 advisors from mining companies, other Federal agencies, and academic institutions.

The area of interest selected by the Task Force extends from the 3-mi territorial sea line (outer State water limit) to the 50-m water depth line, about 125 km offshore and spans the entire area off the coast of Georgia, which is about 30,000 km^2 (fig. 1).

The first phase of the Task Force project was a data compilation and an economic and engineering feasibility study; the study was contracted to the Zellars-Williams Company (1988). Because specific deposits of phosphate and heavy minerals have not been identified off the coast of Georgia, hypothetical sites and ore grades were used to make the feasibility study. The report concluded that considerably more geological and geophysical data are needed to adequately evaluate the mineral potential in the area of interest and considerably higher prices for phosphate and heavy minerals (or much higher grades than those assumed) would be necessary for offshore mining to be economically feasible. The report concluded that phosphate prices would have to rise from the current $25 to $30 to $35 to $42 per tonne for offshore mining to be profitable. Heavy-mineral prices would have to rise from a current average price (for five different mineral commodities) of $127 to at least $152 per tonne to mine these minerals economically offshore. Phosphate mining is considerably more capital intensive than heavy-mineral mining in processing and disposing of waste materials. Mining heavy minerals and phosphate offshore would be technologically possible by using currently available equipment. Mining, processing, and transportation system designs are described in the report, including the use of an artificial island to hold processing and barge loading facilities.

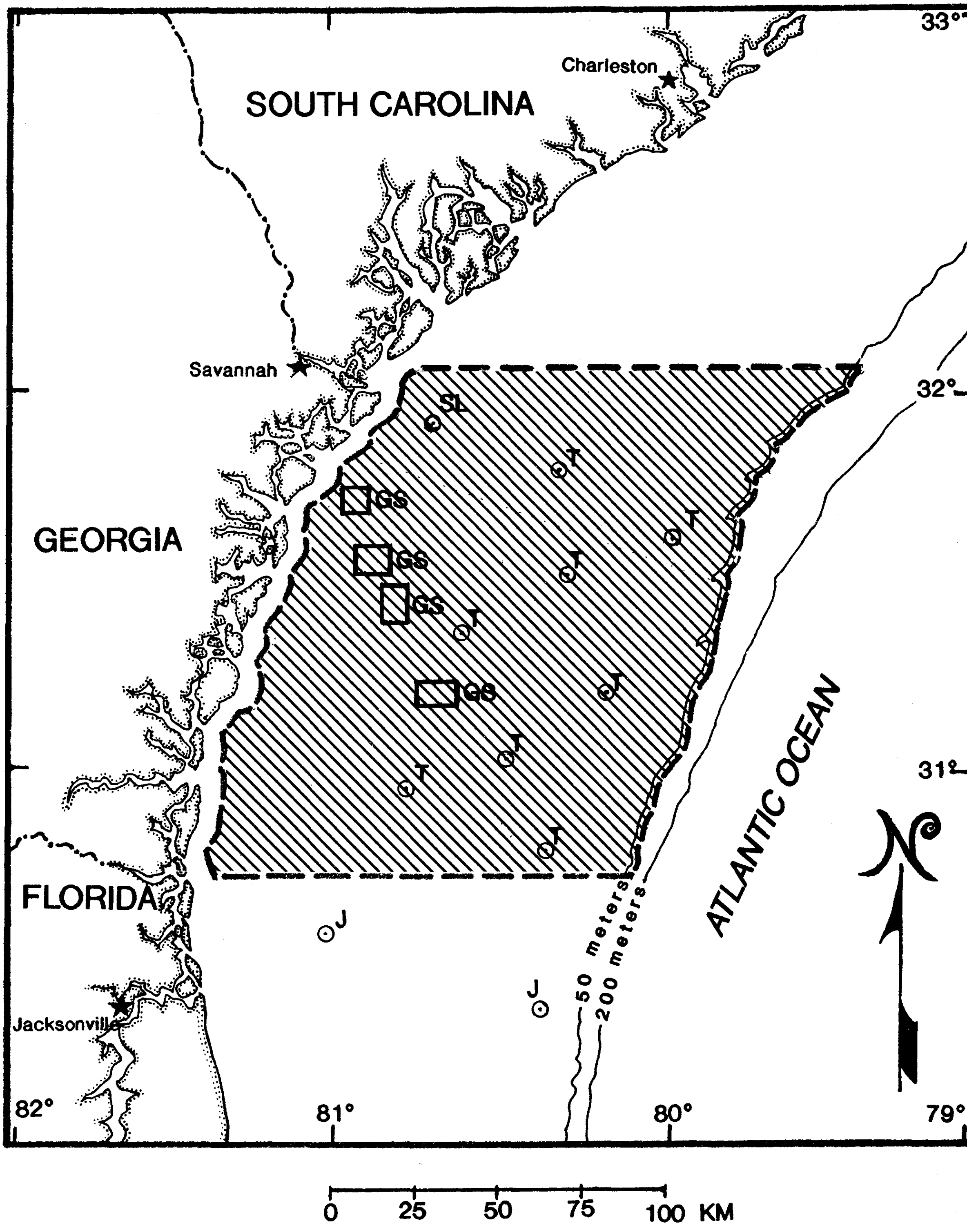

Figure 1. Location of the Task Force study area showing sites of coreholes used in the study. TACTS cores are "T," Savannah Light Tower is "SL," JOIDES cores are "J," and the small boxes ("GS") are sites of vibracores and neutron activation data obtained in 1989 by Georgia State University.

PHOSPHATE DEPOSITS

Phosphate occurs in the middle Miocene-age Hawthorne Formation along the coast of and offshore Georgia and in the Pleistocene channels offshore. The Kerr-McGee Corporation sought permission to mine phosphate in eastern Chatham County along the Georgia coast in the late 1960's but failed to obtain all the necessary permits (Furlow, 1969). Two core holes were drilled in 1962 for the Savannah Light Tower, which is 16 km east of Tybee Island, Ga. (McCollum and Herrick, 1964). The cores encountered about 10 m of sand containing up to 40 percent phosphate pellets. Later drilling off the coast of Georgia, including AMCOR 6002 and JOIDES No. 2, also indicated enriched phosphate zones in the Miocene (Schlee and Gerard, 1965; Manheim, 1989). A map of the zone of phosphate sediments is shown in figure 2.

The Task Force received samples of cores from eight U.S. Navy Tactical Air Command Test Site (TACTS) platform sites offshore Georgia in 1988 (fig. 1). The coreholes were drilled by the McClelland Company for the U.S. Navy to a depth of about 100 m. Because they are widely spaced and penetrate the Miocene section, the coreholes represent important new data for evaluating the mineral-resource potential of the study area. The Georgia Geological Survey and the U.S. Geological Survey (USGS) are currently doing geological and chemical analyses on these core samples for the Task Force.

Studies of three of the eight TACTS cores have shown that phosphorite is well developed in the Miocene and younger strata and has P_2O_5 values as high as 21.6 percent. The most enriched phosphate zones occur at or near unconformities, probably because of reworking of the sediments and the dissolution of the carbonate. Most of the phosphate in the Miocene sections appears to be the result of primary or in situ formation, and phosphate in the post-Miocene strata is probably reworked from the older primary beds. The Miocene phosphate beds correlate stratigraphically with the deposits in offshore North Carolina and Florida (Manheim, 1989). In addition to the TACTS core work, the Georgia Geological Survey drilled and is analyzing several moderately deep (50-m) coreholes on Tybee and Skidaway Islands through the Miocene phosphate zone. These will provide important data to tie onshore data with the offshore coreholes.

Henry and Kellam (1988) and Henry and Reuth (1986) identified three areas of high phosphate potential offshore Georgia (fig. 2). Area I lies inside the 20-m isobath and extends from Hilton Head Island, S.C., to Brunswick, Ga. It contains primary bedded phosphate and numerous potential phosphate-bearing channels and scour troughs of Miocene to Quaternary age. Area II lies mostly seaward of the 20-m isobath between Ossabaw Island and Brunswick. It also contains primary bedded phosphate and channels and scour troughs of Miocene to Quaternary age. Area III extends from Brunswick to Jacksonville, Fla., and lies shoreward of the 20-m isobath. It contains probable Pliocene to Quaternary shallow channels that could contain enriched phosphatic sediments.

To determine the extent of the phosphate resource, additional data will be needed. These data needs include drilling deep coreholes through several of the more promising channels and scour troughs, especially in Area I; obtaining a large (1- to 2-tonne) bulk sample for beneficiation testing; and performing an offshore borehole mining test to determine if this new technology is feasible for extracting offshore phosphate deposits.

HEAVY-MINERAL DEPOSITS

Economically valuable heavy minerals in the Southeastern United States include ilmenite, leucoxene, rutile, monazite, zircon, and garnet. Heavy minerals, which have been known to occur in the Atlantic Coastal Plain and the Continental Shelf (Grosz and others, 1986), are being mined southeast of Jacksonville at Starke and Green Cove Springs (fig. 3). Heavy minerals have been mined on Amelia Island, Fla., and at several sites along the Georgia coast. Two companies explored areas offshore Georgia in 1986 for economic deposits of heavy minerals but failed to find high-enough concentrations to justify further evaluation (Whitney, 1987). Heavy-mineral deposits are difficult to find becasue they tend to occur in small lenticular sand bodies, such as well-preserved sand dunes in old barrier beach strands and as lag deposits in certain parts of old river channels. Large numbers of sample points and closely spaced high-resolution seismic data are needed to locate these deposits. New geophysical methods, such as induced polarization and radioactive spectral measurements that use a neutron activation detection sled, also show promise for detection of heavy minerals (Grosz and others, 1986). In 1985, the USGS announced that concentrations of 3 to 5 percent heavy minerals were found in two vibracores and three grab samples off the coast of Georgia. However, further sampling in the same area has not found these concentrations to be widespread.

The Georgia Geological Survey collected 30 vibracores in 1986 in State waters along the coast between Saint Simons and Blackbeard Islands. These were analyzed for heavy-mineral content and other geological characteristics. Eight of the cores were taken in the Altamaha Sound, which is an area believed to have high potential for heavy minerals. However, only 1 (from Altamaha Sound) of the 30 cores contained heavy minerals of over 2 percent (Bonn, 1988). An additional 14 vibralift borings were collected from four areas 7 to 35 mi off the coast of Georgia in 1989 (fig. 1) as part of a heavy-minerals evaluation project sponsored by the Task Force. The boreholes were drilled on a series of scarps that occur parallel to the coastline offshore and could hold heavy-mineral concentrations. High-resolution seismic and neutron activation data also were collected over the scarps. These data are being analyzed, along with chemical analyses of 50 grab samples taken in the study area. In addition, shallow (15-m-deep) cores, which have been obtained along the coast by the Georgia Geological Survey, are being evaluated for heavy-mineral content.

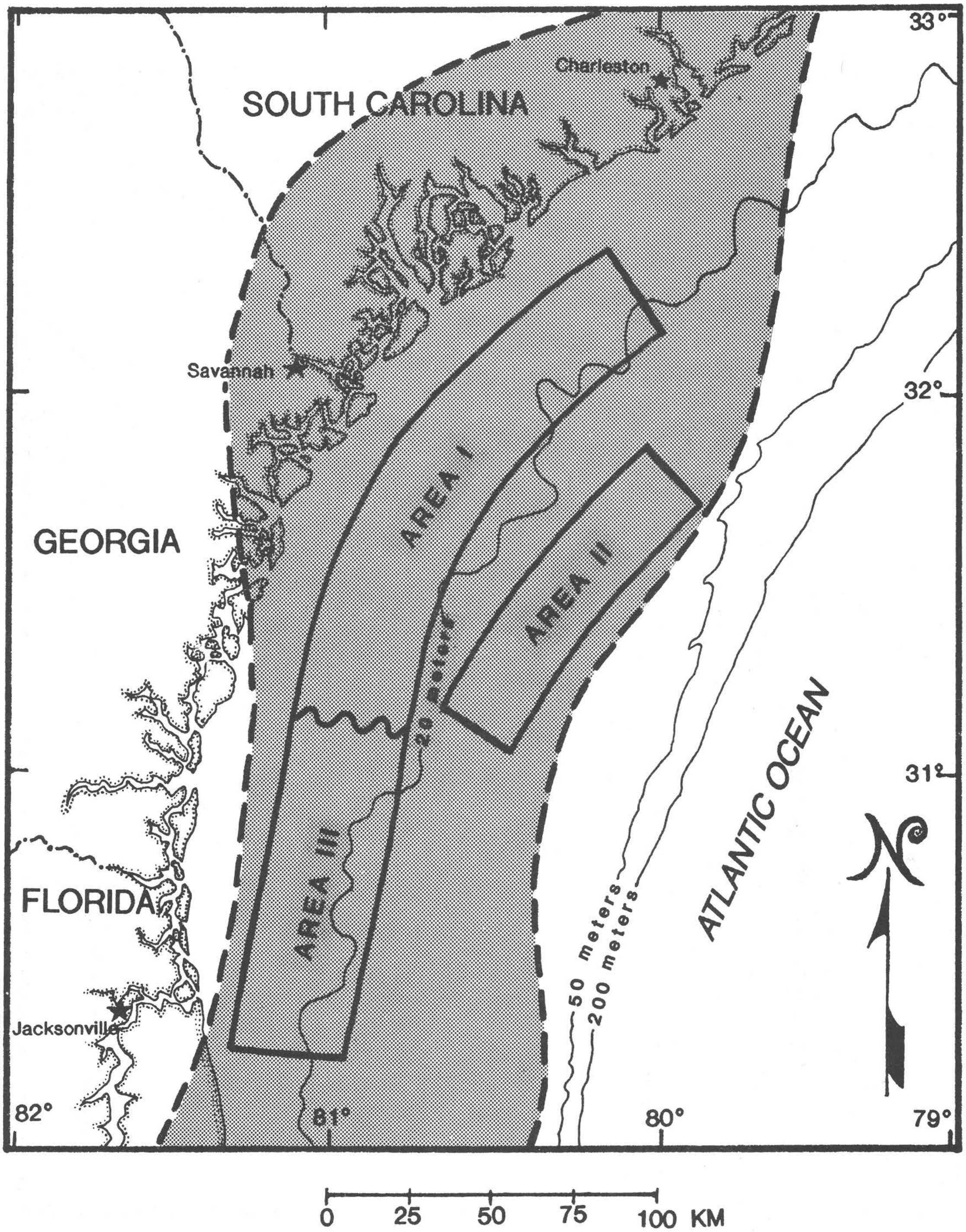

Figure 2. Zone of Miocene and younger phosphate-rich sediments offshore Georgia showing the areas of high potential. Modified from Henry and Kellam (1988).

When results from these studies are compiled, maps will be prepared that show the distribution of heavy minerals offshore Georgia, and predictive models will be made to guide future exploration. Additional work to discover commercial deposits will likely focus on a better definition of the various heavy-mineral concentrations in sedimentary features by using seismic and other geophysical data along with vibracoring.

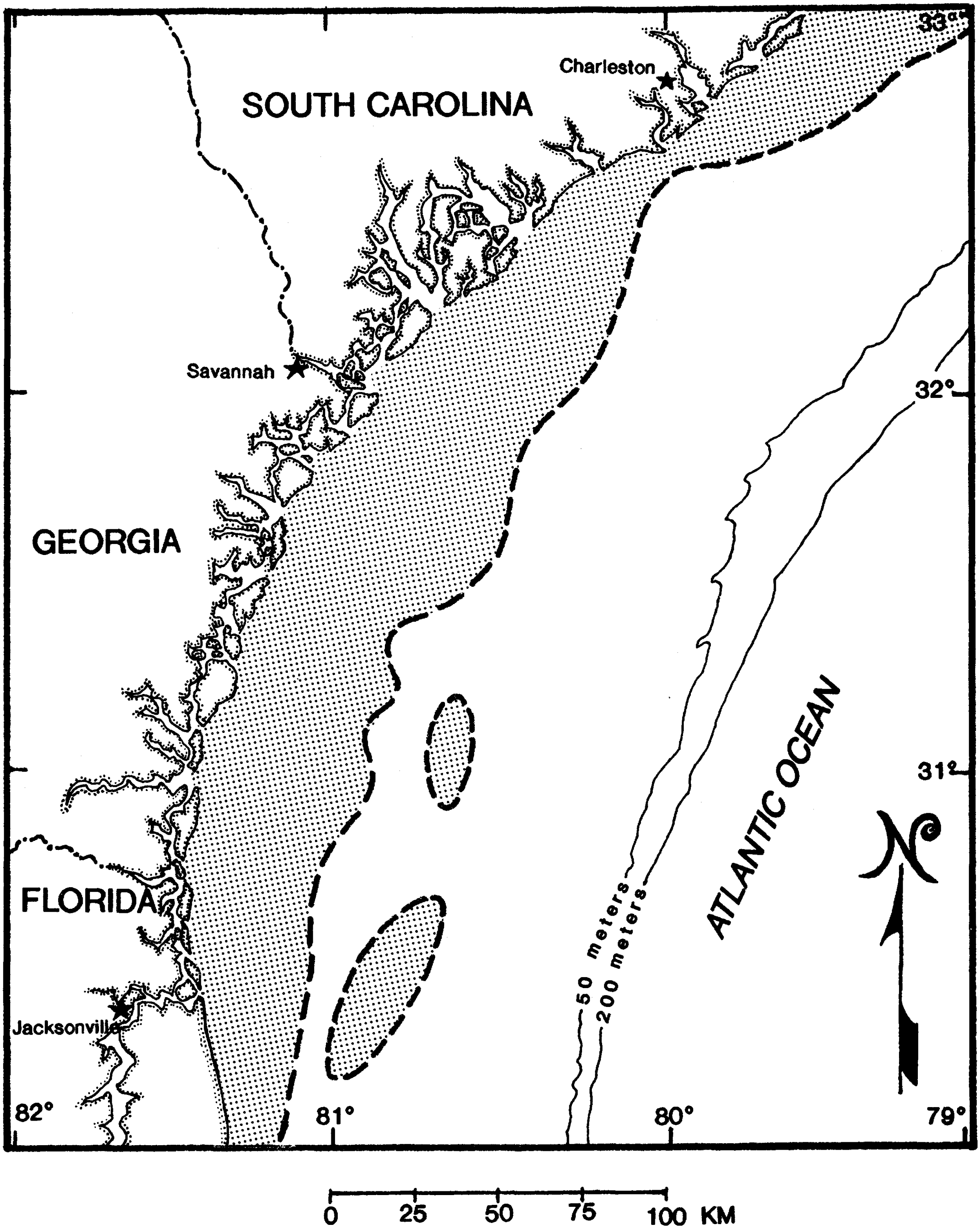

Figure 3. Areas of high potential for heavy-mineral placer deposits offshore Georgia and parts of Florida and South Carolina. From Grosz (1987).

CONCLUSIONS

The following summarizes the major points regarding phosphate and other nonenergy minerals off the coast of Georgia:

- On the basis of data from a few coreholes, large deposits of phosphate are believed to occur offshore Georgia. These deposits are shallow enough to be dredged in the vicinity of the Savannah Light Tower; further offshore, they could only be reached by borehole mining, which is an unproven technology.
- Recent data acquired by the Task Force include an assessment of the economics and the technologies for mining phosphate and heavy minerals offshore Georgia. The assessment concluded that phosphate and heavy-mineral prices would have to rise by at least 35 percent and perhaps even double for offshore mining to be economically feasible. Current dredge technology is adequate to recover the near-surface deposits; however, borehole mining technology would have to be developed for the deeper deposits.
- Other new data acquired by the Task Force include geological and chemical analyses of eight TACTS platform cores, drilling several deep (50-m) holes for heavy minerals and phosphate along the coast of Georgia, drilling 14 vibralift holes, acquiring new seismic and neutron activation geophysical data offshore, and analyzing 50 offshore grab samples for heavy minerals.
- Although no heavy-mineral deposits have been discovered offshore Georgia so far, there is considerable evidence from onshore deposits and a few scattered sites offshore that points to the possibility of finding such deposits.
- The current plan of the Task Force is to assemble analyses of the data collected to date, make maps of mineral concentrations offshore, develop predictive models for offshore exploration, and make another assessment of the economic feasibility by using the newly acquired data. The Task Force is working closely with the minerals industry by incorporating their advice and information and transferring new data and models for commercial application. As each stage of work is completed, the Task Force makes recommendations for future actions to State and Federal officials.

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Quaternary Geology of the Chesapeake Bay

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College of William and Mary

INTRODUCTION

The Chesapeake Bay, which is a classic coastal plain estuary, is located on a trailing edge continental margin. It has a surface area of nearly 6,000 km^2 and ranges in width from 8 to 48 km. The morphology of the bay clearly reflects its formation as a response to fluctuating sea level during and following the last major continental glaciation. The shoreline is highly irregular, the tributaries form an intricate dendritic drainage pattern, and a deep axial channel occurs along much of its length (fig. 1). Water depths commonly exceed 30 m in this deep channel, which is flanked by broad shallow benches. Overall, the bay is quite shallow and has an average depth of only 8 m.

The prominent axial channel has been widely viewed as the relict Susquehanna River paleochannel that was incised into the Coastal Plain strata during the last major sea-level lowstand. This channel has been only partially filled with sediments during the Holocene transgression. Ryan (1953), who used borings taken across the bay for the Annapolis-Kent Island Bridge, identified its base at a depth of approximately 61 m. A basal sequence of sands and gravels identified as fluvial deposits partially filled this channel. Overlying these sediments was a sequence of muds deposited when true estuarine conditions were established in the channel. Ryan (1953) projected the longitudinal profile of the channel along the length of the bay and estimated the depth to be 91 and 112 m, respectively, at the bay mouth.

In the early 1960's, borings were obtained in the bay mouth vicinity for the Chesapeake Bay Bridge-Tunnel. On the basis of these borings and the first seismic reflection profiles obtained in the bay, Harrison and others (1965) identified a fluvial channel at a depth of approximately 49 m under the northern end of the present-day bay mouth. They proposed that a minimum of 12 m of uplift had to occur in the bay mouth region relative to the Annapolis region to account for the difference in the channel depths observed at the two bridge crossings, assuming no channel gradient. By using projected channel gradient, Harrison and others (1965) suggested that a maximum of 52 m of relative uplift had occurred at the mouth. Because of the lack of continuity of the axial channel along the length of the bay, the relation between the bay mouth paleochannel and the channel at the Annapolis-Kent Island bridge remained problematic. Harrison and others (1965) argued against the possibility that the late Wisconsinan channel of the Susquehanna River crossed the Delmarva Peninsula north of the bay mouth.

Other channels crossing the peninsula have been identified or postulated, and multiple generations of channels of the Susquehanna River seemed likely, given the cyclic nature of sea level rise and fall over the past 0.75 m.y. Hansen (1966) identified a fluvial channel near Salisbury, Md., and suggested that it represented the course of the Susquehanna River during the low sea level associated with the Illinoian glaciation. However, the full extent of the channel was never adequately defined. Harrison (1972) identified reworked crystalline gravels along the Atlantic shoreline of the Delmarva Peninsula near Metomkin Island and postulated that an ancestral channel of the Potomac River or the combined Susquehanna-Potomac Rivers crossed the peninsula in this vicinity at some point in the past. By using seismic reflection techniques, Schubel and Zabawa (1973) identified a paleochannel in the lower reaches of the Chester River and projected its course through the lower reaches of the Miles and the Choptank Rivers. They postulated an Illinoian age for this channel and suggested that it may connect to the Salisbury paleochannel of Hansen (1966) and cross the peninsula on its way to the Atlantic. In the main portion of the bay, Kerhin and others (1980) identified two paleochannels by using seismic reflection techniques. One extended down the eastern side of the bay from the mouth of Eastern Bay to Taylor's Island. They

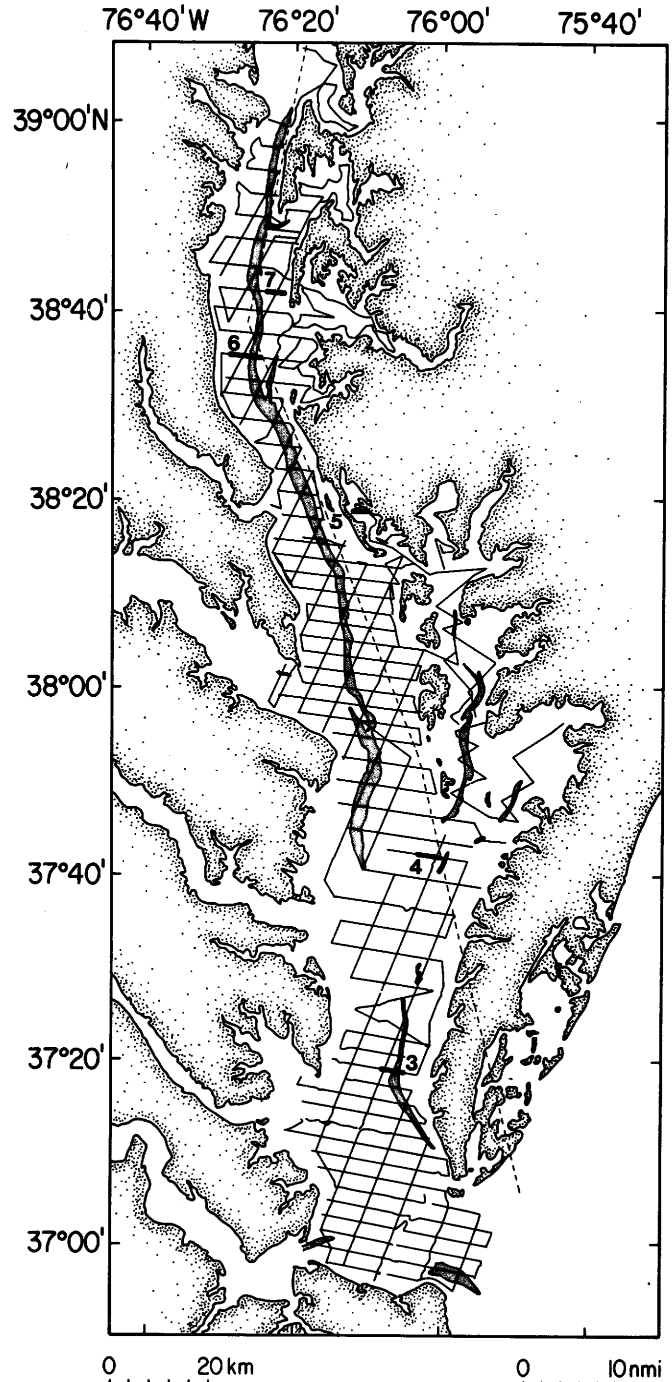

Figure 1. The Chesapeake Bay from the vicinity of Annapolis to the mouth showing tracklines of the seismic reflection profiles. The profile shown in figure 2 is located along section 5. Areas that have water depths of greater than 18.3 m (60 ft) are shaded.

suggested that this channel was the southern extension of the one identified in the Chester River by Schubel and Zabawa (1973), which, therefore, did not turn to the east under the Delmarva Peninsula. They further postulated a connection between this channel and one identified to the south in the Tangier Sound area. Kerhin and others (1980) also placed an Illinoian age on this channel. Because its southern extent was never established in the bay, the location of its exit to the Atlantic shelf remained in doubt. On the Virginia portion of the Delmarva Peninsula, Mixon (1985) identified two major paleochannels by using borehole data. The trend of these channels indicated that they crossed from the bay to the Continental Shelf, and at least one probably connected to the channel identified by Kerhin and others (1980).

In an attempt to reconstruct the late Wisconsinan channel system in the Virginia portion of the bay, Carron (1979) utilized transducer-based seismic reflection techniques. Because the penetration capability of these systems was limited, Carron (1979) suggested that the Susquehanna River flowed down the eastern side of the bay in Virginia and that the western shore tributaries flowed along the western side turning to the east and exiting the bay just north of Cape Henry and eventually joining the Susquehanna on the Continental Shelf.

BACKGROUND OF THE STUDY

Although it was widely recognized that the Chesapeake Bay formed as the lower reaches of the Susquehanna River were flooded during the Holocene transgression, the details of the bay's formation in response to this latest and the Pleistocene sea-level fluctuations remained to be worked out. Several major problems were in need of resolution. The present-day axial channel of the bay was not continuous along its length; the deeper portions of the channels in Virginia were separated from the major portion in Maryland. The disparity in channel depths observed in borings at the Annapolis-Kent Island Bridge and the Chesapeake Bay Bridge-Tunnel appeared to indicate uplift or a lack of continuity of the two channels. The relations between the multiple isolated channel segments identified or postulated under the Delmarva and in the bay and the Susquehanna River drainage system were unclear, as were their historical development. Variations in present-day axial channel bathymetry strongly suggested differences in sediment depositional centers during the Holocene transgression. In addition, it was felt that improved knowledge of the bay's formation and depositional history could assist in understanding the present-day sedimentation processes occurring in the system and, therefore, in addressing some of the management questions arising from the ongoing efforts to improve the health and the productivity of the Chesapeake Bay.

Researchers within the States of Maryland and Virginia were acutely interested in addressing these problems and had made efforts through the studies conducted by Carron (1979) and Kerhin and others (1980). They recognized, however, that they did not have the complete in-house technical capability to adequately solve these problems and that a research program directed at the complete bay system was necessary to tie together the various pieces of subsurface data that had been collected. Through a series of discussions initiated by the Maryland Geological Survey with the the U.S. Geological Survey (USGS), it was agreed that a cooperative effort should be mounted to resolve the Quaternary geology of the Chesapeake Bay. To insure the inclusion of the southern portion of the bay and representation by a Virginia institution, the Virginia Institute of Marine Science was involved early in the planning stages of the study. It was decided that the project would initially involve the collection of high-resolution seismic reflection profiles throughout much of the main portion of the Chesapeake and additional coverage up tributaries where deemed appropriate. Each of the institutions would provide a coprincipal investigator and portions of the profiling equipment. The States would provide vessels to serve as the data-gathering platforms, and the USGS would provide an electronic technician to maintain the equipment in the field. Travel and per diem costs were provided by each institution for their personnel. Except for some funding that passed from the USGS to the Virginia Institute of Marine Sciences to support vessel time, no formal funding mechanisms were established.

METHODOLOGY

Over the course of four field seasons beginning in 1984, almost 2,600 km of high-resolution seismic reflection profiles were collected in the main part of the Chesapeake Bay from the mouth northward to the vicinity of Annapolis, Md. (fig. 1). Data were collected by using a boomer-type system supplied by the USGS and 3.5- to 5.0-kHz transducer-based systems provided by the State institutions. Both types of systems were fired at 0.25- to 0.50-s intervals. The boomer system was run at 280 J, and the data were filtered between 300 Hz and 5.0 kHz. Firing times of the two types of systems were offset to minimize crosstalk. Loran-C was used as the primary navigation system, and all data were recorded on analog tape for archival purposes.

RESULTS

The Chesapeake Bay lies within the Coastal Plain province of the mid-Atlantic region. Uplands surrounding the bay, from its head at the mouth of the Susquehanna River southward 260 km to its mouth at Cape Charles, are composed of unconsolidated sediments deposited during the Cretaceous and later time. These form a series of wedge-shaped deposits that rest on the crystalline basement rocks and dip to the southeast at rates of between 1.9 and 7.5 m/km. The shallow Tertiary seismic stratigraphy prevalent beneath much of the bay consists of a series of long, strong, continuous subhorizontal reflectors that dip slightly to the southeast. These reflectors correlate well with the major unconformities observed in adjacent land-based well records.

Incised into these Tertiary strata are distinct paleochannels that have strong basal reflectors and U-shaped valleys as shown on the seismic records (fig. 2). Characteristically, the sediments that fill these valleys exhibit two forms of seismic reflectors. At the base of each valley, the reflectors are commonly strong, discontinuous, and irregular. Above this basal sequence, the fill sediments either exhibit weak, long, and smooth reflectors or are nearly reflection free. Lithologic data obtained from land-based (Mixon, 1985) and bridge boreholes (Ryan, 1953; Harrison and others, 1965) indicate that the lower channel fill sequence consists of coarse sand and gravels deposited in a fluvial environment. In contrast, the upper sequence is finer grained and was deposited in estuarine environments as the former river valleys were flooded. The environments of deposition of this unit range from narrow river estuary to open bay and nearshore marine near the bay mouth. Lithologies are complex in the estuarine-marginal marine unit, especially near the bay mouth, where boreholes indicate that the sediments consist of interbedded muddy sand, silt, and peat (Mixon, 1985). Further landward, in the central part of the estuary, the unit is likely to be finer grained, as suggested by the character of the seismic reflections (fig. 2); however, no boreholes penetrate this portion of the fill sequence.

Three distinct generations of the paleochannel system have been identified beneath the Chesapeake Bay (fig. 3) and have been informally named the Cape Charles, the Eastville, and the Exmore in order of increasing age. Each has a main trunk channel running approximately parallel to the axis of the present Chesapeake Bay and numerous tributary channels that join the main stem. Seismic reflection and borehole data indicate that the three paleochannel systems are of different ages and that the sediments that fill them are separated by unconformities. The paleochannel systems were incised by the Susquehanna River and its tributaries at times of lowered sea level during the mid- to late Quaternary. Their relative ages can be determined by crosscutting relations on the seismic reflection profiles. Although the geometries, the depths, and the seismic character of the fill sequences are similar in all three channels, which makes distinction in individual seismic reflection profiles difficult, the multiple, closely spaced profile lines (fig. 1) permitted their courses to be traced throughout the length of the bay.

The Cape Charles paleochannel is the youngest and was clearly incised at the time of the last major sea-level lowstand, which was during the late Wisconsinan. Because this channel has been only partially filled with sediment

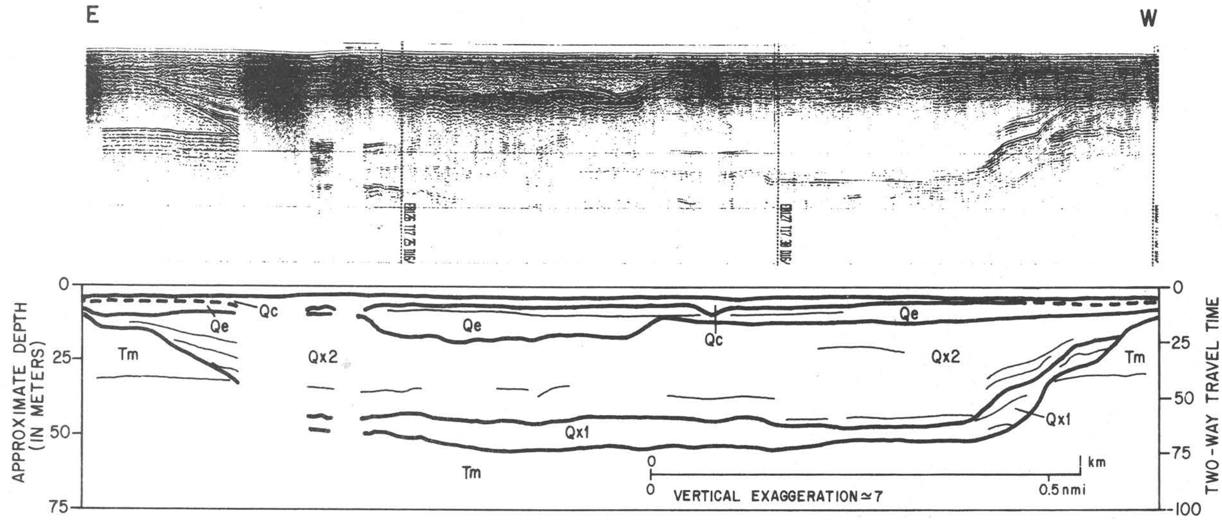

Figure 2. High-resolution seismic reflection profile obtained by using the boomer system and interpretive cross section of the Exmore paleochannel. The location of profile 8 is shown in figure 1. Depth scale assumes a speed of sound in water and sediments of 1,500 m/s. G, record obscured by biogenic gas in the sediments; Tm, late Tertiary marine sediments; Qc, undifferentiated sediments correlative with the fill of the Cape Charles paleochannel; Qe, undifferentiated sediments correlative with the fill of the Eastville paleochannel; Qx1 and Qx2, basal and upper units, respectively, of the fill of the Exmore paleochannel. Note the horizontal reflector in the Tertiary sediments on the left side of the figure.

during the Holocene transgression, it underlies, for the most part, the present bathymetric channel of the bay (compare deep areas outlined on fig. 1 with fig. 3). In a few areas where Holocene spit progradation has occurred, the modern axial channel is offset from the paleochannel; for example, south of the mouth of the Potomac River. In other areas, such as off the mouth of the Rappahannock River, Holocene sedimentation has filled the Cape Charles paleochannel to the extent that there is no present bathymetric expression of the paleochannel location. The most notable change has occurred at the mouth of the Bay where the modern tidal channel is offset by as much as 12 km from the Cape Charles paleochannel (fig. 3). In the vicinity of the mouth, the paleochannel underlies the southern tip of the Delmarva Peninsula (Cape Charles), and Holocene progradation of the peninsula to the south has filled the former paleochannel and forced the tidal channels to the south (Colman and others, 1988).

Under much of the bay, the base of the Cape Charles paleochannel is obscured by the presence of biogenic gas produced by bacterial decomposition of organic matter in the Holocene channel fill sediments (Halka and others, 1988). However, the width can be determined on most of the profiles, and depths are known from profiles where biogenic gas is absent and from bridge borings at the Annapolis-Kent Island Bridge and the Chesapeake Bay Bridge-Tunnel. In general, the main trunk channel is 2 to 4 km wide and is incised into the underlying Tertiary strata to depths of 50 to 70 m. Overall, the channel has only a slight overall gradient.

The Eastville paleochannel crosses the Delmarva Peninsula approximately 40 km north of the present bay mouth (fig. 3) and is filled with estuarine sediments overlain by a barrier-spit complex (Mixon, 1985). This complex appears to have been deposited during the last major interglaciation (the Sangamon) and the paleochannel presumably incised during the preceding major glaciation about 150 ka (Colman and Mixon, 1988). Under the bay, this paleochannel is generally located to the east of the Cape Charles paleochannel, although it crosses that channel and lies to its west off Calvert Cliffs (fig. 3). At the northern end of the study area, the Eastville channel passes under Kent Island and the Poplar Island group. Sediments comprising these islands have been identified as estuarine deposits belonging to the Kent Island formation, which are time equivalent with the barrier-spit complex overlying the channel to the south. The dimensions and depths of the Eastville paleochannel are better known than the Cape Charles because biogenic gas is absent in these older channel fill sediments. The channel has similar widths and depths as the Cape Charles channel, and the gradient, which is very slight, has an overall seaward slope of only 0.038 m/km.

The Exmore paleochannel crosses the Delmarva Peninsula another 40 km north of the Eastville paleochannel (fig. 3). This channel is the oldest of the three and along

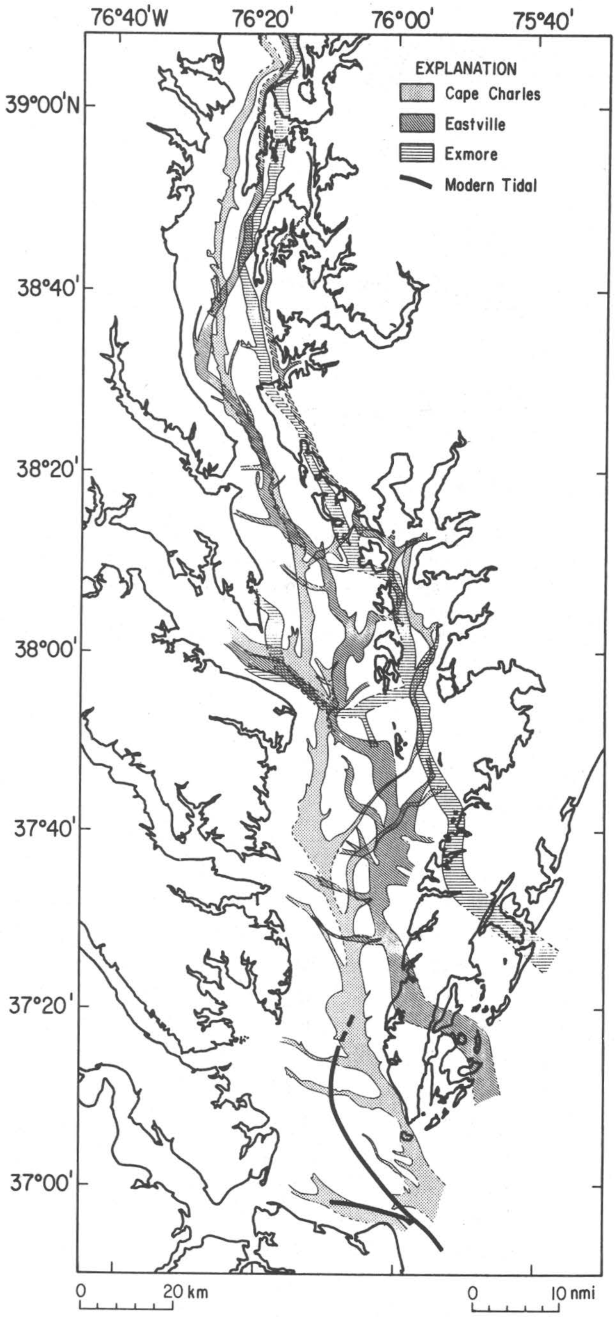

Figure 3. The three major Quaternary paleochannel systems of the Susquehanna River and tributaries beneath the Chesapeake Bay and the Delmarva Peninsula and the location of the modern tidal channels in the bay mouth area.

almost its entire length is located to the east of the Eastville and the Cape Charles paleochannels and passes under Kent Island at the northern end of the study area and the western side of Dorchester County, Md. As with the Cape Charles and the Eastville, the trunk channel has widths of 2 to 4 km and is incised 50 to 70 m into the underlying Tertiary sediments. Linear regression analysis of the channel depths, which is shown on the seismic reflection profiles (fig. 2), indicates a very slight overall landward slope, although the gradient is probably not significantly different from zero. This channel is also overlain by a barrier-spit complex where it crosses under the Delmarva Peninsula (Mixon, 1985); however, the age of this deposit is less certain than that overlying the Eastville (Colman and Mixon, 1988). It has been suggested that the barrier-spit complex was deposited either approximately 200 or 400 ka and that the underlying channel was incised during either of the preceding major sea-level lowstands at about 270 or 430 ka (Colman and Mixon, 1988).

SUMMARY

In what may be a unique case, a cooperative program was established between Federal and State agencies in which each institution contributed programmatic funds toward a research program with little transfer between institutions. The USGS, the Maryland Geological Survey, and the Virginia Institute of Marine Science forged a working relation that resulted in a significant increase in knowledge about the late Quaternary history of the Chesapeake Bay region.

This effort tied together the various paleochannel segments identified in previous studies and showed that a series of at least three fluvial paleochannel systems and their fills dominate the stratigraphy beneath the Chesapeake Bay. Each of the trunk paleochannels identified lies to the west of and, on its way to the Continental Shelf, crosses the Delmarva Peninsula to the south of its predecessor. The southward progression of the channels through time resulted from the southward progradation of the Delmarva Peninsula when interglacial high sea level filled the preceding paleochannel with sediments. This process is continuing at the present time with the displacement of the modern bay mouth tidal channels southward approximately 12 km from the late Wisconsinan paleochannel. The fluvial channels record times of relative low sea levels, the channel fill sediments record the formation and filling of estuaries during the ensuing transgressions, and the subaerial barrier-spit complexes on the Delmarva Peninsula record times of sea-level maxima. As such, the Chesapeake area has preserved a remarkable record of sea-level changes over the past few hundred thousand years and, with it, a record of climatic variations over the same time period. As interest in deciphering the history of climatic changes increases, the record from the Chesapeake area can be expanded to supply data for deciphering that history. The cooperative program established between the Federal and the State agencies has provided a solid base of information that can be utilized to further our understanding of recent climatic changes occurring on Earth. The success of this cooperative program indicates that informal cooperatives can provide significant information without direct transfer of funds and can offer advantages to all the institutions involved. The question remains—how much more could be accomplished with a formal agreement and appropriated funding for similar studies?

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National Oceanic and Atmospheric Administration Multibeam Mapping in the Gulf of Mexico

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National Oceanic and Atmospheric Administration

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) has been systematically mapping the Gulf of Mexico since early 1988 as part of its multibeam mapping program of the U.S. Exclusive Economic Zone (EEZ). This program is managed by NOAA's Office of Charting and Geodetic Services (C&GS). Forty-eight surveys covering over 19,000 nmi^2 have been conducted during this program by using the sophisticated sea-floor mapping systems SeaBeam and Hydrochart II. Unprecedented accuracy for large-area bathymetric surveys has been attained by the use of satellite-based navigation systems and medium-frequency navigation systems for horizontal control. Many multibeam survey techniques and quality-control methods have been developed by C&GS during this project. Large areas of the Gulf of Mexico are being imaged in great detail, and many new discoveries are being made. The better management of our Gulf Coast resources and environment will result from this program.

MAPPING PROGRAM

Goals of the Gulf Coast Mapping Program

NOAA's mapping program in the Gulf Coast area addresses seven distinct goals. Attainment of these goals will help all segments of the Gulf Coast oceanic community. These goals are as follows:

- Build the foundation of a marine environmental geographic information system for solving global and regional change problems.
- Improve targeting of scientific and engineering efforts that involve manned subsmersible investigations and remotely operated vehicle operations.
- Manage the living and the mineral resources of the EEZ.
- Model the physical oceanography of the Gulf of Mexico, including factors affecting water mass movements, acoustic propagation paths, and sediment transport regimes.
- Model geological and geophysical hazards that affect coastal regions and offshore construction.
- Discover and (or) define unique or previously unknown marine environments for designation as marine sanctuaries or protected areas.
- Improve and enhance nautical charts and bathymetric maps.

Progress and Accomplishments

NOAA has mapped over 19,000 nmi^2 off the coasts of Alabama, Mississippi, and Louisiana in the Gulf of Mexico by using multibeam sounding systems (fig. 1). All areas shown on figure 1 are available in preliminary blackline copies or published maps. To date, NOAA has defined domes on the upper slope southeast of the Mississippi River Passes (fig. 2), the upper reaches of the Mississippi Fan, large symmetrical basins on the eastern side of the Texas-Louisiana Slope (fig. 3), lineations running for tens of miles in the same area as the basins (fig. 3), and over 150 mi of the Sigsbee Escarpment.

Mapping Methods

In conjunction with the U.S. Geological Survey and after consultation with the Minerals Management Service (MMS), NOAA has established as its highest priority surveying the Texas-Louisiana Slope from 88° W. to the Continental Shelf break off the coast of Texas. Surveys are being conducted between the offshore limit of the EEZ and the 150-m isobath (fig. 1). To date, over 19,000 nmi^2 of this area have been surveyed by NOAA multibeam survey vessels. Following completion of this area, NOAA vessels will proceed to the east from 88° W. until completing the entire U.S. portion of the EEZ in the Gulf of Mexico. It will take an additional 5 yr of surveying to complete the Gulf at the present rate of progress.

The NOAA Ship *Mt. Mitchell* is equipped with SeaBeam, which is a hull-mounted, narrow-beam, multibeam sounding system. NOAA uses this system in water

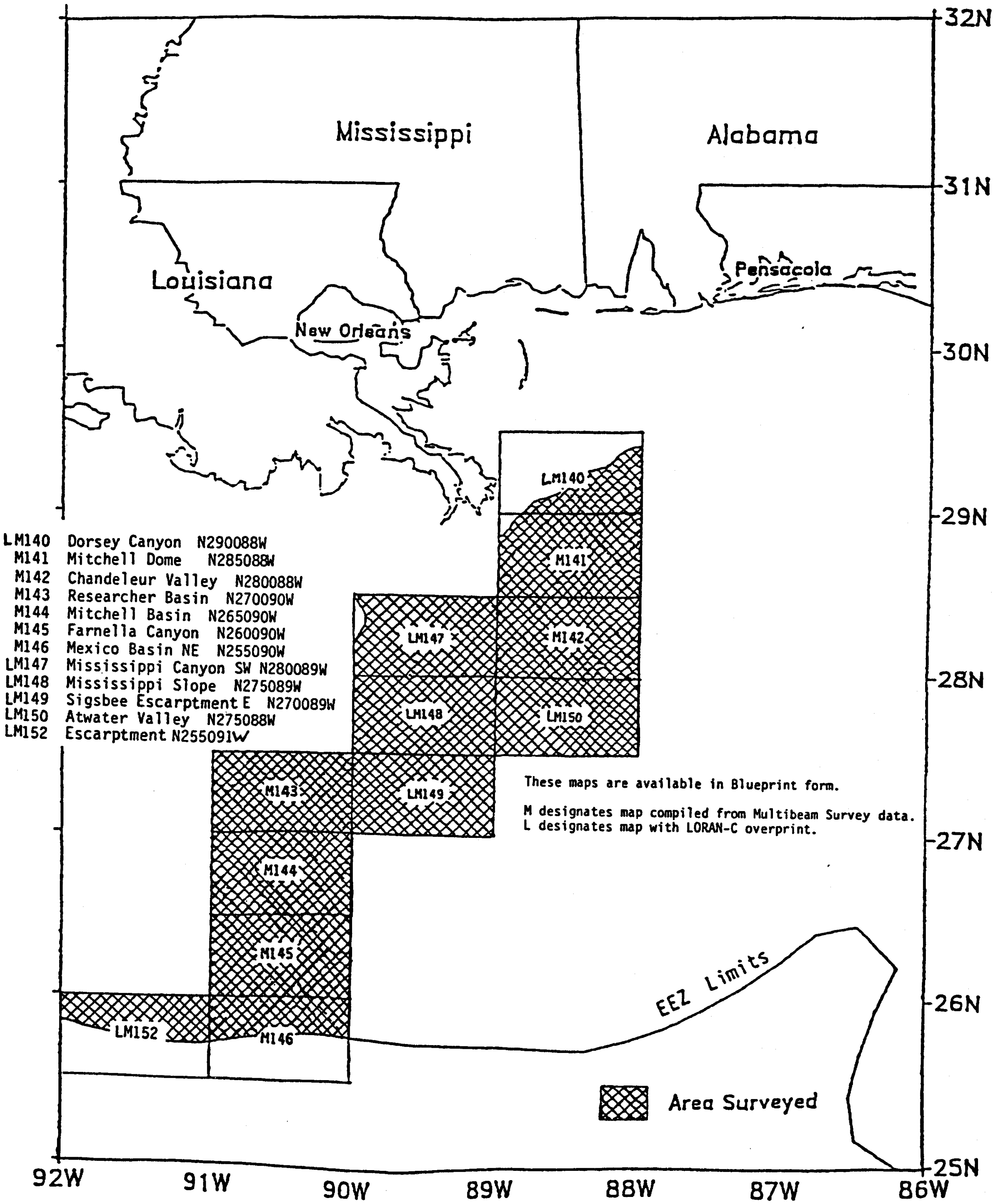

Figure 1. Gulf of Mexico bathymetric map index.

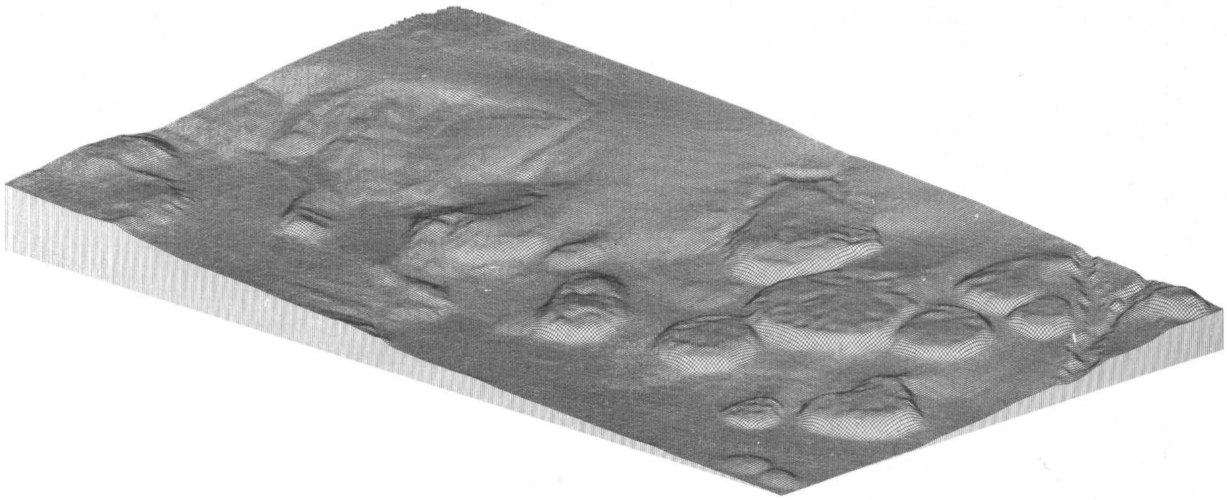

Figure 2. A three-dimensional view of an area that has salt domes on the upper continental slope off the Louisiana-Mississippi coast. Vertical exaggeration is 6:1, and the viewing angle is 35° from horizontal. The image was made from measurements of the sea floor obtained from NOAA ships that used multibeam echo sounders to map the EEZ.

depths of between 1,000 m and full oceanic depths. The NOAA Ship *Whiting* is equipped with the Hydrochart II multibeam sounding system and is normally used in between 150 and 1,000 m water depth. The mission of both ships during survey operations is to attain 100-percent bottom coverage (that is, all the bottom has been ensonified) of the survey area and to maintain International Hydrographic Organization standards for map accuracy. NOAA strives to maintain navigational accuracy, such that 90 percent of all soundings obtained during EEZ surveys have a horizontal positioning error of less than 50 m and sounding accuracies within 1 percent of true depth. To those ends when using a medium-frequency navigation system, calibrations are performed with the Global Positioning System on a daily basis. While in the working area, gyrocompass drift is monitored to assure proper swath alinement, and sound velocity tables are periodically updated by conductivity, temperature, and depth (CTD) observations supplemented by daily expendable bathythermograph (XBT) observations.

Data Processing

Shipboard data acquisition and processing is accomplished on a MicroVAX II that has acquisition software written by the University of Rhode Island's Ocean Mapping Development Center in conjunction with NOAA's System Technology Division. This software allows generation of contour, point sounding, colored symbol, and navigation track plots; these aid the field unit in determining whether the data are error free. Once inspection of these various plots assures the bathymetrist of the veracity of the raw data, the ship proceeds to select statistically significant soundings from the total raw data set. This step is required because of the huge size of the multibeam sounding data sets relative to conventional hydrography. Maximum, minimum, and average depths are selected for unit areas approximately 250 m on a side throughout the survey area. These representative soundings are plotted to further assure total bottom coverage before the data are submitted to the Ocean Mapping Section (OMS) for verification and product generation.

Verification is an independent review of the data to assure that proper procedures were followed during data acquisition, that no blunders had occurred during shipboard processing, that no erroneous data had been inadvertently passed forward, and that full bottom coverage had been attained. When a survey has passed the verification stage, it is accepted into the OMS database. The selected sounding data are then further processed to develop a 250-m latitude, longitude, depth (XYZ) Universal Transverse Mercator (UTM) grid. The gridded data are used to develop contour files, three-dimensional imagery, and other specialty products.

Products

Standard National Ocean Service (NOS) products developed from the gridded data include 1:100,000-scale printed maps, three-dimensional perspective and orthographic plots of each printed map, and the UTM grid on a high-density floppy disk. Future products will include full-resolution sounding data (each individual sounding and its accompanying geographic position), variable color contour maps of selected areas, and electronic maps incorporating contours, Loran-C lines of position, bottom charac-

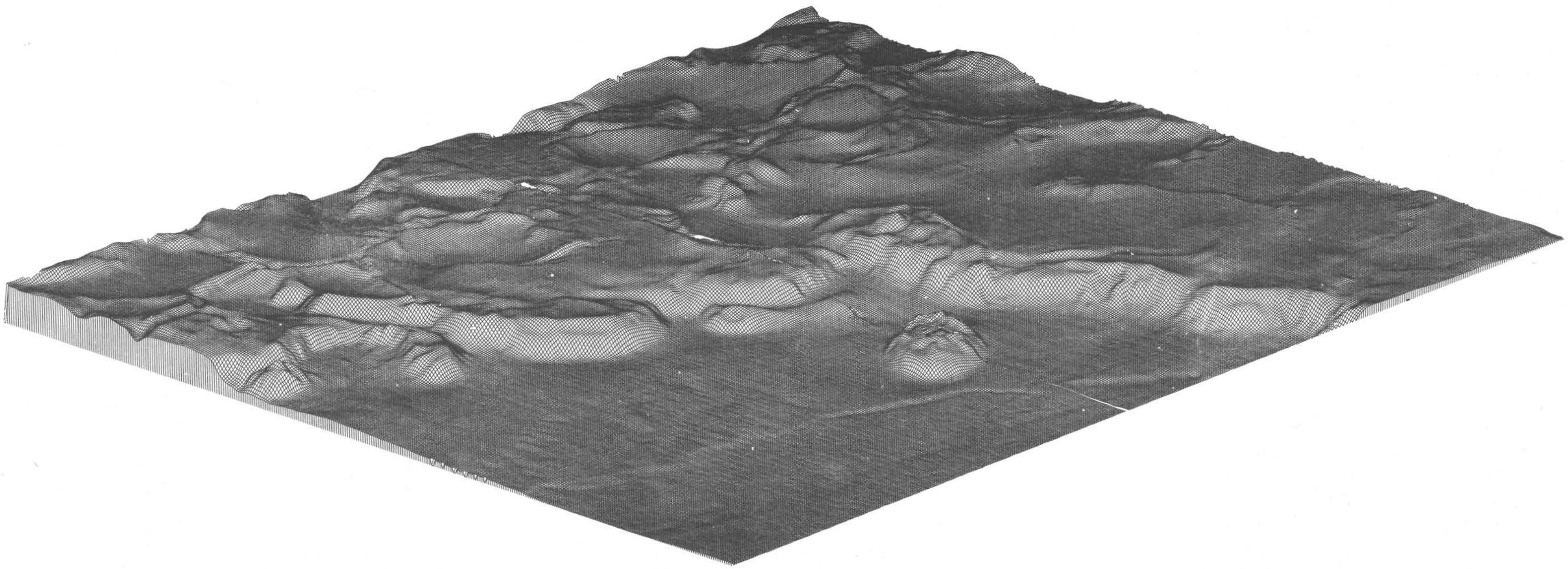

Figure 3. Three-dimensional plot of NOAA's multibeam data collected by the NOAA Ship *Mt. Mitchell* on the Sigsbee Escarpment, Gulf of Mexico, in 1989. This plot was made by the the Ocean Mapping Section of the National Ocean Service.

teristics, and MMS lease block diagrams. Other possible products include such items as an atlas of imagery of scientifically interesting "type localities," slide sets of "type localities" for students and teachers, and videos of "flying" through the spectacular scenery of our continental margins. A movie, *The Gulf of Mexico*, will be a very real possibility within a few years.

New maps, blackline copies of preliminary map manuscripts, and revised editions of maps shown on indices will be reflected in the annual NOS publication of *Bathymetric Mapping Products Catalog 5*. These new maps and copies of the catalog can be ordered by contacting:

Distribution Branch (N/CG33)
National Ocean Service, NOAA
6501 Lafayette Avenue
Riverdale, MD 20737
Telephone 301–436–6990

Additional information about bathymetric products may be obtained by contacting:

Graphic Mapping Unit (N/CG2241)
National Ocean Service, NOAA
6001 Executive Blvd.
Rockville, MD 20852
Telephone 301–443–8855

Minerals Management Service Data Inventory and Mapping Programs—Gulf of Mexico Outer Continental Shelf Region

J. Courtney Reed
Minerals Management Service

INTRODUCTION

The Minerals Management Service (MMS) of the Department of the Interior administers all activities associated with mineral-resource development on the Federal Outer Continental Shelf (OCS) of the Gulf of Mexico (fig. 1). These activities include exploration, leasing, development, and production of oil, gas, sulphur, and hard minerals. The Gulf of Mexico OCS Region has 14.5 percent of all submerged lands in the United States. There were 5,595 active leases in the Gulf as of November 27, 1989. Of these leases, 1,163 are productive and yield 90 percent of all domestic production of oil and natural gas and 100 percent of the sulphur from the OCS. This totals approximately 11

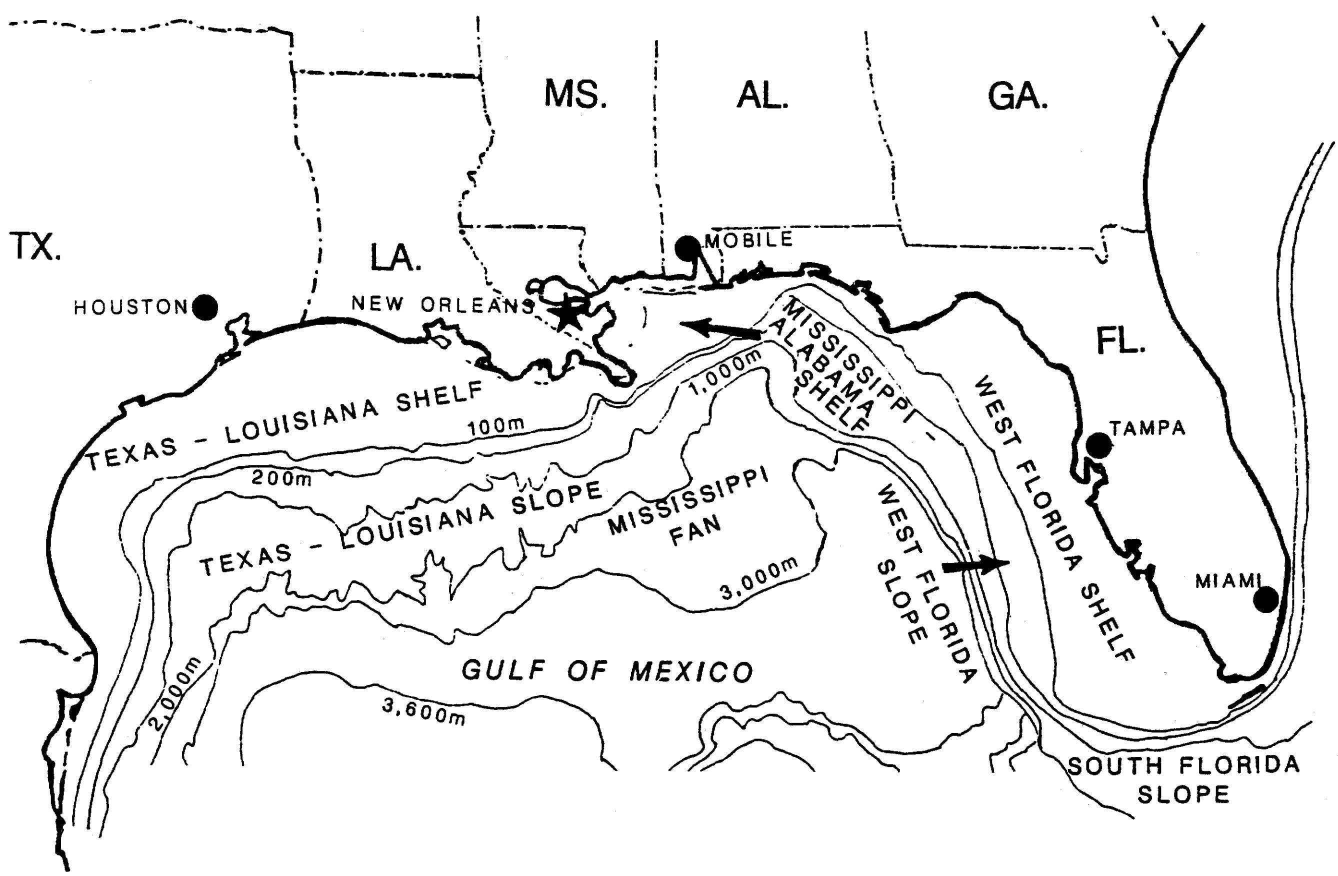

Figure 1. Physiographic provinces of the northern Gulf of Mexico.

percent of the Nation's annual oil production and 25 percent of the annual gas production.

DATABASE

The mission of the MMS Gulf of Mexico Regional Office is to lease apppropriate areas for resource development, determine fair-market value for acreage leased, and ensure that pre- and postlease operations are conducted efficiently and safely and in an environmentally sound manner. To accomplish this mission, the MMS collects geological, geophysical, engineering, and production information relating to mineral resource activities. Most information is acquired pursuant to the Code of Federal Regulations (CFR), especially Title 30 CFR 250 and 251. Proprietary data is releasable to the public in a time frame based on the type of information and the data acquired.

The MMS acquires geological and operational information, such as well logs (electrical, radioactive, acoustic, dipmeter), core descriptions (sidewall cores), paleontological summaries and reports, applications to drill, reports of drilling operations, and well completion reports. Approximately 27,250 wells have been drilled by oil and gas companies since 1954. Well logs from these wells are releasable either when the lease expires or 2 yr after completion of the well. Approximately 90 percent of the well logs are publicly available. Since 1968, 14,000 paleontological reports have been acquired. Company-submitted reports are releasable either when the lease expires or 10 yr after completion of the well. Paleontological reports prepared by the MMS from well cuttings are releasable either when the lease expires or 2 yr after completion of the well. Approximately 45 percent of the paleontological reports are available to the public in microform or paper format.

Geophysical information has been collected by the MMS since 1968. It consists of processed Multichannel Common Depth Point (CDP) seismic reflection data that is stacked, migrated, and enhanced for relative amplitude (bright spot); well velocity surveys; high-resolution profiles; and interpretations by contractors. Processed seismic (CDP) data mileage acquired from the Gulf of Mexico OCS region amounts to 512,500 mi [234,500 offshore Louisiana, 157,000 offshore Texas, 121,000 offshore Mississippi, Alabama, Florida (MAFLA); fig. 2]; the data,which are in the form of mylar films and magnetic navigation tapes, are releasable 25 yr after submittal. Except for 356 mi acquired in an exclusive contract and released through the National Oceanic and Atmospheric Administration's National Geophysical Data Center (NGDC), the first CDP data will be releasable in 2001. Approximately 2,000 well velocity surveys have been received by the MMS since 1970 and will be releasable either when the lease expires or 10 yr after submittal. Over 60 percent of these well velocity surveys are publicly available. High-resolution profiles acquired from 1972 to 1980 through exclusive contracts with the MMS total 80,200 mi and are available from the NGDC on microfirm or vellum. Information on oil and gas reserves in the Gulf of Mexcio is available as original recoverable reserves, cumulative production, and remaining recoverable reserves and is published in annual open-file reports. As of December 1988, there were 632 proven oil and gas fields (166 in Texas, 466 in Louisiana), 163 new, undeveloped fields (49 in Texas, 112 in Louisiana, and 2 in MAFLA), and 46 depleted or abandoned fields in the Gulf of Mexico. To date, 500 fields and 17,000 reservoirs have been mapped. A total of 7.5 billion bbl of oil and 84 trillion ft^3 of gas have been produced offshore Gulf of Mexico. The remaining recoverable reserves in the Gulf of Mexico are conservatively estimated at 3.39 billion bbl of oil and 42.4 trillion ft^3 of gas.

MAP INVENTORY

A variety of proprietary and nonproprietary maps are prepared and maintained by the MMS Gulf of Mexico Regional Office, although not all are publicly available:

Map	Format
Nonproprietary public information	
Well location	Printout, tape
Leasing (blocks, operators, bids, and so forth).	Do.
Protraction diagrams	MMS Denver, print out, tape.
Bathymetric	USGS, National Ocean Survey, scale 1:250,000.
Pipeline	Print out, tape 1 in. = 2,000 ft.
Environmental[1]	Scale 1:1,200,000.
Proprietary	
Prospect	1 in. = 4,000 ft.
Drainage	Do.
Field	1 in. = 2,000 ft/4,000 ft.
Regional	1 in. = 4,000 ft; 8,000 ft; 16,000 ft.
Contractor interpretations	Do.

[1]The environmental maps include historic leasing and infrastructure, commercial fisheries and endangered and threatened species, recreation and areas of multiple use, bottom sediments and vegetation, geologic and geomorphic features, and index of environmental studies.

MINERALS MANAGEMENT SERVICE MAP APPLICATIONS

The MMS mapping program has the following major applications:

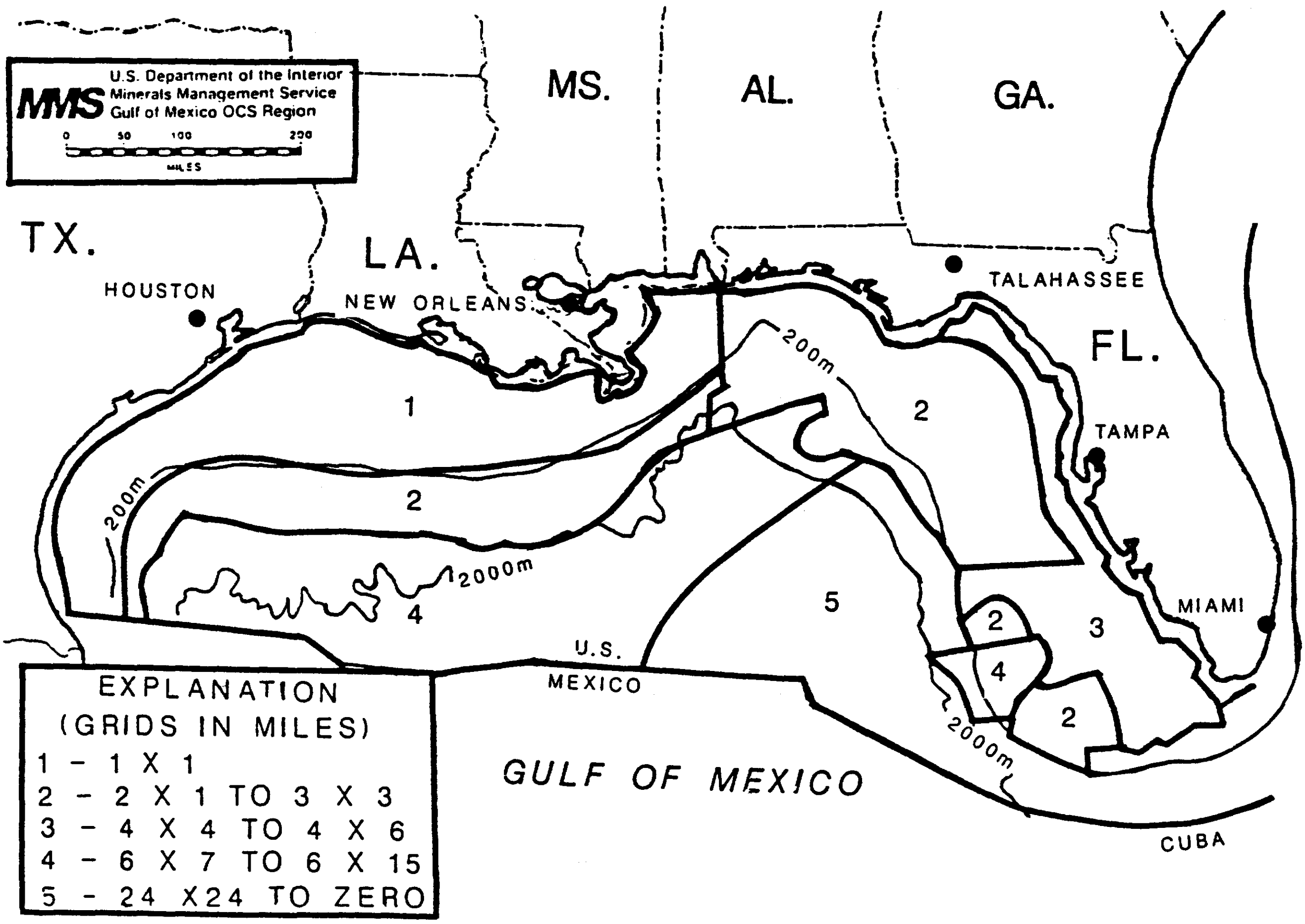

Figure 2. The Gulf of Mexico region Common Depth Point seismic data coverage.

- Lease sales—Assure fair market value for oil, gas, and sulfur resources.
- Oil and gas field studies—Determine reservoir potential.
- Reservoir determinations.
- National assessment of oil and gas resources—Determine resource potential of the country.
- Unitization of fields—Regulate efficient development of resources.
- Approval of well and platform sites—Ensure safe drilling and producing operations.
- Regional geologic studies and publications—Promote public awareness and geologic knowledge of the Gulf of Mexico.

Recent (1988) publications related to resource evaluation activities include *Correlation of the Cenozoic Sediments, Gulf of Mexico, Outer Continental Shelf* and *Estimated Oil and Gas Reserves, Gulf of Mexico.*

Correlation of the Cenozoic Sediments includes a series of regional cross sections delineating 26 production trends in the northwestern Gulf of Mexico Study Area 1 on figure 3; 247 well logs and 2,000 line mi of seismic data appear on the published sections. A well data summary is included for each well on the section; also included are 183 paleontological reports and 142 well velocity time-depth charts. The correlations of regional stratigraphic horizons are presented on closely parallel electric log and seismic cross sections (fig. 4). The correlation grid includes 7 regional east-west and 12 north-south electric log cross sections, which are presented on 33 sheets. The seismic cross sections include 6 east-west and 12 north-south lines, which are presented on 38 sheets. A text and maps are included that present the geology of the northwestern Gulf of Mexico (fig. 5). An open-file report on estimated oil and gas reserves includes reserve data by area and geologic age for approximately 800 fields in the Gulf of Mexico (Mast and others, 1989). Data are presented on field- and reservoir-size distributions, production rates, and discovery trends.

The Gulf of Mexico OCS will remain a very attractive oil and gas basin; leasing and drilling will remain active well into the next century. The most important cause of active leasing in the Gulf of Mexico is the complex geologic structure and stratigraphy coupled with improvements in exploration technology. Future exploration activity in the

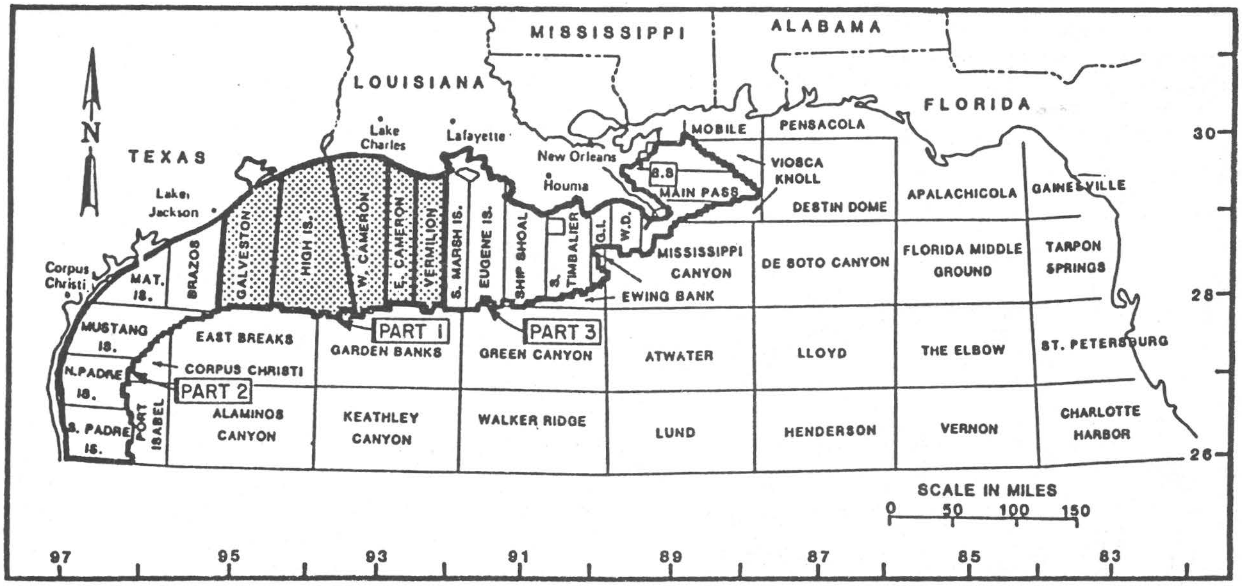

Figure 3. Study areas of the Gulf of Mexico (parts 1, 2, 3). Part number indicates order of publication. Names in blocks are from National Oceanic and Atmospheric Administration bathymetric maps that have lease block locations as an overlay.

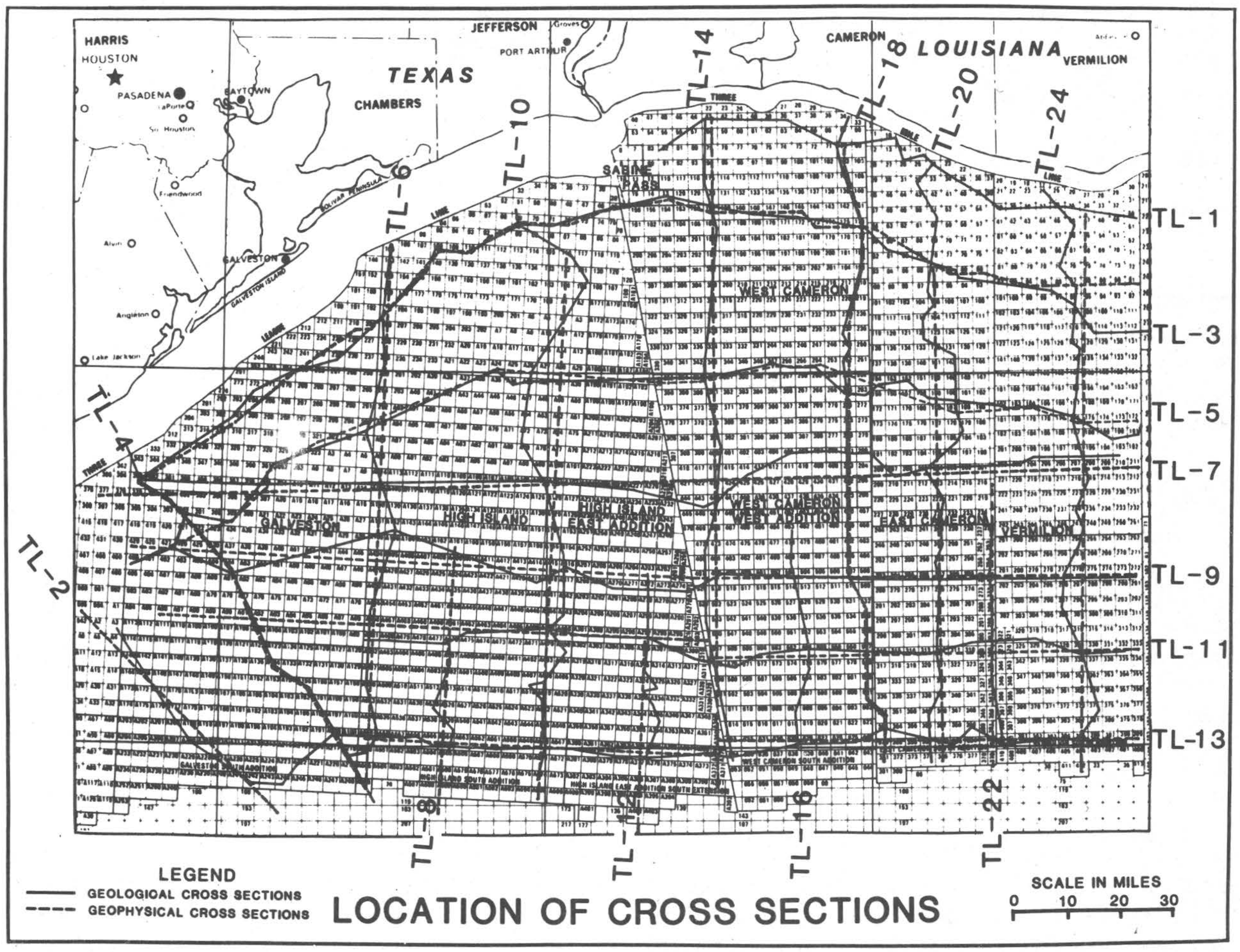

Figure 4. Location of electric log and seismic cross sections. TL, Texas-Louisiana seismic cross sections.

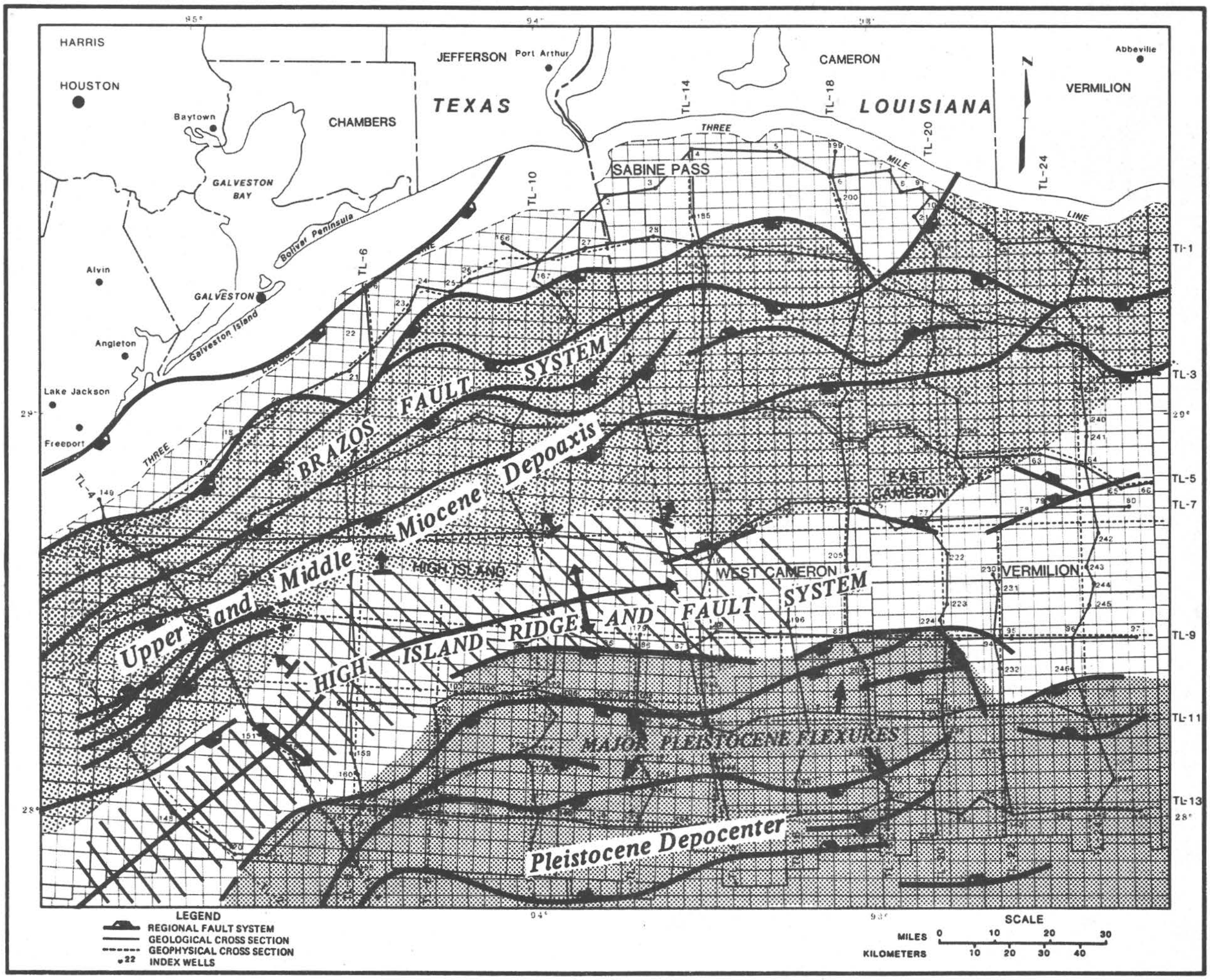

Figure 5. Principal structural elements.

Gulf can be predicted by comparing the Federal OCS with the geologically similar and highly developed onshore southern Louisiana region. The first discovery well in south Lousiana was drilled on the Jennings Dome in 1901. For the past 50 yr, onshore southern Louisiana has experienced continuous exploration and development, punctuated by many peaks of accelerated activity. Many of these peaks followed a major advance in technology—from the development of the torsion balance, which was first used to identify buried salt domes, to refraction and reflection seismic methods. Parallel to the advances in seismic technology were major improvements in drilling and well logging capabilities. Each technological advance created new ideas and prospects within an already "thoroughly" explored hydrocarbon basin.

Similar cycles of development, but on a much larger scale, can be expected on the OCS. The OCS has greater high-side potential than most onshore areas. The Gulf of Mexico offshore is more attractive for oil and gas exploration than most onshore areas because of lower exploration and land acquisition costs. The acquisition of geophysical data is approximately 10 times cheaper offshore than onshore; this results in improved mapping capability that reduces drilling risk.

Consequently, independent operators have become more active with new exploration ideas, resulting in the continued drilling and development of smaller structural and stratigraphic traps and deeper plays. The offshore information database has expanded significantly during the past 5 yr with additional well control, accurate deep seismic data, and three-dimensional seismic data. The recent decision by the Department of the Interior Solicitor's Office to release all well log data on wells drilled before 1976 provides an important database previously unavailable to the industry. This should provide an opportunity for increased "close-in" development drilling by smaller companies.

Inquiries concerning the availability of offshore data from the MMS Gulf of Mexico regional office should be directed to the following address:

Minerals Management Service
Gulf of Mexico Outer Continental Shelf Region
Public Information Unit (OPS-3-4)
1201 Elmwood Park Boulevard
New Orleans, LA 70123-2394

The public information unit may be reached by telephone at (504) 736-2932 or FTS 680-9932.

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Oregon's Perspective on Ocean Resource Research and Mapping

Jeff Weber
Oregon Department of Land Conservation and Development

Abstract

With the exception of bathymetry, Federal agencies emphasize research and mapping activities that facilitate the extraction and the use of marine resources. Without Federal support, oil and gas development, fishery management, marine mammal protection, and many other ocean resource uses would not be possible at today's levels. Coastal States, however, must manage the environmental and the social effects of resource uses that are supported by Federal research and mapping programs. Such environmental and social disruptions are predictable, given the appropriate information.

States cannot afford to independently develop the necessary information systems to predict environmental and social disruptions that occur on a regional basis. In addition, the need to share resource-management responsibilities and to communicate in the long term requires that State and Federal agencies use a common database. The Federal-State partnership in the Exclusive Economic Zone mapping must be based on the ability to predict the effects of a given activity and the willingness to prohibit or otherwise mitigate a Federal resource-use initiative. Otherwise, its effects will be too disruptive to coastal communities. In short, the partnership must reflect the resource-management needs of the States. It must be commensurate with a growing Federal-State partnership in Exclusive Economic Zone resource management.

INTRODUCTION

The interest in mapping the sea floor of the U.S. Exclusive Economic Zone (EEZ) is astounding. The entrepreneurial and the scientific attention on the ocean floor makes it look like low tide now delineates the edge of a frontier. Land resources have been so depleted that the ocean and the submerged lands are increasingly cited as sources of hard minerals, food, and energy resources. As we cross into this frontier—as researchers, resource managers, or entrepreneurs—our first responsibility is to ensure that we have fully learned the land-resource-management lessons of the 20th century.

The first lesson is that the ocean is a frontier only to certain users. For others, it is no more of a frontier than Manhattan is for us today. Many individuals and businesses already depend on the steady productivity of the Nation's ocean waters. Cultures far older than ours have been harvesting from the ocean for ages. They, along with countless contemporary fishermen, put a premium on the resources in and under those rich and productive waters.

On the basis of the observation that many of our resources on land have not been properly managed, current users have sufficient reason to be concerned about the consequences of new ocean uses. They must be assured that the alleged returns to society from a new ocean use do not represent, in reality, a transfer of resources from one user to another.

The State of Oregon's perspective on sea-floor and EEZ mapping derives entirely from its broader effort to develop and implement a comprehensive ocean resource-management program. The comprehensiveness of Oregon's program sets it apart from other efforts to manage ocean resources. Rather than emphasizing the use of a single ocean resource to the possible detriment of other uses, Oregon seeks balance among all ocean uses, once their real benefits and total costs are known. The State is accomplishing this by coordinating and balancing the mandates, the policies, and the programs of every State agency that has some responsibility or concern for the use of ocean resources.

The balance Oregon seeks to strike is distinctly different from that sought elsewhere. Consequently, Oregon's playing field may appear to outsiders to have a decided tilt. Indeed, it does. Oregon's law gives clear priority to the protection of renewable ocean resources over the use of nonrenewables. This decided tilt is designed specifically to protect the State's long-term economic interests.

If Oregon's responsibility is simply to respond to Federal resource initiatives, then it will be satisfied with whatever research is necessary to make an economic decision. If, however, Oregon is to further its own vision of how resources are to be used to best benefit its citizens, then it should be as fully informed as possible before making a decision.

Oregon's perspective translates directly into research priorities. The rule guiding Oregon's offshore mapping and research priorities is as follows: Research programs that facilitate the extraction of a nonrenewable resource from the ocean must be complemented by research on the effects of such extraction on existing ocean users. In Oregon's view, such research is a cost of business that must be borne by the party that stands to gain the most.

BACKGROUND—THE OREGON OCEAN RESOURCES MANAGEMENT ACT

For the past 2 yr, Oregon has been developing policies and priorities to guide the future use of its ocean resources. Research and mapping have been an integral part of the policy development process. Research shows where specific policies and management practices are needed or where they need to be changed to meet Oregon's resource objectives. The systematic look at the future use of the ocean also has revealed large areas where research must be completed before policies can be adopted. Consequently, Oregon's policy development process, supported by a considerable amount of research, will likewise guide future mapping and research.

Oregon's process of developing ocean-resource policies is largely an exercise in coordination and information trading. At least a dozen distinct interests participate in the process. Nine State agencies manage programs that do or that could affect ocean uses.

Several Federal agencies are acutely interested in how the State intends to manage its ocean resources. Several ports support commercial and recreational fishing fleets, and three support international maritime traffic. Every coastal community has a comprehensive land-use plan, developed according to State law, that affects the location of support facilities for offshore activities. These land-use plans reflect Oregon's mandate to conserve the natural resources that are the basis of the State's economy. Finally, Oregon's tradition of open decisionmaking means that citizens and interest groups participate in the policy development process from beginning to end.

Obviously, all the actors and the interests do not want the same thing. Some are intent on beginning oil and gas exploration without any further understanding of its effects on Oregon's fishing industry and, therefore, its coastal economy. Others take such a cautious approach to ocean-resource use that they would prohibit all future marine mineral research and exploration. The State's responsibility is to balance those demands, and the result of that process will be determined, in part, by a law that was passed by the Oregon Legislature in 1987.

This law resulted partly from the State's participation in the Federal process to lease offshore lands for oil and gas exploration and development. To make a long story manageable, Oregon was repeatedly dissatisfied with the Federal response—or lack of appropriate response—to the State's comments, concerns, and need for information throughout the Federal process. Although the State's participation in the prelease process was hampered by the bias in the process for Federal prerogatives, the real disagreements concerned the nature and the amount of information available to make sound resource-use decisions. Consistently, the State has held that Federal resource managers lack sufficient information to proceed with decisions that lead to a lease sale.

These disagreements, which continue in some form to this day, led the legislature to take unprecedented measures to protect Oregon's interest in the management and the use of its ocean resources.

In 1987, the Oregon Legislature enacted the Oregon Ocean Resources Management Act, apparently the first law of its kind in the United States. Since then, several Western States have considered legislation modeled on Oregon's law.

At the outset, the legislature noted the following:

- The Pacific Ocean and its many resources are of environmental, economic, aesthetic, recreational, social, and historic importance to the people of this State.
- Exploration, development, and production of ocean resources likely to result from Federal agency programs in Federal waters and initiatives of private companies within State waters will increase the chance of conflicting demands on ocean resources for food, energy, and minerals, as well as waste disposal and assimilation, and may jeopardize ocean resources and values of importance to this State.
- The fluid, dynamic nature of the ocean and the migration of many of its living resources beyond State boundaries extend the ocean-management interests of the State beyond the 3-mi territorial sea limit currently managed by the State pursuant to the Federal Submerged Lands Act.
- The 1983 Proclamation of the 200-mi U.S. EEZ has created an opportunity for all coastal States to more fully exercise and assert their responsibilities pertaining to the protection, conservation, and development of ocean resources under U.S. jurisdiction.

The legislature also noted that the Coastal Zone Management Act of 1972, the Magnuson Fisheries Conservation and Management Act of 1976, and the Outer Continental Shelf Lands Act Amendments of 1978 all provide for State participation in Federal ocean-resource-management decisions.

Many Oregonians use the ocean and its resources. They derive from it sustenance and pleasure. They recognize the responsibility of stewardship. They know that the marine ecosystem, complex and vast as it is, is vulnerable. Oregonians also know that the consequences of many ocean-resource uses and activities can be felt many tens, even hundreds, of miles away. Although these statements are the basis for an Oregon law, they apply equally in any Coastal State.

All this sets the stage for legislative policy. The legislature stated that Oregon will conserve the long-term values, benefits, and natural resources of the ocean within the State and beyond by giving clear priority to the proper management and the protection of renewable resources over nonrenewable resources.

This policy is the cornerstone of Oregon's ocean-resource-management program. (The legislative policy, in effect, restates Oregon's Statewide Planning Goal 19, *Ocean Resources*, which was adopted by the State on October 19, 1984.) All ocean-resource-management decisions must meet its test—Does the decision guarantee the protection of renewable resources?

The legislature also said that Oregon will assert its interests as a partner with Federal agencies in managing ocean resources and will promote research, study, and understanding of ocean resources, marine life, and other ocean resources and acquire the information necessary to understand the impacts and the relation of ocean-development activities to ocean and coastal resources.

Oregon law requires the conservation of its renewable ocean resources. Oregon vows to assist Federal research efforts and to become a comanager of resources in the EEZ with the U.S. Government.

THE OREGON OCEAN RESOURCES MANAGEMENT PLAN

The 1987 Legislature also created the Ocean Resources Management Task Force and directed it to prepare an Ocean Resources Management Plan for adoption in 1990. In October 1989, the Task Force completed its draft ocean-resource-management policies and distributed them for public review. In keeping with a tradition of open decisionmaking, Oregon insists that those most likely to be affected by a decision have more than a cursory or obligatory opportunity to participate in the decisionmaking process.

Oregon's conservation policy expresses the major difference between Federal and State ocean-resources-management responsibilities. In Oregon, regardless of a State agency's mission, its ocean-resource-management activities shall ensure that renewable resources are conserved. The task force defines conservation to mean that "the integrity, diversity, stability, complexity, and productivity of marine biological communities and their habitats are maintained or, where necessary, restored." Because Oregon's welfare relies, in part, on the long-term use of renewable ocean resources, the State's responsibility is to ensure that nothing impedes their continued production.

Conservation is also the mandate of some Federal agencies. However, those agencies tend to be severely underfunded. In recent years, if an agency is adequately funded, then the chances are good that its primary responsibility is not the conservation of a natural resource, but rather the sale of public resources to feed the Federal treasury.

States have the ability to coordinate agency policies to make conservation a primary resource-management objective. Coordination is one of the primary objectives of the Task Force and the Ocean Resources Management Plan. Oregon agencies meet with sister agencies to weigh and balance their apparently contradictory mandates. Given the size of Federal agencies, the same coordination would be exceedingly difficult, if not impossible, without direction from the President.

At the State level (at least in Oregon), apparently differing interests are easier to coordinate and subsume under a single overarching policy. Consequently, States are able to replace a single-resource approach to system management with a systemic approach to resource management. In a highly compartmentalized resource-management framework, as the Federal Government's, the single-resource approach prevails and shall probably prevail for years to come.

OREGON'S OFFSHORE MAPPING AND RESEARCH NEEDS

The draft Ocean Resources Management Plan addresses the research and the information needed to make sound ocean-resource decisions. The plan was compiled in consultation with State and Federal agencies, industry experts, and university researchers. Each chapter referred to research that was necessary for proper resource management. All these research requirements have some bearing on mapping and research off Oregon.

For the purposes of research, the ocean off Oregon can be separated into three zones—the intertidal, the continental margin, and the area westward off the margin to the EEZ boundary. The need for information varies according to the level of activity or potential for conflicts with other uses in the zone. The intertidal zone and the rocks, the islands, and the estuary mouths require research and mapping in the greatest detail. On the continental margin, research and mapping must allow State and Federal agencies to balance their resource-management mandates. The need for great detail falls off dramatically beyond the margin because few new ocean uses will occur there in the foreseeable future.

The needs for information off Oregon are varied andextensive. Naturally, their priority depends on the likelihood that a given activity will occur. Some data, such as substrate composition, bottom currents, meteorological averages, seasonal currents, upwelling, water temperature, and water chemistry, may be utilized in nearly every decision. These parameters will be correlated with data on the location of many marine species and will provide a basis for managing marine habitat.

Oregon's marine birds and mammals need to be counted and monitored. Over one-half the marine birds on the West Coast spend at least some part of their life on the rocks and the islands along the Oregon coast. Anything that affects Oregon's coastal ecosystem will affect bird populations along the entire West Coast.

The objectives of State-Federal cooperative research programs need to be developed cooperatively, so the data serves the needs of all interested parties. Without exception, the data needs in State waters are identical to—perhaps even greater than—those in the EEZ.

Oregon will need data to protect current viable ocean uses from new ones, so as to protect the integrity and the vitality of the communities that depend on such resource uses. When approached with a proposal to develop a new ocean resource, Oregon will ask, "What will our coastal communities be expected to give up or forego to accommodate this new activity?" Although it may not hold true in other States, Oregonians believe that returns to the State from offshore oil, gas, or mineral development will be far less than the returns from existing ocean uses. Furthermore, such returns would be distributed to only a handful of people.

CONCLUSIONS

With proper management, the ocean can continue indefinitely to provide resources for the livelihood of hundreds of coastal communities. Any restriction of an existing economically and ecologically sound resource use or any appropriation—whether by consumption, contamination, or destruction—of a resource best left for future use constitutes poor resource management. It is also poor economics. The fact is, economic health depends on a healthy ecosystem.

Oregon's sea-floor mapping needs evolve from its ocean-resource-management priorities. The State's top ocean-resource-management priority is quite simple. Oregon law recognizes and acknowledges the long-term economic value of its renewable ocean resources. The Oregon Legislature has found that the proper use and development of renewable ocean resources creates more jobs and keeps more revenues in the State than does the development of nonrenewable ocean resources. Consequently, Oregon's top ocean-management priority is to protect the long-term productivity of its renewable ocean resources. Oregon's priority is economically sound in any State, but it is especially sound where communities still rely absolutely on the use of natural resources for their economic well-being. Without exception, Oregon's research and mapping priorities will reflect the need to protect the present and the potential use of its renewable ocean resources.

At this moment, Oregon continues its efforts to incorporate its information needs into Federal agency work programs. Contrary to some protests, Oregonians do not want information for the sake of information. Rather, they need information for the sake of management. At least in some cases, Oregon's ocean-management concerns appear to be vastly different from those of Federal agencies. Its research needs will differ to a corresponding degree.

A View of Sea-Floor Mapping Priorities in Alaska From the Mining Industry

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Western Gold Exploration and Mining Company

INTRODUCTION

The shallow waters off the coast of Alaska, which are defined as water depths of less than 100 m, represent a tremendous potential resource for the exploitation of hard minerals from the seabed. The Exclusive Economic Zone (EEZ) Proclamation of 1983 provides the framework for exploring and commercially developing potential marine placer ore bodies.

The vast extent of the metalliferous regions known to be glaciated makes the task of focusing on the most prospective areas a difficult problem for industry. Although it is not the intent of this paper to suggest that Federal agencies should take an active role in proving ore reserves, it is in the interest of the United States to inventory the hard-mineral resources within the EEZ. In this regard, the mapping and the evaluation of potential offshore placer deposits within the EEZ should be a priority for the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA).

This paper outlines the criteria necessary for the mining industry to prioritize those areas in the Alaska EEZ in which to conduct sea-floor mapping programs. Three specific high-priority areas are outlined, and recommendations regarding geophysical and drilling equipment, data processing, and resource evaluation also are discussed.

CRITERIA FOR EXPLORATION PRIORITIES

For the purposes of hard-mineral exploration within the Alaska EEZ, the areas of greatest economic interest have been selected by using the following criteria:

- Areas adjacent to known mineralized terrains on land.
- Areas where Quaternary glaciation would be the principal mechanism for offshore sediment transport.
- Areas that have water depths of less than 100 m.

The areas of primary interest, which fulfill the criteria outlined above are as follows, in order of priority:

- Offshore Nome on the southern coast of the Seward Peninsula.
- Offshore northeastern Gulf of Alaska from Cape Suckling to Cape Fairweather.
- The shelf area south of Kodiak Island and east of the Shelikof Strait.

AREA 1—OFFSHORE NOME

Near Nome, the area within a 6-mi radius of Anvil Mountain has produced approximately 5 million oz of gold from glaciofluvial and glaciomarine placers (Nelson and Hopkins, 1972; Cobb, 1984b). Glaciated areas east of Nome near Solomon and Bluff also have recorded significant gold production from placer deposits onshore. Figure 1 illustrates the known occurrences of lode and placer gold and platinum in the coastal regions of Alaska.

Since 1985, mining activity by Western Gold Exploration and Mining Company, Limited Partnership (West Gold), has verified the existence and the viability of glaciomarine gold placers offshore Nome within lands administered by the State of Alaska (Bronston, 1990). In excess of 100,000 oz of gold has been recovered from the seabed by the Mining Vessel *Bima* during the first full 3 production years of the West Gold operation.

The presence of economic gold concentrations in the offshore environment within the 3-mi State limit and the favorable potential for additional deposits in the adjacent EEZ make the Nome area from Cape Rodney on the west to Cape Darby on the east (fig. 2) the first priority for sea-floor mapping and exploration within the Alaska EEZ.

AREA 2—NORTHEASTERN GULF OF ALASKA

The presence of gold on the beaches from Cape Yakataga to Yakutat Bay has been documented since the early 1900's. Although relatively unexplored, regional bathymetric studies by NOAA indicate the area possesses a broad continental shelf that extends well into the EEZ. The adjacent coastal regions have been heavily glaciated during the Quaternary. Figure 3 illustrates the maximum extent of

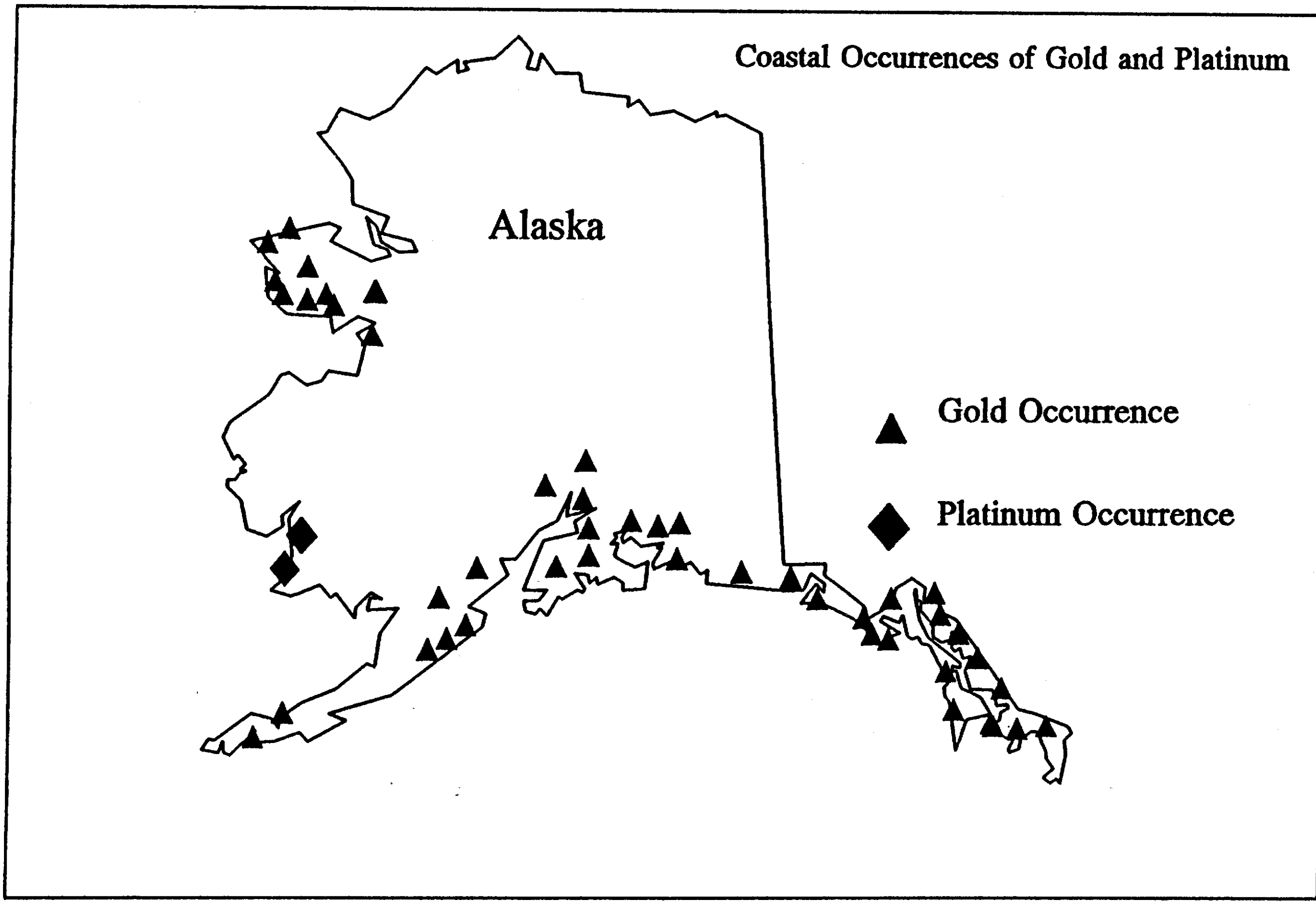

Figure 1. Coastal occurrences of gold and platinum. Modified from Cobb (1960, 1984a, b).

Quaternary glaciations in Alaska superimposed on the gold and the platinum occurrences in figure 1. The area from Cape Suckling on the northwest to Cape Fairweather on the southeast (fig. 4) is of particular interest for gold and heavy-mineral placers.

AREA 3—SOUTHERN SHELF OFF KODIAK ISLAND

This area is located on the Continental Shelf south of Kodiak Island and within the 100-m isobath (fig. 5). Although this area is virtually unexplored for its marine placer potential, it is included because of its proximity to potential epithermal lode sources in heavily glaciated terrain. Gold in beach sands has been reported in the Trinity Islands south of Kodiak Island.

The high-energy sea state and tidal forces may represent efficient physical processing conduits for the concentration of precious-metal and heavy-mineral placers. However, this area is known for its difficult sea conditions, which could make exploration and mining activities difficult logistically.

EXPLORATION METHODOLOGIES

In any sea-floor mapping program, the primary tools are geophysical; these are supplemented by drills and other sea-floor sampling devices for verification. The use of modern digital recording and signal processing equipment and techniques for high-resolution sea-floor mapping applications (Graul and others, 1989; Matthias and Newton, 1990) should become the mainstay of future USGS and NOAA mapping efforts. The following geophysical instrumentation should be utilized:

- Two- and three-dimensional, multichannel, high-resolution, digital, seismic surveys.
- Digital swath bathymetry.
- Digital sidescan sonar (Q-Mips).
- Digital 3.5- to 7.0-kHz subbottom profiling.
- Digital marine magnetometer.

All systems should be recorded in the appropriate industry standard format on media, which can be readily utilized by the public, such as nine-track magnetic tape, floppy disk, and CD-ROM. Line spacing should be regional in scope, and the emphasis should be placed on evaluating large areas of potential mineral-bearing sea-floor sediments.

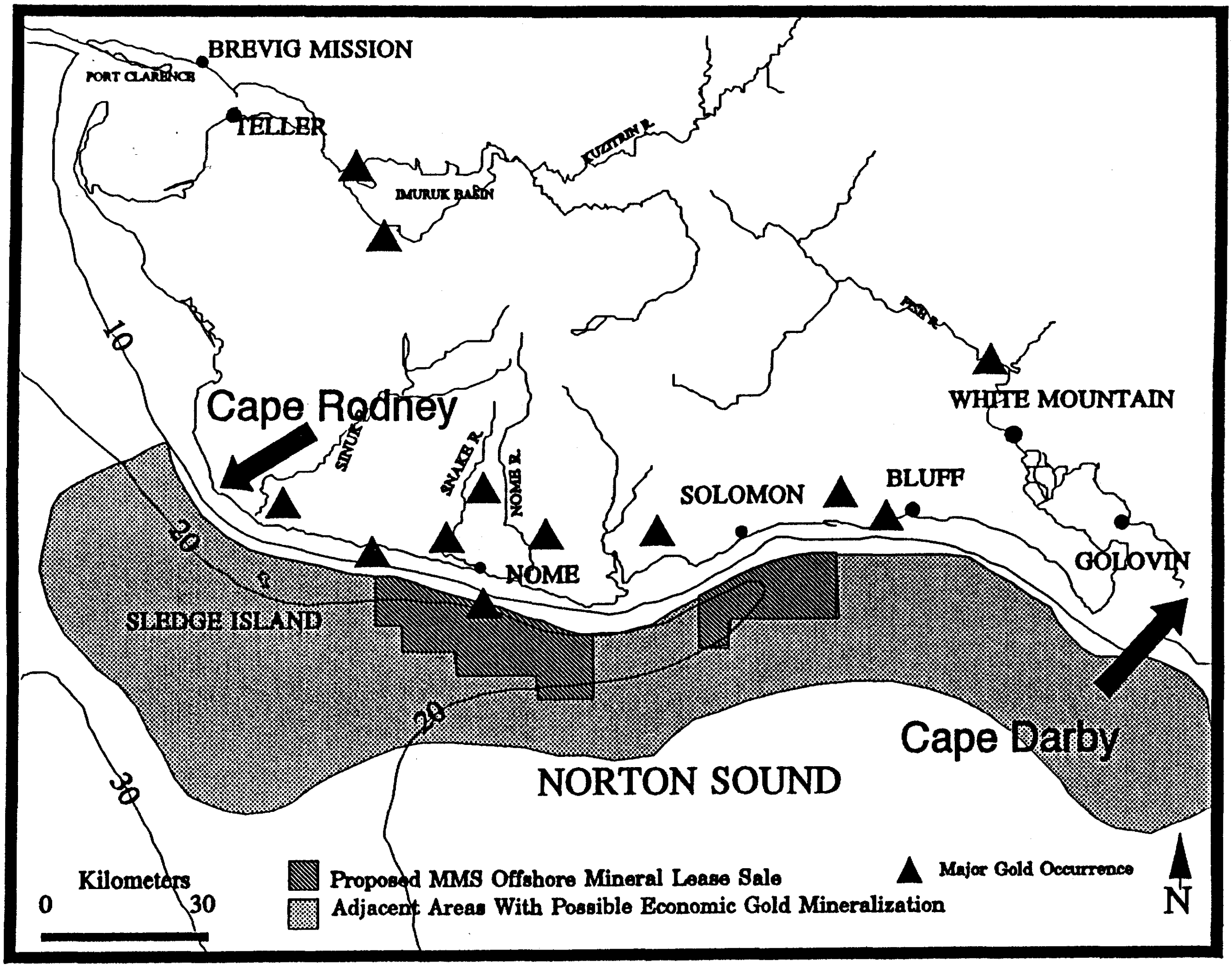

Figure 2. Nome priority exploration areas.

DRILLING AND SAMPLING

Following geophysical evaluations, prospective areas should be evaluated to determine the areal size, the grade, and the mineralogy of potential placer deposits. Sea-floor sampling programs may be reconnaissance in nature if a pipe dredge or a bottom grab sampling technique is used. Although these techniques do not provide a reliable point-specific grade of the deposit (as they are restricted to the relatively unconsolidated surface sediments), they do give a relative indication of the abundance of the mineral of interest in a given area. These techniques are quick and relatively inexpensive compared to offshore drilling programs.

In areas where sea-floor surface sampling indicates that a placer of considerable economic importance may exist, a drilling program is the most effective means of determining the three-dimensional distribution of the resource. Drill types that have been shown to be effective in sampling marine placers are as follows:

- The Becker hammer drill is used off the ice and in relatively calm, shallow water (Daily, 1969; Bronston, 1990). The Becker drill is particularly effective in glacial terrains that have indurated sediments and coarse sedimentary lithologies.
- The remote placer drill is used for reconnaissance and development drilling in rough seas and rocky substrates to a maximum of 6 m depth (Woolsey and Noakes, 1989).
- The vibracore is used in well-sorted sediments in deep water.
- The vibrahammer is used in coarse sea-floor sediments in deep water.

SAMPLE PROCESSING

Sea-floor samples collected during bottom sampling and drilling programs should be processed by using mining

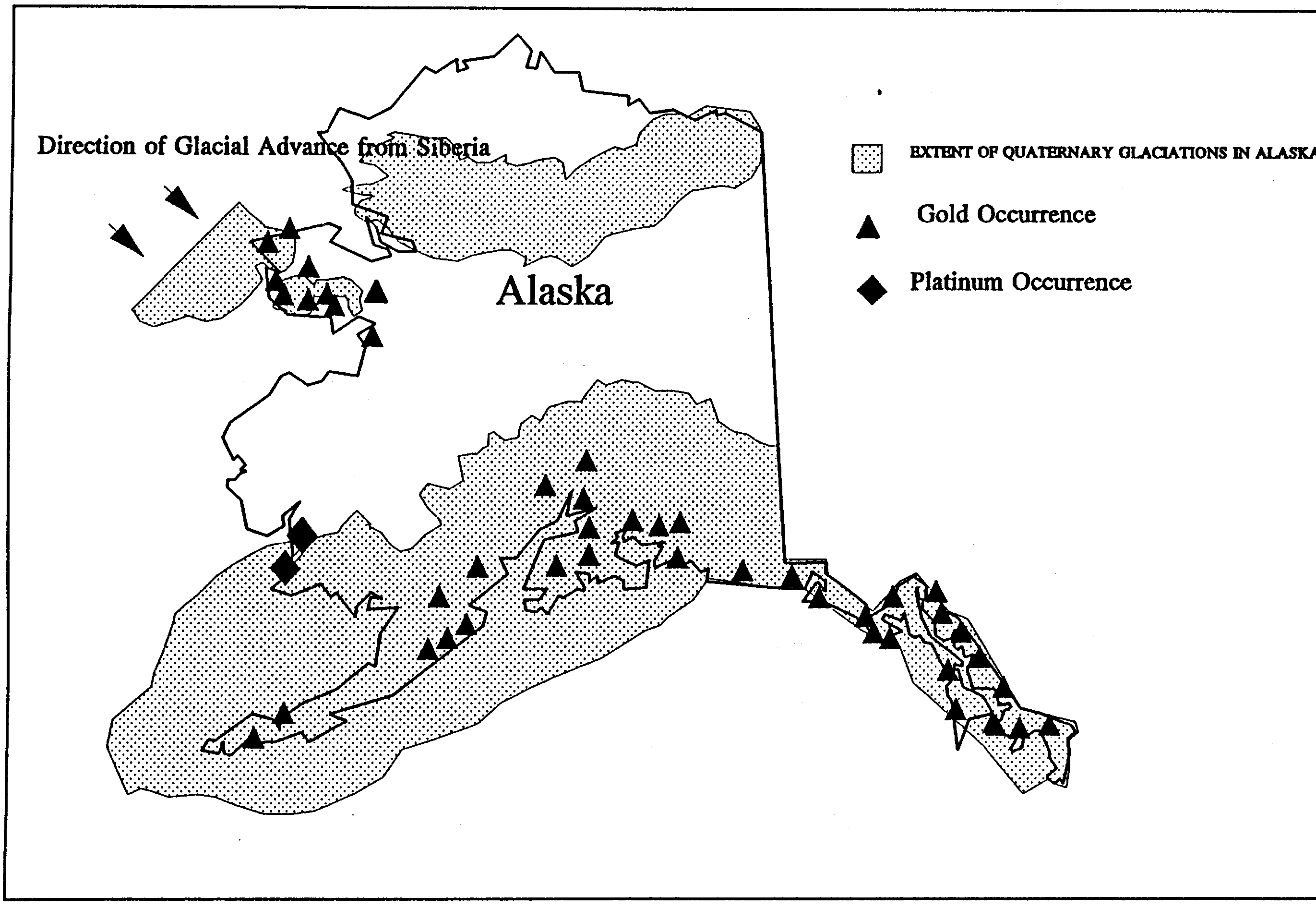

Figure 3. Maximum extent of Quaternary glaciations superimposed on gold and platinum occurrences. Modified from Cobb (1960, 1984) and Pewe (1975).

industry standard procedures. In particular, precious-metal-bearing placer sediments should be concentrated by using gravity separation techniques, and the gold particles counted, amalgamated, and weighed. Other analysis techniques, such as fire assay and atomic absorption, should be avoided because they do not accurately represent the grades that would be recovered by gravity methods on a mining vessel. Ore grades should be reported as metal content per standard unit volume; for example, in milligrams per cubic meter or ounces per cubic yard.

BULK SAMPLING

If a potential mineral deposit is discovered during exploration and resource evaluation programs and if it is of major economic significance, then a bulk sampling program may be invaluable in verifying the drill-indicated grades and the physical nature of the deposit. Bulk samples may be taken by using a hydraulic clam shell excavator mounted on a barge or by a robotic underwater miner; the latter is similar to the alluvial mining "tramrod" tested at Nome by West Gold in 1989. Bulk sampling programs, though expensive, will confirm the horizontal and the vertical grade distributions of the deposit and may be useful as prototype mining tests. A bulk sampling system should be interfaced with a gravity separation system similar to those used on commercial mining vessels so that accurate metal recoveries may be calculated.

CONCLUSIONS

The EEZ adjacent to Alaska represents a large potential resource for hard minerals that are concentrated in marine placer deposits. The mapping and the evaluation of these deposits should be a priority for the USGS and NOAA.

Geophysical and bottom sampling surveys should be conducted in areas adjacent to known mineralized terrains where water depth is less than 100 m and where glaciation would be the agent for the transport of metal-bearing sediments offshore. On the basis of these criteria, the areas offshore Nome, the northeastern Gulf of Alaska, and the shelf south of Kodiak Island should be of particular interest.

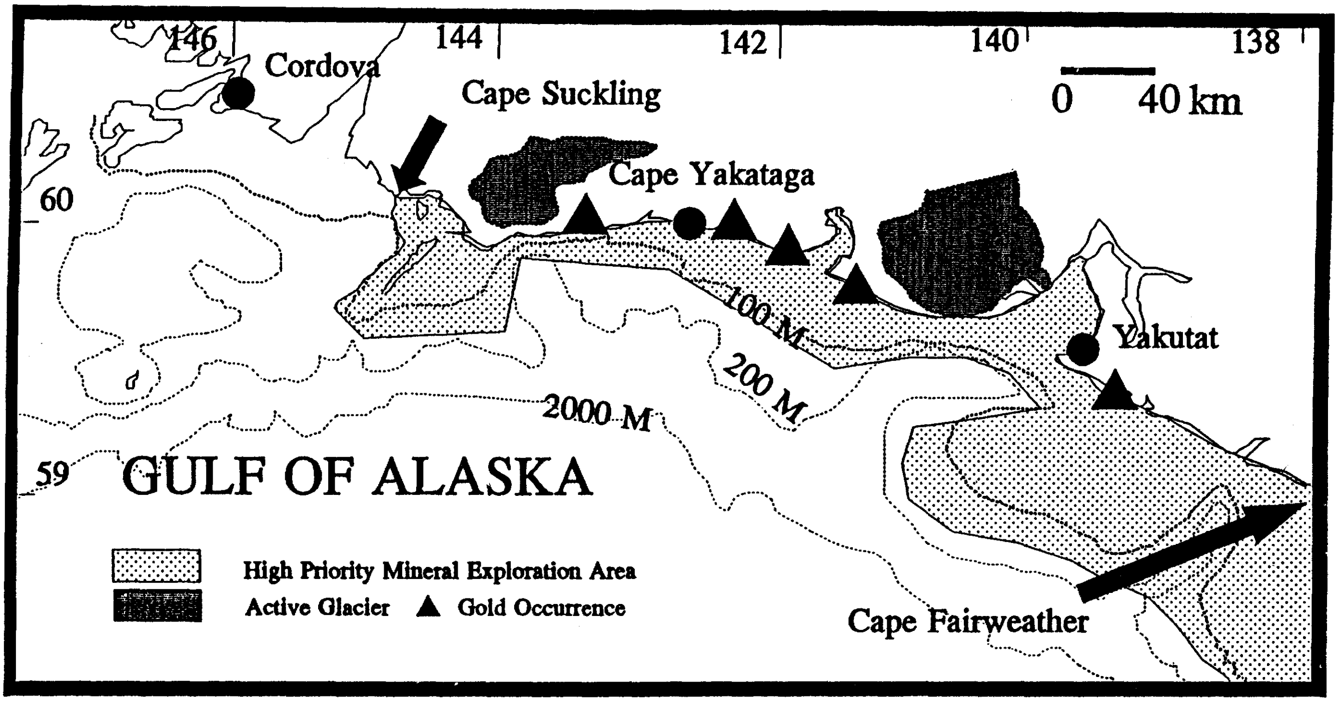

Figure 4. Priority exploration area for the northeastern Gulf of Alaska.

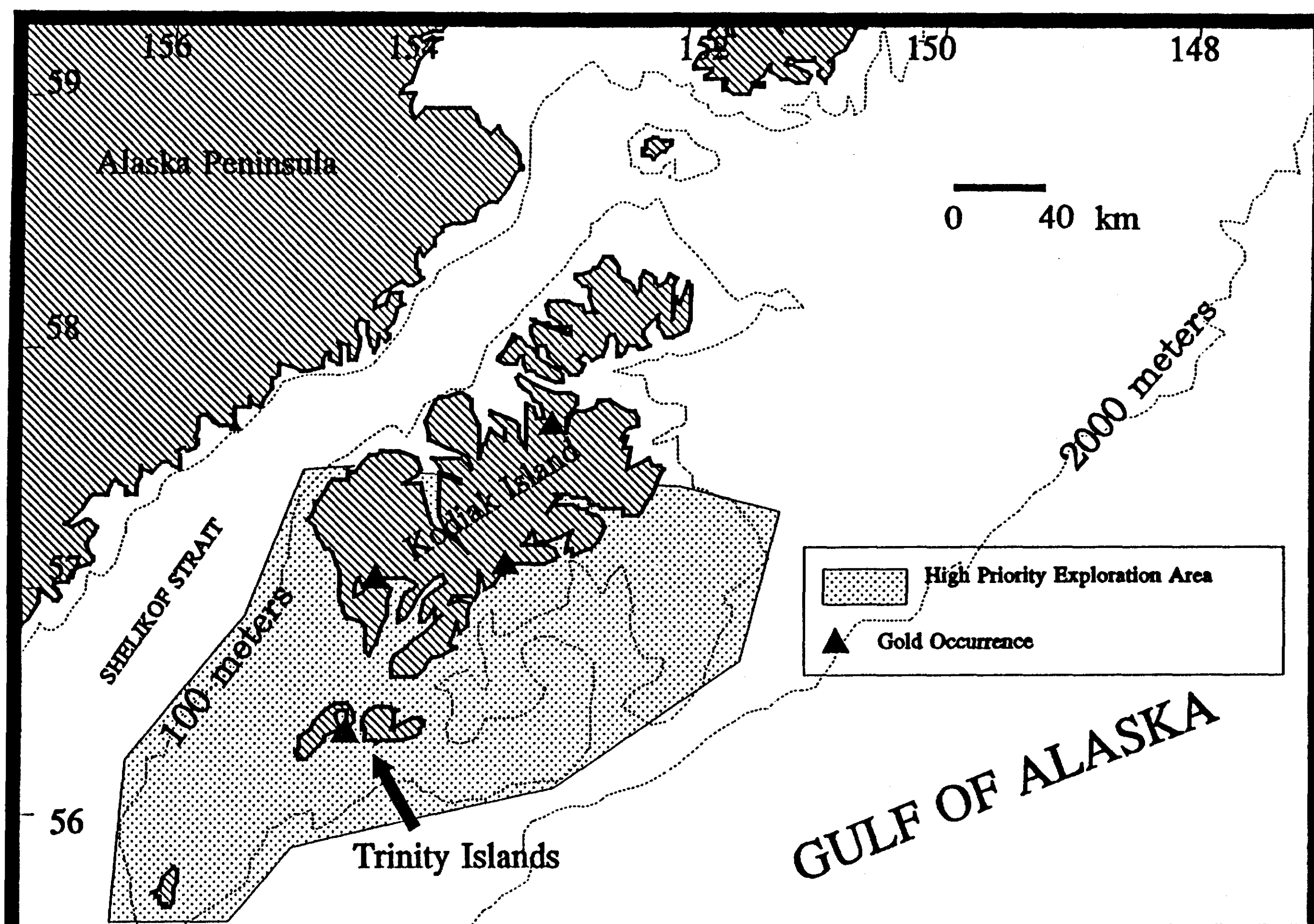

Figure 5. Priority exploration area for the Kodiak Shelf.

State-of-the-art, digital, geophysical, acquisition hardware should be utilized for reconnaisance surveys and followed by bottom sampling for verification. Deposits of potential economic importance should be drilled to define the extent of the resource and bulk sampled to verify drill-indicated grades. Evaluation of the resources discovered should be completed to standard mining industry specifications.

Following the criteria stated in this paper, a sea-floor mapping program in Alaska would establish an inventory of hard-mineral resources within the Alaska EEZ and would benefit the United States by expediting the development of hard minerals from the seabed, thereby decreasing our dependence on foreign supplies.

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Exclusive Economic Zone Scientific Activities in the Branch of Pacific Marine Geology, U.S. Geological Survey

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INTRODUCTION

Throughout the later half of the 1980's, the scientific staff in the Branch of Pacific Marine Geology (BPMG) of the U.S. Geological Survey (USGS) has been deeply involved in mapping and research activities in the U.S. Exclusive Economic Zone (EEZ). The initial field program in this region came shortly after the 1983 Proclamation of the EEZ by President Reagan when a unique and comprehensive sea-floor mapping project was initiated by BPMG in 1984. This project was supported by a funding augmentation to the Offshore Geologic Framework Program of the USGS and was designed to provide for mapping and followup research of the entire EEZ over a long-term period (greater than 10 yr).

To accomplish the mapping goals of this project, a long-range sidescan-sonar system, GLORIA, was obtained from the Institute of Oceanographic Sciences (IOS), a British research laboratory, through a long-term cooperative agreement for scientific studies in the U.S. EEZ. GLORIA, which is a one-of-a-kind instrument system, provides sidescan-sonar images up to a maximum of 60 km across the ship's tracks (typically operated to cover 45 km in the EEZ project) and is capable of resolving geological features of 50 to 100 m in horizontal dimensions. Because the sonar data are acquired digitally, a variety of USGS-developed computer-image-processing techniques are applied to render geometrically corrected images that are enhanced for clarity and definition.

GLORIA MAPPING OF THE PACIFIC U.S. EXCLUSIVE ECONOMIC ZONE

In 1984, scientists from BPMG and IOS mapped the entire EEZ area off California, Oregon, and Washington by means of the GLORIA system. These surveys covered about 750,000 km^2 of sea floor and were accomplished in only 100 d. The images obtained had overlapping records so that a mosaic of the entire EEZ could be assembled, thereby facilitating the interpretation and the understanding of the results. During each of the cruises, other types of geophysical data were collected along the ship's tracks, including dual-channel air-gun, seismic reflection profiles, 3.5-kHz high-resolution and 10-kHz bathymetric profiles, and magnetic field and gravity measurements. The GLORIA sonar imagery and the other data have been processed, analyzed, presented in a readily available atlas publication (EEZ-SCAN 84 Scientific Staff, 1986), and summarized (EEZ-SCAN 84 Scientific Staff, 1988).

Since 1984, BPMG scientists have obtained GLORIA sidescan-sonar records of the EEZ in the Bering Sea, the Gulf of Alaska, and the Aleutian Islands and around the Hawaiian Island chain. The data collection effort for the latter region is planned for completion in 1991. The Bering Sea data have been completely processed, assembled, and interpreted; the atlas of GLORIA imagery and ancillary data is awaiting publication. The sidescan data for the other regions are at various stages of processing and analysis.

POST-GLORIA INVESTIGATIONS OF THE PACIFIC EXCLUSIVE ECONOMIC ZONE

Shortly after the initial 1984 GLORIA cruises, investigators at BPMG and their IOS collaborators began follow-on ("ground-truth") studies of the EEZ by using the newly acquired GLORIA results to design the work. Projects have been initiated in relating the acoustic backscatter in the sidescan-sonar data to geological and physical properties of the sea floor and in probing important geological problems revealed in the sonar imagery; an example of an ongoing study of the geological interpretations associated with the acoustic backscatter is the field, laboratory, and theoretical work on the Monterey Submarine Fan. This study began in 1987 with high-resolution seismic profiling, sampling, and an underwater photographic/video survey of a distal section of the fan by using the Research Vessel *Farnella*. Since then, two other research cruises to the region have been undertaken that have included additional surveying and sampling and have focused on the physical properties of the samples. A fourth scientific expedition to the study area will be undertaken in June 1990 by using a towed midrange sidescan-sonar system (TOBI), which has been developed recently by IOS engineers. This system will provide more detailed imagery of the area and sonar data at a higher frequency (about 30 kHz) for comparison with the GLORIA data (nominally at 6.5 kHz).

Figure 1 shows the mosaic of a GLORIA image from the 1984 data; this mosaic is an improved version of that shown in the EEZ atlas (EEZ-SCAN 84 Scientific Staff, 1986). Figure 2 is a simplified interpretation of the mosaic in figure 1. These figures have been taken from an article by Gardner and others (in press). This intensively studied

Figure 1. Mosaic of GLORIA imagery taken in 1984 (EEZ-SCAN 84 Scientific Staff, 1986). Images have been enhanced and improved by J.V. Gardner (USGS). The area shown is delineated in figure 2 and includes Monterey Bay, Calif. (upper right corner), and the Monterey Submarine Canyon Fan System in the central California EEZ.

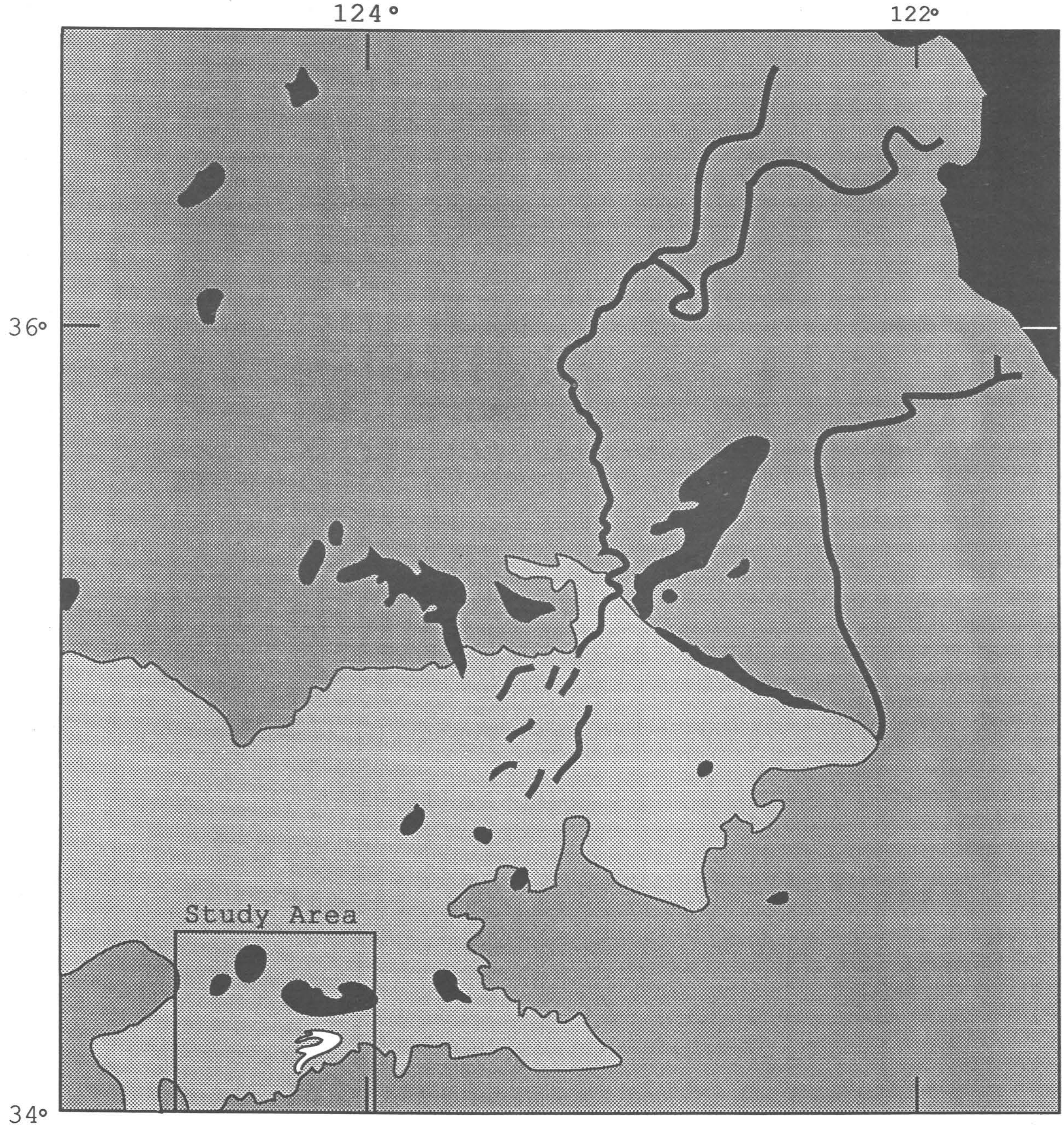

Figure 2. Interpretation of the mosaic of GLORIA imagery presented in figure 1. Basement rocks are shown in black; canyon and channels are delineated by heavy black lines; distal portion of fan sediment is the lighter of the two gray shaded zones. Interpretation is courtesy of Gardner and others (in press).

region, which has been the focus of the "ground-truth" effort, is shown by the box in the lower left portion of figure 2.

A second example of the post-GLORIA investigations of the EEZ is the present sea-floor study of the continental margin off San Francisco, Calif.; we refer to this segment as the Farallon continental margin. In early 1986, scientific investigators in BPMG, in cooperation with scientific personnel from the Branch of Atlantic Marine Geology (BAMG), USGS, Woods Hole, Mass., undertook a series of research cruises to the continental shelf in this segment. The initial work provided a sidescan-sonar reconnaissance survey of the shelf followed by a closely spaced grid of bottom grab samples throughout the region (fig. 3). The sonar used in this survey was a conventional 100-kHz system, which obtained across track coverage of about 400 m.

A smaller portion of the shelf area was selected for a closely spaced sidescan-sonar survey and sampling grid, as shown in figure 3. In this smaller survey area, a mosaic has been completed from the digital data obtained by using a 120-kHz midrange sidescan-sonar system. This mosaic is being readied for publication by BPMG and BAMG scientists.

Sidescan-sonar data collection will continue during summer 1990 when a research cruise to the continental slope in the Farallon segment will be conducted by using a 30-kHz midrange system. It is anticipated that overlapping coverage of the upper to middle slope will provide data for a detailed mosaic of that area. This mosaic then can be

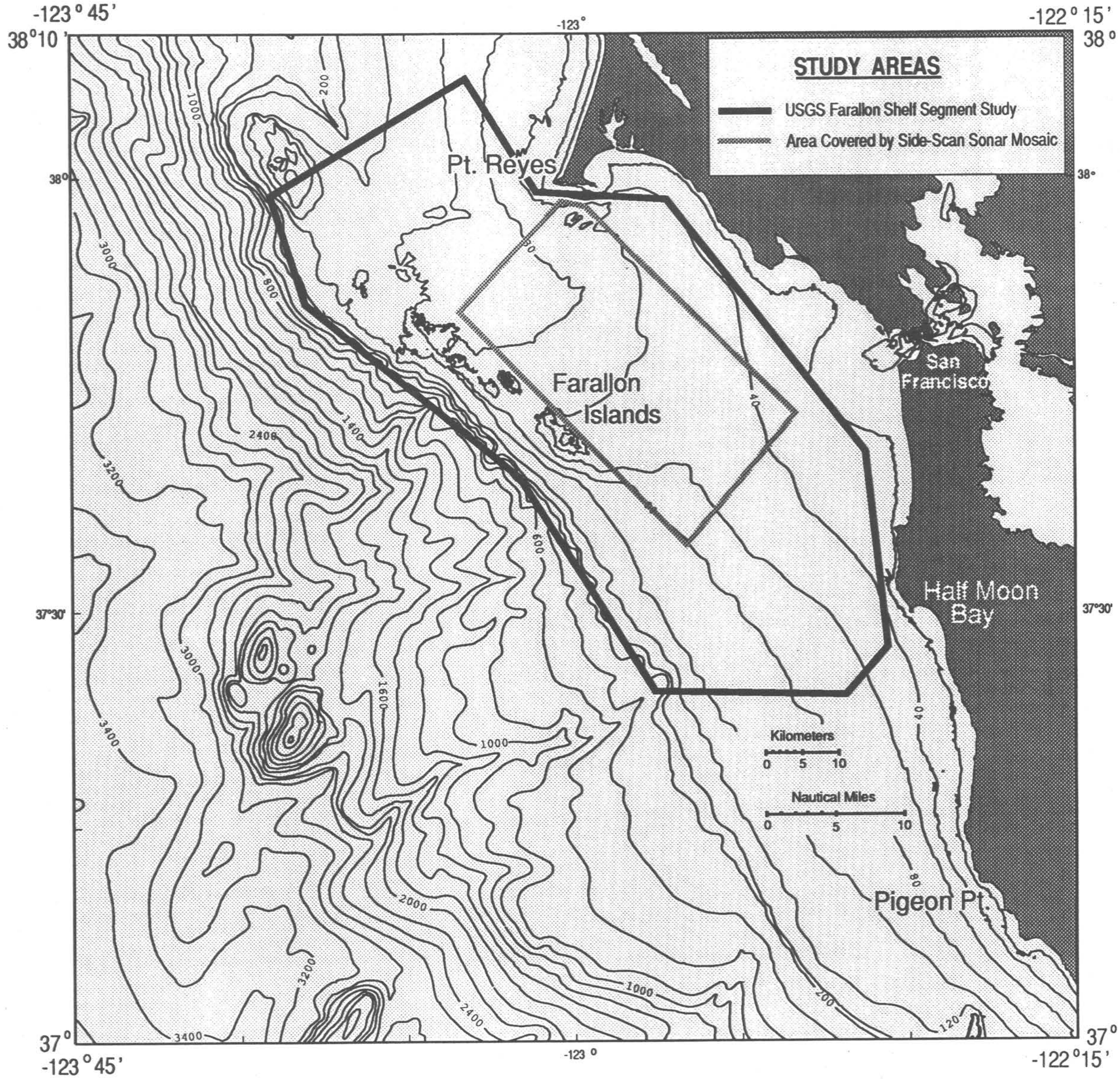

Figure 3. Farallon continental margin segment off San Francisco, Calif. Areas of reconnaissance sidescan-sonar survey are outlined by the heavy black line. A more detailed mosaic of sidescan imagery was undertaken within the smaller box that is outlined by the lighter lines. Bathymetric depths are in meters.

compared and contrasted with the available GLORIA imagery to investigate the acoustic returns at two distinctly different frequencies along the same section of sea floor.

During April and May 1990, scientific personnel at BPMG completed multichannel seismic profiling on the Research Vessel *Samuel P. Lee* that included tracklines in the Farallon continental margin segment. These data are being processed at BPMG, and the results will appear later in 1990. These data are significant for understanding seismic activity and crustal deformation in the active central California offshore.

FUTURE PLANS AND SUMMARY

The results of the multidisciplinary, multifaceted investigations in the Monterey Submarine Canyon Fan System and within the Farallon continental margin will appear as published articles. In particular, we are planning to assemble all the recent work in the Farallon study area into a comprehensive atlas-type publication. This volume will include sections on the shelf and the slope sediment distributions, geologic framework and structure, surface morphology, and sedimentary processes. The results of this work will be important for identifying offshore disposal sites, determining transport of sediments and incorporated pollutants, and predicting seismic activity and bottom slope stability.

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Mapping Requirements for Planning the Outer Continental Shelf Mining Program Norton Sound, Alaska, Lease Sale

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Abstract

Preparations are being made by the Alaska Outer Continental Shelf Regional Office of the Minerals Management Service to conduct the first Outer Continental Shelf Mining Program lease sale to be held anywhere in the United States—in Norton Sound. Past gold mining activity and the present prelease process, which is being coordinated with the State of Alaska, are discussed. The various mapping and graphics products used in preparation for the Norton Sound mining sale are emphasized. Future mapping needs along the Alaskan coast that would delimit the State-Federal boundary are presented.

INTRODUCTION

More than 4.5 million troy oz of gold have been recovered from onshore placer deposits in the Nome District since 1899. Most of the recovery was from strandline deposits, such as the modern beach at Nome or the ancient beaches further inland. The gold was initially eroded from lode deposits on the Seward Peninsula and reworked by fluvial, glacial, and marine processes. During the Pleistocene, advancing glaciers moved coarse gold particles onto the Continental Shelf of Norton Sound. Enrichment factors, such as marine scour and fluvial erosion, have reworked some of the gold from the glacial deposits into minable placers. Since 1986, gold ore has been dredged in State waters within the area covered by glacial deposits. The maximum annual recovery to date was 36,700 troy oz in 1987.

In the Federal Outer Continental Shelf (OCS), submerged beach ridges occur on the seabottom at depths of 21, 24, and 27 m. Buried ancient channels also are recognizable on seismic profiles. It is possible that enriched placer deposits similar to those mined onshore may exist in Federal waters. The distribution of glacial deposits is based on the mapping of surficial sediments and the interpretation of seismic profiles. Because subsurface samples from the OCS are sparse, there is little information on ore grade and ore-body volume in Federal waters.

On the basis of available data, the highest potential blocks in the proposed sale area are those closest to the gold-bearing glacial deposits offshore Nome. The 21- and 24-m beach ridges occur within these blocks, as well as buried channels that may contain gold eroded from the nearby glacial deposits. Following Inspiration Gold, Inc.'s, very successful 1987 offshore gold dredging season in State waters, it was a natural followup for them to begin planning the acquisition of more leases.

PRELEASE PROCESS

The process was initiated in November 1987 when Inspiration Gold, Inc., wrote a letter to the Assistant Secretary for Land and Minerals Management of the Department of the Interior requesting a leasing program for gold mining in the OCS near Nome, Alaska. (Since 1987, West Gold has succeeded Inspiration Gold, Inc., through reorganization of the company.) West Gold (and its predecessor companies) have conducted offshore gold-dredging in State waters near Nome since 1985. In anticipation of an OCS mineral sale, the Governor of Alaska, in a letter of November 1987, requested that the Secretary of the Interior establish a joint Federal-State task force similar to the one established in the State of Hawaii for similar purposes. The Governor requested a task force:

> ...to evaluate the feasibility of development of mineral resources in waters adjacent to our coast and to develop technical guidelines and procedures for the safe, effective, and environmentally sound exploration and mining of such resources...review of economic feasibility and look at information needs for EIS development...[and] identify renewable and nonrenewable resources that are present in Norton Sound and possible use conflicts.

The Secretary of the Interior responded to the Governor's request by agreeing to establish a Federal-State task force. The Secretary of the Interior designated the Director of the Minerals Management Service (MMS) to implement the program. The presale process bears some resemblance to that for oil and gas sales, but there are some substantive differences in the leasing process and in the postlease operations as set forth in new regulations.

A Request for Information and Interest and a Notice of Intent to prepare an Environmental Impact Statement (EIS) was published. Nominations were received, and an area was identified on which to prepare an EIS, a draft EIS was published, and a public hearing was held. The remaining steps include a rewrite of the EIS after acquisition of new water-quality data, a proposed leasing notice, a review by the State of Alaska, the leasing notice, and the sale, probably in the first quarter of 1991.

STATE COORDINATION

Implementation of the program began with a meeting between the MMS and the State Division of Governmental Coordination staff to work out details for the Federal-State task force. It was agreed that the task force would be called the "Coordination Team," or CT. The membership list for the CT was finalized in February 1988—31 members from Federal, State, and local agencies and interest groups.

An agreement was signed between the MMS and the State of Alaska to transfer $120,000 to the State to cover expenses of staff from several State agencies attending six proposed meetings through the course of the prelease process and for time to review documents. From the beginning, the MMS envisioned the CT primarily as a forum for the exchange of information and a channel for comments on offshore mining policy formulation. The CT has been integrated into all major steps of the prelease process, including scoping, review of the draft EIS, review of the EIS rewrite, and so forth. The coordination process is continuing, and it is working.

MAPPING AND GRAPHICS

As stated above, preparations for the first OCS mining sale have proceeded along steps similar to preparation for an OCS oil and gas sale. The *Federal Register* Notice on the Request for Information and Interest and the Notice of Intent to Prepare an EIS was accompanied by a map of the Norton Sound area that was based upon Official Protraction Diagrams (OPD). The OPD maps depict a rectangular grid of potential leasing blocks approximately 3 mi on a side. On the basis of the Universal Transverse Mercator projection, the maps are at a scale of 1:250,000. These lease block diagrams are sold to the public for common planning purposes and are extensively used in all planning documents by the MMS (fig. 1). In addition, these OPD maps, which show the proposed sale outline, are used extensively as illustrations for all comments received and for correspondence.

Concurrently with the Request for Information and Interest, an in-house assessment of the potential mineral resource lease was being made by using available geological and geophysical information. In this case, seismic and borehole data from proprietary and U.S. Geological Survey sources were used. Figure 2 shows a submerged strandline and a subsea channel.

After the assessment, subbottom geomorphic features were mapped in relation to distribution patterns of particulate gold derived from sea-floor sediment samples. These maps were constructed to be compatible with the OPD's used to depict the proposed lease sale area (fig. 3).

During the scoping meetings, maps of the proposed sale area are used to portray known oceanographic and biological data and to record areas of special concern to local residents. During the writing of an EIS, these maps are refined and published as part of the EIS and provide the reader with essential information needed to clarify the text. Figures 4 through 6 are examples of maps in the draft EIS. The scale of the maps is adjusted so that the resource can be shown in relation to the proposed sale area and to accommodate the normal 8- by 11-in. EIS page size. Other examples of graphics used to supplement the EIS maps and text are shown in figures 7 and 8.

The MMS base map requirements are largely being met internally. The OPD maps are generated by the MMS's offshore survey group in Denver. The geological and geophysical data are generally received from OCS permittees at a scale of 1:96,000, or 1 in. = 8,000 ft. The various divisions and regions within the MMS then use a number of different computer mapping systems to change scales and manipulate the data. Computer-assisted design graphics applications are also in wide use within the organization.

Future plans call for the MMS to standardize its general-purpose mapping needs by adopting a geographic information system. Also planned are evaluations and feasibility studies for utilization of interactive computer work stations for manipulation of geological and geophysical data. Cartography and drafting throughout the organization are being upgraded to utilize the new computer-assisted design programs, such as AUTOCAD.

FUTURE MAPPING NEEDS

The State of Alaska and the MMS regularly conduct oil and gas lease sales along the coastal zone of Alaska. In addition, the State has ongoing offshore mining, and the MMS has an offshore mining sale in progress. At many places along the Alaskan coast, especially to the west and the north, nautical charts either are out of date or have inappropriate scales. A vigorous coastal zone mapping program to delimit salient points for establishing the State-Federal boundary would be of great help to the State of Alaska and the Department of the Interior. Present and

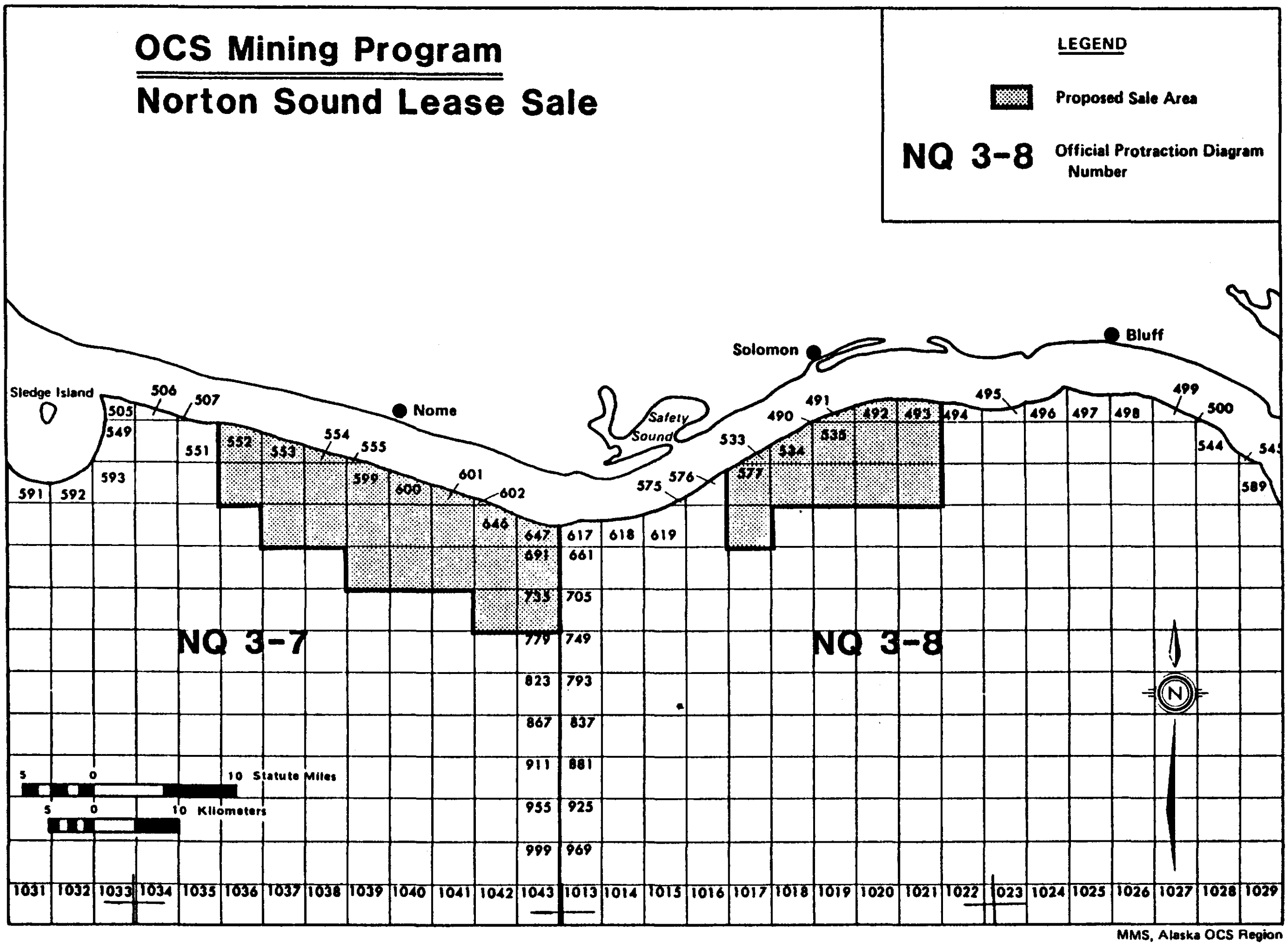


Figure 1. Lease block locations for the Norton Sound area.

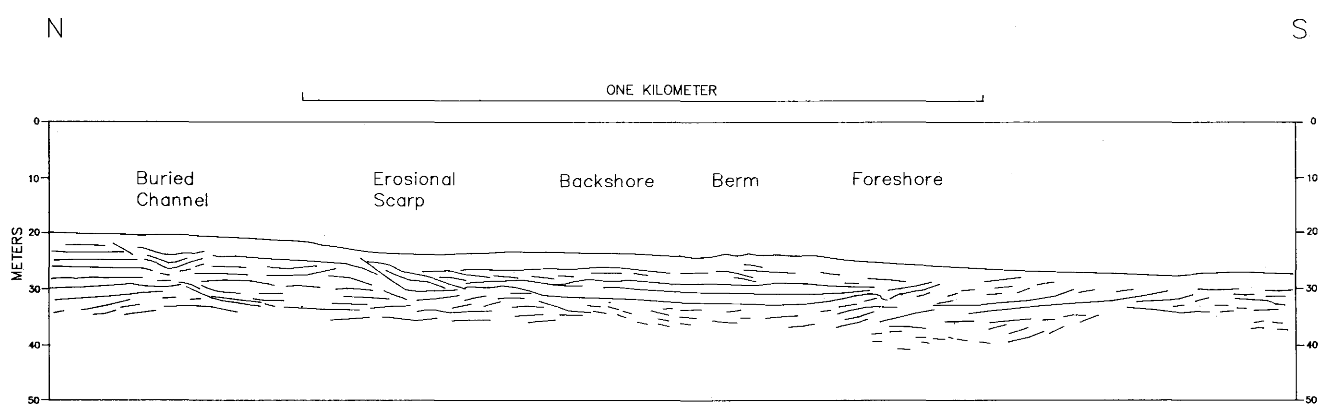


Figure 2. Line drawing of seismic profile across the 24-m beach from the survey conducted in 1976 by the U.S. Geological Survey. The beach deposits are probably 5 to 6 m thick at the berm and nearly 1 km wide.

future offshore leasing schedules should be used to set priorities for this work. At this time, it appears that the Alaskan shoreline areas should be surveyed in priority order, as depicted on figure 9.

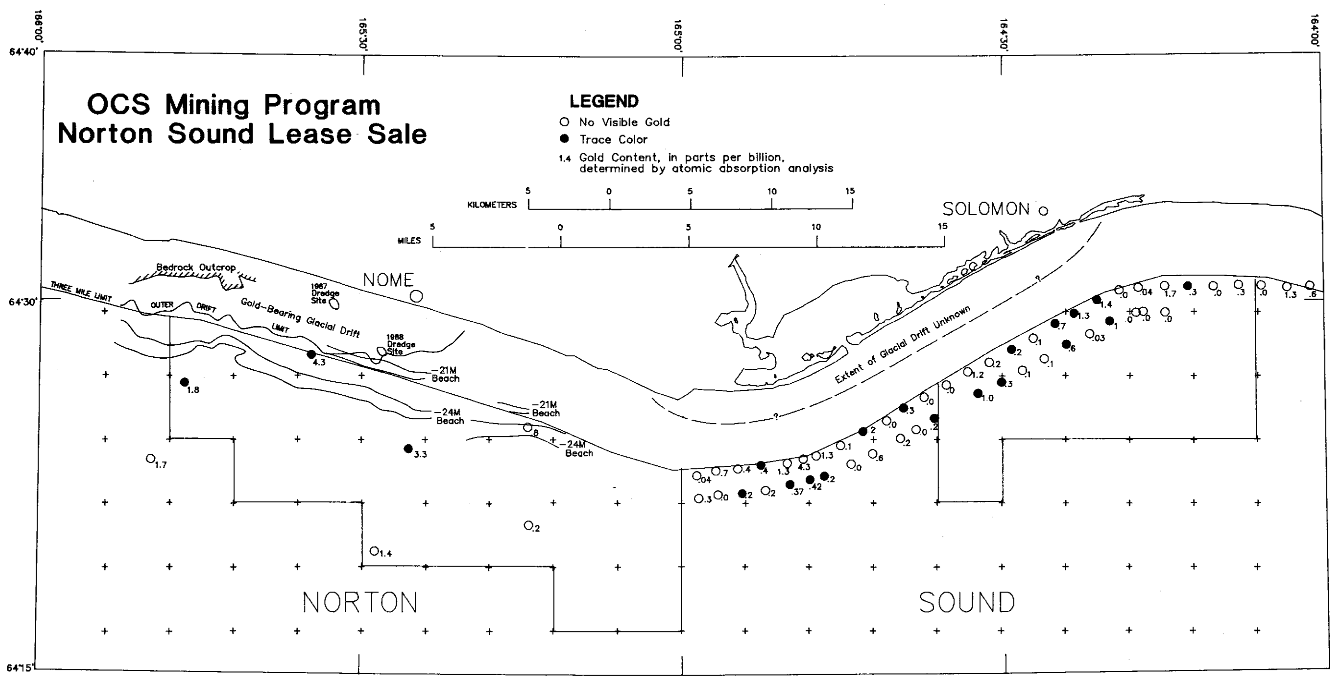


Figure 3. Distribution of particulate gold in sea-floor sediment samples beyond the 3-mi limit; modified from Nelson and Hopkins (1972). Location of submerged beach ridges and gold-bearing glacial drift; from Tagg and Green (1973).

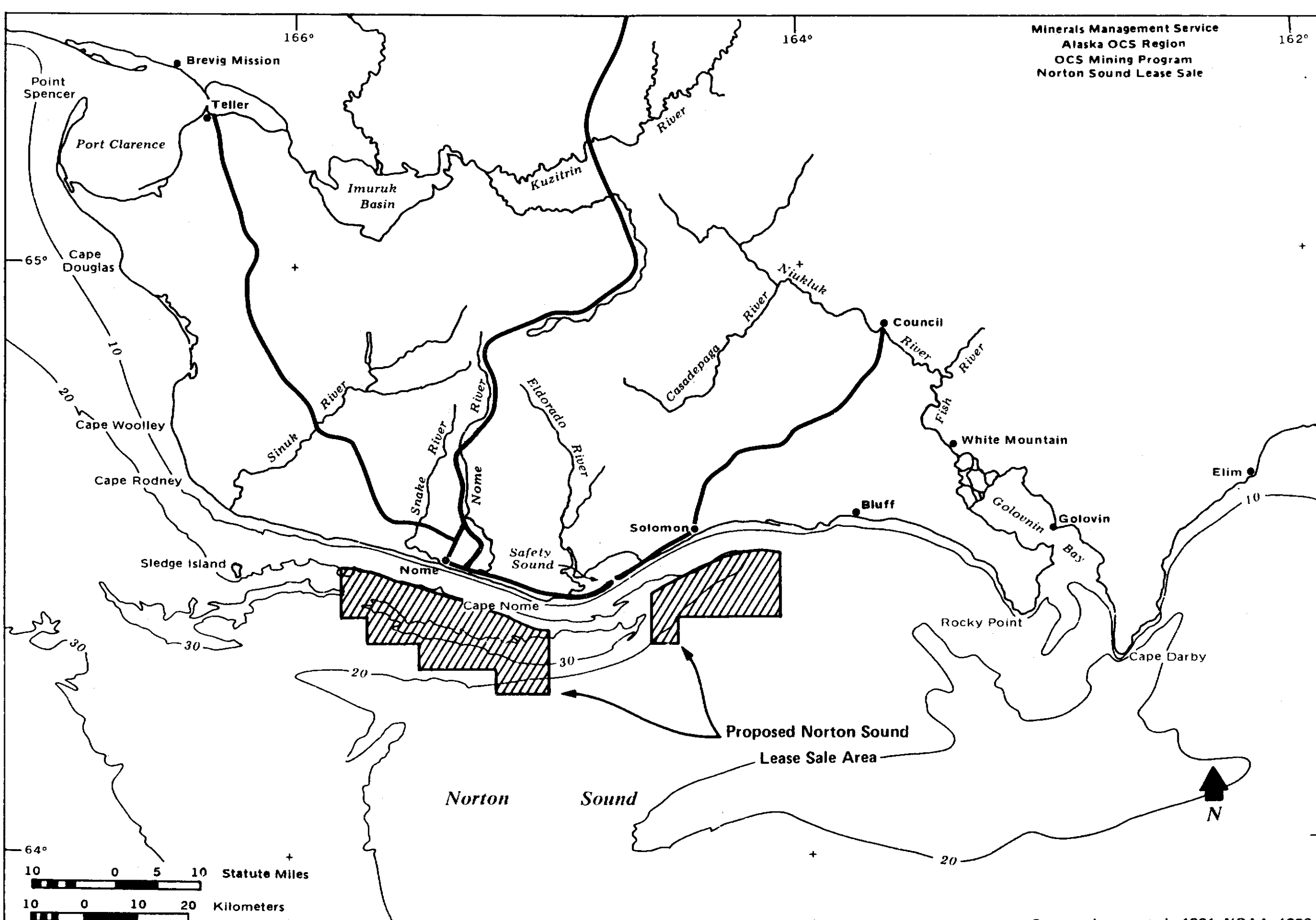


Figure 4. Generalized bathymetry (in meters) of the Norton Sound area.

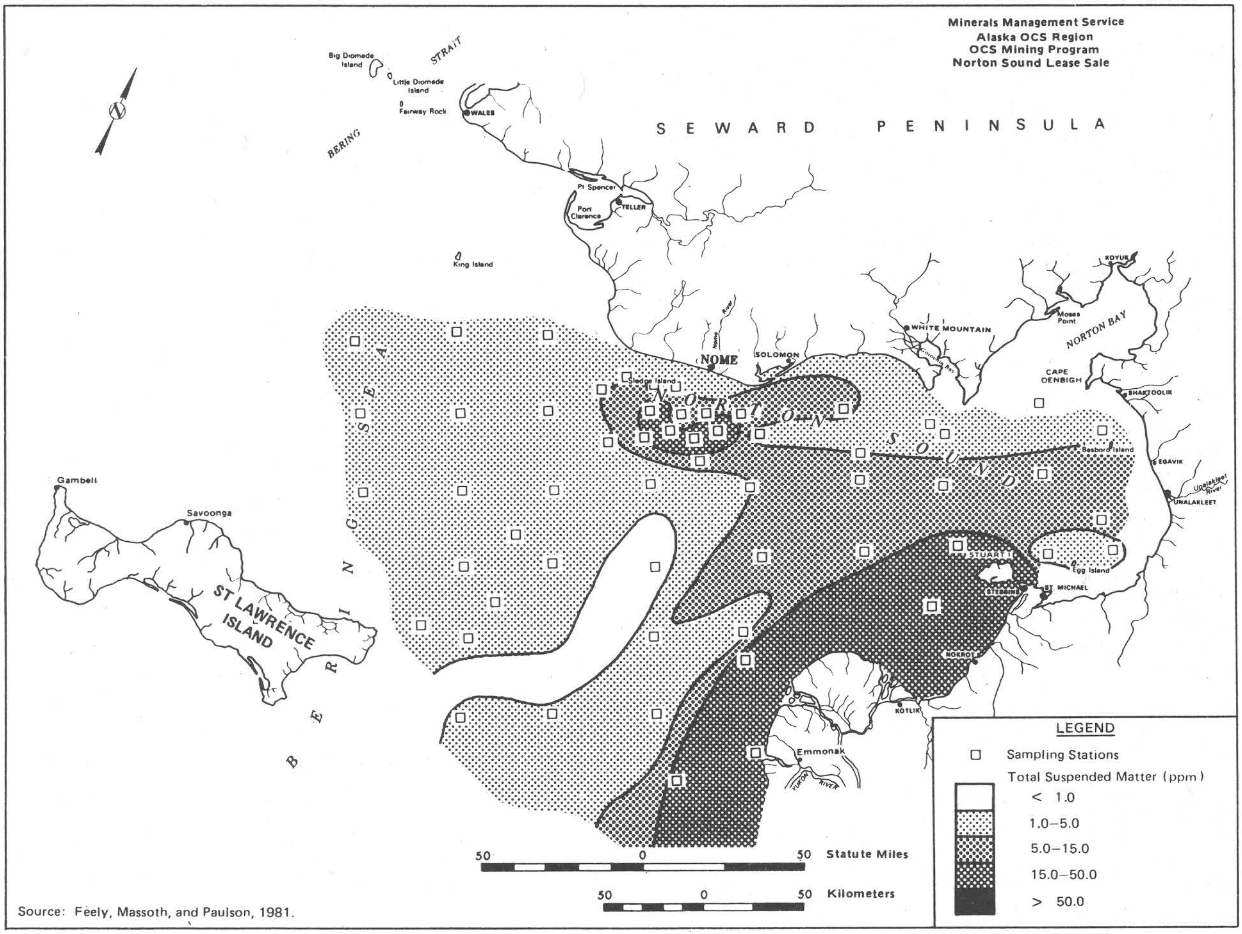


Figure 5. Distribution of suspended matter at 5 m above the bottom in Norton Sound, July 7–18, 1979.

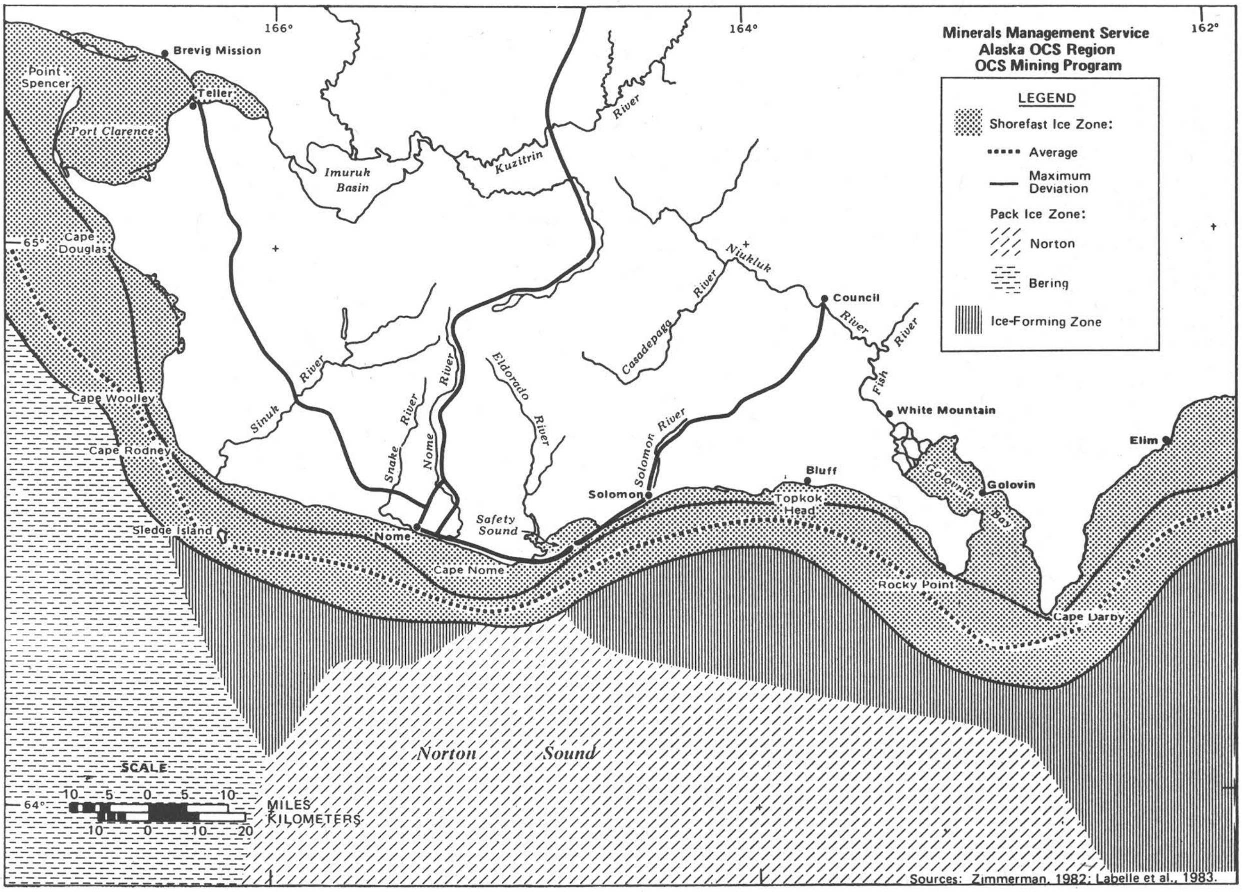
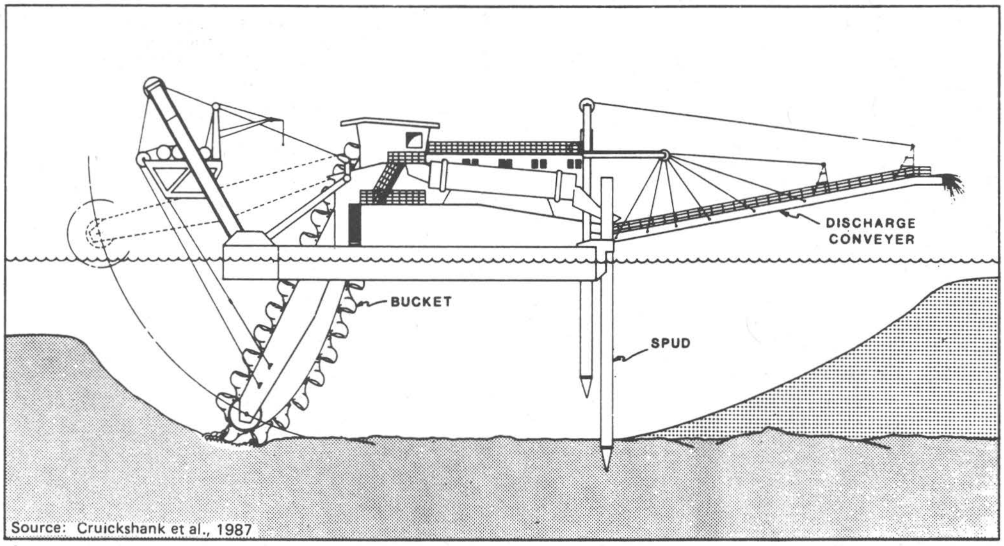


Figure 6. Sea-ice zonation in Norton Sound.



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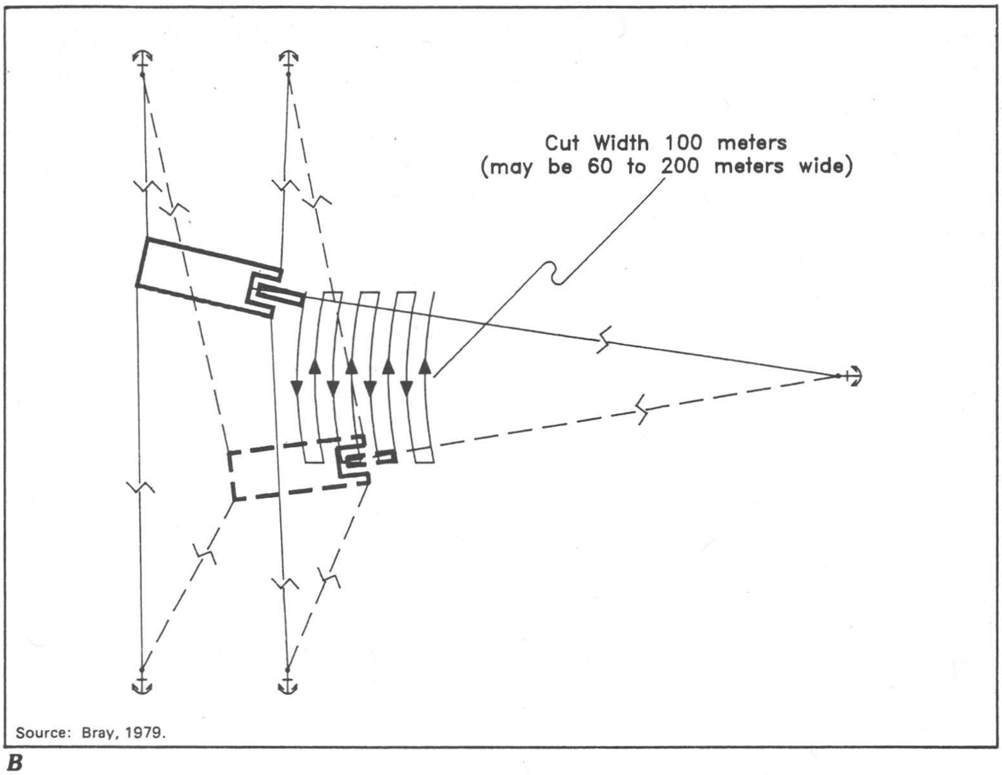

B

Figure 7. Bucket ladder dredge. *A*, Gold mining in sheltered waters. Note: Spuds are used to control dredge movement in shallow waters. Anchors would be used to control dredge movement in the deeper, more exposed waters of the lease sale area. *B*, Operations.

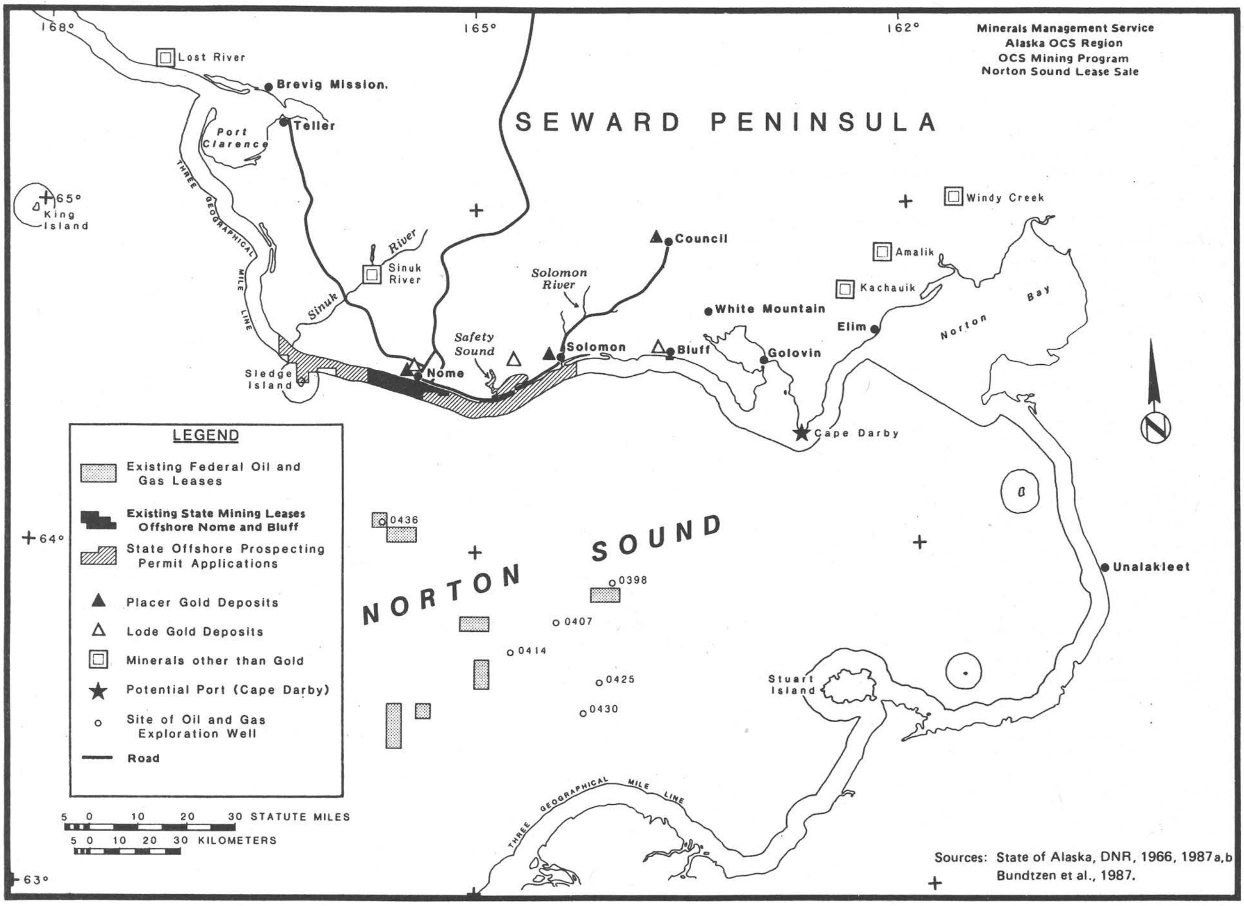

Figure 8. Activities and significant mineral deposits in the Nome area that are included in the cumulative case.

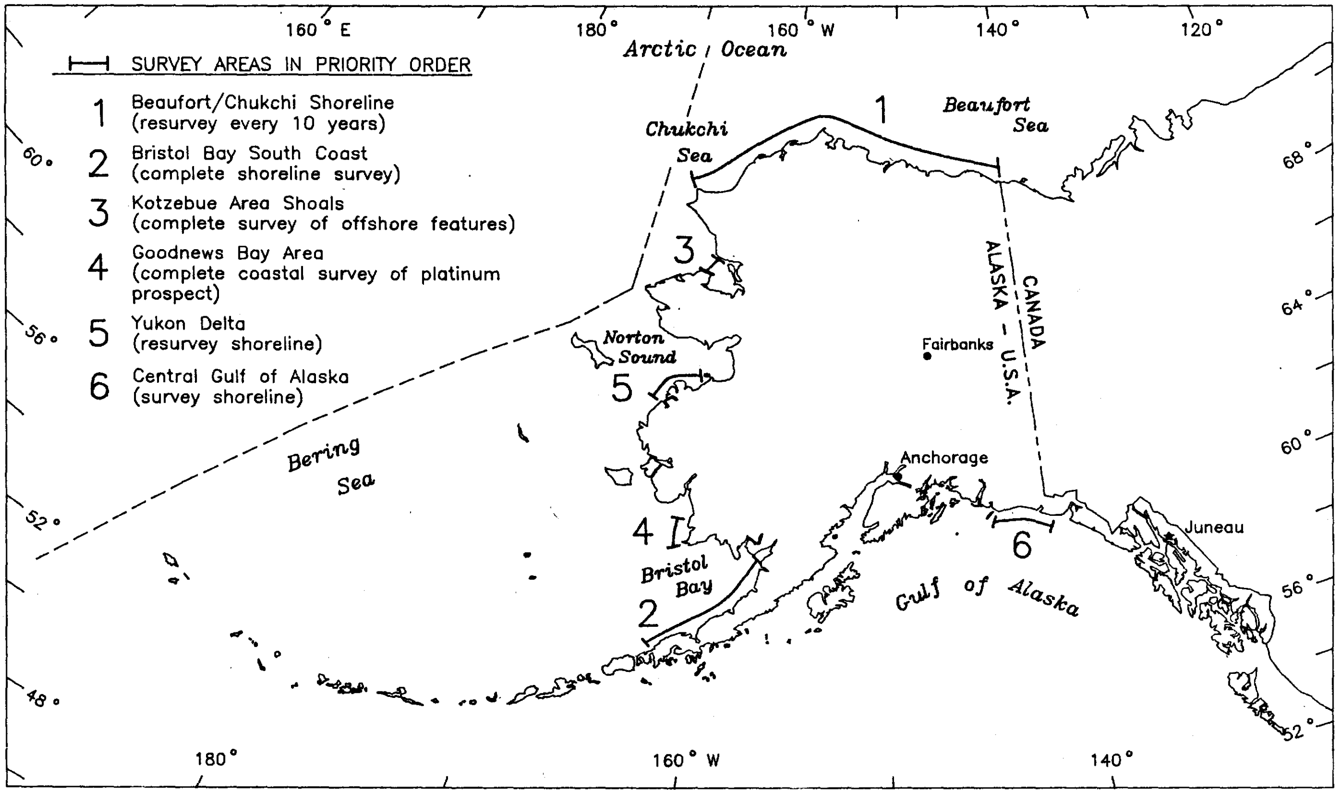

Figure 9. Recommendations for National Ocean Service 10-yr plan, survey priorities for Alaska Federal-State boundary needs.

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Case Studies of U.S. Geological Survey's Mapping Activities in the Islands' Exclusive Economic Zone

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INTRODUCTION

More than one-half the area of the U.S. Exclusive Economic Zone (EEZ) surrounds island territories, commonwealths, possessions, and the State of Hawaii (table 1). The geology of the islands' EEZ, as well as the political, social, and economic motivation for studying it, are, in many ways, distinctive compared to the continental EEZ, which commonly necessitates a different approach to the planning and the execution of mapping and research activities (Richmond and Morgan, 1988). This section presents three case studies that illustrate the special character of island EEZ mapping and research.

CASE STUDY 1—OFFSHORE SAND RESOURCES OF TUTUILA ISLAND, AMERICAN SAMOA (Dingler and others, 1986, 1987)

Tutuila Island (fig. 1) has strictly limited sources of onshore sand because the volcanic island is steep and heavily vegetated and the irregular coast contains only small pocket beaches. Traditionally, sand was taken from the nearest beach, but increased demand for commercial and personal uses and a concern for the integrity of the beaches prompted a request by the American Samoa Coastal Management Program for a study to ascertain whether exploit-

Table 1. Approximate areas of the U.S. Exclusive Economic Zone for the Pacific and the Caribbean islands
[From Richmond and Morgan, 1988]

Island(s)	Political status	Length of coastline miles	(km)	Total area of EEZ square nautical miles	(km^2)	Geologic type
American Samoa	Territory	73	(138)	125,000	(428,800)	Oceanic island
Caribbean		373	(690)	61,100	(209,600)	
-Puerto Rico	Commonwealth					Island arc
-Virgin Islands	Territory					Island arc
Guam	Territory	68	(126)	60,600	(207,900)	Island arc
Hawaii	State	653	(1208)	697,000	(2,390,700)	Oceanic island
-Midway	Possession	7	(13)			
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 Mariana	Commonwealth	179	(331)	224,300	(769,300)	Island arc
Palmyra Atoll-Kingman Reef	Possession	10	(19)	120,000	(411,600)	Oceanic island
Wake	Possession	10	(19)	120,000	(411,600)	Oceanic island
Total		1,387	(2,565)	1,741,400	(5,973,100)	
% U.S. total		12%		51%		

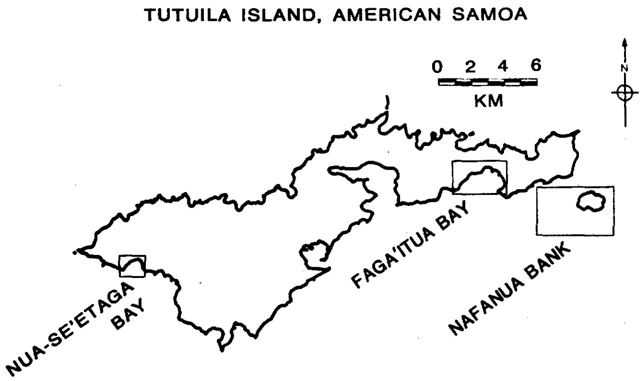

Figure 1. The study areas on Tutuila Island, American Samoa.

able sources of sand exist offshore, particularly on the fore reef, in water depths shallow enough to be dredged (less than 30 m). In addition, there is a need for siliciclastic (for concrete) and carbonate (for beach fill) sands, which necessitates identification of sand composition. The investigation began in April 1985 with a reconnaissance sampling of beaches predominantly on the southern side of the island. The assumption was that the proportion of siliciclastic grains derived from the volcanic rocks of the island to the reef-derived carbonate grains would indicate the composition of fore reef sand deposits. On the basis of existing reports and the results of the reconnaissance sampling, subsequent geophysical and diving surveys in July 1985 were concentrated in Fagátua Bay on the southeastern end of the island and in Nua-Séetaga Bay area on the southwestern end of the island. High-resolution sidescanning sonar images showed areas of sea-floor ripples that were interpreted as indicating sand deposits, whereas irregular distributions of light and dark areas, which were accompanied by rugged bathymetry, indicated reefs. A third pattern of uniform shading indicates fine-grained, muddy deposits. Subsequent surveying by using a high-resolution acoustic reflection profiler allowed determination of the thickness of sedimentary deposits by the appearance of stratification in the subbottom profiles. Lastly, divers collected samples for textural and compositional analysis and probed the thickness of the unconsolidated sand deposits.

A subsequent study during February and March of 1986 was conducted on Nafanua Bank just west of Aunu'u Island. The objective of the study was to evaluate the potential for sand deposits there as a source of fill at the beach of a resort hotel.

Maps constructed from the geophysical data indicated the existence of sand deposits of varied texture and composition in water depths of less than 30 m over 400,000 m^2 in Fagátua Bay and 80,000 m^2 in Nua-Séetaga Bay. Some deposits appear large enough for mining, although their thickness is too poorly known for firm estimates of recoverable resource. The subbottom profiles indicate the deep extent of some sedimentary deposits, but probes by divers encountered a hard surface within a few meters of the sea bottom that might indicate the depth extent of recoverable unconsolidated sand. Sand composed mostly of siliciclastic grains occur at several places near the southwestern end of the island, in particular in water depths of less than 15 m in Nua-Séetaga Bay. The rest of the sampled deposits are predominantly calcareous.

The survey of Nafanua Bank found patches of carbonate sand near Aunu'u Island and on the western end of the bank commonly in water depths of less than 20 m and over an area of approximately 68,000 m^2. However, the total amount of sand was estimated to be enough for only a few small beach-fill projects. There are indications of sand deposits in water deeper than 30 m, but recovery would be expensive.

Several recommendations were made by the participating scientists. Cores need to be taken to determine more comprehensively the thickness and the composition of unconsolidated deposits. Furthermore, because of time and funding constraints, only a few areas were studied; more exploration might reveal better deposits. Lastly, the environmental impact of removing sand from the shallow fore reef should be evaluated, especially the effect on incident wave energy and the exchange of sand between the beach and offshore so that beach erosion does not result from the mining.

CASE STUDY 2—COBALT-RICH FERROMANGANESE CRUSTS IN THE JOHNSTON ISLAND AND THE HAWAIIAN EXCLUSIVE ECONOMIC ZONES

(Hein and others, 1985, 1987a, b, in press)

Metallic deposits of various types and origins occur on the sea floor and are a potential resource for the future. In particular, cobalt-rich ferromanganese crusts (hereafter referred to simply as "crusts") coat the hard substrate on the flanks of volcanic ridges, seamounts, and guyots (Hawaii, Johnston Island, Howland-Baker, Wake, Kingman-Palmyra) in the U.S. EEZ. The U.S. Geological Survey (USGS) has studied crusts in the Johnston Island and the Hawaiian EEZ's, as well as in other Pacific areas, as part of a program to understand the distribution, the origin, the scientific implications, and the resource potential of these deposits. Beginning in 1983, cruises were conducted on Necker Ridge in the Hawaiian EEZ and on Horizon Guyot, Karin Ridge, and Johnston Island Ridge in the Johnston Island EEZ (fig. 2; table 2). Additional areas in the Hawaiian and the Johnston Island EEZ's were studied on cruises in cooperation with the government of the Federal Republic of Germany, which has carried out its own extensive program of crust studies. The U.S. Bureau of

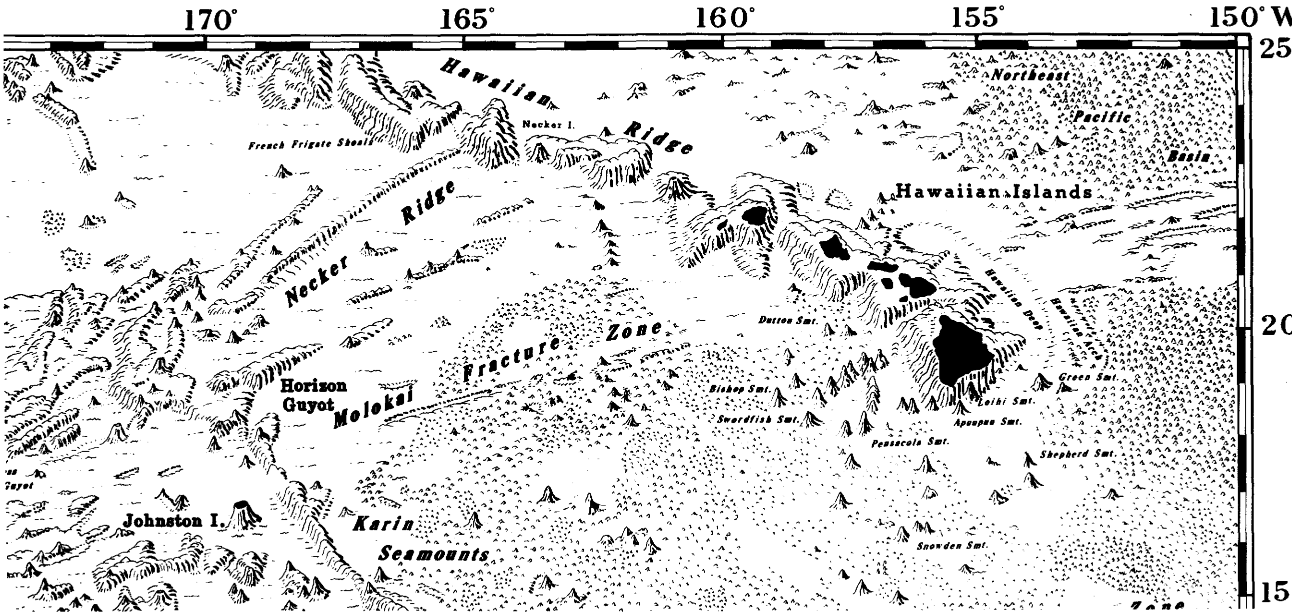

Figure 2. Cobalt-rich ferromanganese crust study areas.

Table 2. Composition of cobal-rich crusts

	Cobalt (%)	Nickel (%)	Manganese (%)	Iron (%)	Number of analyses
Necker Ridge	0.56	0.27	19.3	20.1	19
Horizon Guyot	0.71	0.39	25.3	17.1	18
Karin Ridge	0.56	0.32	18.3	14.1	40
Johnston I. EEZ	0.72	0.43	21.3	14.6	126

Mines cosponsored the cruise to the Johnston Island EEZ. The University of Hawaii also has been active in studying the Pacific EEZ crusts, especially in the Hawaiian and the Kiribati EEZ's.

The principal mineral of crusts is vernadite (ς-MnO_2), and the potentially exploitable metals are cobalt, manganese, nickel, platinum, and cerium. The cobalt, the manganese, and the nickel contents decrease with increasing water depth and increasing latitude. Regional mapping of crusts is difficult; no reliable techniques have been developed for identifying crust accumulations with reconnaissance instrumentation, although it is believed that crusts occur on virtually all hard-rock surfaces. However, knowledge about the formation of crusts suggest several criteria that can aid in exploration; for example, cobalt-rich crusts form by hydrogenetic processes only in water depths of between about 800 and 2,500 m. Because the crusts accumulate slowly (a few millimeters per million years) and when the substrate is in contact with fresh seawater, significantly thick hydrogenetic crusts are found only if the substrate is a minimum age of about 20 Ma and is constantly swept by strong currents, which prevents accumulation of sediment. Moreover, the edifice must not be capped by large modern reefs or have unstable sediment-covered slopes because these situations might be a source of sediment that can cover the substrate or destroy the crusts by mass movements. An absence of local volcanism is necessary for a similar reason. To be considered as a potential resource, the crusts in a particular area must average greater than 0.8 percent cobalt, the average crust thickness must exceed 4 cm, the small-scale relief must be subdued for efficient recovery operations, and a relatively large edifice must be present.

The resource potential of crusts is illustrated in calculations made by the U.S. Bureau of Mines, which indicate that in water depths of less than 2,500 m, 96,000 t of cobalt occur in 12 million t of crust on a single seamount in the Hawaiian EEZ. Annual recovery of 1 million t/yr by a mining operation could yield over 5,600 t of cobalt, which was about 85 percent of reported U.S. consumption in 1986 (Ritchey, 1988).

In addition to mapping the extent of crusts and determining their chemical composition, the USGS employs a multidisciplinary approach to understanding the contributing aspects of physical oceanography and sediment dynamics that influence the accumulation of crusts. Basic mapping employs high- to medium-resolution acoustic reflection profilers to locate sediment-free, topographically smooth areas that are likely sources for thick crust accumulations. Detailed mapping and inspection of small-scale features is accomplished by using underwater still and television cameras. Sample collection uses dredges for recovery of large quantities of crust-bearing rock, up to 1 t per dredge, and hard-rock corers for spot samples. Oceanographic measurements are made by using current meters and sensors for conductivity (salinity), temperature, and oxygen at recorded depths. The acoustic reflection profiles and the current measurements aid in the sedimentologic studies, and sediment samples for laboratory analysis are collected by using gravity corers. In addition, other seamount mineral deposits are collected and studied along with crusts; for example, phosphorites and iron oxide deposits.

Necker Ridge is an elongate volcanic edifice that extends more than 600 km along a trend of N. 32° W. It rises about 3 km above the adjacent sea floor to a minimum water depth of less than 1,600 m. The Necker Ridge surveys show that parts of the ridge crest are sediment covered and have associated sediment-flow deposits on the flanks, whereas other parts are relatively sediment free. Crust samples are from 7 to 70 mm thick and average about 25 mm. The substrate typically is volcanically derived rock that, in places, is phosphatized, which indicates a possible additional resource if phosphates are locally abundant. The crusts have internal thin layering, and a pronounced, paper-thin, phosphate layer separates distinct inner and outer zones. Cobalt, nickel, and manganese average 0.56, 0.27, and 19.3 percent, respectively.

Horizon Guyot is an isolated, flat-topped, volcanic ridge about 300 km long and 75 km wide that rises about 3.5 km above the sea floor to about 1,440 m water depth. The flanks of the ridge have a maximum gradient of 19° and have well-developed talus aprons at their base. The guyot is capped by a deposit of biogenic ooze that reaches a maximum thickness of 500 m. Camera surveys reveal that sediment from the pelagic sediment cap spills onto the flanks. They also reveal that sediment occurs in small pods on most slopes and, by the presence of small ripples, shows evidence of active transportation by ocean currents, which implies a repeated covering and uncovering of the crust at least in some places. Most of the upper slopes are covered with sediment. Although the physical properties of the sediment indicate that it is stable under gravitational forces on slopes up to 27°, recovery of debris-flow deposits indicates that downslope, gravity-driven movement occurs. Crust samples range up to 50 mm thick and show the two-zone internal structure separated by a phosphate layer. Cobalt, nickel, and manganese average 0.71, 0.39, and 25.3 percent, respectively.

Karin Ridge extends for about 300 km and rises about 4 km above the surrounding 5,600-m-deep sea floor. One of the primary purposes of the cruise to this area was to collect 5 tons of crust-bearing samples for development of processing techniques by the U.S. Bureau of Mines and to test one of their new dredge designs. These goals were met. One recovered crust is 160 mm thick, which is about the thickest ever recovered, and most crusts exhibit the two-zone internal structure. In addition to volcanic substrate rocks, thick crusts also occur on siltstone and limestone. The composition of the bulk (crust and substrate) dredge samples are comparable to an ore that would be collected by a rotary rip-up or scrape-up system. The average cobalt content for the bulk samples is 0.21 percent, and surprisingly, the average phosphate (P_2O_5) is 4.3 percent. The average cobalt, nickel, and manganese composition of the crusts are 0.56, 0.32, and 18.3 percent, respectively.

From 20 to 30 Ma of oceanic and atmospheric history are recorded within crusts that are from 40- to 80-mm thick. Their composition reflects that of ambient seawater at the time of precipitation. Initial studies suggest phosphorite-impregnated crust of the inner zone represent periods of high oceanic productivity and phosphogenesis. Crust textures reflect fluctuations in Antarctic bottom water activity, where increased activity is represented by botryoidal intervals and decreased activity, by laminated intervals. Changes in isotopic and chemical composition of laminae reflect seawater chemical changes. Changes in quartz content and detrital particle sizes indicate changes in atmospheric circulation and intensity of winds.

CASE STUDY 3—RECONNAISSANCE MAPPING OF THE HAWAIIAN, THE PUERTO RICO, AND THE U.S. VIRGIN ISLANDS EXCLUSIVE ECONOMIC ZONES

(Scanlon and others, 1988; Moore and others, 1989)

In 1984, the USGS began a cooperative program with the British Institute of Oceanographic Sciences to map the U.S. EEZ by using the GLORIA sidescanning sonar system. The program is still in progress, and, to date, completed mapping of island areas includes 222,000 km^2 around Puerto Rico and the U.S. Virgin Islands and nearly 1 million km^2 of the southern Hawaiian Ridge. Although a primary objective of the surveys is to provide medium-resolution base maps for guiding future EEZ studies, the sonar images and other geophysical data collected simultaneously contain a considerable amount of scientific information on their own.

The GLORIA sidescan-sonar system is a reconnaissance system that produces swath acoustic images of the sea floor in water depths of greater than about 300 m and covers a net area of about 10,000 km^2/d, not including areas of overlap. The system operates by the transmission of a 2-s acoustic pulse centered at 6.5 kHz every 30 s that insonofies a band of sea floor approximately 22 km perpendicular to each side of the ship's track and digitally records the backscattered energy. The encoded strengths of the backscattered energy are transmitted to a ship-board recorder, computer, and camera that produce a line-by-line (pulse-by-pulse) photoacoustic image on which the strongest backscatter appears white and the weakest appears black. Placement of the images along a properly scaled rendering of the ship's tracklines forms a mosaic of the sea floor similar in appearance and resolution to Landsat mosaics of the Earth's land surface.

Giant landslides are one of the major geologic features appearing on the GLORIA images of insular slopes; for example, north of Puerto Rico is a large amphitheater-shaped scarp, which is approximately 55 km across and 3,700 m high and appears as an area of high backscatter (fig. 3). The scarp represents removal of about 1,500 km^3 of strata and probably was formed as a consequence of landslide movement induced by gravitational and earthquake forces associated with convergent and left-lateral slip along the boundary between the North American and the Caribbean plates at the Puerto Rico Trench. Gravitational stress has been constantly increasing as the result of a northward tilt of the insular slope since Pliocene time. Faults that trend into the scarp also may have aided the slope failure. If the sliding was sudden and cataclysmic, then it might have generated a tsunami that had a major impact on the nearby northern coastal areas of prehistoric Puerto Rico.

GLORIA surveys also have documented the presence of giant submarine landslides on the Hawaiian Ridge. Seventeen major slides appear in images that extend from the southern end of the ridge 700 km north to the latitude of Kauai (fig. 4). Some of the slides spread debris more than 200 km from the source, even moving more than 300 m uphill on the seaward slope of the Hawaiian Deep. The largest slide is about 10,000 km^3 in volume. Before the GLORIA surveys, the existence of the slides was controversial, and their great extent certainly was unknown. Some slide blocks previously had been interpreted as being volcanic seamounts; individual blocks are up to 1.2 km above the adjacent sea floor and 17 by 35 km in area. Sliding occurs mainly during the growth of the volcanoes and continues at a reduced rate after dormancy. The slides extend to the upper flanks of the islands, many to elevations above sea level, and show an association with faulting (rift zones) on the islands. They probably are triggered by volcanic activity during dike injection. The widespread dispersion and uphill travel of slide debris attests to a cataclysmic origin for some slides, which suggests the possible generation of a tsunami. A gravel deposit at 365-m elevation on Lanai has been attributed to a slide-generated tsunami.

Slide movement poses a hazard if cataclysmic motion produces a tsunami, although the possibility of this is remote; dating of large-scale slide movement is uncertain,

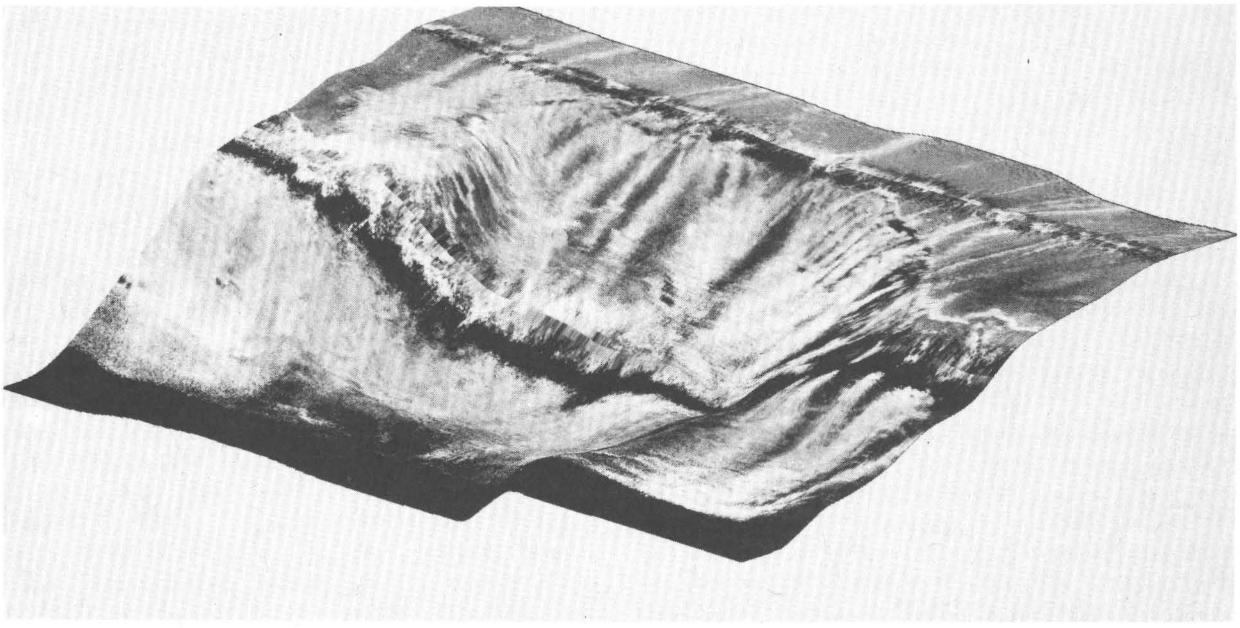

Figure 3. Perspective view of a GLORIA sonograph of the amphitheater-shaped scarp north of Puerto Rico.

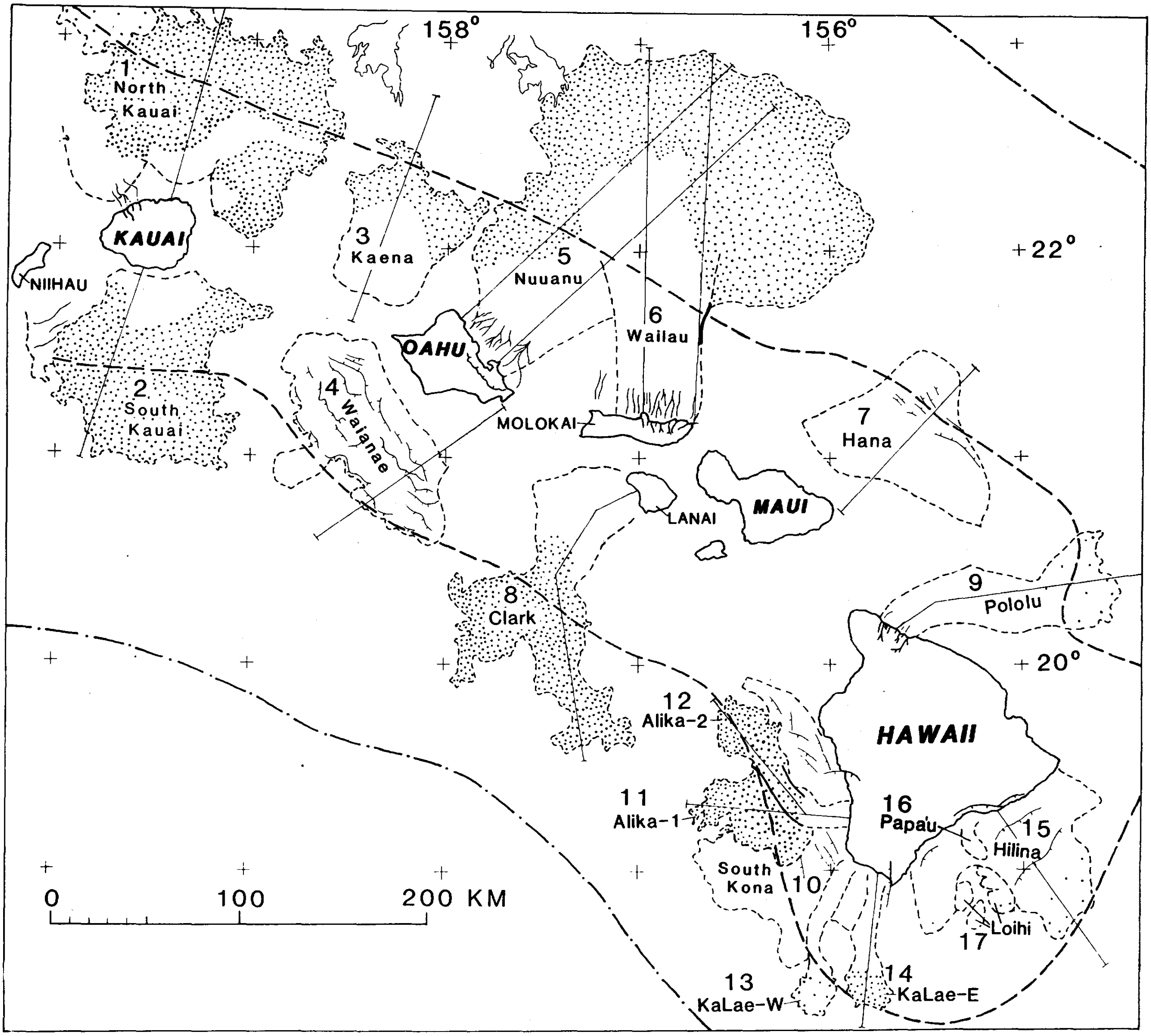

Figure 4. Map of giant submarine landslides, southern Hawaiian Ridge.

but most likely the interval between such slides is on the order of tens of thousands of years. Another possibility is that the slides occur dominantly during low sea-level stands, not during high stands, such as at present. A more immediate danger is from the small-scale movement of the slides above sea level; for example, the Hilina slump on the southern flank of Kilauea Volcano subsided up to 3.5 m during a magnitude 7.5 earthquake in 1975.

CONCLUSIONS

Each of the case studies points out a special aspect of island EEZ studies. The Tutuila Island example illustrates the need to search offshore for a resource that is easily obtainable on most land areas but not on many small islands. The cobalt-rich crust example points out the unique existence of an abundant reserve of strategic mineral resources in island areas, resources that presently are imported almost entirely from foreign sources. Lastly, the GLORIA mapping example documents the existence of giant landslides that play an important role in the morphologic evolution of islands and that pose an environmental hazard. Landslides of similar size occur on some continental margins but not with such combined abundance and great distance of movement.

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Policy Issues for Detailed Bathymetric Mapping in the Hawaiian Exclusive Economic Zone and Hawaii's Marine Mining Program

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Abstract

Detailed bathymetric maps are needed of seamounts in the Exclusive Economic Zones around Hawaii and Johnston Island to carry out exploration and development programs for cobalt-rich manganese crusts. Bathymetric maps contoured on a 10-meter interval are necessary to allow submersible diving, which has been proven to be the best tool for detailed exploration of marine minerals. Map limitations have restricted submersible mineral exploration programs in the Hawaiian Exclusive Economic Zone to Cross and Loihi Seamounts. Jurisdictional questions and questions of State marine policy may be solved through the new Hawaii Council on Ocean and Marine Resources and an innovative State-Federal joint Exclusive Economic Zone management program known as the Marine Mineral Joint Planning Arrangement. The newly created Pacific Mapping Program should solve many of the former bathymetric data analysis and archiving problems.

INTRODUCTION

The Hawaiian Exclusive Economic Zone (EEZ), which covers one-third of the North Pacific Ocean, stretches from 200 mi southeast of the island of Hawaii to 200 mi northwest of Kure Atoll (fig. 1). This immense ocean area has been the focus of countless marine expeditions, including the current broad-scale GLORIA mapping efforts. We are now beginning to see the growth of commercial developments in the Hawaiian EEZ. These began with precious coral harvesting and moved on to deepwater sewer outfalls; we are now looking at emplacements for deepwater ocean thermal energy conversion pipes, artificial reefs, anchoring sites for fish aggregation devices and a deep-space neutrino detector an underwater volcano monitoring station, and a deepwater interisland power cable, among other things. All these developments demand very detailed maps.

Since President Ronald Reagan's declaration of the EEZ in 1983, the Federal Government has been pursuing its mandate to evaluate the resources of the EEZ. This has brought an increasing interest on the extractable resources of this vast zone. Research carried out by the University of Hawaii, the U.S. Geological Survey (USGS), the U.S. Bureau of Mines, and West German interests has defined an attractive resource of cobalt-rich manganese crusts on the tops and the sides of seamounts in the Hawaiian and Johnston Island EEZ's.

The shock of price rises and supply disruption for oil twice in the 1970's has made the Nation realize the potential power of commodity cartels. Several metals critical to steel production are not mined in the United States. Two of these, cobalt and manganese, are largely supplied by Third World countries. The rate of cobalt use in the United States is increasing while, even barring supply disruption, the potential supply from the known African deposits is slowly decreasing. Cobalt-rich manganese crusts may offer the potential for the development of a very large domestic source of both of these metals and platinum. However, before this goal can be realized, a critical need for detailed bathymetric maps must be filled. In this paper, I will discuss the need for this detailed mapping and the policy issues it raises in the context of Hawaii's mineral exploration and development program.

To effectively follow up on the initial manganese crust reconnaissance exploration, an extensive deposit mapping program must be undertaken. Unlike the earlier mapping work, which was very broad scale, this new mapping work will have to focus on the details that determine whether deposits, such as those identified, can, in fact, be mined and with what environmental implications. There are just over 100 known seamounts in the Hawaiian EEZ. Of these only, six are presently mapped well enough to allow detailed exploration.

Work on manganese crust deposits in the Hawaiian Archipelago has shown that the best tool for exploring these

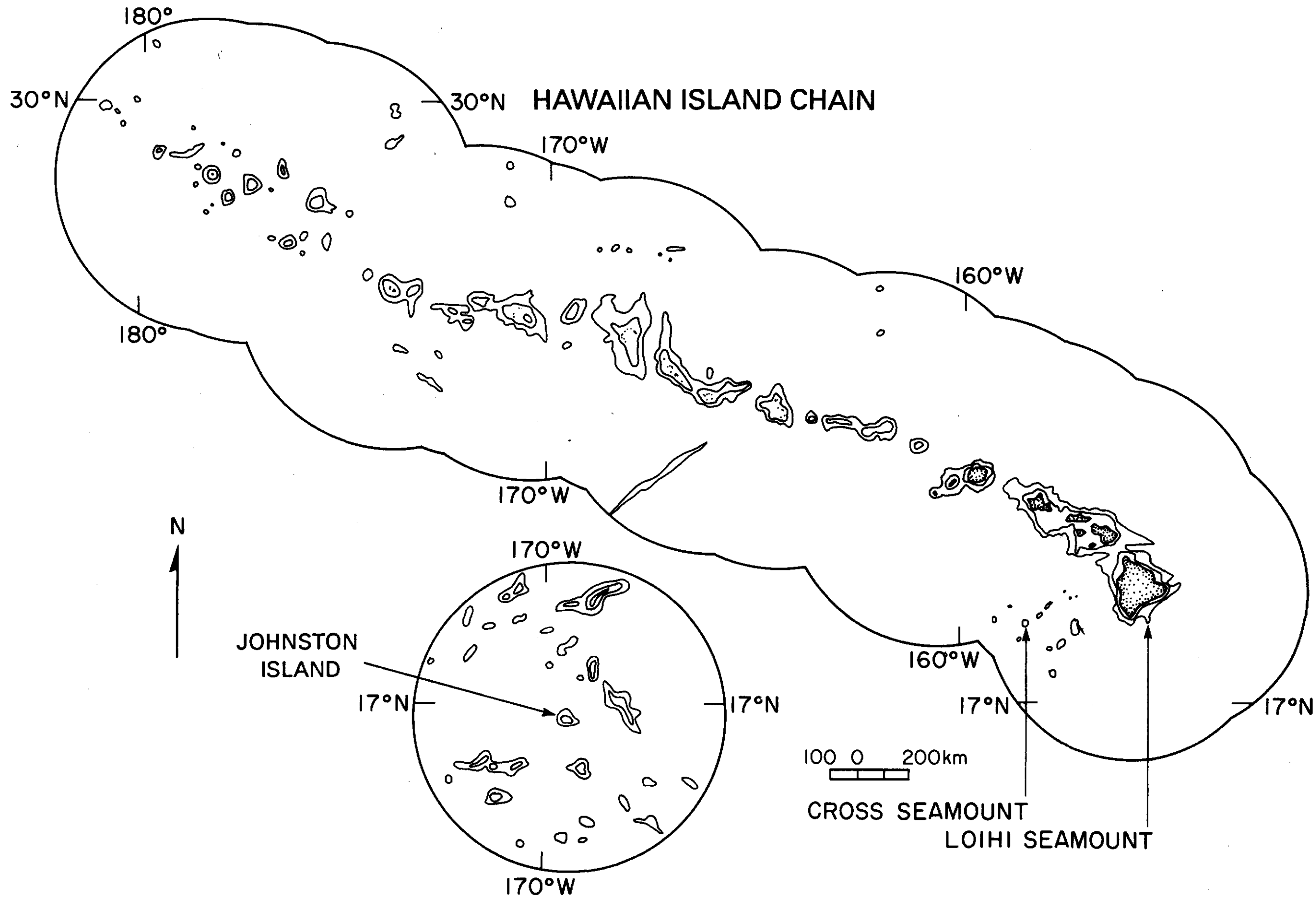

Figure 1. The Hawaiian Islands and the Johnston Island EEZ's.

deposits in detail is a submersible (Wiltshire and McMurtry, 1987; Wiltshire, 1988). The major reason for this is that competing techniques, such as deepsea camera tows, cannot distinguish between thin and thick crust and cannot take selected samples or assess topography on large and fine scales for minability (a real problem on many Hawaiian seamounts). Fortunately, the National Oceanic and Atmospheric Administration's (NOAA) Hawaii Undersea Research Laboratory (HURL) at the University of Hawaii has two research submersibles. One of these, the *Pisces V*, is capable of 2,000-m dives and is available for the extensive exploration of mineral deposits. However, only two of the seamounts in the Hawaiian chain have been mapped in enough detail to have been subject to major diving programs.

The notion of detailed mapping for mineral exploration and development programs raises some serious policy questions when these programs are conducted in the context of academic and government research. Effectively, this puts public sector institutions in charge of selecting mapping sites for the purpose of future private sector development. It also necessitates a process for mapping site and technique selection and a method of archiving and distributing the resulting information. When Federal, State, and local governments have a major stake in the outcome, the issue of jurisdictional overlap in itself becomes a significant policy issue in any arrangement. To put such policy issues into a framework, the background of the State of Hawaii's economic development program and its relation to Federal programs needs to be considered.

The State of Hawaii has a narrow-based economy that depends largely on tourism and smaller contributions from construction, agriculture (sugar cane and pineapple), and military expenditures. For this reason, economic diversification has been a major State goal for many years. In the current economic climate, the best chance for such diversification is through new high-tech industries. While the State searches for new industries, it is highly conscious that land area is at a premium. Hawaii is the only State in the United States that is completely surrounded by water. If the EEZ adjacent to Hawaii were actually part of the State of Hawaii, then the State would be 99 percent water and less than 1 percent land. It is clear that some of Hawaii's new 21st-century industries must come from this large ocean area. One potentially significant commodity from the EEZ is hard minerals. This potential is well recognized and, in fact, has been codified in the State Plan in policy 226–10(b)7 (State of Hawaii, 1978), which calls for the development of ocean mining and other ocean-related economic activities. The State has been interested in an ocean minerals industry for 18 yr. This interest has a direct bearing on EEZ mapping policy.

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HAWAII'S MARINE MINING PROGRAM

Since 1972, the State of Hawaii has had a marine mining program. Initially, this program was focused on the development of a manganese nodule processing industry. Following a period of intense research and evaluation, industrial interest in nodules declined, and it became apparent that a nodule industry was many years off. At this point, the interest of the program was shifted from nodules to cobalt-rich manganese crusts. Some of these manganese crusts may be world-class deposits of cobalt that have grades as high as 2 percent. This is 20 times the grade currently being mined in Zaire. The potential for a significant mining operation in the next century is considerable.

Working with the Federal Government and the University of Hawaii, the State of Hawaii provided oversight for a large research program that involved four research cruises, two submersible expeditions, and an extensive program of laboratory analyses in the EEZ's surrounding the Hawaiian Islands and Johnston Island. This work clearly showed that a potentially economic resource was at hand.

The next step involved the commissioning of a series of engineering studies. Consultants were hired to examine resource potential, mining system technology, transportation technology, and the technology of processing (Marine Development Associates, 1987). It was ascertained that, from an engineering point of view, the mining, the transporting, and the processing of manganese crusts was feasible. Subsequently, a series of three economic studies gave conflicting results as to whether or not the mining of crusts would be economic (Japan Resources Association, 1986; Ritchey and others, 1986; Plasch and others, 1987). Nonetheless, a task force composed of Federal and State officials decided that an investigation into the development potential of this crust resource merited serious consideration in view of the relevant Federal and State positions with respect to securing domestic sources of raw materials and diversifying the State economy. The next step was an assessment of the environmental effect of the development of a minerals industry.

An Environmental Impact Statement (EIS) was written for a proposed Department of the Interior minerals lease sale (U.S. Department of the Interior, 1990). Within the confines of the available data, it indicated that mining could be conducted in an environmentally sound manner. This will allow a lease sale to proceed, if the U.S. Department of the Interior moves forward with its plans. However, with respect to mining at sea, there still remain a number of unanswered questions. Before any actual mining occurred, site- and technology-specific studies would be required. Much of what was determined to be lacking will require detailed mapping and characterization of seamount benthic environments.

The first phase of these needed benthic studies was started on Cross Seamount because it was the only crust-covered seamount that had bathymetric maps of sufficient quality to allow the necessary submersible operations. Generally, such bathymetric maps require data sufficient for contouring at a 10-m interval. The only other seamount mapped with this detail to have allowed a major submersible exploration program is Loihi. The results from these two very different seamounts emphasize our need for detailed maps.

Cross Seamount

Cross Seamount (fig. 1) was chosen as a site to study the geology of manganese crusts in detail for the purposes of the EIS. The seamount is due south of Honolulu at long. 158°15′ W., lat. 18°40′ N. Its summit is flat and at a water depth of 500 m. Detailed bathymetric mapping was done by using a multibeam system from the German Research Vessel *Sonne*. HURL was forced to use this foreign source because, at that time, all domestically acquired data were classified. (The classification issue of bathymetric data has now been largely resolved.) A series of dives on several occasions have examined the seamount in great detail. Initially, dive sites were picked on the basis of 10 camera tows and dredge hauls taken from the University of Hawaii Research Vessel *Moana Wave*. The dives on Cross showed a dissected seamount, which apparently has undergone continuous mass wasting since its formation. This mass wasting has exposed radial or elongate dike structures within the edifice and has formed long, wide talus chutes extending from the summit to the base of the seamount. The seamount is covered with sediment-rich gullies and areas of manganese crust, loose basalt, and sand. Many areas had no cover of manganese crusts, whereas other areas had significant cover. The seamount was not flat topped as anticipated but showed major faults and walls on the scale of meters and tens of meters. At times, the submersible came into contact with 30-m-high walls instead of a smooth slope as indicated on the bathymetric map. Manganese crust covered a wide range of terrains from a very thin coating on the basalt to thick pieces of crust. It became obvious after the diving mission that wide areas of thick crust were quite rare. The largest continuous crust patches were along the base of talus chutes.

Having been dissected by a series of tectonic events and mass wasting, the seamount appears to be fundamentally unminable. A paleoreconstruction traced Cross Seamount back to its point of origin on the East Pacific Rise some 84 million yr ago (Malahoff and Kelly, in press). From that distant origin, the seamount has moved across the Pacific by traveling with the Pacific Plate to reach its present position; in the course of this journey, it went over the Hawaiian Arch. This may be one of the factors responsible for seamount dissection and mass wasting. If the long journey is responsible for this disruption, then it may be expected that other seamounts in the same vicinity also may have suffered similar mass wasting. This is very significant because if a large number of seamounts are characterized by such mass wasting slopes, then they also may be fundamentally unsuited to mining.

Loihi Seamount

Loihi Seamount (fig. 1) is situated about 28 km southeast of the island of Hawaii. The summit is in 969 m of water. This volcano has been documented as the southernmost extension of the Kahoolawe-Hualalai-Mauna Loa volcanic line (Malahoff, 1987). It probably marks the latest activity of the Hawaiian hot spot. Most of the volcanic activity has occurred through periodic volcanism on a northwest- to southeast-striking 31-km rift. The summit of the volcano contains a calderalike depression 2.8 km wide and 3.7 km long and steep inner and outer walls. Inside the caldera, there are two pit craters; one is 0.6 km in diameter and 73 m deep, and the other is 1.2 km in diameter and 146 m deep.

Between 1978 and 1981, a series of detailed surveys were conducted over the summit and sides of Loihi by the NOAA's Survey Ships *Fairweather* and *Rainier*. These surveys used high-resolution, narrow-beam, echo sounders on tracks spaced 400 to 800 m apart. Navigation made use of the miniranger that had the network tied to the old Hawaiian datum. Further work was conducted on the whole volcanic edifice by using the narrow-beam 64-beam Sonar Array Survey System (SASS) aboard the U.S. Navy Ship *Hess*. The combination of this survey work was sufficient to allow a map that was an accuracy of 10 fathoms to be constructed. This map was refined in the area of the summit crater by including detailed photographic work done by the Woods Hole Oceanographic Institute by using their ANGUS camera system, which is equiped with an altimeter and is navigated by using acoustic transponders. A further detailed 10-m-contour interval map was constructed from multibeam sonar bathymetry taken in conjunction with a 1987 Deepsea Research Submersible Vehicle *Alvin* diving program (Fornari and others, 1988). Active hydrothermal vents have been discovered at the summit of Loihi Seamount (Karl and others, 1989). Warm hydrothermal fluids are venting at a temperature of 30 °C in an area referred to as Pele's vents. The active field is characterized by iron-rich nontronite deposits, extensive bacterial mats, and the conspicuous absence of large benthic animals; Malahoff and others (1982) postulated higher temperatures in the material below seabed and active deposition of polymetallic sulfides. Measured deposits include elevated concentrations of gold, manganese, copper, nickel, lead, and cadmium. Although the high concentration of sulfide-forming metals on Loihi is not a potentially economic polymetallic sulfide deposit, the presence of these materials does make Loihi an excellent natural site for studying ore-forming processes.

POLICY ISSUES

The detailed characterization of Cross and Loihi Seamounts was just the beginning. The detailed maps now needed will provide the ability to develop a whole new group of EEZ projects. However, the detailed mapping of the EEZ clearly raises a number of policy issues, many of which are fundamental in nature. A State such as Hawaii, which is completely surrounded by water, has a major stake in the EEZ. It cannot leave the jurisdiction and the management of this vast resource solely in the hands of the Federal Government. Effective management is based on knowledge. Gaining and using this knowledge are prerequisites for effective management. For this reason, the State needs a role in acquiring detailed bathymetry.

A related issue—commercial development—is the overall reason for mapping. This brings up the question as to whether those parties who will undertake the commercial development itself should not bear all the expenses. However, given that the prospects for commercialization are far in the future, this seems unreasonable. The position reduces to a situation of mapping at government expense or not having a comprehensive mapping program at all. Yet more than one government is legitimately involved. In the past, the Federal Government has reserved the entire right to plan and execute government mapping programs. Although States, such as Hawaii, have excellent resources in the form of university research vessels and submersibles, such as the HURL operation, to undertake mapping programs, they do not have the necessary funds to do this mapping. Further, the major tax revenues from a future commercial operation will largely accrue to the Federal Government in terms of

Federal and corporate income taxes on the workers in any commercial venture, not to mention revenues from the rentals, the royalties, and the bonuses paid on the actual mineral leases themselves. By contrast, the greatest expense liability will be on the local government forced to put in new roads, sewers, schools, and so forth, before any income is raised from property tax or trickle down from State government (Fischer, 1988). This problem could create the difficulty so commonly experienced in offshore oil and gas leasing—massive local community opposition.

To help alleviate some of the opposition, administration of ocean resources will have to be delegated to allow greater participation by State and local authorities (Fischer, 1988). Even more important is a clear and open process to achieve policy consensus. In the case of detailed mapping, policy issues are essentially process issues. The specific areas to map, the techniques to be used, and the resolution at which to map will all change as technology and perceived needs change. However, the decisionmaking processes and the forums for discussion of needs can be institutionalized to insure a consistent and well-thought-out program.

The State of Hawaii has been innovative in refining these processes to ensure that the best decisions are made. Hawaii started with a realization that Federal-State cooperation was essential, not only on a policy level, but also on a day-to-day government working level. The Joint Federal/State Manganese Crust Task Force was formed in 1984 to create a body to supervise crust research and the writing of the EIS (Wiltshire, 1984). This successful Task Force was further institutionalized in 1988, when the Governor of Hawaii and the Secretary of the Interior signed an agreement for joint management of marine minerals in the Hawaiian EEZ (Pacific Basin Development Council, 1989). The agreement created the Hawaii Marine Minerals Joint Planning Arrangement (JPA). This joint management body is two tiered—a senior, politically appointed body oversees a working-level, technical body. The major questions concerning detailed mapping will be handled by the technical committee, which is composed of representatives of all key Federal and State departments and a large group of advisors selected for specific technical expertise or, in the case of representatives of environmental groups, for their environmental concern.

The questions of how many and which seamounts to map and how accurately to map them are decided by the technical review panel. The question of which seamounts to map is certainly a critical parameter and is totally dependent on the purpose of the mapping exercise. Assuming that the mapping is geared for mineral exploration, the maps should be constructed by using prime mineral targets. An assessment of these targets needs to be made in conjunction with the greatest number of interested parties that are knowledgeable about the nature of mineral development. Ideally, this would include those industries concerned with crust development. In practice, it is more likely to include Federal and State agencies and university scientists. The question of how many seamounts to map is a direct fall-out of the funds available for the project and the ability of the committee to pool and focus the resources of several agencies. A list of priorities will be drawn up to map the seamounts in the most efficient way.

Following target selection, a mapping technology needs to be selected that is sufficient to give the resolution necessary for diving studies. Typically this would be SeaBeam, SASS, or a similar multibeam system, depending on the ship available. Navigational accuracy is, of course, critical. When available, the Global Positioning System is used. At the present, time it is available about 12 hr/d in the Hawaiian area. It is hoped the this situation will rapidly improve in the coming years as new satellites are deployed. Nearshore miniranger or other transponder systems have been used successfully on most of the Loihi Seamount surveys. However, such systems are not applicable to most seamount surveys, which are out of range of possible shore-based station locations.

After the surveys are completed, the data need to be worked up, maps made, and the data properly archived. In the past, this has been a major weak link in the entire process. Because of classification problems in the past, maps and data were not available as needed, and decisions on which seamounts to dive and investigate in detail were made not on geological grounds per se, but on the basis of map availability; for example, early in 1986, the Governor of the State of Hawaii formally requested that the Secretary of Commerce authorize the detailed mapping of a series of seamounts so that they could become candidates for future diving investigations. Unfortunately, the level of detail needed was considerable, and NOAA was unable to release these maps because of the necessity for military classification. This year, some of these maps have been declassified and released as the result of the major easing of classification requirements.

INSTITUTIONAL INNOVATIONS

One major institutional innovation to help overcome the loggerhead of bathymetric data analysis and archiving is the new Pacific Mapping Program, which is at the University of Hawaii and was officially dedicated on March 15, 1990. This center is a cooperative program between the USGS, NOAA, the Pacific International Center for High Technology Research, and the State of Hawaii through the University of Hawaii's College of Engineering. This program and the Pacific Regional Data Center, which it includes, will conduct ocean mapping research. Activities will include establishing a database (bathymetry, gravity, sea-surface temperature, magnetic, seismic) for the Pacific region, analysis of data and systems, establishing mapping requirements for resource-rich areas, and providing academic training, including a certificate program. The Center will emphasize cooperative programs with industry, in particular marine mining and fisheries. Having a dedicated center to provide guidance on detailed mapping requirements and to collect and analyze all existing data will greatly facilitate the work of optimizing Hawaii's marine mining exploration program.

Another institutional innovation is the Hawaii Ocean and Marine Resources Council. This body, which was created by the State of Hawaii Legislature in 1988, provides a forum for comprehensive ocean policy formulation, public and private sector coordination, information dissemination, and planning, coordinating, and facilitating the development of the Hawaii Ocean Resources Management Plan (State of Hawaii, 1990). The body has 11 members representing the heads of 6 State departments, including the University of Hawaii's School of Ocean and Earth Science and Technology, and 5 members representing commercial, recreational, environmental, and research interests. The Council has a professional research staff attached to it specifically for the development of policy issues and tracking the implementation of the Council's solutions. The council responds directly to the Governor and the legislature through the State Department of Business and Economic Development. The Council will set and review State policy for a range of 10 specific areas, including marine minerals, ocean energy, waste disposal, and fisheries. Hawaii now has a public body directly charged with setting EEZ policy, which, in turn, will dictate the framework under which a mapping program will operate. This body will provide the overall State ocean policy guidance that the Marine Minerals JPA will translate into requirements for the State Marine Mining Program, in particular requirements for detailed mapping.

CONCLUSIONS

The State of Hawaii has an active marine mining program that needs high-resolution bathymetric mapping to efficiently carry out its function. Although broad-scale coverage, such as GLORIA, serves a general reconnaissance purpose, it is primarily of scientific interest to sort out large-scale tectonic patterns. For the State to carry out specific projects in the EEZ, as is now the intention, detailed maps must be available.

Detailed characterization of mineral deposits has been done most successfully by using submersibles. In the Hawaiian EEZ, this has focused on Cross Seamount for crust deposits and on Loihi Seamount for sulfide deposits. These particular deposits were selected largely because of map availability. Subsequently, NOAA has mapped six other seamounts.

The State of Hawaii has set up a process to evaluate mapping needs in the context of marine mining in the form of the Joint Federal-State Marine Minerals JPA. In addition, another legislated body, the Council on Ocean and Marine Resources, provides State policy guidance for all EEZ matters. A mapping institution, the Pacific Mapping Program, also has been formed to serve the archiving and analysis function critical to carrying out the needed mapping programs. With the ominous classification issue now behind us, Hawaii has shown the leadership to set up the institutional and the policy mechanisms to move rapidly forward with the detailed mapping necessary for the commercial development of the EEZ.

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High-Resolution Sea-Floor Mapping in Hawaii

J. Frisbee Campbell
Seafloor Surveys International, Inc.

Abstract

The Exclusive Economic Zone surrounding the principal Hawaiian Islands has been the focus of a variety of high-resolution seafloor mapping surveys. The U.S. Geological Survey has completed GLORIA surveys of the southeastern end of the Hawaiian Exclusive Economic Zone, and the National Oceanic and Atmospheric Administration has completed multibeam surveys of part of the area.

At the State level, several surveys have been conducted that are more project specific in nature. These surveys have involved several State agencies and the University of Hawaii. These high-resolution mapping projects range from the use of the University's SeaMARC II to map seamounts that have potential sources of cobalt-rich manganese crusts to the use of Seafloor Surveys International's high-resolution mapping systems to produce maps for fishery-resource studies. Most of, but not all, these focused mapping projects involved Federal agencies either as a direct partner or as a source of funding.

Although several cooperative programs between State and Federal agencies are already in place, some of which involve mapping in the Hawaiian Exclusive Economic Zone, there is a need for closer cooperation. This is especially true for mapping the shallower water areas where there is more potential for short-term economic benefit, and the State and the Federal Governments have an interest.

INTRODUCTION

The Exclusive Economic Zone (EEZ) surrounding the Hawaiian Islands is about one-fifth of the total U.S. EEZ and, at present, the least studied of any part. The State of Hawaii extends for nearly 2,500 km from the island of Hawaii to Kure Atoll at the northwestern end of the archipelago. The Hawaiian Archipelago varies from high volcanic islands at its southeastern end, which are still being formed by the Hawaiian hot spot, to the inhabited atolls of Midway and Kure in the northwest. Most of the islands west of the eight major Hawaiian Islands are low islands associated with atolls formed on the eroded remnants of volcanoes that moved away from the hot spot. Because of the linearity of the Hawaiian Ridge and the spacing of the islands on the volcanoes along the ridge, the Hawaiian EEZ covers a swath nearly 400 mi wide along most of its length.

Aside from the volcanoes on the Hawaiian Ridge that were formed by the Hawaiian hot spot, there are numerous other seamounts in the Hawaiian EEZ that were presumably formed when this portion of the Pacific lithospheric plate was created at the East Pacific Rise. Included in the Hawaiian EEZ are portions of Necker Ridge, the Musicians and the West Hawaiian seamount groups, and several smaller groups of seamounts in the vicinity of Midway. Although the major seamount groups are fairly well charted, there are likely to be undiscovered seamounts in the poorer mapped portions of the EEZ.

HIGH-RESOLUTION MAPPING

The charting of the waters surrounding Hawaii most likely started with the arrival of the first Polynesians; however, the first known published chart dates from 1778 when Captain James Cook visited the islands. Until the EEZ declaration, charts of the Hawaiian area were generally prepared for navigation, scientific, and military uses and, in most instances, would not now be considered high resolution. Since the EEZ declaration in 1983, the U.S. Geological Survey (USGS) has undertaken a regional GLORIA mapping program, which has surveyed the area at the southeastern end of the Hawaiian EEZ surrounding the principal Hawaiian Islands, and the National Oceanic and Atmospheric Administration (NOAA) has begun systematic charting of the EEZ by using SeaBeam swath-mapping technology. These data sets have not been published as yet; however, details already made public, specifically some of the GLORIA data, are extremely interesting. The discovery of large submarine lava flows and confirmation of large landslides surrounding the islands has provided new information on the geologic history of Hawaii.

These regional scale mapping projects are ongoing efforts on the part of the USGS and NOAA and most likely will continue for several years. Because the technologies being used for these regional mapping projects are not particularly suitable for mapping in shallow water, these programs are mapping only the deeper slopes of the islands and the surrounding sea floor. More site-specific studies of individual seamounts have been conducted by the Hawaii Institute of Geophysics (HIG) and the Hawaii Underwater Research Laboratory (HURL); these surveys involved high-resolution mapping that used HIG's SeaMARC II and HURL's submersibles. These programs were aimed at providing a general assessment of the potential for mining cobalt-rich manganese crusts from seamounts in the Hawaiian EEZ.

High-resolution mapping in the shallower waters (0–1,000 m) of the Hawaiian EEZ has been done only on a project-specific basis. Generally, these mapping efforts were in support of State projects; however, these often involved some Federal funding. A good example of this type of program is the Hawaii Deep Water Cable Program; the goal is to determine if it is feasible to design, build, and lay an electric transmission cable from the geothermal resources on the island of Hawaii to the city of Honolulu, where electric power is needed. This project is being conducted by the Hawaiian Electric Company with grants from the State and the U.S. Department of Energy. Hawaiian Electric's project manager for the study, Parsons Engineering, has relied on the University of Hawaii, Seafloor Surveys International, the Scripps Institute of Oceanography (SIO), and Makai Ocean Engineering to provide detailed bathymetric charts of various parts of the route. Various mapping tools have been used by these groups—SeaMARC II, SeaMARC/S, the SIO Deep Tow, and a high-resolution bottom roughness sampler—to provide the bathymetric resolution necessary to determine the location of a feasible cable route.

An example of a totally State-supported high-resolution survey was the production of a series of detailed charts by Seafloor Surveys International for the Aquatic Resources Division of the State's Department of Land and Natural Resources. These charts were prepared for use by the Aquatic Resources Division in determining where to position fish aggregation devices. These 1:25,000-scale charts had a 5-m contour interval. Because the charts showed a series of drowned reefs, they were also of interest to bottom fishermen and scientists working on the subsidence history of the Hawaiian Islands.

High-resolution mapping of Loihi Seamount has been carried out by scientists who use SeaBeam, SeaMARC II, and submersibles; for mapping potential Ocean Thermal Energy Conversion sites, SeaMARC II and submersibles were used; and for engineering and the installation of fiber optic communications cables, SeaBeam and SeaMARC/S were used. Unfortunately, much of the information collected for these project-specific studies is not widely distributed.

FEDERAL-STATE COOPERATION

Soon after the declaration of the U.S. claim over the EEZ, the State of Hawaii's Department of Business and Economic Development and the Minerals Management Service of the Department of the Interior formed a task force to oversee exploration and leasing of areas that have potential for cobalt-rich manganese crusts and other hard minerals in the Hawaiian EEZ. This cooperative program provided funding to the University of Hawaii to conduct preliminary assessment of the resource and to prepare a preliminary Environmental Impact Statement.

The establishment of the Center for Ocean Resources Technology at the University of Hawaii is another example of a Federal-State cooperative program. This is a joint program of the University and the U.S. Bureau of Mines. The Center is presently undertaking a program to explore the feasibility of mining offshore sand deposits as a source of aggregate for construction and beach replenishment. Although plans for this program are not complete, the need for detailed sea-floor mapping by this program is readily apparent. Other smaller scale joint efforts, such as involvement of the University of Hawaii personnel in the USGS GLORIA mapping program, and cooperation between the Office of State Planning and the USGS in setting up a State geographic information system are examples of cooperation between State and Federal agencies.

Although these cooperative efforts are commendable, it seems as though there is lack of overall coordination. There is no single agency, particularly at the State level, that is responsible for coordinating an overall submarine mapping effort. The USGS-NOAA Joint Office for Mapping and Research (JOMAR) is a logical Federal office for coordination of a detailed mapping program. Their work in mapping the deeper water areas of the EEZ has been successful, although not very well coordinated with State or even other Federal agencies.

At the Hawaii State level, selecting an agency to be responsible for coordination with JOMAR is a problem. The office containing the State Geologist is the Water Resources Office in the Water and Land Development Division of the Department of Land and Natural Resources. This office has had little experience or interest in submarine mapping. Several groups at the University of Hawaii have interests in detailed submarine mapping, but they are primarily involved with some aspect of their own research and not in an overall mapping program. The same is true for other State agencies that have been involved in offshore mapping efforts in the past.

The State agency that should have most potential interest in an offshore mapping program is the Department of Land and Natural Resources. Although it does not have a mapping branch, its responsibilities in the area of mineral and fishery resources make it the most logical office for such a program. Another agency that might take responsibility is the Office of the State Surveyor. At present, they are primarily responsible for tax maps.

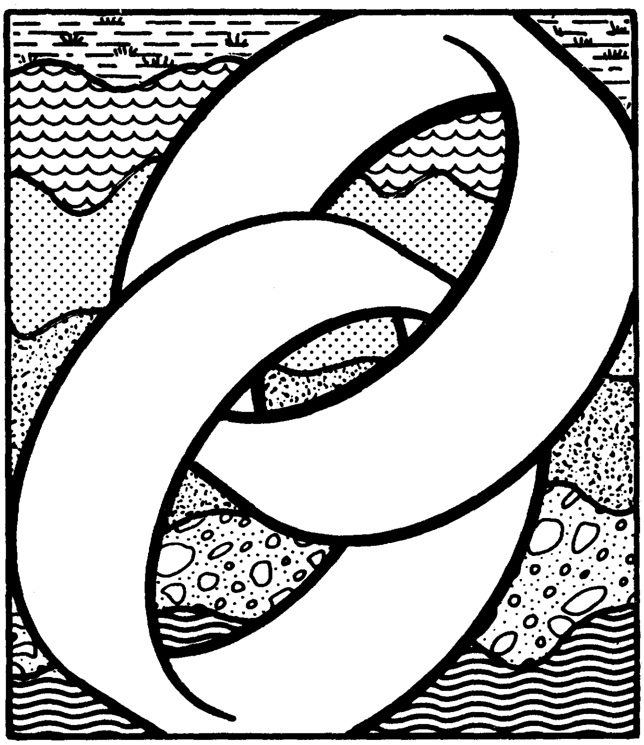
In the Hawaiian EEZ, it is obvious that there are resources of near- and long-term economic interest that have a need for high-resolution charts; aggregate is badly needed for beach replenishment, fishery resources could be better managed, alternate energy sources need to be developed, and the potential of mining hard minerals, such as cobalt, should be realized. The regional mapping projects presently underway will provide information on where more detailed mapping will be necessary and whether the technology exists to produce the high-resolution maps needed to plan and manage the exploitation of these resources. What is needed now is a decision on who should be responsible for the mapping programs and what Federal-State coordination is needed. If there is a serious interest to produce high-resolution maps in water depths between 0 and 1,000 m at the Federal level, then that interest would likely be shared at the State level.

APPENDEXES 1–3

APPENDIX 1:

1989 EXCLUSIVE ECONOMIC ZONE SYMPOSIUM

FEDERAL-STATE PARTNERS



IN EEZ MAPPING

Implementation of the National Plan for Mapping and Research in the Exclusive Economic Zone

USGS-NOAA Office for
Coordination of Mapping
and Research in the EEZ

November 14-16, 1989

SYMPOSIUM OVERVIEW

This will be the fourth in a series of biennial symposia dedicated to the development and implementation of a National Program for Mapping and Research for the non-living résources of the seafloor of the United States Exclusive Economic Zone (EEZ). Through overview presentations, four (4) individual panel discussions, and six (6) technical workshops, a framework for EEZ mapping and research will be developed. 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 Workshops will cover a range of technical and policy issues including: High resolution seafloor mapping, image analysis and processing, marine mining laws, EEZ leasing considerations, and systems for data and information management. A tour of the USGS's GIS Development Laboratory will also be available on the last day of the symposium.

SYMPOSIUM OBJECTIVES

- Identify seafloor scientific objectives of interest to states and relate these to national needs or goals for mapping and research in the EEZ.
- Recommend specific products and services necessary to meet these objectives.
- Coalesce, on a regional basis, priorities for collecting data to fill information gaps.
- Recommend regional implementation and coordination approaches including cooperative projects and the roles of federal, state, academic and the private sector.

SYMPOSIUM STEERING COMMITTEE

Chairmen:
Gary W. Hill, U.S. Department of the Interior, U.S. Geological Survey
Millington Lockwood, U.S. Department of Commerce, National Oceanic and Atmospheric Administration

Bonnie A. McGregor, U.S. Geological Survey
Robert L. Rioux, U.S. Geological Survey
Christian Andreasen, National Oceanic and Atmospheric Administration
Donald E. Pryor, National Oceanic and Atmospheric Administration
Joseph R. Vadus, National Oceanic and Atmospheric Administration
John W. Padan, Minerals Management Service
George Dellagiarino, Minerals Management Service
Edward Kruse, Minerals Management Service
Peter G. Chamberlain, U.S. Bureau of Mines
Hendrick G. Van Oss, U.S. Bureau of Mines
Virginia Fox-Norse, Environmental Protection Agency
Thomas W. Richards, Oceanography of the Navy

Symposium support is provided by Buhler and Abraham, Inc., 8700 First Avenue, Silver Spring, MD 20910, 301-588-4177.

SYMPOSIUM SPONSORS

- U.S. Geological Survey — National Oceanic and Atmospheric Administration Joint Office for Mapping and Research in the Exclusive Economic Zone
- Association of American State Geologists

PROGRAM AGENDA

Tuesday, November 14, 1989

10:00 a.m. **Registration** and **Review Exhibits**
(Lunch available at USGS Cafeteria at 11:00 a.m.)

1:00 p.m. **Welcome** (Auditorium)
Introduction and Purpose of the Symposium
Millington Lockwood — Deputy, Joint Office for Mapping and Research

1:15 p.m. **Mapping the New Ocean Frontier**
John Knauss — Under Secretary of the Commerce for Oceans and Atmosphere and Administrator, NOAA

1:45 p.m. **Outline of the 10-Year Plan — Summary of Goals**
Gary Hill — Chief, Joint Office for Mapping and Research

2:00 p.m. **Ongoing Activities**
10-15 min. overview with emphasis on existing or planned State-Federal relationships — Needs and Opportunities

Role of the State Geological Survey
Kenneth Weaver — Maryland Geological Survey

View from the Coastal States
Gary Magnuson — Director, Coastal States Organization

Cooperative Federal-State Studies in Coastal Regions
Asbury Sallenger — USGS Coastal Studies Division

NOAA Coastal Ocean Program
Donald Scavia — Acting Director

Department of the Interior's National Marine Mining Technology Center
J. Robert Woolsey — University of Mississippi

National Science Foundation Continental Margin Research and Future Plans
Donald Heinrichs — Oceanographic Centers and Facilities Section

National Academy of Science's Continental Margin Studies
John Sclater — Chairman, Ocean Studies Board

3:15 p.m. **Coffee Break — Review Exhibits**

3:45 p.m. **Our Seabed Frontier: Challenges and Choices**
Armand Silva — University of Rhode Island

Minerals Management Service's Offshore Activities
William Bettenberg — Associate Director, Offshore Program

Environmental Protection Agency's Marine Program
Ronald Keizenbeck — Acting Deputy Director

Drowning in Data, But Learning to Swim
Charles Ehler — NOAA's Office of Oceanography and Marine Assessment

Mapping the Ocean Floor
Christian Andreasen — NOAA National Ocean Service

5:30 p.m. - 7:00 p.m. **Reception/Exhibits**

PROGRAM AGENDA

Wednesday, November 15, 1989

8:00 a.m. **Morning Refreshments** and **Review Exhibits**

9:00 a.m. **Welcome**
Introduction to the second day of the Symposium
Dallas Peck — Director, USGS

9:15 a.m. **Assessing EEZ Mapping Requirements**
Peter Lucas — Chairman of the NRC Marine Board Study on EEZ Information Needs, Shell Development Company

The second day of the symposium will consist of a series of four panel discussions by expert practitioners in sea floor mapping and information needs. A case study approach will be used to discuss individual activities. Keeping with the theme of the Symposium, each talk should stress Federal/State cooperative activities from the point of view of "users" of sea floor data and information. A paper will be written by each panel member for inclusion in the Symposium Proceedings.

Panel members have been selected to represent the range of interests from the Federal Government, State, local, academic and the private sector. Each talk will be approximately 10 minutes, thus allowing adequate time at the end of each session for audience questions.

Morning Session
Moderator: Millington Lockwood — NOAA

Panels:

9:30 a.m. **East Coast**
George Marshall — Amboy Aggregates; Brad Butman — USGS-AMG Woods Hole; Joseph Kelley — Maine Geological Survey; Roger Amato — Phosphate Task Force, MMS; Jeffrey Halka — Maryland Geological Survey

10:45 a.m. **Coffee Break** and **Review Exhibits**

11:15 a.m. **Gulf Coast**
Skip Theberge — NOAA Ocean Mapping Program; Courtney Reed — MMS; Charles Groat — Louisiana State Geologist; Tom La Pointe — NOAA, Strategic Assessment Atlas Project; Environmental Protection Agency

12:30 p.m. **Lunch** (USGS Cafeteria)

Afternoon Session
Moderator: Bonnie McGregor — USGS

1:30 p.m. **West Coast and Alaska**
Jeff Weber — Oregon Ocean Resources Program; Robert Wolotira — NOAA, Strategic Assessment Mapping Project; Mark Bronston — West Gold, Alaska; Dave Cacchione — USGS, Farallon Islands Mapping Project; Irven Palmer — MMS Alaska Region; Environmental Protection Agency

2:45 p.m. **Coffee Break** and **Review Exhibit**

3:15 p.m. **Hawaiian Islands and Territories**
Monty Hampton — USGS Pacific Marine Geology; John Wiltshire — University of Hawaii; J. Frisbee Campbell — Seafloor Surveys International; Guam/Western Pacific Islands

4:30 p.m. **Summary Discussion —** Gary Hill — USGS

Conclusion of Formal Symposium

WORKSHOPS

Thursday, November 16, 1989

8:30 a.m. - 12:00 noon **Technical Workshops**

These workshop sessions will be approximately 1 hour in length with a period for audience question and answer. They will be in the Main Auditorium, the Visitors Center or Room BA102-AB in the National Center.

There will be 6 workshops. In three topical "Blocks". There will be 2 workshops sessions in each block — one from 8:30 a.m. to 10:00 a.m., the second will be from 10:30 a.m. to Noon. Following lunch in the USGS cafeteria, there will be a 1 hour tour of the USGS's GIS laboratory.

The following workshops will be given:

Block 1 — Room BA102-A/B

8:30 a.m. **NOAA Multibeam Data: Processing and Analysis**
Albert (Skip) Theberge — Chief, Ocean Mapping Section, NOAA

10:30 a.m. **Applications of Computer Technology to Interpret Sonar Imagery and Multibeam Data**
Dave Twichell — USGS, Donald Pryor — NOAA, Bob Tyce — University of Rhode Island

Block 2 — Main Auditorium

8:30 a.m. **Leasing Considerations: Assessment and Evaluation Models**
Moderators: Palak Ray and Marshall Rose
Participants: Carolita Kallaur, Pulak Ray, Barry Dickerson, Thomas Farndon, Marshall Rose — Minerals Management Service

10:30 a.m. **EEZ and Territorial Sea Mining Laws of the World**
Moderator: James Workman — Minerals Management Service
Participants: John Padan, James Woolsey, Michael Cruickshank, Anthony Giordano, LeRon Bielak

Block 3 — Visitors Center

8:30 a.m. **CD-ROM Tutorial and Demonstration**
Moderator: Jerry McFaul — USGS
Examples: GLORIA, SEABEAM, DNAG (Decade of North American Geology), DSDP (Deep Sea Drilling Project), other geoscience data and literature data bases

10:30 a.m. **Management of Data and Information — Computer Applications and GIS Developments**
Moderator: Douglas Posson — USGS

12:00 noon **Lunch**
(USGS Cafeteria)

1:30 p.m. - 3:00 p.m. **Tour of USGS's GIS Development Laboratory**
Nich Van Driel — USGS

Charter for Coordination of Federal Exclusive Economic Zone Mapping and Research Programs

Purpose

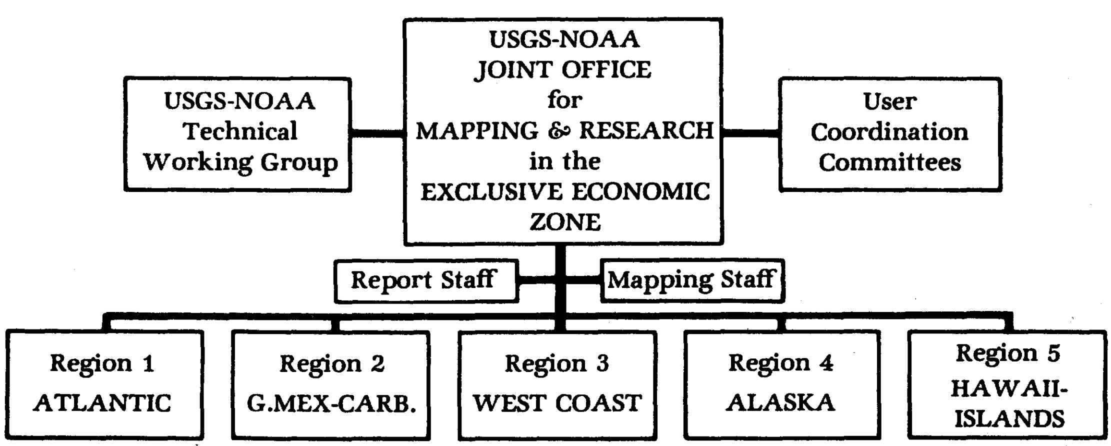
The Exclusive Economic Zone (EEZ) of the United States has a vast potential for resource development. In order to develop these resources in an efficient manner, it is necessary for a coordinated mapping and research endeavor to be formed, involving the Federal Government, State governments, private 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

- **EEZ Digital Mapping** — U.S. Geological Survey
- **Geological Studies at Low-Level Radioactive Waste Sites in the Atlantic Ocean** — U.S. Environmental Protection Agency
- **Multibeam Surveys of the Exclusive Economic Zone** — National Oceanic and Atmospheric Administration's Mapping Program
- **Coastal Geology and Continental Shelf Research** — Louisiana Geological Survey
- **Quaternary Geology of the Chesapeake Bay** — Maryland Geological Survey
- **Oregon Ocean Resources Program** — Oregon Department of Land Conservation and Development
- **Marine Minerals Technology Center** — Hawaii Minerals Technology Center
- **Overview of Minerals Management Service's Offshore Activities**
- **U.S. Geological Survey's Coastal Erosion Program**
- **Seafloor Surveys International's High Resolution Seafloor Mapping around the Hawaiian Islands**
- **The U.S. Geological Survey's Continental Margin Map Project**
- **Minerals Management Service's Overview of Minerals from the Sea**
- **Bureau of Mines Minerals Information and Research Pertaining to the EEZ**
- **U.S. Geological Survey's Massachusetts Bay Mapping Project**
- **Farallon Island Shelf Mapping Using High Resolution Sidescan Sonar**
- **The U.S. Geological Survey's Earth Science Data Directory**
- **NOAA's Library and Information Services**
- **NOAA's Undersea Research Program**

SYMPOSIUM RESULTS

A symposium proceedings volume will be prepared following the meeting. This will include the overview presentations, regional panel member talks and workshop summaries. Each symposium attendee will receive a copy of the proceedings upon publication.

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).

APPENDIX 2:
LIST OF REGISTRANTS FOR THE EXCLUSIVE ECONOMIC ZONE SYMPOSIUM NOVEMBER 14–16, 1989

Roger V. Amato
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APPENDIX 3:

Workshop Block 1 - Room BA-102 A/B

(basement near cafeteria)

Session 1 - Thursday, November 16 - 8:30 - 10:00 a.m.

NOAA Multibeam Data - Processing and Analysis

Moderator: Cdr. Skip Theberge, NOAA, National Ocean Service, Ocean Mapping Section

This workshop will consist of an overview presentation of the steps involved in processing and production of maps and digital data sets from the NOAA multi-beam surveys of the Unites States EEZ. The objective is to get a consensus from attendees at the EEZ Symposium regarding data form and formats to serve as a "guide" in the development of NOAA's multibeam mapping system.

Following a brief tutorial on NOAA's multibeam ocean survey program, including a description of the flow of data from the ship to the paper (map) product, there will be discussion (with audience participation) on the following subjects: optimal formats for data exchange, for example: selected individual soundings, single swath, merged geographical positioned data sets, contoured soundings.

There will also be discussion about the procedures NOAA is developing for the release of the data and maps to the general public, the preferred media (Magnetic tape, floppy disc, CD-ROM etc.) and an evaluation of the 250 m gridded data sets as appropriate for geological and geomorphic applications.

Session 2 - Thursday, November 16, 10:30 - Noon

Applications of Computer Technology to Interpretation of sonar Imagery and Bathymetry

Moderator Don Pryor, NOAA -- Participants Dave Twitchell USGS, Bob Tyce, University of Rhode Island, Roger Bowen, Consultant

Discussions at this workshop will cover new developments in sonar mápping systems, integration and analysis of data from varied types of data, and techniques for handling seafloor mapping data on a small computer seafloor.

Bob Tyce will provide some insight into new survey technology that is becoming available. Results of the recent Seafloor Mapping Workshop in Lake Powell, Arizona, suggests that the direction of further development will be toward calibrated systems producing multi-dimensional, quantitative results. A short video, "Cruise Without Water," will be shown to demonstrate the impact of visualization of the single dimension of bathymetric data.

Dave Twitchell will discuss multi-dimensional data integration and analysis using examples from GLORIA and SeaBeam surveys of the Florida Escarpment. The combination of such data types has great potential for improving our understanding of the geologic processes active in complex terrains.

Roger Bowen will provide a demonstration of a version of the MIPS software that was used for integration of these data and has been adapted for operation on a personal computer.

Don Pryor will summarize some of the other tools and techniques available for manipulating high-resolution mapping data in a small computer environment.

Workshop Block 2 - Main Auditorium

Session 1 - Thursday, November 16 - 8:30 - 10:00 am

Leasing Considerations: Assessment and Evaluation Models

Moderators: Pulak K. Ray, Marshall B. Rose, and Carolita Kallaur - Minerals Management Service.

This workshop will cover four areas: EEZ Resource Assessment and Evaluation, Hydrocarbon Resource Evaluation models, Hard Minerals Mining and Economic Considerations.

A decision to lease Federal OCS lands involves balance between the expected resource and their impact on the environment. There are three critical elements to be addressed: 1. Is the commodity present?, 2. How much is present?, and 3. Where is it concentrated? In frontier areas, answers to such questions are sought through probabilistic models based on several sources of data and analog studies. It is the responsibility of MMS to assure that the U.S. Government receives a fair share through bonuses and royalities. This workshop will include discussions of the various considerations that are incorporated into the models used at MMS in assessing and evaluating resources. These considerations are grouped into three categories: 1. geologic, 2. engineering, and 3. economic.

Discussions will address hard minerals modeling, hydrocarbon resource evaluation models and economic considerations of lease terms. Speakers will discuss various approaches to assessing resource potential, exploration and development costs, and operating costs. Computer simulation models are used to assist in resource economic value calculations and resource assessments for the hard mineral commodities offered for lease. Models include a sulphur model, a placer deposit model, PRESTO and ROCKVAL, and a sand and gravel model that is in the process of development.

Session 2 - Thursday , November 16, 10:30 - Noon

EEZ and Territorial Sea Mining Laws of the World.

Moderator, James Workman, Program Director, Office of Strategic and International Minerals, MMS.

This workshop will review United States, State, and International laws and regulations that govern exploration and development of hard minerals of the U.S. Outer Continental Shelf, the seabed under the jurisdiction of the respective coastal States, and the seabed under the jurisdiction of the other countries of the world.

Anthony C. Giordano, Geologist from MMS will discuss a compilation of State laws recently published by the MMS's Office of Strategic and International Minerals including the similarities and differences, highlight State initiatives, and discuss the laws and regulations. LeRon E. Bielak, from MMS will outline the OSC Lands Act and recent hard minerals regulations for prospecting, leasing and operating. There will be a discussion of an alternative legal regime as developed by the EEZ Hard Minerals Working group and H.R. 2440, the "Jones Bill". John Padan, Senior Technical Advisor, with the OSMI will discuss foreign offshore Sand and Gravel Mining Laws, especially European and Japanese laws and practices, as observed by the speaker. Jim Woolsey, Director of the Mississippi Mineral Resources Institute will discuss exploration for placer and phosphate deposits in the South Pacific and offshore Africa and comment upon laws and practices with which he has had experience. Michael J. Cruickshank, Technical Director, Ocean Basins Division of the Marine Minerals Technology Center at the University of Hawaii, will discuss mining of offshore tin placers in a large industry in S.E. Asia.

Workshop Block 3 - Visitors Center

Session 1 - Thursday, November 16 - 8:30 - 10:00 a.m.

CD-ROM Tutorial and Demonstration

Moderator: David Traudt, USGS. Participants, Russ Ambroziak, NOAA, Carla Moore, NOAA and Carol Watts NOAA.

The CD-ROM as a data and information publication medium has revolutionized the distribution of digital data. With a capacity nearing 1 million megabytes, and at a fraction of the cost of conventional media, the CD-ROM is becoming accepted as the standard for information dissemination. Two recent articles on this subject are attached.
During this workshop session we shall be demonstrating four CD-ROMs' containing data and textual information of interest to the Earth Science Community.

East Coast GLORIA Data: These data were collected by the U.S. Geological Survey in 1987 as part of the GLORIA sidescan surveys of the United States. The CD-ROM contain the digital GLORIA imagery collected off the East Coast of the United States during the winter and spring of 1987. The data sets consist of the 2° square mosaicked data, the individual 6-hour segments of "raw" data, ship trackline information, and magnetic anomaly data. The data will be displayed by software developed through JOMAR by Russ Ambroziak of NOAA's National Environmental Satellite Data and Information Service.

Deep Sea Drilling Project: During 16 years of operation the Drill Ship Glomar Challenger drilled over 1000 holes at 624 sites in the global ocean. With the release of this CD-ROM any researcher can access the full suite of digitized DSDP data, including geophysical, geological, and downhole logging data, compiled by the Data Management Group in La Jolla, California. Carla Moore, Project Director from the NOAA National Geophysical Data Center in Boulder, Colorado will demonstrate the CD-ROM and the capabilities of the specialized software available to display the information on a personal computer.

Geophysics of North America: This disc consists of a consolidated collection of land and marine geophysical data for North America collected under the auspices of the Geological Society of North America's Decade of North American Geology - including magnetic, gravity, earthquake, seismology, thermal aspect, and stress data. Satellite imagery data, topography, and additional grids of magentics and gravity are also included in this compilation.

NOAA's Library Collections: This CD-ROM contains "Card Catalog" from NOAA's office of Library and Information Services. It contains over 1 million references to various types of published and unpublished literature dealing with meteorology, oceanography, living marine resources, and hydrology.

Session 2 - Thursday, November 16, 10:30 - Noon

Management of Data and Information, Computer Applications and GIS Developments

Moderator: Douglas Posson, USGS, Information Systems Division
During this session we will be demonstrating three areas of computer applications and GIS Developments:

Arctic Data Interactive (ADI) - This is a pre-prototype CD-ROM from which the following types of information pertaining to the Arctic can be linked: The Arctic Environmental Data Directory, bibliographic information, selected data sets, text, images, tables, and other information useful to Arctic researchers. The powerful search, retrieval and presentations capabilities of this system will be demonstrated

Oregon Ocean Resource Program - Pilot GIS Project - John Sharrard, Oregon Department of Land Conservation and Development

The Oregon Ocean Resource Program is exploring the use of GIS technology as a "tool" to assist in the decision making process for the development of Oregon's ocean resources. A pilot GIS project was undertaken to investigate the feasibility of developing a comprehensive GIS database for Oregon's entire coastal zone. The pilot project is limited to a small section of the coastal zone and utilized only pre-existing geographical data from a variety of sources.

USGS Geographic Information System Research Laboratory - Nick Van Driel, Chief, GIS Laboratory

The USGS GIS Research Laboratory in Reston, Virginia is a shared bureau resource operated by the National Mapping Division. The Lab supports studies in Spatial Data Research, GIS Development, Image Processing, Visualization, and Spatial Data Collection and Exchange. Scientists from all of USGS's divisions use the GIS and image processing facilities of the lab to advance their research projects. The laboratory's state-of-the-art software and hardware systems are used in cooperative demonstration projects among USGS Divisions, Federal Agencies, and state, regional, and local agencies. The lab hosts tours and demonstrations for a wide variety of visitors, and it is the training site for several application specific courses including map scanning, GIS, and visualization. A tour of the USGS GIS Laboratory is scheduled for Thursday at 1:30. Please sign-up at the registration desk.